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Advances in Animal Biosciences

Animal Science Fit for the Future

Proceedings of the British Society of Animal Science

Including

A brief history of the British Society of Animal Science
1944-2019

75 years of improving the understanding of animal science

advances in animal biosciences

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Advances in Animal Biosciences

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Advances in Animal Biosciences is an associated publication to the journal *animal*. It aims to publish high-quality conference, symposium and workshop proceedings about animal-related aspects of the life sciences with emphasis on farmed and other managed animals. These can be in the form of a book of abstracts, summaries or complete papers. The format will highlight the title of the meeting and organisations involved but the publications will have the added advantage of forming a series under *Advances in Animal Biosciences.*

Subject areas can include aspects of Breeding and Genetics, Nutrition, Physiology and Functional Biology of Systems, Behaviour, Health and Welfare, Livestock Farming Systems, Human Health and Product Quality.

However, due to the integrative nature of biological systems, monographs and conference proceedings dealing with the translation of basic and strategic science into the whole animal and farming system and the impact on Productivity, Product Quality, Food Security, the Environment, Climate Change and Humans will be particularly welcome.

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Proceedings

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2019

Advances in Animal Biosciences

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The Proceedings of the British Society of Animal Science constitute summaries of papers presented at the Society's Annual Conference, *BSAS 75th Annual Conference 2019* held at the Edinburgh International Conference Centre (EICC), 9-11 April 2019.

The summaries have been edited. Views expressed in all contributions are those of the authors and not those of the BSAS.

This publication contains all the summaries that were available at the time of going to press.

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001

Yesterday's science; an unsafe foundation for future discovery?

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Introduction Building upon established findings is the understood foundation for an adequately successful life in animal science; indeed, it is the way applied scientists are trained. It ensures sympathetic peer review, helps draw supporting funds from both government and industry, and is (of course) the wholly necessary basis for effective Development work (impact). It is less clear however how such behaviour helps to establish scientific truths and create inventive (i.e. simultaneously different and useful) understandings of animal science and technology.

Material and methods Research for a historical review of The British Society of Animal Science facilitated the re-visiting of much exciting science, and the finding of other that has gone unrecognised. This provided the background data base (BSAS archive 1944-2018) for a reflective consideration of both the utility and the danger of using past research as the foundation for future work.

Results Although a case was evident for the development of some new technologies useful to the animal industries even in the absence of understanding through experimentation (e.g. management systems), most successful Development work has resulted from the linear building of yesterday's science into today's production systems (e.g. livestock feeding, animal breeding). John Hammond, founding first President of BSAP, was firmly of the view that science – including basic research – should have a useful end purpose. The Society's second meeting was '*Science in the service of production'*. There is nothing in this understanding of 'applied science' that denies the benefit of original and innovative thinking equal in weight to any of that required for 'blue-skies' inquisitive research. Hammond's view of 'Applied Science' has unfortunately got lost. Through until around the millennium, being *out of step* with ones peers and superiors rarely resulted in immediate gains of either research funding or promotion. In the 1960s and1970s the (mundane) determination of nutritive values for feeding-stuffs was a far better place to be than stacking algorithms into (exciting) predictive computer models or thinking about an animal's behavioural needs! Keeping *in step*, designing experiments with established techniques to support (and embellish) the already known, was the safe way for an animal scientist to build a career; but it did rather less to build animal science. Editors and peer-reviewers of Animal Science publications responded cooly to unestablished notions. This coincided with a falling impact factor in such journals. Applied science came to be seen by some as implying lack of imagination and a contentment to merely continue scientific investigation along already established and 'near-market' pathways. For the animal scientist with a career to pursue, a creative imagination seems not to have necessarily been a good idea!

Wood (1975) suggested that an experimenter might have motives other than benefitting the farming industry. He talks of research workers as jockeys riding other people's hobby horses, or as seeking recognition rather than truth. Wood implies that both the experiment chosen, and the analysis used, might not always reflect impartiality toward the outcome. These observations are still relevant. The decades immediately before the millennium saw a movement away from the government funding of applied research, and toward more basic studies from where the big biological (often health-related) breakthroughs were to come. The presumption that industry would adequately pick up on the funding of applied research proved mistaken. Since that time the rate of publication of high-quality original applied research has diminished.

It was evident from the BSAS publications record that the majority of 'original' research papers were of the type that built the science base incrementally over time. Conversely, it was those propositions that arose in the scientist's own imagination that most readily led to myths being refuted, notions overturned and new ways of livestock farming developed. Science breakthroughs tended to come from those knowledgeable of yesterday's science, but who were not constrained by it.

Conclusion Science which targets applications in the livestock industries is inherently prone to being bound into a pattern of behaviour that requires building upon 'established findings'. However, only by breaking free of the conventional progression path for applied science can mis-interpretations be exposed (rather than perpetuated), and enlightened innovations pass from science into industry. Those who would pursue true innovation and question convenient wisdom should reject the paradigm that science should build only upon yesterday's findings. Unfortunately, obtaining funding for imaginative new science in a field which is by its definition of usefulness 'applied', is now even more difficult than ever.

Acknowledgements The views expressed are those of the author, who nevertheless gratefully acknowledges fifty years of support from the British Society of Animal Science.

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002

The role of animals in a circular food system

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The sustainable consumption and production of animal source foods (ASF) is at the centre of the current debates on how to meet several of the sustainable development goals. Some argue that to feed an increasing population, we have to produce more ASF with less impact and focus on reducing the environmental footprint of individual ASF products. Others argue that consuming ASF is resource-intensive and conclude that eating no ASF is best for the environment. However, both arguments do not include the use of animals to recycle biomass unsuited for human consumption back into the food system. While recycling through animals might be the solution.

In a recent study published in Global Change Biology (Van Zanten *et al*., 2018) we showed that animals reared under the circular food systems concept can contribute significantly to human food supply, while at the same time reducing the environmental impact of the entire food system. These farm animals then would not consume human-edible biomass, such as grains, but convert biomass that we cannot or do not want to eat, into valuable food, manure and other ecosystem services (Figure 1). Biomass that we cannot or do not want to eat consists of biomass from grassland and leftovers. Leftovers include crop residues left over from harvesting of food crops, co-products left over from industrial processing of plant-source and animal-source food, and losses and waste in the food system. By converting these leftover streams, livestock recycle nutrients back into the food system that otherwise would have been lost in food production. Under this concept, the competition for land for feed or food would, therefore, be minimized and compared to no animal-source food, including some animal-source food in the human diet could free up about one quarter of global arable land.

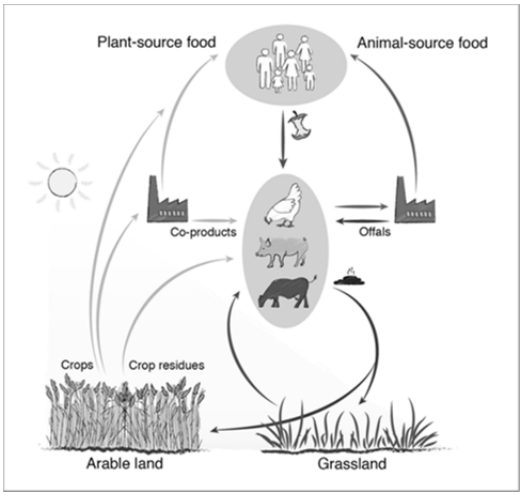

Figure 1 The role of animals in a circular food system. Livestock convert biomass that we cannot or do not want to eat into valuable products, such as animal-source food and manure. Van Zanten *et al*., 2018.

The availability of biomass from grassland and leftovers for animals will to a large extent determine the boundaries for animal production and consumption. We demonstrated that farm animals raised solely on those biomass streams could provide a significant, non-negligible part (9-23g/per capita) of our daily protein needs (~50-60 g/per capita). The average protein supply in Europe is 51 g per person per day (excl. fish), implying that moving towards circularity would require a substantial reduction in the consumption – and hence production – of animal-source food. The exact reduction in the consumption of animal-source food in high-income countries needed, however, is not known and requires more research.

Finally, rearing animals under this circular paradigm will require a transition from our current linear food system towards a sustainable food future which makes optimal use of the earth's natural resources. This represents a radical shift away from current trends and will require increased collaboration between governmental institutions, private industries and civil society in order to put in place the necessary policies, investment and other resources necessary, ensuring farm animals can contribute to meeting critical sustainable development goals in the near future.

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003

Application of computer vision and machine learning to assess physiological responses of consumers and livestock

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Application Computer vision (CV) combined with machine learning (ML) and artificial intelligence (AI) can be used to measure physiological responses in both consumers and livestock to improve assessment of emotional and physiological state in real time.

Introduction For many years, precision agriculture has been a feature of plant industries where it is becoming now a part of everyday life for viticulture, horticulture and cropping producers. The livestock industries have been slower to adopt the use of precision livestock systems (PLF) since they are often more complex involving free-living animals with individual differences, time-varying, and more dynamic system. The measurement of physiological responses such as heart rate (HR), blood pressure (BP), respiration rate (RR) and temperature (Temp) can provide insight into emotional and physical states of both humans and livestock, and when combined with ML and AI offer great opportunities for the livestock industries.

Material and methods A series of consumer studies investigating chocolate, beer, wine and meat were conducted in a sensory laboratory, which utilised an integrated visible/infrared thermal camera system controlled by an Android Bio-sensory application (App) developed by our laboratory (Gonzalez Viejo *et al*. 2018a; Fuentes *et al*. 2018). The integrated camera along with the App are able to record red/blue/green (RGB) videos from the participants, additionally an infrared thermal camera (FLIR AX8™) is able to automatically capture images to measure Temp from the eye section while conducting a sensory tasting test in sensory booths. The raw video analysis (RVA) used a computer vision algorithm based on luminosity changes on the different RGB colour channels using three face-regions (forehead and both cheeks) to predict HR and BP. To validate the proposed method and ML models, a home oscillometric monitor and a finger sensor were used to simultaneously measure HR and BP. A number of ML models were developed using artificial neural networks (ANN) to relate the biometric measures to liking for various food products. A similar validation study was conducted where an integrated RGB video and FLIR AX8™ camera was used to collect images from grazing dairy cattle that were milked in an automatic milking system (AMS) and were fitted with HR monitors and vaginal temperature probes. The data were further analyzed using customized algorithms that can work automatically by selecting the eye as the region of interest (ROI) within the RGB image. The algorithms are able to track this ROI to obtain automatically the maximum temperature of this section from the FLIR based on relationships with RGB (Gonzalez Viejo *et al*., 2018). The nose was selected as an additional ROI to determine respiration rate from the change in temperature due to respired gases. This information plus cow and milk production and composition data obtained form he AMS were used to construct two ML models to predict milk quality parameters such as milk production and feed intake (Model 3) and fat and protein content in the milk (Model 4) per cow.

Results For the consumer studies, there were high correlations between HR measured using the HR oscillometric monitor and luminosity changes in the G colour channel (R = 0.83). Two ML models were developed using three face-regions: (i) Model 1 to predict HR and BP using the RVA outputs with R = 0.85 and (ii) Model 2 based on time-series prediction with HR, magnitude and luminosity from RVA inputs to obtain HR values every second with R = 0.97. An application for the sensory analysis of chocolate showed significant correlations between changes in HR and BP of panellists with chocolate hardness and purchase intention (Gonzalez Viejo *et al*. 2018a). Similarly, there were correlations between HR, Temp and emotions measured by changes in facial expression and consumer preference in beer (Gonzalez Viejo *et al*. 2018b).
For dairy cattle there was a similarly strong correlation between HR measured using the HR monitor and luminosity changes in the G colour channel (R = 0.82). There was also a strong correlation between core Temp obtained from the vaginal loggers and eye Temp obtained from FLIR images (R = 0.88) and the correlation between RR from visual observations and FLIR image processing were also strong (R = 0.89). The developed models were highly accurate to predict milk production and feed intake (R = 0.90 for Model 3) and milk fat and protein content (R = 0.97 for Model 4). Similar studies have now been conducted in beef cattle during transport stress and in pigs during a disease challenge.

Conclusion CV combined with ML and AI offer great opportunities for the livestock industries to measure physiological responses in both consumers and livestock to improve assessment of emotional and physical state in real time.

Acknowledgements The authors gratefully acknowledge funding from Australian Research Council [Grant number IH120100053] 'Unlocking the Food Value Chain: Australian industry transformation for ASEAN markets' and MLA.

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004

Novel approaches to investigating embryo-maternal interactions in cattle: Understanding life, the uterus and everything

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Successful early pregnancy is contingent on appropriate and synchronized interactions between the maternal environment and the developing embryo and/or conceptus (embryo and associated extraembryonic membranes). In most mammalian animals, including cattle, the majority of pregnancy loss occurs in the first three weeks of pregnancy. A key checkpoint during this time is the day of pregnancy recognition (Day 16), when an appropriately developed conceptus signals it present to the mother via Interferon Tau. In addition, this process also enhances uterine receptivity to implantation. Pregnancy loss in this time can be attributed to inadequate communication between the conceptus and the maternal uterine environment. Moreover, even if early pregnancy is successful, exposure of the embryo to maternal stresses via the uterine environment, can have consequences for lifelong health and disease status of that offspring. Using a multi-omics approach and new *in vitro* techniques such as microfluidics we are identifying novel molecules and interactions between the maternal environment and the developing embryo and conceptus. This talk will focus on a combination of proteomics and *in vitro* techniques to determine what proteins are de novo synthesised by the Day 16 conceptus. A number of recombinant forms of these proteins have been produced and used in different *in vitro* endometrial models to mimic the pregnancy recognition process in cattle. Their effects have been determined via RNA sequencing to help understand how they alter uterine receptivity to implantation and pregnancy recognition signalling. In addition, we are also investigating how molecules such as genes, proteins and microRNAs may be conserved in a range of species and may be involved in the pregnancy recognition process. Collectively these data will enhance our understanding of the communication events that are required for successful early pregnancy and will identify novel molecules for intervention to reduce early pregnancy loss in cattle and other species.

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005

The potential of near infra-red spectroscopy (NIRS) to authenticate the dietary history of beef

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Application NIRS has the potential to be a rapid, non-invasive method of discriminating between grass-fed and concentrate-fed beef. Its use would reassure consumers concerned about the provenance of the beef they purchase.

Introduction Consumers today have growing concerns around environmental sustainability and ethical food production. Pasture-based systems have come to be regarded by some consumers as more environmentally and animal welfare friendly alternatives to intensive/feedlot systems of production (Li *et al*., 2016). Animal products labelled as "grass-based", can command a price premium but authentication methods are required to validate the system of production and make it less likely that counterfeit products be fraudulently sold under such labels. Use of NIRS has been used to authenticate a variety of non-meat foods and was able to discriminate between beef aged for different periods *post-mortem* (Moran *et al.,* 2018). The objective of this study was to determine the potential of NIRS to discriminate between beef from cattle fed different diets before slaughter.

Material and methods Samples of *longissimus* muscle were collected from two cattle experiments. In experiment 1, suckler bulls were offered: grass only (G0), rolled barley-based concentrate (BC), or with half of the rolled barley replaced with maize meal (MM50) or flaked-toasted maize (FM50) *ad libitum*. In experiment 2, Angus heifers were offered: grass only (Grass), grass silage plus 0.45 dietary intake as concentrates (GSR); GSR but in which the final concentrate was supplemented with plant oil (GSN) or concentrates *ad libitum* (CON*)*. At 72 hours *post-mortem* and after 1 hour of oxygenation, 5th rib steaks were scanned (350-2500 nm at 1 nm intervals, raw spectra) in reflectance mode using a portable ASD Labspec 5000 (ASD Inc., Boulder Colorado, USA) NIR spectrometer fitted with a high-intensity contact probe with a 10 mm spot size and using the Indico Pro program (ASD Inc.). Raw spectra were recorded in duplicate and exported as JCAMP [log(1/R)] to the Unscrambler X version 10.3 (CAMO ASA, Oslo, Norway) for chemometric analysis.

Results The results of the principal components analysis are shown in Figure 1. For experiment 1 (left panel), samples from grass-fed bulls were clearly separated from samples from the bulls fed concentrates. There was no separation between samples from bulls fed the different concentrates. For experiment 2 (right panel), samples from forage-fed heifers were also clearly separated from samples from heifers fed concentrate-based rations. There was some evidence that NIRS could distinguish between heifers fed grass only or grass silage supplemented concentrates before slaughter.

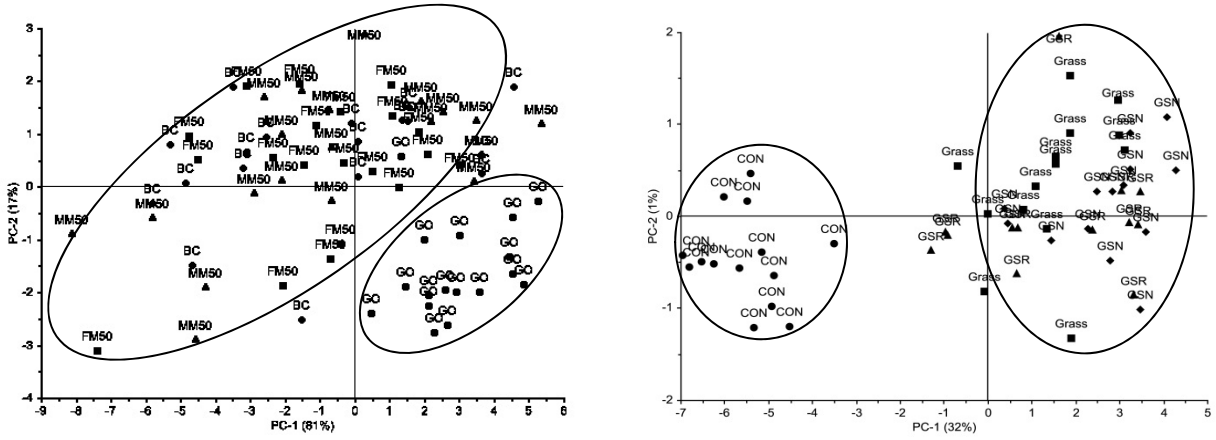

Figure 1 Principal components analysis of NIR spectra of beef from cattle fed different rations

Conclusion This preliminary analysis has shown that NIRS can be used to discriminate between grass-fed and concentrate-fed beef. This potential can be enhanced by further chemometric analysis.

Acknowledgements The experiments described were from projects (11/SF/322 and 13/F/514) funded by the Irish Department of Agriculture, Food and the Marine's competitive research programmes.

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006

Regional effects on consumer acceptability of grilled beef

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Application Consumers from Great Britain (GB), Northern Ireland (NI) and Republic of Ireland (ROI) like the same steaks, although British consumers give higher scores. Therefore, sensory panels conducted in any of these regions are comparable.

Introduction ROI and NI supply a large quantity of beef to GB. The industry has asked if sensory panels conducted in NI or ROI can predict the quality assessments of consumers in GB. Differences in consumers' overall liking score for beef have been found between four cities in the United States (Neely *et al*., 1999) while Australian studies have shown that, while there may be differences between small groups, consumers from all countries and regions show good agreement (Polkinghorne *et al*., 2008). AFBI have investigated how regions of the British Isles and socio-demographic factors influence consumer liking of beef (Chong *et al*., 2018).

Material and methods Beef striploins were taken from treatments selected to give a range of eating qualities. The steak was grilled by a common protocol and samples of the same striploins assessed by 120 consumers in each of Belfast (NI), Cork (ROI) and Reading (GB). They scored on a line-scale for tenderness, juiciness, flavour liking and overall liking.

Results Region had significant effects on all consumer sensory scores as shown in Table 1. GB consumers gave higher mean scores for the beef striploin samples, with highest differences observed for tenderness and juiciness. However, region x treatment interactions were not significant, showing that consumers from these regions liked the same steaks.
The differences between GB and ROI/NI consumers were not explained by sociodemographic factors, such as age, gender or income. However, there is some evidence that the higher scores from the GB consumers may arise from their greater consumption of less tender cuts, such as rump steak and topside roasts (Figure 1).

Table 1 Effect of region, treatment and interaction on consumer scores for palatability traits

	Region					Treatment		R.T	
Attribute	NI	ROI	GB	SED	Sig	SED	Sig	SED	Sig
Aroma liking	55.9^{a}	57.4^{a}	62.3^{b}	1.76	<0.001	2.04	0.001	2.91	0.180
Tenderness	55.9^{a}	57.4^{a}	62.3^{b}	1.76	<0.001	3.82	<0.001	4.35	0.125
Juiciness	53.2^{a}	51.6^{a}	56.8^{b}	1.57	0.003	3.79	<0.001	4.32	0.079
Flavour Liking	54.3^{ab}	50.8^{a}	55.3^{b}	1.77	0.033	2.93	<0.001	3.62	0.453
Overall Liking	55.6^{a}	55.7^{a}	59.6^{b}	1.64	0.023	3.24	<0.001	3.82	0.322

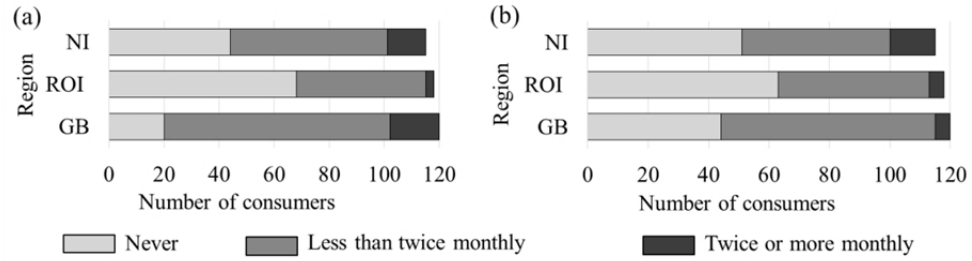

Figure 1 Differences in consumption frequency between regions for (a) rump (P<0.001) and (b) topside (P<0.01)

Conclusion Sensory panels conducted in NI, ROI or GB provide comparable results for exporters of beef to GB. Such consumer studies provide retailers and processers with an understanding of consumers and enables more directed marketing.

Acknowledgements The authors gratefully acknowledge funding through the Sensory Food Network Ireland by the Department of Agriculture and Food's Food Institutional Research Measure (FIRM: 13 SN 401).

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007

Can the fatty acid profile of muscle discriminate between steers finished at pasture or indoors on *ad libitum* concentrates?

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Application If concentrates are needed to meet a carcass weight target, the fatty acid profile of beef will be negatively affected.

Introduction Compared to concentrates, feeding fresh grass results in a higher proportion of *cis-9, trans-11* conjugated linoleic acid (CLA) and n-3 polyunsaturated fatty acids (PUFA) in muscle lipids. The latter contributes to a beneficial decrease in the n-6: n-3 PUFA ratio (Scollan *et al*., 2014). In production systems where grass-fed cattle may require concentrate supplementation to meet a target weight/fatness, the effect of grazing on the fatty acid profile of beef is diluted. Increasing the grazing period before concentrate finishing may ameliorate this effect. Our first objective was to determine the effect on muscle lipids of concentrate finishing of previously grazed cattle. Animal products labelled as "grass-based", can command a price premium but authentication methods are required to re-assure consumers. Our second objective was to determine the potential of the fatty acid profile to discriminate between beef from cattle from different production systems.

Material and methods Fifty-four male calves, the progeny of Holstein-Friesian cows were used. They were grazed for 132 days until August when they were blocked on sire breed and liveweight and assigned to 3 finishing strategies, i.e. pasture for a further 94 days to slaughter (Grass), concentrates *ad libitum* indoors for 94 days to slaughter (CON), pasture for a further 94 days followed by concentrates *ad libitum* indoors for 94 days to slaughter (GCON). At 24 hours *post mortem*, samples of *m. longissimus dorsi* muscle were collected and stored at -20^{0}C for fatty acid analysis (Moreno *et al*., 2008). Data were subjected to analysis of variance with a model that had block and finishing strategy as effects. Data were also subjected to multivariate analysis using MetaboAnalyst 4.0.

Results For Grass, CON and GCON, mean carcass weight was 244, 287 and 329 (sed 7.2), respectively .Concentrate finishing for the same period as pasture increased intramuscular fat concentration and the n-6: n-3 PUFA ratio and deceased the proportion of CLA (Table 1). A longer period at pasture prior to concentrate finishing did not enhance the fatty acid profile. Principal components analysis indicated good separation between Grass and concentrates *per se* with some potential for separation of the two concentrate-feeding systems (Figure 1).

Table 1 Fatty acid composition of intramuscular lipid in steers finished at pasture or on *ad libitum* concentrates indoors

	Grass	CON	GCON	sed	Sig
Total (mg/100g muscle)	2198	3369	3955	244.9	***
Linoleic acid[1]	27	42	42	2.2	***
Linolenic acid[1]	14	6	6	0.4	***
CLA[1,2]	6	3	4	0.3	***
SAT[1,2]	457	421	416	7.5	***
PUFA[1,2]	82	78	77	3.1	NS
PUFA:SAT	0.18	0.19	0.19	0.009	NS
n-3:n-6 PUFA	1.72	4.79	4.29	0.189	***

[1]g /kg fatty acids, [2]conjugated linoleic acid, saturated , monounsaturated and polyunsaturated fatty acids.

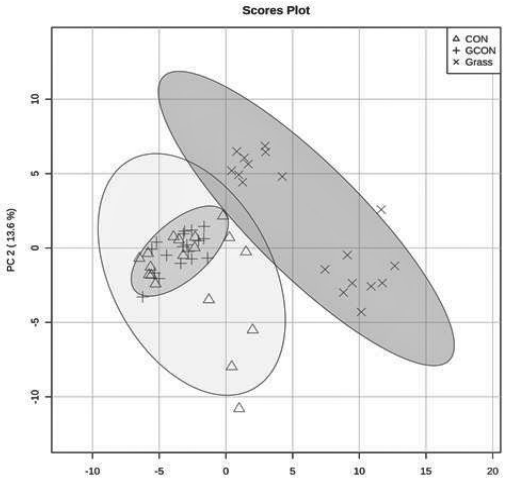

Figure 1 Principal components analysis of the fatty acid profile of beef

Conclusion The influence of pasture on the fatty acid profile of beef was confirmed. From a fatty acid perspective, there was no benefit from prolonging the grazing period. The preliminary chemometric analysis confirmed the potential of the fatty acid profile as a tool to authenticate the dietary history of beef.

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008

Estimation of fatty acid profiles in meat using rumen microbiome information from beef cattle

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Application The use of relative rumen microbial gene abundances, based on one rumen sample taken in the abattoir, to estimate meat fatty acids profiles has great potential as proxy traits for breeding. This also provides the opportunity to be combined with estimation of methane emissions and feed conversion efficiency using the same sample and methodology.

Introduction Beef provides high quality proteins, vitamins, minerals, bioactive substances and antioxidants but contains high amounts of saturated fatty acids contributing to obesity in humans, a main risk factor for cardiovascular disease. To alleviate this adverse effect, breeding for an increase in unsaturated fatty acids such as omega-3 fatty acids and conjugated linoleic acid (CLA) are of interest. The variation in fatty acid composition between and within breeds is large and the heritability is moderate to high, indicating the potential for changes through selective breeding (Hocquette *et al.,* 2017). However, the measurement of fatty acids in meat is costly so that the estimation of fatty acid profiles using rumen microbial information may provide an opportunity for accurate and cost-effective estimates of fatty acids in meat on a large population of beef cattle which is necessary to obtain reliable breeding values for these traits.

Material and methods The data were obtained in an experiment using a 2 × 2 factorial design of breeds and diets comprising of 72 rotational crossed Aberdeen Angus and Limousin steers. The animals were offered one of two complete diets *ad libitum* consisting (g/kg DM) of 480 forage to 520 concentrate or 80 straw to 920 concentrate. Ingredients and chemical composition of diets are reported in Rooke *et al*. (2014). The rumen microbial gene abundances were determined using whole metagenomic sequencing of microbial DNA extracted from post-mortem rumen samples (fluid digesta) and by aligning the obtained reads to the KEGG database as described in detail by Roehe *et al.* (2016). Orthogonal partial least squares analysis (OPLS) using R (Thevenot *et al.,* 2015) was applied to identify the rumen microbial gene abundances significantly (Variable Importance in Projection (VIP) > 0.70) associated with fatty acid composition (mg/100 g muscle) in the 10th rib loin muscle. In the model the experimental factors of breed and diet were considered as well as relative abundances of microbial genes.

Results The relative abundances of rumen microbial genes presented in Table 1, considering breed and diet as fixed effects, explained 52.7% of the variation in CLA. These microbial genes are involved in biological processes such as amino acid, glycogen and L-serine biosynthesis suggesting complex interactions of these processes and fatty acid metabolism. For example enhanced glycogen biosynthesis increased CLA whereas L-serine biosynthesis reduced CLA in meat. In further analyses, we found that the relative microbial gene abundances could also estimate the omega-3 fatty acids such as α-linolenic, eicosapentaenoic and docosahexaenoic acids with an explained variation of 47.1%, 12.4% and 8.6% respectively.

Table 1 OPLS analysis estimating CLA in meat based on relative abundances of rumen microbial genes

KEGG ID	Description	Coef.	VIP	Biological process
K01507	Inorganic pyrophosphatase	0.022	1.06	Electron transport phosphoryl.
K00700	1,4-alpha-glucan branching	0.174	1.05	Glycogen biosynthesis
K00826	Branched-chain amino acid aminotransferase	0.079	0.97	Amino acid metabolism
K01649	2-isopropylmalate synthase	0.189	0.94	Amino acid biosynthesis.
K00290	Saccharopine dehydrogenase (NAD+, L-lysine)	0.025	0.93	Amino acid biosynthesis
K00600	Glycine hydroxymethyltransferase	-0.002	0.83	Methyltransferase
K00058	D-3-phosphoglycerate dehydrogenase	-0.102	0.81	L-serine biosynthesis
K00265	Glutamate synthase (NADPH/NADH) large chain	0.172	0.74	Glutamate biosynthesis
K01834	Phosphoglycerate mutase (PGAM)	0.081	0.74	Glycolysis

Conclusion The relative abundances of rumen microbial genes were able to estimate fatty acids such as CLA at a level of accuracy to be of relevance for genetic improvement programmes. The identified microbial genes associated with CLA are involved in biological processes which in other studies using *in vitro* techniques have been shown to affect CLA production.

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009

Evaluation of the structural and rheological properties of wheat and maize ingredients that underpin differences in growth performance and meat quality in broilers

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Application Birds offered maize-based diets had improved feed conversion ratios. However, wheat-fed birds demonstrated improved carcass quality, with lower drip losses and more desirable meat colour traits for UK markets.

Introduction Wheat and maize are two of the most commonly utilised cereals globally in broiler feeds. While maize is considered to have a highly suitable composition to support broiler performance, wheat has various properties, such as a lower digestibility of starch components compared to maize (Kiarie *et al.*, 2014), and contains anti-nutritional factors (Amerah , 2014), which could impact the birds ability to reach genetic potentials (Choct and Annison, 1990). However, the carotenoids present in maize, such as lutein and zeaxanthin, can impact meat colour and perceived carcass quality (Odunitan-Wayas *et al*., 2016). Despite these differences in composition, comparative studies depicting overall benefits of feeding either maize or wheat on broiler growth performance and meat quality remain unexplored. The overall objective of the study was to determine if cereal composition contributed to variations in growth performance and carcass quality of maize-fed and wheat-fed broilers.

Material and methods A total of 72, 10-day old, Ross 308 broiler chicks were housed in groups of 6 in metabolism cages and offered maize or wheat-based grower diets (n = 6 / treatment) until day 24. From day 25 to 38, a maize or wheat-based finisher diet (n = 6 / treatment) was offered. Enzymes were not added to either dietary treatment. Production parameters analysed included growth performance indicators; such as feed intake, body weight gain, feed conversion ratio, mortality and European Production Efficiency Factor (EPEF). Meat quality was assessed by analysing drip loss rate, colour, temperature, pH and shear force, as well as lipid peroxidation. Dry matter, neutral detergent fibre, acid detergent fibre, gross energy, ash, crude protein and crude fat contents along with starch structure, starch viscosity, water absorption and solubility index of maize and wheat samples were measured and statistical analysis using t-tests were conducted as appropriate, using Microsoft Excel.

Results Birds offered maize-based diets had improved feed conversion ratios due to significantly lower feed intake during the finisher phase compared with wheat-based diets. This contributed to an EPEF improvement of 5.97% in the maize-fed broilers. However, wheat-fed birds demonstrated improved carcass quality, with lower drip loss, a significantly lower meat pH 24-hours post-slaughter and less yellow coloured meat, which is a desirable trait in UK markets. Microscopic images captured indicated that starch granules within wheat are larger than those in maize. There are also fewer visible starch granules within the solubilised wheat in comparison to maize. Finally, the overall structure of the starch molecules differ, with wheat starch granules being distinctly spherical and maize starch granules taking a polygonal form. Starch pasting profiles depicted a higher peak viscosity at an earlier time-point in maize samples than wheat, indicating a comparatively superior breakdown and digestibility of starch granules within maize samples.

Table 1 Results of performance parameters analysed for maize or wheat-fed broilers (n=12)

Measurement	Wheat	SEM	Maize	SEM	P Value
Final Body Weight (kg)	3.180	0.037	3.150	0.039	0.300
Finisher – ADG(g)	0.114	0.003	0.112	0.002	0.289
Finisher – ADFI (g)	228.989	5.219	193.067	2.344	< 0.001
Finisher – FCR	1.987	0.026	1.710	0.011	< 0.001

Conclusion Maize-fed broilers had a superior growth performance compared to wheat-fed broilers. In contrast, the carcass quality excelled when wheat was fed as the primary cereal. Therefore, future studies to determine if an optimum cereal combination of both maize and wheat exists to enhance both growth performance and meat quality is essential in improving overall broiler production efficiency and economic performance.

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010

Novel methods of extending the shelf life of minced beef

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Application Studies have been carried out to evaluate the effect of High Pressure Processing (HPP) and active packaging on the shelf life of raw minced beef. Results show that lemongrass oil based active packaging can extend shelf life by 2 days, while HPP application alone extended shelf life by 28 days. Synergistic effects between active packaging and applied HPP have been shown to extend shelf life of raw minced beef by as much as 52 days.

Introduction Shelf life extension has long been a major goal of the meat industry. Currently, producers use combinations of packaging solutions, storage conditions and food additives to minimize microbial spoilage. HPP has been shown to extend the shelf life of a variety of food stuffs (Stratakos *et al*., 2015) and there is growing interest in the antimicrobial properties of essential oils (Burt, 2004). The aim of the present study was to identify the synergistic effects of both HPP and antimicrobial oil based active packaging on the shelf life of raw minced beef.

Material and methods Selected essential oils were screened for potential antimicrobial activity by means of disk diffusion assays. Following screening, three oils were selected: lemongrass, clove and cinnamon. Active packaging materials were prepared by applying appropriate concentrations of each oil on to food grade film. Minced beef (near sell by date) was purchased from local retail outlets and portions were applied aseptically to the prepared active packaging. Active packaged minced beef samples were then HPP-treated (0, 400 & 500MPA). Samples were stored at 4^{o}C until required. Samples were analysed for aerobic and anaerobic Total Viable Count (TVC) and Lactic Acid Bacteria (LAB). Sampling continued until bacterial numbers had stopped increasing and/or reached approximately 1 x 10^{10} CFU/g.

Results Figure 1 shows the observed aerobic TVC counts for all treatments. The results show that each active packaging treatment, alone, effected a significant ($P<0.05$) 2 Log reduction in aerobic TVC (after 7 days) when compared to a control treatment, though there was no difference after 14 days. Observed shelf life extensions using the HPP treatments were consistent with previous findings (1). Synergistic effects were observed when active packaging treatments were HPP treated. Here, the lemongrass oil active packaging treatment performed best with shelf life being extended by 18- 24 days (400MPA), 48-52 days (500MPA). Similar results were observed for TVC anaerobic and LAB counts.

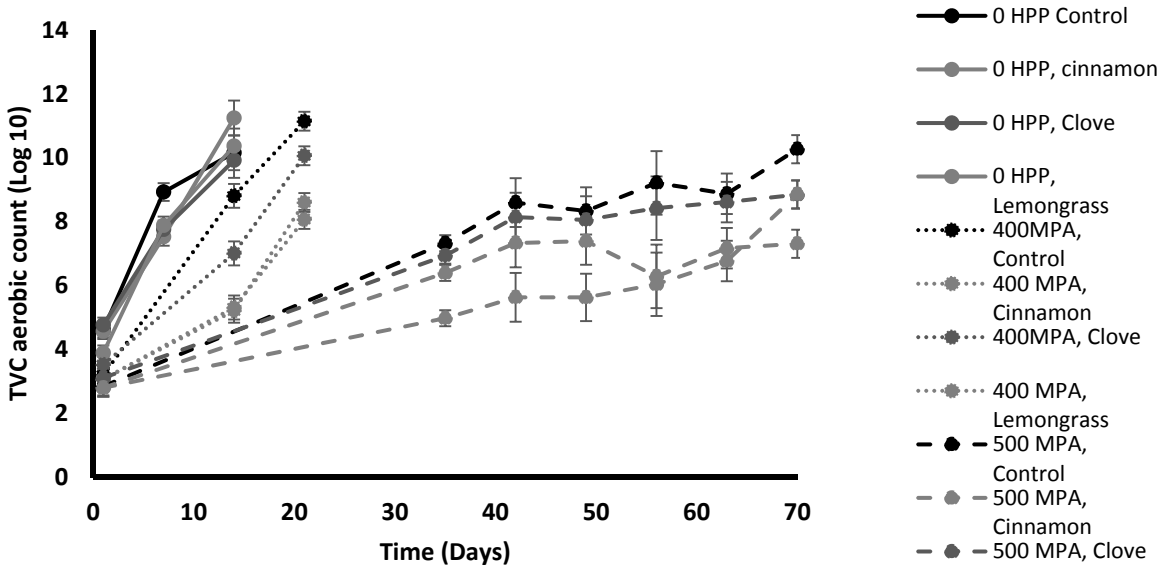

Figure 1 Effect of active packaging and HPP on TVC (aerobic) count (Log10)

Conclusion The synergism between HPP treatment and active packaging significantly increased the shelf life of raw minced beef. Further studies investigating the effect on pathogenic organisms and sensory evaluation are required.

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011

Using pre-weaning lamb liveweight as a predictor of carcass quality

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Application Improved understanding of the relationship between a lamb's early growth and the resultant carcass quality can help inform on-farm management decisions, for example whether to supplement ewes during pregnancy and lactation.

Introduction Within the European Union lamb carcases are graded according to the conformation score (carcass shape) and the fat class (visible subcutaneous fat), a system that aims to grade animals according to their genuine economic value (Johansen *et al*., 2006). Although attempts have been made to utilise finishing liveweight as a predictor of carcase fat and muscle composition (Lambe *et al*., 2008), the impact of a lamb's early development on carcase grades is not well-understood. This study therefore investigated the feasibility of predicting these quality parameters from pre-weaning liveweight information.

Material and methods Data on liveweight, carcass conformation and fat class of 2103 Suffolk cross lambs were collected at the North Wyke Farm Platform (Takahashi *et al*., 2018), a BBSRC National Capability grazing trial in Devon, UK, between 2011–2017. Lambs were 49.9% female and 50.1% male, with a mean slaughter age of 162 days. Ewes had a mean age of 4.3 years at lambing (ranging from 2–7 years) and reared an average of 1.8 lambs per season. Liveweight of lambs was recorded at four weeks, eight weeks and 90 days (immediately before weaning) from birth and then every two weeks thereafter until finishing, on meeting the target weight of ~40kg. Conformation score and fat class was obtained from the slaughterhouse. The causal relationship between liveweight at various ages and carcass quality was tested on R 3.5.1 by the means of multinomial probit regressions with a Markov chain Monte Carlo algorithm (Imai *et al*, 2005), under which year, birth litter size and sward type (permanent pasture, reseeded monoculture, grass/clover mix: Orr *et al*., 2016) were treated as fixed effects.

Results Amongst the liveweight recorded at various ages, both conformation score and fat class showed a strong correlation with that at weaning; with a heavier weight associated with a better conformation score ($p < 0.001$) and a lower fat class ($p < 0.001$) at slaughtering (Figures 1 and 2). Eight-week weight was also significantly different between fat class groups ($p < 0.001$) but not between conformation score groups ($p = 0.26$). The results of multinomial probit regressions supported the causal relationship between weaning weight and both the quality parameters; posterior predictions based on fitted (Bayesian) models indicated that, across the entire sample, a 1kg increase in weaning weight increases the likelihood of observing conformation scores E and U, and fat classes 1 and 2. Most fixed effect parameters were shown to have negligible impacts on carcass quality. An auxiliary analysis to explore further causal chains revealed that the lamb's liveweight at weaning, in turn, was significantly and positively correlated with the ewe's body condition at lambing ($p < 0.001$).

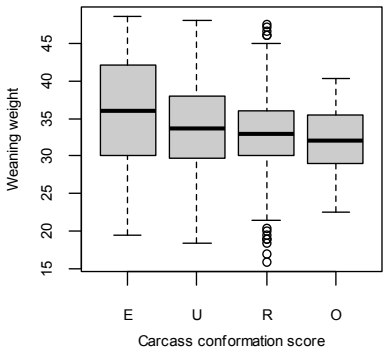

Figure 1. Weaning weight by carcass conformation

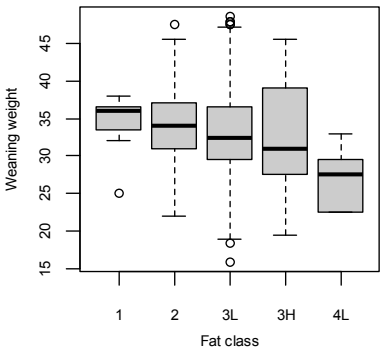

Figure 2. Weaning weight by fat class

Conclusion The above findings suggest that the fat and muscle composition of lambs may be largely determined prior to weaning. A stronger focus on ewes' condition before and during lactation could prove beneficial for the system-wide profitability.

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012

Herd incidence of *Fascioliasis hepatica* and its impact on slaughter traits in beef cattle

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Application *Fascioliasis hepatica* (FH) reduces the efficiency of beef production through higher inputs whilst getting lower outputs. Feedback from meat inspection data could improve awareness and influence solutions to be developed.

Introduction In a preliminary study of routinely recorded meat inspection data we found that the liver was the most common part condemned and FH was the most common cause for condemnation in cattle. *Fascioliasis hepatica,* the liver fluke, is a common parasite affecting the health and welfare of ruminant livestock globally. Many affected cattle still achieve target weights and show no ill health but the infestation is considered important because of financial losses to the industry from condemned livers. Further considerations include the resistance to flukicides, the risk of residues entering the food chain and the impact due to reduced production efficiencies. The objectives of this study were to a) produce a dataset combining abattoir data on carcase attributes and condemnations together with cattle movement data from the British Cattle Movement Service (BCMS) database and b) to investigate the association between FH and carcase attributes.

Material and methods Condemnation together with carcase data (net weight, conformation and fat class) were supplied from three abattoir companies between 2012 and 2016 which were further integrated with cattle movement data. The resultant edited dataset comprised of 225,112 animals from 16 sire breeds. Animals were classed as 1 (affected by FH) or 0 (assumed not affected) and incidence was categorised into four groups (0 to ≤5%, >5 to ≤25%, >25 to ≤50%, and >50%) for each finishing herd and year of slaughter grouping (FHYS). The effect of FHYS incidence of FH on slaughter traits (age at slaughter (AGE), net carcase weight (NCW), average daily carcase gain (ADCG), conformation (CONF) and fat (FAT) class) were investigated using a linear regression model employed in ASReml (Gilmour *et al,* 2009). The model included incidence group fitted as a fixed effect together with sire breed, dam breed, age group of dam, category of animal (heifer, steer, young bull), year and month of slaughter, abattoir, and dairy percentage of the dam as a covariate. Convergence was reached for each slaughter trait and t-tests were carried out to determine the significance of differences ($P \leq 0.05$) of predicted means between pairwise comparisons of FHYS incidence groups.

Results Animals from the highest FHYS incidence group were predicted to be slaughtered 97 days later with a lower carcase weight difference of 7kg compared with animals from the lowest FHYS prevalence group (Table 1).

Table 1 Predicted means (SE) for herd incidence groups of FH for slaughter traits

Incidence Group	n animals	AGE (days)	NCW (kg)	ADCG (kg/d)	CONF (1-15)	FAT (1-15)
0 to ≤5%	68,749	671.0 (0.48)	348.1 (0.16)	0.54 (<0.001)	8.31 (0.006)	9.10[a] (0.007)
>5 to ≤25%	121,089	695.9 (0.36)	350.4 (0.12)	0.53 (<0.001)	8.35(0.004)	9.11[a] (0.005)
>25 to ≤50%	30,401	729.3 (0.70)	344.8 (0.24)	0.50 (<0.001)	8.18 (0.008)	8.89 (0.010)
>50%	4,873	767.9 (1.65)	340.9 (0.56)	0.48 (<0.002)	7.96 (0.020)	8.50 (0.023)

[a] incidence groups were significantly different with the exception of superscripts with the same letter. CONF and FAT were adjusted to a 15 point numerical scale.

Conclusion The results from our study indicate that herds with higher incidence of FH condemnations were associated with a greater number of days to slaughter, lower net carcase weight, lower average daily gain, lower conformation score and a lower fat score. Meat inspection data can act as a surveillance tool for health problems such as FH. However, at present UK abattoirs are not required to provide feedback between the abattoir and the farmer on condemnations, which means that producers might not be aware of some problems or their extent. Benchmarking, such as providing farmers with the percentage of liver condemnations due to FH may urge action to take place, particularly among high prevalence herds, to find solutions to reduce the burden in their cattle.

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013

A further evaluation of the effects of supplementing ewes with Co, including method of administration on ewe and lamb performance

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Application Supplementing ewes with Co from 7 weeks pre-joining to 6 weeks prior to lambing has no effect on ewe or lamb performance.

Introduction Sixty nine percent of Irish sheep farmers supplement their flock with minerals/vitamins, 50% of those supplement ewes pre-joining with multi-minerals and Co predominantly (Hession *et al*. 2018a). Reproductive performance may be restricted when an animal is deficient in a particular mineral (NRC, 2007). In a previous study at Athenry (Hession *et al*. 2018b) it was found that supplementing ewes with Co from 7 weeks pre-joining until late pregnancy had no effect on ewe reproductive performance or the performance of their progeny. The aim of the current study was to further evaluate the effects of supplementation with Co, from pre-joining to late pregnancy, on ewe and lamb performance.

Material and methods A total of 250 ewes (Belclare, Belclare×Suffolk and >75% Suffolk; mean initial live weight 76.2 (SD 9.26) kg) were allocated at random, within genotype, to 1 of 3 treatments from 7 weeks pre joining to 6 weeks prior to lambing. The treatments were: no supplementation (control), Co via drench (drench) or Co via bolus (bolus). The concentration of Co in the drench was 2.1 mg/ml as $CoSO_4$ $(H_20)_7$; 15 ml were administered to the ewes at 14-day intervals equivalent to 2.25 mg/d. The bolus, administered at the start of the study, also contained $CoSO_4$ $(H_20)_7$ with an expected release rate of 1 mg/d and duration of efficacy of 6 months. The ewes were managed as one group in a rotational-grazing system until housing in December. Ewes were synchronised using progesterone impregnated sponges and joined with a panel of Charollais rams. Ewes were shorn at housing and offered grass silage *ad libitum*. Concentrate (containing standard mineral and vitamin levels) was offered from 6 weeks pre-lambing, the level offered depending on scanned litter size. Ewes and lambs were turned out to pasture within 2 days of lambing and managed in a rotational-grazing system; ewes rearing triplets received 0.5 kg concentrate daily for the first 5 weeks post-lambing while their lambs were supplemented with concentrate (up to max. of 300 g daily) until weaning (14 weeks of age). No supplement was offered to singles or twins or their dams. Samples of herbage were taken from each paddock pre-grazing and a representative sample of silage offered was collected once weekly for mineral analysis. The data were analysed as a randomised study using Proc MIXED of SAS to fit a model with fixed effects for treatment, breed and ewe age and ewe as a random term for lamb growth traits. Mortality data were analysed using Proc GENMOD and back transformed means are presented in Table 1.

Results The mean Co concentration of the herbage from 7 weeks pre joining to housing was 0.08 mg/kg DM. The effects of supplementation with Co and method of Co administration on ewe and lamb performance are presented in Table 1. Neither Co supplementation or method of administration had an effect (P>0.05) on litter size, number of lambs reared/ewe joined, ewe BW, ewe BCS, lamb weight at birth or weaning, or on lamb mortality.

Table 1 The effects of Co supplementation and method of administration on ewe and lamb performance

		Treatment				Contrast	
		Control (C)	Drench (D)	Bolus (B)	s.e	D v B	C v D+B
Ewe BW (kg)	- mid pregnancy	78.2	78.6	79.4	0.62	NS	NS
	- lambing	78.0	77.9	79.1	0.87	NS	NS
BCS	- mid pregnancy	3.6	3.6	3.6	0.04	NS	NS
	- lambing	3.5	3.4	3.5	0.07	NS	NS
Litter size		2.11	2.22	2.12	0.101	NS	NS
Lambs reared/ewe joined		1.77	1.80	1.63	0.120	NS	NS
Lamb weight (kg)	- birth	4.8	5.1	4.9	0.10	NS	NS
	- weaning	34.5	34.4	34.7	0.58	NS	NS
Lamb mortality (%)		7.6	7.9	9.7	-	NS	NS

Conclusion Supplementation with Co, either via drench or bolus, had no effect on ewe reproductive performance or the performance of progeny up to weaning.

Acknowledgements DH gratefully acknowledges support from the Teagasc Walsh Fellowship scheme.

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014

Determination of the bioavailability of nanoparticle copper oxide using a copper depletion, repletion technique in growing lambs

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Application Increased bioavailability of nano copper oxide (CuO) compared to conventional CuO could reduce the dose required to maintain the copper (Cu) status of ruminants and reduce excess Cu excretion into the environment.

Introduction In ruminants the apparent absorption of Cu is low, with between 0.02 and 0.07 of Cu from sources such as CuO being absorbed (Parkins *et al*., 1994), resulting in high levels of excretion into the environment. Improving the bioavailability of Cu could reduce the dose required and subsequently decrease the amount excreted into the environment (Swain *et al*., 2016). There is a general lack of information on the bioavailability of nanoparticle Cu and its effect on performance and health in ruminants. It is has been shown that supplying other trace minerals as nanoparticles improves their bioavailability compared to conventional sources, mainly because of their small particle size and functional coating. To date, most of the work has focused on selenium (Se) and zinc (Zn). For example, Rajendran *et al*., (2013) reported a significant increase in plasma Zn concentrations in cows receiving nano-Zn compared to ZnO with an associated improvement in milk yield. The objectives of the study were to establish the bioavailability of nanoparticle CuO compared to conventional CuO in growing lambs.

Material and methods Twenty eight, six month old Welsh Mountain lambs were used. The lambs were fed a Cu depletion diet (Table 1) for a period of 6 weeks until plasma Cu concentration was 9 µmol/L. The lambs were stratified and blocked according to plasma Cu concentration and liveweight and allocated to one of two treatments: **N**; nano CuO and **O**; conventional CuO for Cu repletion where Cu was supplemented at a rate of 9 mg/kg DM on top of the repletion basal diet (Table 1). Lambs were housed in individual, sawdust bedded pens and fed at 95% of *ad libitum* intake. Water was continuously available. Blood samples were collected at week 0, 1, 2, 4 and 8 at approximately 11.00 h by jugular venepuncture and stored at -20°C for subsequent analysis by ICP-MS, All sheep were slaughtered at a commercial abattoir at the end of the 8th study week (n=14 per treatment). Livers were collected at slaughter and stored at -20°C for subsequent analysis. Data was analysed by repeated measures analysis of variance using Genstat 18 as a randomised block design using data recorded in week 0 as a covariate where appropriate.

Table 1 Cu, Mo, Fe and S content of the basal diet for depletion and repletion phases

Mineral	Depletion	Repletion
Cu mg/kg	10.7	10.0
Mo mg/kg	5.9	0.5
Fe mg/kg	792	232
S g/kg DM	5.2	1.7

Results There was no effect of form of Cu on live weight gain ($P > 0.05$) with a mean value of 150 g/d. There was no effect ($P > 0.05$) of form on plasma Cu concentration but there was an effect of time ($P < 0.001$), with plasma Cu concentration increasing from week 0 to week 1 and then plateauing between week 1 and week 8 (Figure 1). Hepatic Cu concentration was increased ($P < 0.05$) in lambs supplemented with nano CuO compared to conventional CuO (Figure 2).

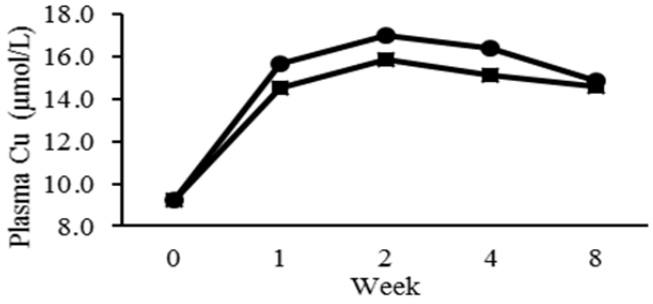

Figure 1 Effect of form of Cu on plasma Cu, µmol/L in growing lambs fed a diet containing nano CuO (●) or CuO (■) following Cu depletion.

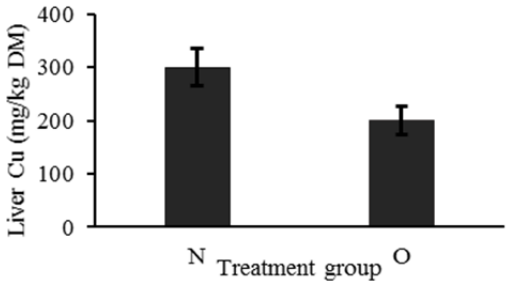

Figure 2 Effect of form of Cu on liver Cu (mg/kg DM) in growing lambs fed a diet containing nano CuO or CuO following Cu depletion. Error bars indicate the SEM.

Conclusion Nano CuO has a greater bioavailability than conventional CuO. Supplying CuO as a nanoparticle did not have any effect on the health or performance of growing lambs.

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015

Is the maintenance energy requirement for current sheep flocks higher than recommended?

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Application Updated maintenance energy requirements for sheep have been developed.

Introduction There is evidence indicating that current energy rationing systems used in the UK (AFRC, 1993) may underestimate maintenance energy requirements for the current sheep flock (Cottrill *et al*., 2009). The aim of the present study was to address this knowledge gap by developing updated maintenance energy requirement using sheep calorimeter chamber data.

Material and methods A total of 131 calorimeter chamber observations were collated from five sheep experiments undertaken in the Agri-Food and Biosciences Institute (Hillsborough, UK) from 2013 and 2017. These studies were designed to evaluate effects of a range of animal (maternal sire vs. terminal sire; lamb vs. ewe; male lamb vs. female lamb vs. castrated lamb) and dietary (restricted vs. *ad libitum* feeding; forage only vs. forage+concentrate; fresh grass vs. grass silage) factors on energetic efficiencies. All animals were individually housed in pens and offered experimental diets for at least 19 d. Afterward, animals were transferred to individual calorimeter chambers and stayed there for 5 d with measurements of energy intake and outputs in the final 4 d. Energy balance (E_g) was calculated as the difference between GE intake and a sum of faecal energy, urine energy, methane energy and heat production (HP). Date were analysed using the REML analysis to develop the relationship between E_g or HP and ME intake. The effects of experiment, age of animal, chamber number, dietary type, sheep sire, gender and physiological stage on the relationship between E_g or HP and ME intake were removed. The statistical program used in the present study was Genstat statistical package.

Results and Discussion The linear regression relationships are presented in Table 1 and Figure 1. The r^2 value in the relationship between E_g or HP and ME intake was 0.765 or 0.534, and all the relationships were highly significant ($P < 0.001$). The net (NE_m) and metabolisable (ME_m) energy requirements for maintenance derived from these relationships were 0.358 and 0.486 MJ/kg$^{0.75}$, respectively. The present NE_m (0.358 vs. 0.256 MJ/kg$^{0.75}$) and ME_m (0.486 vs. 0.348 MJ/kg$^{0.75}$) values are respectively 40% higher than those calculated using the equations of AFRC (1993) and the mean live weight (42.2 kg) and ME/GE (0.669) obtained in the present study. Similarly, the present NE_m value is higher than that (0.234 MJ/kg$^{0.75}$) recommend by NRC (1985).

Table 1 The relationship between E_g or HP and ME intake[1,2]

Equation	r^2	NE_m	ME_m
$E_g = 0.736_{(0.057)}$ ME intake - $0.358_{(0.066)}$	0.765	0.358	0.486
HP = $0.264_{(0.057)}$ ME intake + $0.358_{(0.066)}$	0.534	0.358	

[1]Unit = MJ/kg$^{0.75}$ for E_g, ME intake, HP, NE_m and ME_m.

[2]Values in parentheses are SE.

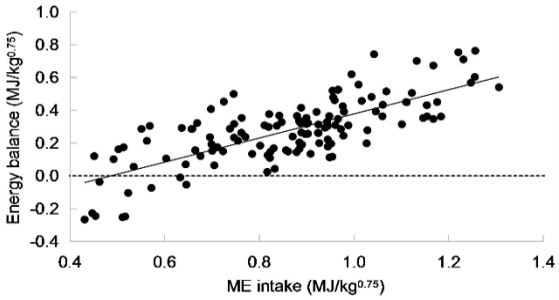

Figure 1 Relationship between ME intake and E_g

Conclusion The present result indicates that using the energy system of AFRC (1993) to ration the current sheep flocks may underestimate the maintenance energy requirement. Therefore, there is a need to update this system to reflect the higher maintenance energy requirements of the current sheep flocks.

Acknowledgements This work was co-funded by DAERA, AHDB and AgriSearch.

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016

Sheep grazing system performance under continuous stocking or cell grazing management during an unusually dry grazing season in Devon

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Application Under extreme dry weather conditions the cell grazing system allows pasture to recover from defoliation, maintaining herbage mass at desirable levels and preventing removal of animals from pasture.

Introduction The aim of grazing management is to supply the quality and quantity of forage required for grazing animals which is best achieved by moving livestock among smaller grazing units to regulate grazing pressure (Badgery *et al*., 2017). Cell grazing divides pastures into equally-sized cells which are rotationally grazed based on pasture growth, herbage mass, forage quality and animal performance. Here we report on the first year's results from a long-term experiment aimed at comparing the performance of different pasture systems under continuous stocking or cell grazing treatments.

Material and methods Four 1-ha permanent pasture plots, arranged in two blocks, were randomly allocated to two treatments (grazing strategy): cell grazing (CG) and continuous stocking (CS). In the CG, each plot was split into 60 equally-sized cells: the rotation length was 20 d until weaning (6 cells allocated every 2 d) and 30 d from weaning (4 cells allocated every 2 d). In CS, sheep had access to the whole grazing area. Each plot was initially grazed by 12 ewes and their 24 lambs from lambing to weaning. Modifying either the grazing area (by fencing-off) or the number of animals are strategies considered for managing any forage surplus or deficit. After weaning, only lambs grazed the plots for 7 weeks until the end of the experimental period. Animals were weighed monthly until weaning and fortnightly after weaning. Herbage mass was assessed weekly with a plate meter using the equation 'kg DM/ha = 125 x + 640', where x is the average compressed sward height. Accumulated rainfall in May was 35 mm and in June-July was 24 mm (50% and 21% of the normal average, respectively). Data on pasture and animal performance were analysed by ANOVA using GenStat® 18th Ed.

Results Initial herbage mass (HM) was similar (p = 0.68) averaging 2385 kg DM/ha and the average HM until weaning did not vary between CG and CS plots (2348 vs. 1902 kg DM/ha, respectively; p = 0.10). However, average HM post-weaning tended to be greater in the CG (2187 vs. 1749 kg DM/ha; p = 0.054), whilst the final HM was greater on the CG (2493 vs. 2034 kg DM/ha; p = 0.044) (Figure 1, ±SEM). Four extra ewes and their twin lambs were added on May 4th to one CG plot and grazed until weaning (July 4th) given the high average HM (above 2500 kg DM/ha). Moreover, 280 kg DM (□ 2511 kg DM/ha) were harvested from 7 cells on June 18th from the same plot, which is equivalent to an increase of 22 kg liveweight (LW). In contrast, two weeks after weaning, nine lambs had to be removed from each CS plot due to the low average HM (1649 kg DM/ha). A rapid decrease on HM in the CS plots was observed in the first weeks whilst the CG plots kept a more constant HM. Although numerical differences were recorded in stocking rate (SR) post-weaning and growth rate of lambs (ADG), no significant differences were observed between grazing systems on SR, LW gain per ha or ADG (Table 1).

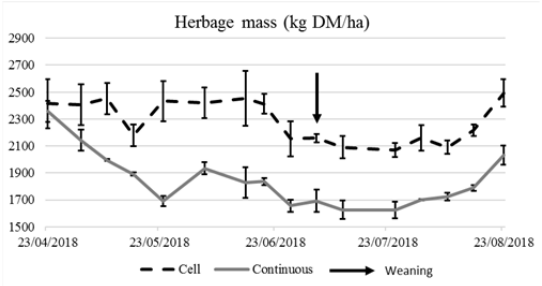

Figure 1. Average pasture cover on CG and CS plots

Table 1 Sheep system performance under cell grazing (CG) and continuous stocking (CS) management (23-04 to 23-08)

	SR (kg LW/ha		LW gain (kg/ha)	ADG(kg/d)	
	Pre-W	Post-W	Exp. Period	Exp. Period	Post-W
CG	1315	755	641.0	0.186	0.136
CS	1350	632	667.3	0.243	0.155
SEM	33.0	35.9	21.4	0.019	0.0230
p value	0.93	0.25	0.55	0.28	0.66

SR: stocking rate (average); LW: liveweight: ADG: average daily gain (lambs); W: weaning (4th July 2018)

Conclusion During the first season of evaluation on a permanent pasture, the cell grazing strategy showed superiority over a continuous stocking strategy in terms of maintaining the average herbage mass above the threshold (1800 kg DM/ha) and keeping the stocking density during the grazing season, even under severe drought conditions. The next step will be evaluating these strategies across time on different sward types and including sustainability-related variables.

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017

Characterizing individual differences in goats responses to a nutritional challenge using milk metabolites

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Application Knowledge of animal resilience to perturbations could be used to tailor management. This paper presents a method for doing this based on milk metabolite measures.

Introduction Characterizing robustness at the level of the individual animal would be valuable for refining management and selection strategies. Accordingly, to explore differences in adaptive capacity we studied responses of animals to a short-term nutritional challenge with the aim of identifying individual variation in milk metabolite profiles.

Material and methods At 2 different stages of lactation, sixteen lactating dairy goats were exposed to a 2-d underfeeding challenge (7-d control period with standard total mixed ration (TMR), 2 d of straw only feeding, and a 10-d recovery period on the TMR). The first challenge was in late lactation and the second was carried out on the same goats early in the following lactation. During these challenges, milk samples were taken at each milking for standard milk composition measures. In addition, milk was analyzed for β-hydroxybutyrate (BOHB), glucose-6-phosphate (G6P), galactose (GAL), free_glucose (Free_Glu), uric acid (UA), lactate dehydrogenase (LDH), triacylglycerol (TAG), isocitrate, urea and cholesterol (Chol). The response profile for each goat was analyzed to describe the relationship between the pre-challenge period, response to challenge and post-challenge using a piecewise model with 4 parameters described by Friggens al. (2016). Cluster Analysis was carried to identify the goats with a similar response profile using the expectation maximization (EM) algorithm. This made it possible to determine the number of clusters for each initial variable as well as the membership of each goat in the different clusters. Using cluster membership, multiple correspondence analysis (MCA) was performed to characterize response profile types across animals.

Results For each milk measure the cluster analysis identified between 3 and 5 types of response/recovery prolife. The distribution of these profile types is shown in the left hand panel below (for the late lactation challenge). This MCA analysis identified 3 groups of animals (hatched squares in the figure). Further, as shown in the right hand panel below, discriminant path analysis was able to separate these groups of multivariate response/recovery profile type based on threshold levels of 2 milk metabolites; BOHB and free-glucose. Similar results were found for the early lactation challenge (not shown) with 3 groups of animals that could be discriminated by threshold levels of BOHB, free-glucose, and uric acid.

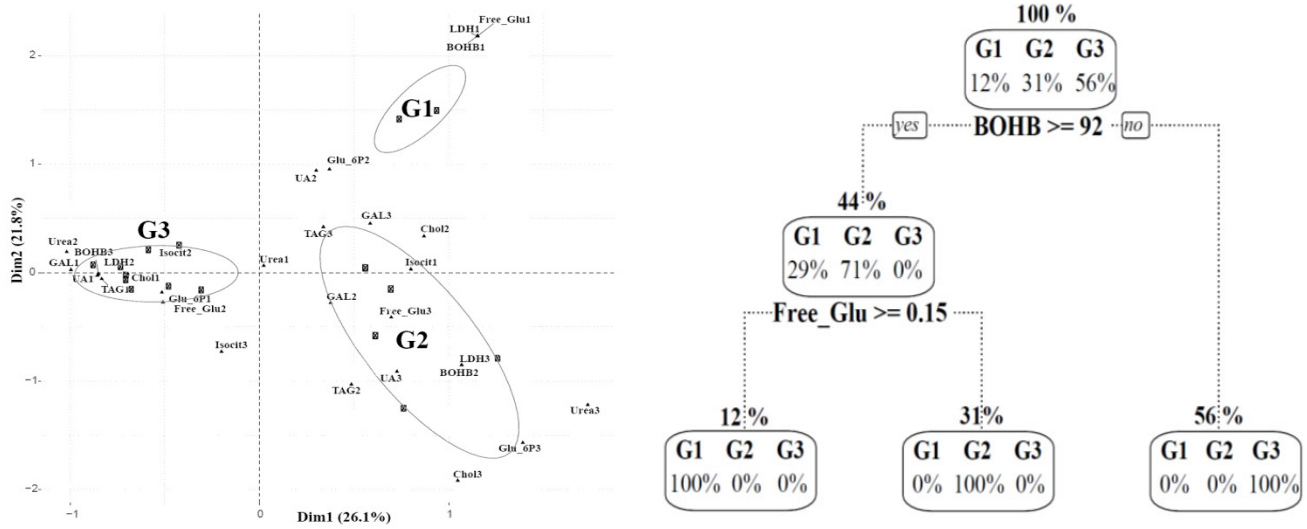

Figure 1 Distribution of response/recovery profile shown by MCA (left) and discriminant path analysis (right)

Conclusion Different types of response to short-term nutritional challenge can be distinguished from a limited panel of milk metabolites.

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018

Rumen parameters of West African dwarf goats offered concentrate supplement containing varying levels of dried Leucaena leaves

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Application Dried leaves of Leucaena (*Leucaena leucocephala*) included in concentrate supplement fed to West African dwarf goats reduced the ruminal concentrations of lactic acid, volatile fatty acids and ammonia N, but maintained rumen microbial populations.

Introduction The genetic potential of goat for growth, reproduction and lactation is dependent on adequate nutrition especially during the dry season when there is little or no quality forage for consumption. Browse species like *Leucaena leucocephala* and agro-industrial by-products like cassava peels, can serve as rich protein, energy and fibre source for goat sustenance during this period (Odeyinka, 2001; Fayemi *et al.,* 2011). Thus, this study tested the ruminal response of goats fed concentrate supplement with cassava and Leucaena as the major ingredients.

Material and methods Four concentrate supplements were formulated to contain four levels of air-dried leucaena leaves (0 g/kg (A), 50 g/kg (B), 100 g/kg (C) and 150 g/kg (D)) as dietary supplements for goats in an experiment that lasted 70 d. Twenty-four West African dwarf (WAD) goats weighing 8.5±0.24 kg housed in individual pens were allotted to four groups in a completely randomised design (Six goats per treatment). The other ingredients used for the concentrate diet are cassava peel, dried brewers grain, palm kernel cake, oyster shell and salt. Goats were served concentrate at 3% of body weight by 0700h, while fresh *Panicum maximum* (as basal diet) and water were made available for *ad libitum* consumption. Rumen fluid samples were collected prior to application of dietary treatments for baseline measurements of rumen parameters. On Day 70 of the experiment, rumen fluid was also collected (6 h post-feeding) from the goats using oesophageal tubes and used for analysis of rumen ammonia nitrogen, volatile fatty acids (Siedlecka *et al*., 2008) and microbial count (Galyean, 1989). Data obtained were subjected to one-way ANOVA.

Results The values obtained for volatile fatty acids decreased ($P < 0.05$) as the level of leucaena increased across the diets (Table 1), with the exception of propionic acid ($P = 0.57$) and butyric acid ($P = 0.85$) which were not affected. Rumen NH_3-N values declined ($P = 0.05$) from 2.16 mg/dL to 1.05 mg/dL at 0 and 10 % levels of Leucaena respectively. Microbial count of the rumen was not affected ($P > 0.05$) by the various inclusion levels of Leucaena.

Table 1 Rumen fermentation parameters of WAD goats fed levels of Leucaena

Rumen parameters	A	B	C	D	SEM
Lactic acid (mg/L)	1.15^{a}	0.92^{b}	0.95^{b}	0.86^{b}	0.039
Acetic acid (mg/L)	0.65^{a}	0.30^{b}	0.30^{b}	0.27^{b}	0.061
Propionic acid (mg/L	0.85	0.70	0.71	0.66	0.048
Butyric acid (mg/L)	0.06	0.04	0.05	0.04	0.007
NH_3-N (mg/dL)	2.16^{a}	1.64^{a}	1.05^{b}	1.20^{ab}	0.275

Table 2 Rumen microbial count of WAD goats fed levels of Leucaena

Microbial count	A	B	C	D	SEM
Bacteria (×106cfu/ml)	0.90	0.93	0.73	0.69	0.128
Protozoa (×106cfu/ml)	0.27	0.33	0.40	0.47	0.040
Fungi (×106cfu/ml)	0.00	0.03	0.03	0.07	0.019

Conclusion The decrease in rumen fermentation parameters of goats fed leucaena leaves demonstrates lowered ruminal degradation of diets and possible higher availability of feed materials for gastric digestion further down the tract. The inclusion of leucaena did not alter the microbial count of the rumen, maintaining the microbial balance of the rumen, an important factor for proper degradation and utilization of feed ingredients. The use of fresh or wilted leaves of leucaena can be investigated to ascertain the possibility of a different result to that which is obtained in this study.

Acknowledgements This research was carried out at the Directorate of University Farms, FUNAAB, Nigeria.

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019

Effects of dietary and animal factors on maintenance energy requirements of sheep

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Application Female lambs need to eat more feed to meet their higher maintenance energy requirements than male and castrated lambs.

Introduction There is little information available on the effects of plane of nutrition, animal sire, physiological stage and gender on maintenance metabolic rates for the current sheep flocks. The objective of the present study was to evaluate if there was any significant effect of a range of dietary and animal factors on maintenance energy requirements of sheep using calorimeter chamber data.

Material and methods Data (n = 131) used in the present study were collated from five sheep experiments undertaken at the Agri-Food and Biosciences Institute (Hillsborough, UK) from 2013 and 2017. The animals were 5 to 18 months old and had live weights of 29.0 to 69.8 kg. The trials were designed to evaluate the effects of sire (maternal sire vs. terminal sire), physiological stage (lamb vs. ewe), gender of lamb (male vs. female vs. castrated), feeding level (restricted vs. *ad libitum*), concentrate supplementation (forage only vs. forage+concentrate) and forage type (fresh grass vs. grass silage) on energetic efficiencies. All animals were individually housed in pens for at least 19 d, and then transferred to individual calorimeter chambers and stayed there for 5 d with measurements of energy intake and outputs in the final 4 d. Energy balance (E_g) was calculated as the difference between GE intake and a sum of faecal energy, urine energy, methane energy and heat production (HP). Linear relationships between E_g and ME intake were developed to evaluate effects of dietary type, sire, physiology stage and gender of lamb on net (NE_m) and metabolisable (ME_m) energy requirements for maintenance. The evaluation was undertaken to compare the constants with a common slope within each comparison. The effects of experiment, age of animal and chamber number on the relationships were removed. The statistical program used in the present study was Genstat statistical package.

Results The results are presented in Table 1. All relationships were highly significant ($P < 0.001$), with r^2 values ranging from 0.764 to 0.807. There were no significant effects of dietary type, sheep sire or physiological stage on the constants (with a common slope) within each comparison, indicating these factors had no effects on the derived NE_m or ME_m values. However, female lambs had a significantly higher constant than that of male or castrated lambs, indicating the former has a higher metabolic rate. The mean NE_m (0.347 MJ/kg$^{0.75}$) and ME_m (0.478 MJ/kg$^{0.75}$) values obtained in the present study are higher than those (NE_m = 0.256 MJ/kg$^{0.75}$ and ME_m = 0.348 MJ/kg$^{0.75}$) calculated from AFRC (1993) using the mean live weight of sheep and dietary ME/GE ratio in the current dataset.

Table 1 The comparison of constants in linear relationships between ME intake and E_g for sheep[1,2]

Item	Equation		r^2	NE_m	ME_m
Dietary type (n = 131)					
Forage	$E_g = 0.746_{(0.0618)}$ ME intake	$-0.363_{(0.0668)}$	0.765	0.363	0.486
Forage+Concentrate		$-0.371_{(0.0733)}$		0.371	0.498
Sire (n = 131)					
Maternal sire	$E_g = 0.741_{(0.0581)}$ ME intake	$-0.366_{(0.0680)}$	0.764	0.366	0.495
Terminal sire		$-0.357_{(0.0651)}$		0.357	0.482
Physiological stage (n = 131)					
Lamb	$E_g = 0.736_{(0.0574)}$ ME intake	$-0.356_{(0.0794)}$	0.765	0.356	0.484
Ewe		$-0.361_{(0.0932)}$		0.361	0.491
Gender for lamb (n = 96)					
Male	$E_g = 0.694_{(0.0629)}$ ME intake	$-0.306_{(0.1071)}$	0.807	0.306	0.441
Female		$-0.352_{(0.1029)}$		0.352	0.507
Castrated		$-0.288_{(0.1043)}$		0.288	0.415

[1]Unit = MJ/kg$^{0.75}$ for E_g, ME intake, NE_m and ME_m. [2]Values in parentheses are SE.

Conclusion The present study demonstrated that there were no significant effects of plane of nutrition, sire or physiological stage on maintenance energy requirement of sheep. However, female lambs required more energy for maintenance than male and castrated lambs.

Acknowledgements This work was co-funded by DAERA, AHDB and AgriSearch.

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020

Absorption and excretion of phosphorus in sheep diets: Towards a sustainable diet

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Application The correct supplementation of phosphorus in the diet, diminish the excretion to the environment and improve their utilization.

Introduction The intensification of livestock production, causes the excessive accumulation of manure, whose content of Phosphorus (P) and nitrogen (N) can get to pollute the water resources. In addition to the problem of eutrophication, the increase in the cost of phosphates should be considered (Girão *et al*., 2007). Therefore, the need to assess the environmental damage of excess P., The objective of this study was to perform a literature review of the amounts of ingested P, excreted P, and P metabolized in sheep and calculate their environmental impact; what will allow us to know the situation worldwide and propose possible solutions.

Material and methods A search were made of information focused on collecting studies in which the P will be supplemented in the diet of the sheep. The publications were obtained from searches in databases such as Elsevier, Google, SCOPUs and Web of Science. The search strings consisted of words with the terms within the "title", "summary", and "keywords". The terms used were: "phosphorus"; "Sheep"; "excretion"; "Requirements"; "saliva"; "blood" and the combination of the terms, selecting the number of 52 articles published from 1982 to 2013. The selected articles must be of sheep, in addition to presenting at least one of the following data: live weight (kg), dry matter intake (DMI kg / d), P ingested per day (g / d), P excreted (g / d), P Fecal (g / d), total excreted P, P in urine (g / d), P retained. A descriptive analysis was carried out, where the maximum, minimum and average of all the variables were obtained, as well as their standard deviation, using the software SPSS (2012) ver. 21.0.

Results Currently the global sheep population stands at more than 1 billion head with 19 per cent found in Asia and Africa (FAO, 2016)., The region has more than 208 million sheep with EU and EFTA having 43 per cent and the UK showing the largest population in this area with more than 31 million, and 47 million sheep in Central Asia and Turkey has around 22 million, if we related to the ingestion and excretion of P (Table 1), on average 3.91 g/d are ingested and 64.65% are excreted. Estimating the losses of this mineral to the environment, being per individual sheep 2.52 g P per day.

Table 1 Intake, excretion (g / d) and efficiency (%) of phosphorus use in sheep.

Variable	Minimum	Maximum	Average	SD
Live Weight, kg	23.00	50.00	39.43	8.97
Dry Matter Intake, kg/d	0.54	1.84	1.00	0.26
P intake, g/d	1.45	7.47	3.91	1.82
P excreted g/d				
Faeces, g/d	0.56	6.54	2.20	1.45
Urine, g/d	0.0046	1.93	0.28	0.47
Total, g/d	0.58	6.69	2.49	1.71
P Balance, g/d	0.07	5.49	1.42	1.35
Efficiency, %	2.95	87.13	35.35	25.50
% P excreted to the environment	12.87	97.05	64.65	25.50

Conclusion The amount of P excreted into the environment by the supplemented sheep is more than half of the amount ingested, which is causing serious environmental problems in the groundwater and terrestrial mantles, however, deficient diets can cause health problems to animals, because which is important to formulate diets with adequate nutritional requirements so as not to cause animal health problems or environmental pollution due to excess of P in the diet.

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021

Variation in individual feed intake profiles recorded in group-housed lambs

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Application Feed intake varies between lambs, so recording on an individual basis is important in order to exploit this variation. Radio frequency identification (RFID) enabled feeders can be used to record individual lamb feed intake.

Introduction Information on feed intake is valuable for feed trials and research on feed efficiency and genetics. Current methods to collect intake information either require individual housing of sheep or group based data collection. Neither method is ideal for determining individual intake for a large number of sheep. Feed efficiency is known to vary between individuals with a 20% difference in intake reported between sheep with the same level of growth (Johnson *et al*., 2015). New feed intake monitoring equipment (FIME) has been developed that uses the sheep RFID number stored in their ear tag to record individual intake at specially designed feed bins and crates. This abstract presents results from a UK pilot trial exploring the possibility of using this technology to collect individual intake data and identify variation between animals.

Material and methods This work was carried out at SRUC's Hill and Mountain Research Centre. A group of 55 male lambs (aged 6-9 months old) were moved into a shed with FIME in January 2018. The FIME included 16 roughage bin feeders and two concentrate dispensing crate feeders. Both feeder types recorded: lamb RFID number; feeder number; date and time of visit to feeder; duration at feeder; and amount of feed consumed. Roughage (grass nuts) was available *ad libitum*, while concentrates were provided in meal portions up to a limit of 506g per lamb per day. After a training/problem solving period of 4 weeks, all intakes were recorded via the equipment for 44 days. Due to issues with concentrate feeders becoming blocked, there were only 17 consecutive days where all feeders were working correctly at the same time. Per feed type, reliable intake records from 23 Scottish Blackfaces lambs were analysed from 43 days for roughage and 17 days for concentrate (39087 total visit records). Multiple regression models (Genstat, 16th edition) tested the effects of lamb, day and initial live weight on daily intake. Further models tested the additional effects of time of day and feeder.

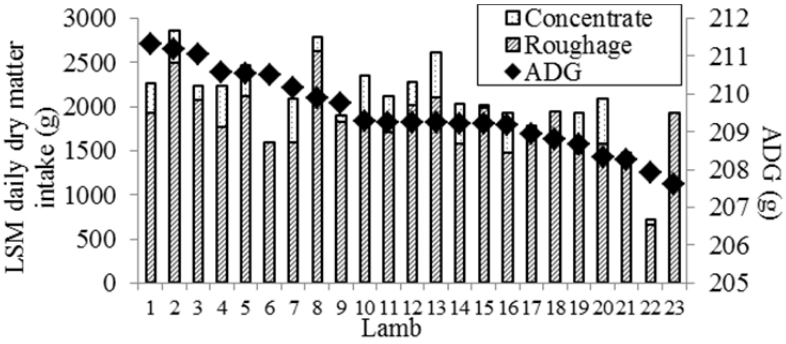

Figure 1 Least-squares means (LSM) for daily intake (g) of roughage and concentrates per lamb. Average daily gain (ADG), adjusted for initial live weight, per sheep also shown.

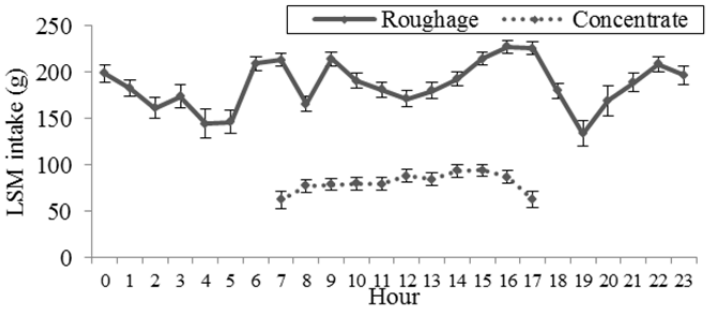

Figure 2 Least-squares means (LSM) for intake per hour (g) of roughage and concentrates.

Results Least-squares means for lamb daily intake were 2122g (169 se) of roughage and 356g (50 se) of concentrate, but varied between individual animals (Figure 1). Lamb, day and initial live weight all significantly affected daily roughage intake (P<0.001), but for average daily concentrate intake only lamb was significant (P<0.001). Values from Figure 1 suggest a two-fold difference between the highest and lowest lamb in dry matter intake per unit growth. Time of day significantly affected lamb roughage intake (P<0.001) and concentrate intake (P<0.05, Figure 2). Lambs consumed different amounts of roughage from different bins (P<0.001), but there appeared to be no overall preference between the 2 concentrate feeders (P=0.188).

Conclusion FIME can be used to record individual feed intake for group-housed lambs. Roughage and concentrate intake varies depending on animal. Roughage intake is also affected by day, time of day, initial liveweight of animal and feeder. Therefore collecting intake data at an individual level has the potential to provide valuable information relating to feed efficiency and its genetic control.

Acknowledgements Intake equipment was funded by the Centre for Innovation Excellence in Livestock (CIEL), through InnovateUK. This work was funded by Scottish Funding Council's Universities Innovation Fund and ERANet SusSheP.

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022

Ireland's national sheep flock: breed composition and source of replacements

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Application Change in breed type is required to improve ewe productivity. Producers should consider producing their own flock replacements using rams from prolific breeds, thus improving both flock biosecurity and profitability.

Introduction Ewe genotype has a major influence on ewe productivity (Hanrahan 2001; Hanrahan and Keady 2014), which is the main factor affecting the efficiency of prime lamb production (Keady and Hanrahan 2006). Hanrahan (2001) reported estimates for the number of lambs reared per ewe joined that ranged from 1.37 to 1.70 among crossbred ewe types; Suffolk-X and Texel-X ewes were towards the lower end of this range while Belclare-X ewes had the highest value. Hanrahan (2008) reported that Suffolk-X and Texel-X ewes accounted for ca. 50 and 10% of the national flock, respectively. The aim of this study was to establish the current breed composition of the Irish ewe population and the source of flock replacements.

Material and methods The survey was based on all farmers with a sheep enterprise in the Teagasc National Farm Survey (NFS). The survey is implemented on-farm by a team of trained recorders. The NFS is part of the Farm Accountancy Data Network of the EU and is the Irish equivalent of the UK Farm Business Survey. The NFS involves a statistically representative (stratified random) sample of approximately 1000 (dairy, beef, sheep, tillage and mixed) farms each year, representing a population of ~90,000 farms. A supplementary survey was implemented on all NFS farms with a sheep enterprise in conjunction with the regular 2016 NFS to acquire information on ewe breed type and source of replacements. The NFS sample included 184 farms with a sheep enterprise, which (based on the NFS population weighting factors) are representative of 18,284 Irish farms with a sheep enterprise. Descriptive statistics were compiled and preliminary analysis conducted using Microsoft Excel.

Results Of the 184 questionnaires completed for the supplementary survey 177 (96%) were usable. Information on breed type of ewes put to the ram in 2016 is presented in Table 1. Suffolk-X is the dominant ewe breed type in Irish sheep flocks. Suffolk-X and Texel-X ewe breed types accounted for 59% of all ewes, similar to the 60% reported by Hanrahan (2008). In lowland flocks the three main terminal sire breeds (Suffolk, Texel and Charollais) account for 73% of ewe breed types, similar to the results of Hanrahan (2008). The predominance in the national ewe flock of ewes sired by terminal-sire breeds may explain why ewe productivity (lambs reared per ewe joined) has not improved over the past 30+ years. Belclare-X ewes have increased from 4.4% in 2008 to 9.5% in lowland flocks in 2016. The source and age of replacements recruited to Irish flocks are presented in Table 2. Nationally, 52.5% of ewe flocks produce their own replacements (i.e., do not purchase any) and a greater proportion of hill flocks breed their own replacements than lowland flocks. Flocks where all replacements are purchased account for 31.7% of all flocks; replacements are a mixture of home-bred and purchased animals in 15.9% flocks. Hoggets (i.e., ~18-month old) are the most common type of purchased replacements for lowland flocks, while ewes are the most common type for hill flocks.

Table 1 Main ewe breed types in the national and lowland flocks

	Percentage ewes by breed type	
Breed type	National Flock	Lowland flock
Suffolk-X	48.5	54.8
Texel-X	10.5	11.0
Charollais-X	6.2	7.4
Belclare-X	8.2	9.5
Hill/Hill-X	17.5	9.6
Other	9.2	7.7

Table 2 Source and type of replacements in Irish flocks (% of farms)

	Flock		
Source of replacements	National	Lowland	Hill
Home bred only	52.4	48.1	77.1
All purchased	31.7	34.5	15.5
≥ 50 to ≤ 100% purchase	6.6	0	7.8
≤ 50% purchased	9.3	7.4	9.6
Purchase ewe lambs only	10.1	10.9	5.6
Purchase hoggets only	23.6	26.6	6.7
Purchase ewes only	7.9	7.4	10.6

Conclusion Suffolk-X continues to be the dominant ewe breed type. With the exception of the proportion accounted for by Belclare-Xs the breed composition of the Irish ewe flock has remained relatively unchanged over the past 10 years. Replacements are purchased for nearly half of all flocks, thus, increasing the risk of exposure to diseases such as enzootic abortion, the incidence of which has increased in recent years.

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023

Effect of inclusion of oregano oil in ewe concentrates on ewe and lamb performance

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Application Oregano oil may influence nutrient partitioning in ewes, and increase lamb performance post-weaning.

Introduction Since the introduction of the EU ban on antibiotics as growth promoting agents in animal feeds in 2006, there has been increasing interest in the use of aromatic plants and their extracts. Oregano (*Origanum vulgare L*) contains the compounds carvacrol, thymol, *y*-terpinene and *p*-cymene, which possess both antimicrobial and anti-oxidant activity. Responses to inclusion of oregano oil in non-ruminant diets have been inconsistent, with several authors reporting an increase in growth performance, and others reporting no significant effects. However, there has been little work carried out with small ruminants. The objective of the experiment was to investigate the effects of dietary inclusion of oregano oil (Orego-Stim©) on ewe and lamb performance in late pregnancy and early lactation.

Material and methods Forty-eight twin bearing Suffolk x Mule ewes were housed individually from week-6 *pre-partum* to week+4 *post-partum* and allocated by parity, live weight (LW) and body condition score (BCS) to one of three treatments. All ewes were offered grass silage *ad-libitum,* together with a concentrate containing either no Orego-Stim© (C), 1.0 g/kg (OSL) or 2.0 g/kg Orego-Stim© (OSH). Concentrates were fed to provide a rising plane of nutrition in late pregnancy and 3.0 litres of milk during lactation (AFRC, 1993). From week+4 *post-partum* ewes and lambs were group housed and maintained on their experimental diets until week +8 *post-partum*, when the lambs were weaned. Lamb creep feed was introduced at week+4 *post-partum* and continued until the lambs were selected for slaughter at 40 kg LW. Silage dry matter intake was recorded by weighing the amount offered daily and weighing back refusal twice weekly. Ewe LW and BCS were recorded weekly, with lamb weight being recorded at 12 hours and then at weeks +4, +8 and slaughter. The experiment was analysed by ANOVA as a randomised block design using Genstat 18.

Results

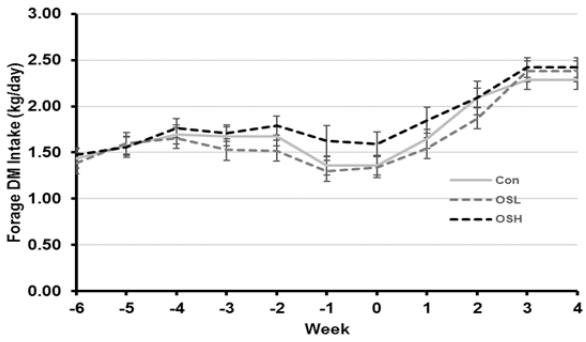

Figure 1 Effect of Orego-Stim© on ewe forage intakes.

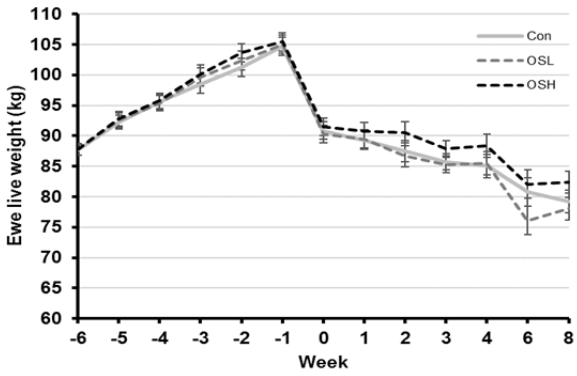

Figure 2 Effect of Orego-Stim© on ewe live weight.

Table 1 Effect of Orego-Stim© on lamb performance (kg/day).

	C	OSL	OSH	SED	P
Birth Weight (kg)	5.65	5.73	5.66	0.178	0.868
Week 0-4	0.35	0.33	0.32	0.015	0.075
Week 4-Finish	0.34	0.35	0.38	0.013	0.055
Week 0-Finish	0.34	0.34	0.36	0.011	0.353

Orego-Stim© at 2.0 g/kg increased ewe forage intake and reduced ewe LW loss during early lactation. Orego-Stim© had no effect on lamb birth weight and tended to reduce lamb LW gain between weeks 0-4. However, lambs from ewes offered 2.0 g/kg Orego-Stim© tended to have a higher LW gain between weeks 4-Finish, such that there was no effect on overall lamb performance.

Conclusion Inclusion of 2.0 g/kg Orego-Stim© in ewe concentrate increased forage intake, and influenced nutrient partitioning during early lactation, maintaining maternal reserves, which may confer benefits in the next production cycle. The increased LW gain of lambs from ewes offered Orego-Stim© between weeks 4-Finish warrants further investigation.

Acknowledgements The authors gratefully acknowledge funding from Anparo Ltd.

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024

Effect of increasing digestible phosphorus around farrowing on performance of sow and litter

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Application It was hypothesised that extra dP result in a shorter farrowing process, but only numerical differences were found indicating that more research is needed.

Introduction The increase in sow prolificacy in the last years has increased litter size, but also resulted in more births of non-viable piglets. Factors affecting piglet vitality include low birth weight and farrowing duration with longer birth intervals increasing the risk for asphyxia (Tuchscherer *et al*., 2000). During farrowing and lactation there is an increase in mineral metabolism for muscle contractions in the uterus and production of milk, including phosphorus (Veldman *et al*. 1990). The objective of this study was to determine whether providing extra digestible P (dP) improves the farrowing process positively influencing sows' performance and piglet vitality.

Material and methods The experiment was conducted in the sow facilities of Schothorst Feed Research (Lelystad, The Netherlands) and was conducted according to the restrictions provided under Animal and Human Welfare Codes/ Laboratory practice codes in The Netherlands. In total 24 primiparous and 23 multiparous sows (parity 4 to 6) were used in this experiment. The experiment comprised two treatments: 1) control diet and 2) increased level of dP (+0.5 g dP/kg). Sows were fed a commercial gestation diet until d108 of gestation and an experimental lactation diet from d109 of gestation till d7 post-partum. After d7 a commercial lactation diet was fed until weaning (d28). Effect of transition diet on faecal consistency, milk production (measured by litter weight gain) and litter performance was determined. For 12 sows (6 primiparous and 6 multiparous sows) the farrowing process was recorded (i.e. time between the birth of the first to last piglet; and piglet interval). The results were screened for outliers using the Doornbos test and subsequently analysed by analysis of variance using Genstat ® software (12th edition). Also correlations were performed between the various sow and piglets observations. For the analysis primiparous sows were separated from multiparous sows.

Results The addition of dP did not influence feed intake (FI), body weight mobilisation, faecal consistency or the composition of colostrum or milk (P>0.05). Furthermore, dP did not affect (P>0.05) piglet rectal temperature 24h post-partum, piglet performance, or pre-weaning mortality. The farrowing process took longer for multiparous than primiparous sows (179 vs. 255 minutes), but the extra dP did not influence the farrowing process of primiparous and only resulted in numerical differences (P>0.05) for multiparous sows (Figure 1). Interesting findings were observed with respect to the correlations. Although weak ($r \leq 0.70$), negative correlations were found between farrowing duration and FI between d108 and d7 post-partum (r = -0.53) and farrowing and d7 post-partum (r = -0.50) for multiparous sows. Positive correlations were found between rectal temperature 24h after birth and piglet growth during the first 24h (r = 0.34; P<0.001).

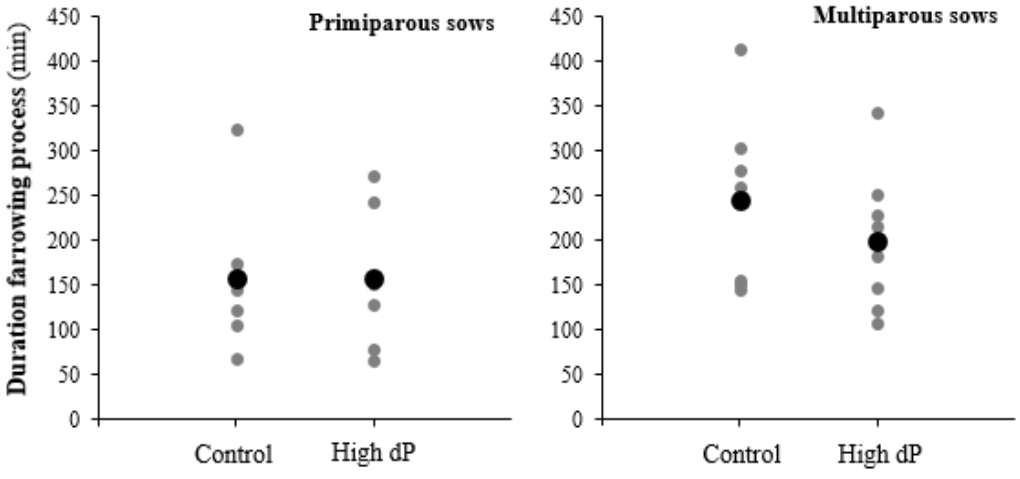

Figure 1 Effect of dietary treatment on the farrowing duration of primiparous and multiparous sows

Conclusion Although it was expected that especially older sows would benefit from additional dP levels due to difficulties with keeping their P levels up to normal levels as a result of a slower bone mineralization compared with younger sows (Veldman *et al*., 1990), only numerical differences were found. The correlations between FI and farrowing duration however suggest that the stress during the farrowing represented by a longer farrowing duration may have resulted in a drop in FI which may have consequences for the performance of the piglets.

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025

Post-weaning performance of pigs fed dry feed vs. wet feed

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Application Pigs fed a ratio of 3L of water for 1kg of diet had higher av. daily gain (ADG) and av. daily feed intake (ADFI) than dry fed pigs without any impairment of the feed conversion ratio (FCR) from weaning to 10 weeks of age.

Introduction Wet delivery of feed is recognized to increase ADG and ADFI of pigs, however there is inconsistency in the impact that wet feed has on efficiency, usually attributing the increase in ADFI to feed waste. Degradation of lysine and other aminoacids, especially in fermented wet feed, has also been described and identified as a possible cause of reduced efficiency (DeRouchey & Richert, 2010). Using a feeding system that delivers water and feed separately in the trough (avoiding degradation of nutrients), the present study aimed to compare growth performance of weaned piglets fed either dry feed or wet feed using different water to feed ratios.

Material and methods A study was conducted under the Animals Act 1986 at AFBI experimental farm, 1133 pigs (10 replicates) were distributed to one of the following treatments at 2 weeks after weaning, balancing for body weight and gender: Dry) pigs were offered dry feed; Wet 1:1) pigs were offered a wet diet at a ratio of 1L of water for 1kg of diet; Wet 2:1) pigs were offered a wet diet at a ratio of 2L of water for 1kg of diet; Wet 3:1) pigs were offered a wet diet at a ratio of 3L of water for 1kg of diet. Pigs were weaned at 28 days of age to a weaner accommodation an allocated in pens of 29 animals. Pigs were offered –*ad libitum*- 3kg/pig of Starter diet 1 (16.5MJ DE/kg, 22.5% CP), followed by 6kg/pig of Starter diet 2 (16.3 MJ DE/kg, 21.5% CP) and then a Grower diet (14MJ DE/kg, 18.6% CP) until the end of the trial. All pigs received the same diets only differing in the proportion of water added. Pigs in a wet treatment were offered a 2:1 ratio during the first two weeks post-weaning before starting treatment implementation (at 6 weeks of age). Pigs were weighed at weaning, at 6 and 10 weeks of age. ADFI, ADG, and FCR after weaning was recorded. Data was analysed using GenStat 16th edition. All models were analysed using the pen as experimental unit.

Results Body weight at weaning (av. 8.89 ± 0.122 kg) and at 6 weeks of age (av. 13.07 ± 0.283 kg) did not differ among treatments (P>0.05, respectively). Body weight at 10 weeks of age was lower (P<0.05) in the Dry treatment (27.5 ± 0.34kg) than in Wet 1:1 (28.7 ± 0.38kg), Wet 2:1 (29.1 ± 0.36kg), and Wet 3:1 (29.1 ± 0.36kg); while no difference was observed among the wet treatments. Performance results are presented in Table 1. ADG and ADFI was higher in the Wet treatments than in Dry treatment from weaning to 10 weeks of age (P<0.05). FCR did not differ between Dry and Wet 3:1 through the trial (P>0.05), and it was lower for both groups than Wet 1:1 and Wet 2:1 from 6 to 10 weeks of age (P<0.05, respectively).

Table 1 Effect of treatment on pigs' growth performance after weaning (av. weaning weight. 8.89 ± 0.122 kg)

	Dry	Wet 1:1	Wet 2:1	Wet 3:1	SEM	P-value
nº pigs/nº pens	283/10	284/10	284/10	282/10		
Weaning to 6 weeks of age						
ADG, g	257^{a}	311^{b}	319^{b}	311^{b}	14.0	0.013
ADFI, g	263^{a}	318^{b}	311^{b}	312^{b}	12.1	0.010
FCR	1.03	1.03	0.97	1.01	0.029	ns
6 to 10 weeks of age						
ADG, g	552	575	579	585	12.9	ns
ADFI, g	970^{a}	1087^{b}	1076^{b}	1067^{b}	19.7	<.001
FCR	1.76^{a}	1.89^{b}	1.86^{b}	1.83^{ab}	0.026	0.011
Weaning to 10 weeks of age						
ADG, g	454^{a}	493^{b}	499^{b}	500^{b}	8.6	0.001
ADFI, g	736^{a}	842^{b}	829^{b}	828^{b}	14.9	<.001
FCR	1.62^{a}	1.71^{b}	1.66^{ab}	1.66^{ab}	0.019	0.022

^{ab}values with different superscripts differ statistically (P<0.05); Wet 1:1, pigs offered a ratio of 1L of water for 1kg of diet; Wet 2:1, pigs offered a ratio of 2L of water for 1kg of diet; Wet 3:1, pigs offered a ratio of 3L of water for 1kg of diet

Conclusion Wet feeding increases ADG and ADFI during the weaner stage compared to Dry feeding. Wet feeding at a 3:1 ratio improved ADG and ADFI compared to Dry feeding while presenting the same FCR through the weaner stage.

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026

Do outdoor reared piglets benefit from a supplemental iron injection?

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Application Providing pigs with 200 mg of supplemental iron within the first day of life may present an economically attractive strategy to improve the productivity of outdoor reared pigs. The cost of iron supplementation is minimal, at just 10 p per pig, however an additional 330 g BW at weaning, as observed in this study, equates to an additional £1.79 per pig sold at weaning.

Introduction Iron deficiency remains prevalent in modern pig production systems (Perri *et al*. 2016). Suckling pigs are most at risk of developing iron deficiency owing to the inherently low Fe content of sow milk and the limited Fe stores in the new-born pig (Venn *et al*., 1947). It is, therefore, common practice for pigs reared indoors to receive ~200 mg of supplemental iron, usually in the form of an intramuscular injection within the first 3 days of life, to prevent the onset of iron deficiency prior to weaning. Pigs reared outdoors, however, tend not to receive supplemental iron, as it is commonly assumed that sufficient iron is obtained from the ingestion of iron-bearing soils (Venn *et al*., 1947). This study set out to determine the effect of supplemental iron on the pre-weaning growth performance of outdoor reared piglets.

Material and methods The progeny of 13 Large White x Landrace x Duroc (by Hampshire sire) multiparous sows were used (168 piglets in total) in this 27 d pre-weaning experiment. Neonatal pigs were weighed within 24 hours post-partum and allotted within litter to one of two treatments, balancing for body weight. Treatments were 200 mg (intramuscular injection of 1 ml gelptoferron in the neck witin 24 h of birth; **+Fe**) or no iron supplementation (**-Fe**). Piglets remained with the sow in individual farrowing paddocks until weaning at 26.5 (SD ± 0.92) d of age. Piglet access to the paddock was limited via the use of a fender, which was removed at 14 d of age. No supplementary feed was offered to the piglets throughout the study. Pigs were weighed at 7 d of age and then again at weaning. Data were analysed using the GLM function of SPSS (version 22) with treatment and sow included in the model as main effects, and initial BW as a covariate. The individual pig was the experimental unit for all growth performance analyses. A *P*-value of <0.05 was accepted as significant, whereas a *P*-value of <0.1 was considered a trend.

Results Piglets that had received supplemental iron within the first day of life tended to have a higher ADG (+6.5%) prior to weaning, which translated to an additional 330 g BW at weaning (*P*<0.1). There was no difference between the supplemented and non-supplemented pigs in terms of growth performance throughout the first week of life, indicating that the benefits of iron supplementation were expressed in the latter stages of the lactation period.

Table 1 Effect of iron supplementation on pre-weaning piglet growth performance

	Treatment			
Item	- Fe	+ Fe	SEM	*P*-value
Start weight (kg)	1.52	1.55	0.036	0.613
Week 1 weight (kg)	2.57	2.58	0.043	0.895
Week 1 ADG (g)	156	158	6.5	0.749
Wean weight (kg)*	6.57	6.90	0.155	0.071
ADG (g)	190	203	5.9	0.073

*Mean wean age (± SD) = 26.5 days (±0.92)

Conclusion In this experiment, piglets reared in outdoor production systems benefited from supplemental iron within the first day of life. This benefit was seemingly expressed in the latter stages of the pre-weaning period, which suggests that piglets were unable to compensate for low iron concentrations in sow milk by obtaining sufficient supplementation from soil. This preliminary study did not provide sufficient data to determine the impact of Fe injection on post weaning performance and subsequent pig health and survival. Based on the current cost of a 7 kg weaner pig (£38.02), an additional 330 g BW at weaning would equate to an additional £1.79 per pig sold at weaning. At approximately 10 pence per pig, the cost of iron supplementation is minimal, demonstrating that an early iron injection may present an economically attractive strategy to improve the productivity of outdoor reared pigs.

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027

The effect of group size on piglet performance post-weaning – what constitutes a representative group for research purposes?

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Application When deciding on optimum group size for experiments be aware that proportional coefficient of variation increases as number of pigs per pen decreases and therefore smaller groups may not be more cost effective in generating reliable results and may lead to misinterpretation of data due to inadequate replication.

Introduction At weaning, piglets are allocated into new social groups to facilitate growth performance and allow for controlled experimental replication. The mixing of piglets at weaning can influence performance through aggression as social hierarchy is established (Peden *et al.,* 2018). In a commercial setting, large group sizes are not uncommon, however, it has been shown that both the average daily gain and average daily feed intake of a piglet post weaning declines linearly with the presence of each additional pig (Turner *et al.*, 2003). Often in a research setting, much smaller group sizes are used than of those seen commercially to facilitate experimental replication however it is important to ensure that the group size chosen does not negatively affect piglet performance or disproportionately increase coefficient of variation and therefore influence experimental outcomes. The aim of this study was to determine whether group size affected piglet performance and coefficient of variation over 20 days post-weaning, when experimental group sizes of 5 or 10 piglets were compared.

Material and methods 240 crossbred piglets (Large White x (Large White x Landrace); age 27.6 ± 1.71 days, mean initial body weight 7.4 ± 1.29 kg) were allocated to pens of 5 (n = 24) or 10 (n = 12), balanced for litter, sex and weaning weight across the 20 pigs used in one replicate. Both pen types provided the same stocking density (0.40m^2 per pig) and space at the feeder and drinkers for each piglet. All piglets received the same commercial weaner diets across the 20 day study period. Piglets were weighed on days 0, 7, 14 and 20 (BW). For each pen, average daily feed intake (ADFI), average daily gain (ADG) and feed conversion ratio (FCR) were calculated. Data was analysed for each fixed factor as a general linear model in IBM SPSS Statistics 21 with replicate included in the model. Variance was analysed using Levene's test. The pen mean was the experimental unit for all performance data. Power analysis was performed using the method described by Morris (2002). Approval was granted by the University of Leeds animal welfare and ethical review board.

Results Over the 20 day experimental period, no difference in ADFI, ADG, FCR or BW was identified between the two group sizes (Table 1). Piglets kept in pens of 5 tended to eat more between days 15-20 than piglets in groups of 10 (646 vs 612 g per day; P = 0.063) but over the whole experimental period, ADFI of the two groups was the same (410 g per pig per day). Accordingly, piglets in pens of 5 also tended to gain more weight from days 15-20 than piglets in groups of 10 (473 vs 433 g per day respectively; P = 0.081). No significant difference in variance was identified for piglet weights and growth parameters measured from day 0-20 between piglets kept in groups of 5 or 10. Across days 15-20, there was higher variance for the ADG of pens of 5 (6 vs 1 g respectively; P < 0.05) and for ADFI from days 8-14 (3 vs 1g; P < 0.05). The coefficient of variation associated with ADG, ADFI, and FCR was generally twice as high for pens of 5 as for pens of 10 with the exception of day 20 weights, such that the results of a power analysis indicated twice as many pens of 5 were needed as pens of 10 for each experimental treatment. This would result in the same number of piglets per treatment.

Table 1 Overall performance of piglets kept in groups of 5 or 10 from day 0 - 20 post-weaning, coefficient of variation and the number of pens required per treatments based on a power analysis with 10% difference at 50% power

	Mean		SEM	P value	Coefficient of Variation		Pens required per treatment for 10% difference	
Piglets per pen	5	10			5	10	5	10
ADFI (kg/day)	0.410	0.410	0.011	0.971	10.7	7.4	9	4
ADG (kg/day)	0.364	0.354	0.009	0.338	9.7	5.9	7	3
FCR	1.13	1.15	0.019	0.227	5.6	3.9	2	1
Day 20 BW (kg)	11.8	11.9	0.189	0.316	10.4	9.9	9	8

Conclusion Group sizes of 5 or 10 piglets per pen had no effect on growth performance during the 20 day post-weaning period. However coefficient of variation was proportionally higher for pens of 5 than for pens of 10 and therefore twice the replication for pens of 5 than for pens of 10 would be required to provide the same experimental power in a research setting, equating to a similar number of pigs.

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028

The effect of a combination of free and buffered acids on production performance and pathogenic microbial shedding in weaned piglets, with and without pharmaceutical zinc oxide supplementation

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Application The addition of buffered and unbuffered organic acids to pig drinking water, alone or in combination with pharmaceutical zinc oxide medicated diets, may be considered comparable for production performance characteristics, under commercial farm conditions.

Introduction Post weaning diarrhoea (PWD) is a common, reoccurring problem in the UK pig industry generally prevented by metaphylactic use of dietary pharmaceutical zinc oxide (ZnO) at up to 3500 mg/kg diet. Withdrawal of therapeutic ZnO from piglet diets is now a requirement by 2022 under EU regulations, prompting research into alternative strategies and practices to prevent PWD to maintain production performance. Previous studies have found the addition of organic acids into the drinking water system reduces gastric pH and inhibits pathogenic growth (Wang *et al.,* 2009). The objective of this study was to investigate the use of organic acids administered through drinking water alone or in combination with pharmaceutical zinc oxide medicated diets in reducing pathogen shedding and maintaining production performance of pigs for up to nine weeks post weaning.

Material and methods Experimental procedures were approved by Harper Adams University Research Ethics Committee. Due to this trial being undertaken on a commercial farm there was no true negative control (NC) as this could have had health implications on the pigs. The experiment was conducted on 2056 pigs on a commercial farm from weaning (~ 21 days of age) to nine weeks (65 days) post weaning. Pigs were housed in pens of ~120 pigs/treatment group, balanced over six farrowing batches, providing six replicate pens per treatment. The positive control group (PC) were fed a commercial basal diet containing 3500 mg/kg pharmaceutical ZnO. The combination treatment group were fed PC + a commercial blend of buffered/unbuffered organic acids through a Dosatron® to achieve a drinking water pH of <3.6. The organic acid only group were fed PC (without ZnO) + the commercial blend of buffered/unbuffered organic acids through a Dosatron® to achieve a water pH of <3.6. On the day of weaning, faecal samples were taken fresh from each pen to determine pH, enterotoxigenic *Escherichia coli* (ETEC) and *Yersinia enterocolitica* (tested by qPCR using a q16 kit from PrimerDesign Ltd). Faecal samples were taken seven days later to test the effect of the treatments against the same organisms. Production performance parameters determined were daily live weight gain and mortality. Statistical analysis was performed in GenStat (18th Edition) using a one-way analysis of variance blocked by batch for performance data and Pearson Chi-square test (confirmed by a permutation test) on a 2 X 3 contingency table for the frequency of positive/negative pathogen detection by treatment group for the microorganism data.

Results There was no significant difference (P>0.05) between the three treatments on production performance variables or the pH of faecal samples (Table 1). There was no positive detection of *Yersinia enterocolitica* in any of the samples, however, 39 % of samples tested positive for ETEC. This was not significantly associated with treatment group either at weaning (X^2=0.45, 2 d.f., P=0.799) or seven days post weaning (X^2=1.50, 2 d.f., P=0.472).

Table 1 The effect of acidified water with a commercial blend of organic acids with (PC) and without (NC) pharmaceutical ZnO medicated feed on production performance and faecal pH of weaned pigs, housed under commercial farm conditions

	PC (ZnO)	PC + acid	NC + acid	SEM (10 d.f.)	P value
BW (kg) at weaning	5.96	5.75	5.79	0.462	0.943
BW (kg) 9 weeks PW	38.2	35.9	37.8	1.83	0.656
DLWG (g/day)	497	465	495	0.0217	0.547
Faecal pH prior weaning	6.77	6.52	6.35	0.1679	0.257
Faecal pH post weaning	6.07	5.98	5.65	0.1416	0.139
Mortality (%)	4.23	5.06	4.52	1.022	0.846

BW=bodyweight; PW=post weaning; weaning was at ~ 21 days of age; SEM=pooled standard error of the mean

Conclusion Under commercial farm conditions the addition of a commercial blend of organic acids to pig drinking water, alone or in combination with pharmaceutical ZnO medicated diets, produced comparable production performance and did not adversely affect the frequency of positive detections of ETEC in faeces one week post weaning. A further study should include a true NC to show whether it is the acid or ZnO that improves performance.

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029

The effects of auditory enrichment on the behaviour of Holstein Friesian dairy cows

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Application Classical music, country music and audiobooks increased the locomotive and positive social behaviour in Holstein Friesian Cattle, and reduced resting and abnormal behaviours. Auditory stimulation may have application as environmental enrichment in the management of dairy cows.

Introduction Concerns have been raised about the welfare of cows when housed in intensive systems. This is due to issues such as lameness, spatial restriction, increased aggression and abnormal behaviours (Broom, 2010). Auditory environmental enrichment has been suggested to have positive behavioural effects in a range of species, however the use of auditory stimulation in dairy cows has been largely unexplored. This study aimed to investigate the effects of classical music, country music and audiobooks upon the behaviour of dairy cows.

Material and methods 70 early lactation Holstein Friesian dairy cattle were utilised in the study. The cows were mixed parturition and were aged between two and thirteen years. The herd is an all year round calving herd and has an average annual yield of 8900 litres. The cows were housed in freestall barns with *ad libitum* access to food, freestall units and a walkway. Cattle were exposed to four auditory conditions; a no auditory control, classical music (The Classical Chillout Gold Collection), country music (John Denver- Legends) and audiobook (Harry Potter and the Philosophers Stone, narrated by Stephen Fry). The cows were exposed to each condition for 4 hours a day for 3 days with an intervening period of 4 days between conditions. Instantaneous scan-sampling was used to record the cows' behaviour every 10 min throughout the 4 h auditory conditions.

Results The cows showed less tongue rolling behaviour ($P<0.001$) and vocalisations ($P<0.001$) and more locomotive behaviours ($P<0.001$) when exposed to all auditory conditions, compared to the no music control. Furthermore, the cows displayed more positive social interactions during exposure to classical music and the audiobook compared to the control and country music conditions ($P<0.001$). Cows also displayed more resting ($P<0.001$) and ruminating behaviours ($P<0.001$) during the control condition compared to all other conditions.

Table 1 The mean (±S.D.) number of times each behaviour was displayed by the cows in the four auditory conditions

Behaviour	Control	Classical	Country	Audiobook	Behaviour	Control	Classical	Country	Audiobook
Lying/ resting	37.29 (9.192)	30.63 (4.547)	32.03 (11.052)	27.11 (6.100)	Stepping in place	3.20 (2.269)	5.20 (2.269)	4.81 (4.648)	8.66 (3.185)
Ruminating	18.97 (8.218)	9.56 (3.313)	13.77 (9.224)	7.26 (3.829)	Locomotion	1.51 (1.380)	14.13 (4.156)	3.81 (3.376)	15.19 (5.588)
Standing still	23.96 (7.033)	20.21 (4.400)	24.71 (9.767)	18.13 (6.171)	Vocalising	2.89 (1.664)	1.37 (1.230)	0.89 (1.336)	1.31 (1.389)
Body care	2.71 (3.084)	2.19 (1.609)	4.24 (5.160)	3.19 (2.202)	Environmental sniffing/licking	0.54 (0.912)	3.20 (1.908)	3.01 (3.100)	4.57 (3.395)
Drinking	3.63 (2.273)	3.64 (1.786)	3.27 (5.524)	3.16 (2.412)	Social interaction	0.63 (0.663)	3.09 (1.412)	1.20 (1.807)	3.74 (2.913)
Eating	5.10 (2.803)	4.46 (2.406)	12.09 (9.543)	8.66 (4.693)	Agonistic behaviour	1.41 (1.388)	1.04 (0.955)	1.14 (1.739)	1.10 (1.495)
Urination/ defecation	2.83 (1.777)	3.06 (1.550)	1.79 (2.346)	2.61 (1.600)	Tongue rolling	2.01 (1.460)	0.71 (0.870)	0.04 (0.266)	0.57 (1.015)

Conclusion Provision of auditory stimulation to dairy cows achieved a number of the goals of environmental enrichment. Use of auditory stimuli reduced abnormal behaviours such as tongue rolling which could suggest reduced stress and increased welfare. Auditory stimuli also enhanced behavioural diversity such that increased locomotive and positive social interactions were seen in dairy cows. However periods of no auditory stimulation also seem to be beneficial in dairy cows. Increased resting and rumination were displayed in the absence of auditory stimulation. This could indicate enhanced relaxation in the cows and also increase productivity. Use of music and audiobooks has the potential to be utilised as environmental enrichment for dairy cows, however incorporating periods of no auditory stimulation should also be considered as part of the management routine.

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030

Feed efficiency in temperate grass-based beef production systems: A review

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Application Improving efficiency of feed utilisation in beef cattle can enhance the profitability, reduce the environmental impact, and thus increase the sustainability of grass-based beef production systems.

Introduction Feed provision represents the largest variable cost in beef production and is a major determinant of profitability. In many temperate regions, such as Ireland and the UK, grass is the principal dietary component for beef production due to the prevailing climatic conditions. Of the predominant feedstuffs available, generally grazed pasture is cheapest, purchased concentrate is the most expensive and grass silage and other conserved forages, intermediate. Due to differences in the relative costs of feeds, 'biological' feed efficiency (FE) may not always align with 'economical' FE. Seasonality of grass growth dictates that pasture-based beef production systems consist of a grazing season and an indoor winter period, with grass silage (+/- supplementation) usually providing the winter forage. Consequently, these systems are largely designed to convert 'human-inedible' forages into 'human-edible' meat products. For example, within grass-based suckler calf-to-beef production systems, the composition of the annual feed budget on a dry matter (DM) basis comprises approximately 0.61 grazed grass, 0.31 grass silage and 0.08 supplementary concentrates (Drennan and McGee, 2009), with the latter primarily used for 'finishing' animals. Commercially, many types of beef production systems exist, using suckler or dairy-bred animals, and are mainly operated as segmented components rather than integrated 'calf-to-beef' systems. Management options and the feeding systems employed, depend on the market endpoint and the capacity of the animal 'type' to meet required market specifications such as gender, age, weight, conformation and fatness. This review focuses on efficiency of feed utilisation within this context.

Feed efficiency is a moderately heritable, multifaceted trait (Kenny *et al.*, 2018). Evaluating FE across the entire integrated beef system is difficult due to the different cattle 'classes', the diverse physiological systems underpinning basal metabolism, growth, lactation and reproduction, coupled with biological residual effects across the different phases. The antagonisms and synergisms that exist among FE and other economically relevant traits are examined. The variance between studies in estimates of repeatability of FE ranking across physiological age, diet quality (genotype x environment interaction), physiological stage and parity is explored. Compared with FE measured in growing cattle fed energy-dense diets, there is limited published information pertaining to FE in cattle offered forage diets, especially grass-based, and even less so in relation to beef suckler cows. In grass-based calf-to-weanling and calf-to-beef systems, the cow herd consumes approximately 85 and 50% or greater of total feed inputs, respectively (Lawrence *et al.*, 2013). Approximately two-thirds of total energy consumed by beef cattle is used to support basal metabolism, resulting in cow maintenance requirements being a considerable proportion of total costs in beef production systems. Accordingly, it is imperative that definitions of maternal productivity for suckler beef production include quantification of feed energy 'input' to the cow and progeny. In this regard, animal weight or 'size' is not a very accurate indicator of feed consumption, or productivity. In both suckler cows and growing cattle, there are large differences in DM intake relative to weight between breed types and, within breed, research examining the trait residual feed intake (RFI) has demonstrated substantial between-animal variance in intake for the same weight and performance (Lawrence *et al.*, 2013; Moloney and McGee, 2017). Productivity and feed efficiency of suckler cows differing in size and milk production is evaluated. Concerning post-weaning performance or finishing systems, ideally 'output' should be expressed at least in terms of carcass composition. For example, our research has shown that FE was circa. 20, 33 and 50% inferior for dairy origin Holstein-Friesian compared to suckler-bred Charolais finishing steers when expressed in terms of kg feed DM per kg gain of live weight, carcass and meat, respectively. There are many different potential growth path trajectories to the same slaughter endpoint (Moran *et al.*, 2017). Previous management, especially factors significantly affecting growth, can influence subsequent animal performance; cattle undergoing compensatory growth typically have enhanced FE. Production systems designed to exploit compensatory growth and the inherent efficiencies in feed utilisation between breed types and animal genders (bulls v. steers) within the context of market endpoints is examined. Finishing cattle from pasture rather than indoors can be economically attractive; concentrate supplementation at pasture may eliminate the need for expensive indoor finishing regimes. The production efficiency of using grazed grass combined with concentrate supplementation is assessed.

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031

Cattle feed efficiency – Value to the beef industry and its perception and uptake

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Introduction Beef cattle production in the UK needs to become more efficient to survive future challenges. The proportion of the beef production cost accounted for by feed is in the range 41-75% (Goddard *et al*, 2016). Therefore, to improve financial performance, a focus on more efficient use of feed is needed. Breeding for feed efficiency requires the recording of individual feed intake on a suitable population of animals. Somewhere around 1800 animals have to be recorded to generate genetic parameters for one breed. Following this, on-going data recording is required to deliver breeding values. Genomic approaches can be used to increase the value of the data collected across the breed, but there remains the need to record a relatively large numbers of animals.

Industry-level benefits It has been shown around the world that selection for feed efficiency results in a significant return on investment at the industry level. A Defra-funded scoping study estimated that recording feed intake in order to include a measure of resource use efficiency into current selection indices would increase the realised benefits in farm level profit by around 39% and in greenhouse gas (GHG) reduction by around 22%.

Industry adoption Following a five-year Innovate UK project the Stabiliser Cattle Company launched an Estimated Breeding Value for Net Feed Efficiency in 2017. Clearly there are industry-level benefits in breeding for feed efficiency and the lower costs and increased profitability from using more feed efficient genetics should accrue financial rewards that could be shared along the value chain. Beyond the Stabilisers, industry engagement is challenging. Most agree that breeding for more efficient cattle is the "right thing to do." Why then, has it not been adopted more widely? The factors influencing low adoption of feed efficiency through breeding are well described in a Canadian study (Goddard *et al*, 2016). Interpreting this for the UK we can conclude that suckler producers have little incentive to invest in more feed efficient bulls, unless there is a premium for feed efficient calves; whereas the rearer and finisher is unlikely to pay more for a feed efficient calf, because "he would rather pay the same price for genomic and regular calves and … increase his own profits. "If the suckler producer will not pay more for a feed efficient bull, there is little incentive for the breeder to invest in testing for feed efficiency.

Other areas of uncertainty Generally there are positive genetic correlations with other aspects of performance (such as growth, carcase composition, or reproductive performance), but less attention has been given to whether there are any relationships with eating quality. One study (Blank *et al*, 2017) indicated no difference in toughness. Similarly, practical farmers question the value of measuring feed efficiency on a standard diet in a feed bin, when production will be animals grazing pasture. Clearly feeding behaviour is different, and the difference in dietary components might affect the animal's ability to utilise feed. The evidence, however, generally indicates that the there is a positive (even if not always very high) correlation between feed efficiency in these different situations.

Conclusion Breeding for improved feed efficiency would deliver clear benefits to beef sector in the UK, and deliver benefits to the public through reduced GHG emissions. The challenge is to find an approach to appropriately share the costs and benefits between supply chain partners and the public.

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032

Comparing the nitrogen utilisation efficiency of growing cattle before and after 2003

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Application Modern growing cattle can utilise dietary nitrogen (N) more efficiently, thus likely excreting less N per kg of meat production, which should also result in slurry with lower ammonia emissions.

Introduction The implementation of the Nitrate Directive and Habitats Directive programmes has imposed a significant impact on beef production systems in Northern Ireland. Nitrogen excretion is a key factor of consideration when addressing measures which enable Northern Ireland to operate within the rules of these directives. As part of the work to establish the N excretion from modern growing cattle, this study compared the N utilisation efficiency of growing cattle using data collated from digestibility studies undertaken before and after 2003.

Material and methods Two datasets were collated from digestibility studies of growing cattle (heifers and steers from both suckler and dairy origin) undertaken at the Agri-Food and Biosciences Institute; (1) the 'Post-2003'data – collated from 157 cattle across 7 diet digestibility studies carried out between 2003 and 2017, and (2) the 'Pre-2003' data from 286 cattle across 16 studies between 1984 and 2002 (Yan *et al*., 2007). All cattle were offered experimental diets for at least 20 days prior to digestibility trials. Animals were then housed in metabolism units for 8 days with feed intake and faeces and urine outputs recorded during the final 6 days. The 2 datasets were then compared for differences in feed intake and N utilisation efficiency via ANOVA. The N utilisation efficiencies between the 2 datasets were also evaluated via the linear regression analysis of N output against N intake. The effects of experiment, trial year, breed/genotype and forage type were removed for both the ANOVA and linear regression analyses.

Results When compared with the Pre-2003 data, the Post-2003 data showed a higher ($P < 0.001$) average live weight (430 vs 381 kg) and dietary forage proportion (0.805 vs 0.701 kg/kg DM). There was no significant difference between the 2 datasets in total DM intake (6.89 vs 6.78 kg/d, $P = 0.549$) or diet CP concentration (0.153 vs 0.155 kg/kg DM, $P = 0.364$). Table 1 presents N utilisation comparisons and Figure 1 presents the relationship between N intake and total manure N output. Although there was no significant difference between the 2 datasets in N intake, faeces N output or total manure N output, the Post-2003 data had a significantly lower urine N output and consequently a higher N retention. The Post-2003 data had a lower ratio of urine N and total manure N, higher retained N, but also higher faecal N as proportions of total N intake. A similar result was obtained when N utilisation efficiencies between the 2 datasets were evaluated using the linear regression of N output in faeces, urine or total manure against total N intake. Compared with the Pre-2003 data, the Post-2003 had a lower slope for urine output (0.448 vs 0.488, $P < 0.001$) or manure N output (0.721 vs 0.748, $P = 0.003$), but a higher slope for faecal N output (0.273 vs 0.259, $P = 0.010$), when the intercepts within each comparison were fixed at a common value (-4.7, 4.9 and 9.6 g/d in comparisons for urine N, manure N and faecal N outputs respectively).

Table 1 Comparison of N utilisation of growing cattle

	Pre-2003	Post-2003	s.e.d.	P value
N intake (g/d)	167	166	4.5	0.879
Faecal N (g/d)	53	55	1.5	0.149
Urine N (g/d)	77	69	2.6	0.002
Retained N (g/d)	37	42	1.9	0.009
Manure N/N intake	0.781	0.743	0.0100	<0.001
Faeces N/N intake	0.321	0.334	0.0056	0.020
Urine N/N intake	0.460	0.409	0.0090	<0.001
Retained N/N intake	0.219	0.257	0.0100	<0.001

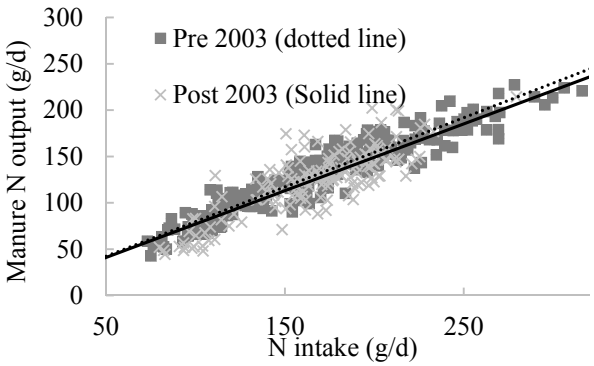

Figure 1 N-utilisation pre/post 2003

Conclusion Modern growing cattle have potential to utilise a greater proportion of dietary N through reduced urine N excretion. Consequently, current beef cattle farming may therefore produce slurry with a lower potential to emit ammonia per kg meat production.

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033

Proteomic analysis of *M. longissimus dorsi* from cattle during dietary restriction and subsequent compensatory growth using label free mass spectrometry quantification

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Application This study provides an insight into the key muscle proteins involved in compensatory growth (CG) in cattle. The proteomic data also validates the muscle transcriptome of these cattle, potentially contributing to the identification of functional DNA based biomarkers for the selection of cattle with a greater ability to undergo compensatory growth and ultimately reducing feed costs by rebalancing feed demand to reduce the expensive overwintering costs.

Introduction CG or catch-up growth is defined as a physiological process by which an animal has the ability to accelerate its growth following a period of under nutrition (Hornick *et al*., 2000). Currently a number of genes expressed in muscle tissue have been identified as contributing to the expression of CG in cattle (Connor *et.al*., 2010, Keogh *et al*., 2016). While transcriptomic data provides useful information on the biology of CG, it is not sufficient to fully elucidate biological function, necessitating a proteomic approach. Thus the objective of this study was to examine the muscle proteome of Holstein Friesian (HF) bulls following a period of restricted feeding and subsequent compensatory growth using shotgun proteomic analysis.

Material and methods This study utilised tissue collected as part of the study of Keogh (2015). Briefly, 40 purebred HF bulls were assigned to one of two groups: (i) restricted feed allowance for 125 days (R1) (RES; n = 20) followed by *ad libitum* access to feed for a further 55 days (R2) or (ii) *ad libitum* access to feed throughout (ADLIB; n = 20). The first 125 days was denoted as Period 1 and the subsequent 55 days, Period 2. At the end of period 1, 10 animals from each treatment were slaughtered. Tissue collection procedures were described by Keogh *et.al.* (2016). Proteins were extracted from samples using a Percellys homogenizer. Samples were subjected to tryptic digestion followed by high performance liquid chromatography tandem mass spectrometry (MS). The acquired raw MS data were processed by MaxQuant followed by protein identification using the integrated Andromeda search engine. Spectra were searched against a Uniprot *Bos Taurus* reference proteome. Protein fold changes were computed based on intensity values. Proteins were considered differentially abundant if the Bonferroni corrected p-value was <0.05 and log2FC >1.

Results During Period 1 RES were managed to achieve a target mean daily growth rate of 0.6 kg/day and 1.9 kg/d for ADLIB The bulls displayed CG with the RES group growing at 1.8 times of the ADLIB group, with an ADG of 2.5 kg/day apparent during re-alimentation in Period 2. 34 proteins were identified as differentially abundant in R2 compared to R1. Figure 1 represents a pie chart of the biological processes these 34 proteins are involved in.

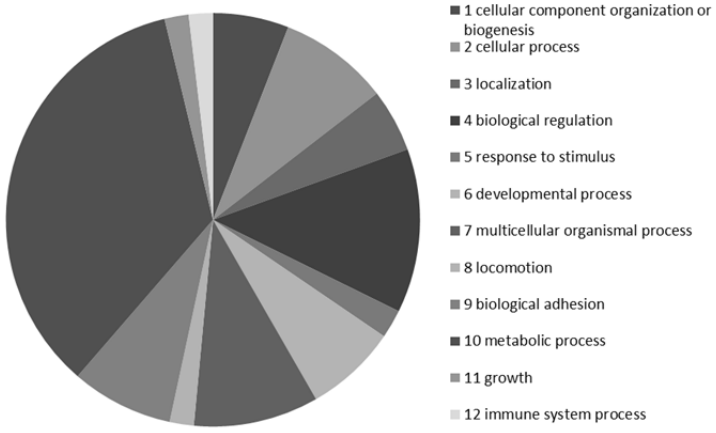

Figure 1 Pie chart of the biological processes in proteins identified as differentially abundant in cattle undergoing compensatory growth

Conclusion A number of proteins found to be differentially abundant in muscle tissue were consistent with differential abundance of genes expressed in the same animals during CG in the study of Keogh *et.al.* (2016) namely; LAMB1, PGM2, SERPINH, TAGLN2, COX5B and MYH4. Proteins found to be differentially expressed in this study are involved in cellular structure, metabolism and energy production. These mechanisms were also consistent in the study of Keogh *et.al.* (2016.) These results show functionality at a phenotype level of the genes coding for proteins identified as differentially abundant. This data aids in the identification of potential biomarkers which can add to genomically assisted breeding programmes in selecting animals with a greater ability to undergo CG and allow for a reduction in feed costs.

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034

Pasture productivity and live weight performance of dairy x beef steers managed under contrasting grazing management systems during an atypical drought year

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Application Cell grazing provides more options and flexibility in grazing management during extreme weather conditions compared to continuous grazing.

Introduction Cell grazing is a relatively new concept to the UK. This grazing management approach builds upon some fundamental ideas proposed by Voisin (1959) and Savory (1969). The concept was further developed by Harry Weir in NZ in the late 1980's into what is now commercially known as TechnoGrazing (TG; Charlton and Weir, 2001). This involves dividing areas of land into precise 'lanes' using bespoke electric fencing and water supply equipment. Lanes are then sub-divided into equally sized cells, which are rotationally grazed based on pasture growth, availability and quality along with target animal performance. A study has been constructed at Rothamsted Research (North Wyke) to investigate the environmental impacts of TG, relative to the current UK baseline grazing management system (continuous stocking; CS).

Material and methods Six permanent pasture paddocks were used for the study: three 1.5ha paddocks for CS and three 1.0ha paddocks consisting of two 0.5ha lanes each split into 21 equally sized cells for TG. Forty-two autumn born dairy x beef steer calves were split into six equal groups and randomly allocated to treatments in April 2018. Calves grazed in their allocated paddocks from April through to October 2018. Pasture cover was measured weekly with a plate meter (EC-20, Jenquip, UK) using equation: kg DM/ha = compressed sward height (cm) x 125 + 640, and cattle were weighed monthly. Cattle live weight (LWT) data were analysed in GenStat 19 (VSNI, Hemel Hempstead, UK) using analysis of covariance (ANCOVA) with previous month's LWT used as a covariate.

Results Average LWT for CS and TG cattle is shown in Table 1. CS cattle had higher LWT in May ($P<0.05$), June ($P<0.001$) and August ($P<0.001$) compared to TG cattle. Daily LWT gain per hectare (DLWG ha^{-1}) was higher for TG cattle in July ($P<0.05$) but lower in August ($P<0.001$). Average pasture cover for CS and TG paddocks is shown in Figure 1. Pasture cover increased between April and May due to pasture growth exceeding feed demand. Thus, 10 cells in two TG paddocks were taken out of the grazing rotation, with the intention of using this deferred grazing to extend the grazing season. However, this deferred grazing was used during June and July due to the unusually dry weather. Also, the stocking rate of TG paddocks was adjusted in line with pasture growth and feed demand relative to target animal performance. No supplementary feed was offered to CS or TG cattle during the drought (unlike many other areas of the UK). The increase in pasture cover in mid-August corresponded with the return of more typical weather conditions for this region.

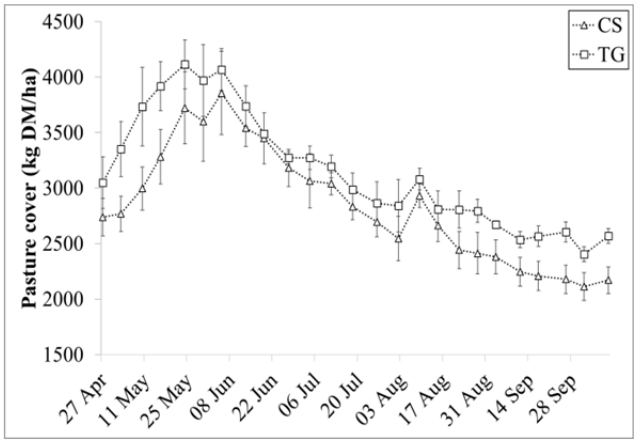

Figure 1 Average pasture cover (kg DM/ha) for CS and TG paddocks during 2018 grazing season

Table 1 Average adjusted live weight (kg) of CS and TG cattle during 2018 grazing season

	May	Jun	Jul	Aug	Sep	Oct
CS	268.9	306.5	316.4	326.61	333.0	316.8
TG	263.4	292.5	315.4	315.72	328.6	326.2
s.e.d.	2.64	2.33	2.38	1.88	2.19	6.11
P	*	***	NS	***	NS	NS

Conclusion Cattle under CS management generally achieved higher LWT compared to cattle under TG management, which is thought to be due to the lower stocking density in CS compared to TG. It is thought that a higher DLWG ha^{-1} can be achieved with TG management versus CS management, yet this was only significantly higher in July for the current study. Conversely, DLWG ha^{-1} was significantly lower for TG in August, which may be a result of possibly poorer nutritional quality of the deferred grazing. It is important, however, to highlight the atypical weather conditions experienced in the UK during 2018 and the likely sizeable effect this had on these results. Further data collected across multiple years is required to establish differences in the sustainability and environmental impacts of these contrasting grazing management systems.

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035

Weaned calf output in relation to suckler cow liveweight in purebred Charolais beef cows

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Application Farmers should be encouraged to evaluate the efficiency of their own suckler herd weaned calf output using this routine "suckler cow efficiency" measure as an annual aid to both technical and financial management of their business.

Introduction Increasing cow size is recognised as one of the determinants of suckler system input costs whilst the weight of calf output at weaning is an important measure of output value. The weight of suckled calf output in relation to the size of the cow (often termed suckler cow efficiency) is one of the major comparative efficiency measures of suckler beef production systems. Previous work (Hyslop, 2018) has detailed the suckler cow efficiency values for a purebred herd of Luing and two sub-herds of crossbred Aberdeen Angus x Limousin (AAxLIM) and Limousin x Aberdeen Angus (LIMxAA) cows. Mean values were: 41.9, 39.6 and 37.8 kg/100 kg cow LW respectively. The objective of the current analysis was to examine the relationships between weaned calf weight and cow size in purebred Charolais (CH) suckler cows and calves.

Material and methods As part of the long term policy at the SRUC Beef and Sheep Research Centre (BSRC), south of Edinburgh, a purebred herd of spring calving Charolais cows were maintained under common management between the years 2006-2015. Routine farm management practices included weighing cows and calves at weaning in autumn along with body condition score measurements. The "suckler cow efficiency" measure was calculated by scaling the individual 200 day calf liveweight (200D LW) measurement of each calf to its dam's liveweight (LW) measured at the same time. REML and linear regression analysis of this routine "suckler cow efficiency" measure (n=178) was undertaken using Genstat 16.

Results Average (s.e.) cow LWs (kg) and calf 200D LWs (kg) were 782 (7.1) and 272 (16.3) for all purebred CH cows and calves respectively. Suckler cow efficiency values (200D calf LW/100 kg cow LW) declined as cow LW increased as expected (Figure 1). On average, suckler cow efficiency values were significantly (P<0.001) higher where steer compared to heifer calves were produced (Table 1).

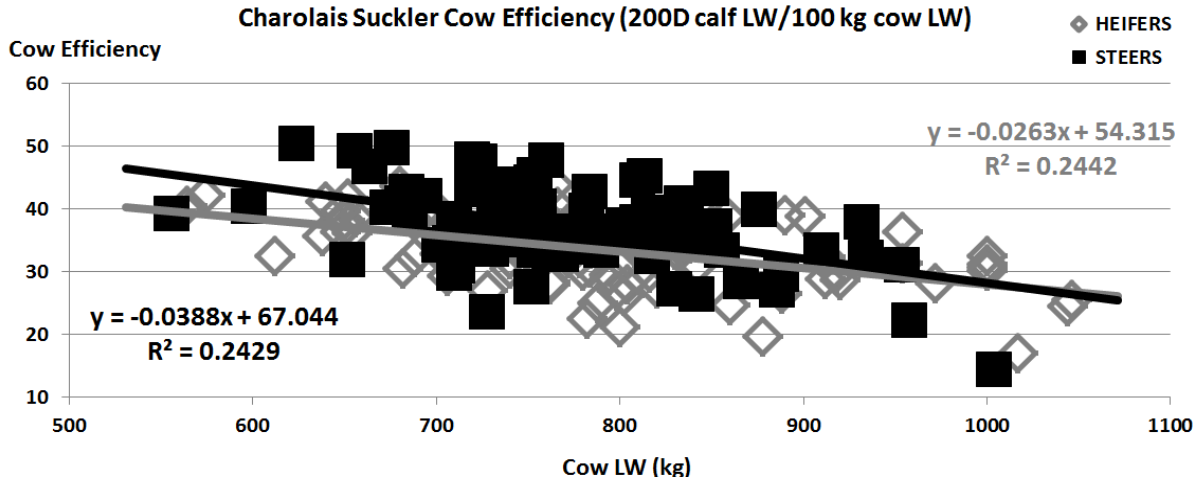

Figure 1 Suckler cow efficiency relationships in purebred Charolais suckler cows

Table 1 Average suckler cow efficiency (200D calf LW/100 kg cow LW)

		s.e.d.	Sig.
Steers	37.1[a]	0.663	***
Heifers	33.5[b]		
Average	35.1		

Values with different superscripts differ (P<0.001)

Conclusion Cows producing calves at above average weights (the regression lines on the graphs) may be suitable as dams of replacement heifers whilst those with lower than average values may not. Calf sex influences suckler cow efficiency values.

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Reference

Hyslop JJ 2018. Advances in Animal Biosciences 9 (1), 146.

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036

The effect of alternative upland pasture management on cattle production

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Application Liveweight gain of cattle may not significantly differ between improved and unimproved upland grazed pasture. Consideration of the economic and environmental trade-offs of improving pasture production is therefore needed.

Introduction A significant proportion of the United Kingdom's uplands are managed for livestock production. Despite this, cattle numbers in the uplands are declining due to many factors including changes in agri-support payments and market pressures. Meanwhile, the red meat sector is under considerable environmental pressure to reduce greenhouse gas emissions from ruminants.
The aims of this ongoing study is to determine the effect of: (1) improved and unimproved upland grazed pasture on cattle performance, (2) improved grazed pasture on cattle urine and dung composition and consequently, (3) greenhouse gas emissions from soil following excretion.

Material and methods The experimental site selected was on a typical upland farm, approximately 9.58 ha at an altitude of ca. 240 m. A herd of 12 heifers were grouped according to their breed (British Blue, British Limousin and Belted Welsh Black) and weight to graze two treatments: improved (lime and fertiliser inputs, 1.54 livestock unit [LSU]/ha) and unimproved (control treatment, 1.03 LSU/ha) pasture. There was no history of lime and fertiliser application to the unimproved treatment since 1950. Soil samples were analysed for their nutrient and pH status prior to treatment establishment. The improved treatment received lime and fertiliser input in accordance recommendations stated in RB209, the Defra Fertiliser Manual.
The heifers were weighed at the beginning and end of the grazing period. Four static chambers were set up for each treatment to assess the effect of inputs on the soil (n = 4). The cattle were denied access to the chambers. The individual chamber applications were as follows: (1) control, (2) lime and fertiliser input, (3) urine, (4) dung. Urine and dung samples were collected from each heifer during the grazing period and stored in sealed containers at <4°C. Samples were removed from cold store approximately 12 hours prior to chamber application. Greenhouse gas samples were collected using the static chamber technique (Chadwick *et al*., 2014) with varied sampling frequency according to chamber application. Gas samples were analysed for nitrous oxide emissions following urine and dung application to the land. Additionally, urine, dung and soil pore water samples were analysed for pH (in water), dry matter, total N, total organic carbon content, urea and readily available N content (ammonium N and nitrate N).

Results There was no significant difference in cattle daily liveweight gain between the grazing treatments ($P > 0.05$) (Table 1). However, due to the greater stocking density, liveweight gain per hectare was greater in the improved treatment (though the experimental design precludes a direct statistical comparison on a per hectare basis).

Table 1 Daily liveweight gain (DLWG) of the cattle from both grazing treatments, expressed as mean per head and per hectare (± = SED).

	DLWG/head (kg)	DLWG/ha (kg)
Improved	0.85 ± 0.04	2.18
Unimproved	0.91 ± 0.04	1.17

Conclusion The results to date suggest there are no significant interactions between pasture improvement (lime and fertiliser applications) and cattle performance, though this may also reflect low statistical power of the dataset. The experiment will continue in 2019 with an alternative herd of cattle. In addition to this, pasture utilisation and altering stocking rates will be assessed.

Acknowledgements The project is funded through the KESS 2 scheme supported by European Social Funds through the Welsh Government. We are pleased to be collaborating with Hybu Cig Cymru, the organisation responsible for the development, promotion and marketing of Welsh red meat.

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037

Effect of production system on the health, performance and carcass characteristics of Holstein bulls

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Application The inclusion of a grazing period with 0 or 2kg concentrate supplementation during the grower period resulted in lighter carcass weights, than bulls offered *ad libitum* concentrates throughout the study.

Introduction Holstein bull beef production often involves an intensive indoor system, with a high level of concentrate feeding. However, the economic viability of such a system is often contested. Consequently, the inclusion of a grazing period in bull beef production may offer the opportunity to greatly reduce production costs. The objective of this study was to investigate the effects of four production systems on the health, performance and carcass characteristics of autumn and spring born Holstein bulls.

Material and methods A 2 (season (S)) x 4 (production system (PS)) factorial design experiment involving 112 Holstein bulls was undertaken. Bulls were split by season into either autumn born (AB) (n=56) (191 ± 10.3d initial age and 196 ± 10.5kg initial live weight) or spring born (SB) (n=56) (106 ± 6.0d initial age and 106 ± 5.8kg initial live weight). The four production systems differed during the summer grower period with treatments including (i.) grazed with no concentrate supplementation (G) (ii.) grazed with 2 kg/day concentrate supplementation (iii.) grazed with *ad libitum* access to concentrates (GA) (iv.) housed with *ad libitum* access to concentrates and silage (HA). During the summer grower period HA bulls were housed on slatted accommodation with access to cubicles, while SB HA also had access to a straw bedded creep area until d72. GA, G2 and G were rotationally grazed in 7 day paddocks from 26/05/17. HA and GA were gradually built up to *ad libitum* concentrate feeding, at the same rate over a period of 8 weeks for AB bulls and 4 weeks for SB bulls. G2 were fed 2kg from the beginning of the trial. AB bulls were housed on 24/08/17, after 90d at grass, while SB bulls were housed on 11/10/17, following 138d at grass. All bulls were housed on slatted accommodation during the finishing period and offered *ad libitum* concentrates and silage; G and G2 were gradually built up to *ad libitum* concentrates over a period of 7 weeks. Bulls were slaughtered at an average age of 15.5 months, mean finishing duration was 197.2 ± 10.7d and 233 ± 10.7d for AB and SB bulls, respectively. Throughout the trial bulls were weighed fortnightly to monitor performance, while health was monitored visually and through the use of rumen temperature boluses. At slaughter carcass weight, fat classification, conformation score and channel fat weight were recorded. In addition, subcutaneous fat depth and MSA marbling score was assessed on the *longissimus dorsi* muscle at 24 hours post slaughter.

Results There was no significant interaction between S and PS, so only the main effects are reported. S or PS had no significant effect on disease incidence, lameness, carcass conformation or fat classification. Bulls on *ad libitum* concentrate feeding achieved superior weight gains during the summer grower period. Weight gains during the finishing period were not significantly different; as a result GA bulls achieved the greatest carcass weight of 315kg, while G bulls had a carcass weight of 279kg. Furthermore, AB bulls had a significantly greater carcass weight than SB bulls.

Table 1 The effect of season and production system on animal performance

	Season (S)				Production system (PS)					
	AB	SB	SED	P-value	G	G2	GA	HA	SED	P-value
Summer DLWG (kg/d)	1.26	1.04	0.100	<0.05	0.74 ^{a}	0.97 ^{b}	1.45 ^{c}	1.43 ^{c}	0.101	<0.001
Housed weight (kg)	268	287	12.27	ns	231 ^{a}	257 ^{a}	312 ^{b}	311 ^{b}	13.42	<0.001
Finishing DLWG (kg/d)	1.47	1.41	0.0413	ns	1.50	1.46	1.41	1.38	0.0567	ns
Slaughter weight (kg)	599	568	12.83	<0.05	547 ^{a}	573 ^{ab}	614 ^{c}	600 ^{bc}	17.65	<0.01
Overall DWLG (kg/d)	1.43	1.25	0.0405	<0.001	1.24 ^{a}	1.29 ^{ab}	1.42 ^{c}	1.40 ^{bc}	0.0569	<0.05
Carcass weight (kg)	308	289	6.992	<0.01	279 ^{a}	291 ^{ab}	315 ^{c}	309 ^{bc}	9.567	<0.01
Kill out (%)	51.2	50.4	0.365	<0.05	50.6	50.6	51.0	51.1	0.493	ns
Channel fat (kg)	19.5	20.0	0.790	ns	18.0 ^{a}	18.5 ^{ab}	21.6 ^{c}	20.8 ^{bc}	1.039	<0.01
MSA Marbling Score	424	471	23.60	ns	420	450	461	459	31.53	ns
Subcutaneous fat depth (mm)	7.43	6.40	0.355	<0.01	6.35	6.75	7.62	6.95	0.478	ns

Conclusion In conclusion, both season and production system had a significant effect on animal performance and carcass weight. *Ad libitum* concentrate feeding resulted in superior carcass weights, while bulls receiving no concentrate supplementation at grass during the summer grower period had the lowest summer DLWG and carcass weight.

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038

A comparison of ability to meet market specification and profit margin achieved by producer when continental steers are slaughtered at 22, 24 or 28 months of age

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Application Finishing cattle earlier can improve farm efficiency through increased profits and the opportunity to finish more cattle in a fixed period of time. It is feasible to slaughter continental breed type steers at 22 months (m) and not significantly affect margin (£/head) compared with steers of 24 or 28 m of age at slaughter allowing a greater throughput and reducing variable costs.

Introduction A premium price per kilogram of carcass produced is offered for cattle which meet market specifications, but these premiums are often negated by producing a higher volume of non-market specification beef. Market specifications are in place to ensure a supply of meat of desirable quality and of consistent size and shape to enhance processing upstream in the supply chain. This study aims to calculate how premiums offered for market specification beef affect profit margins when continental breed type steers are slaughtered at 22 m, 24 m and 28 m.

Material and methods Data was extracted from the BovIS database, which collates abattoir data including carcass characteristics and carcass weight with phenotype data from Northern Ireland's government database (APHIS). Each record was a continental steer slaughtered and included the animal's breed, carcass weight, carcass characteristics and age at slaughter. The data consisted of steers of the most common continental type breeds (Belgian blue (BB), n=14,760; Charolais (CH), n= 151,704; Limousin (LIM), n= 147,355; Blonde D'Aquitaine (DAQ), n= 12,967; and Simmental (SIM), n=29,732). Conformation and fat class were both treated as ordered response variables. In each case an ordered logistic regression (proportional odds model) was fitted with weight and age and their interaction with breed fitted as explanatory variable. Also a linear regression of weight against age and group (and their interaction) was also modelled. The parameter estimates from all these models were then used to form predicted values for each category of weight, conformation and fat class for 22, 24, and 28m slaughter age. Using a base price of £3.50 per kg and the national pricing grid (LMC NI, 2015), carcass price was calculated. The variable costs at each age category were taken from the Department of Agriculture Environment and Rural Affairs (DAERA) farm business data report (Keatley, 2018) and subtracted from carcass price to calculate the gross margin per animal. Difference in margin (£/head) between slaughter age within breed (blocked by conformation/ carcass class) was log transformed and compared by ANOVA.

Results As age increased, an increase in carcass weight was observed for all breeds. The proportion of cattle achieving market specification increased with age for all breeds except SIM, but was relatively stable with a mean variance within breed of 0.78% (Figure 1). Gross income per head increased with age, except for CH where the 24 and 28 m old carcass did not receive a premium because it exceeded market specification weight. Despite gross income (£/head) increasing with age, when the variable costs were taken into account there was no significant difference in margin for any breed except SIM which had a significantly higher margin when finishing at 22 m (Figure 2).

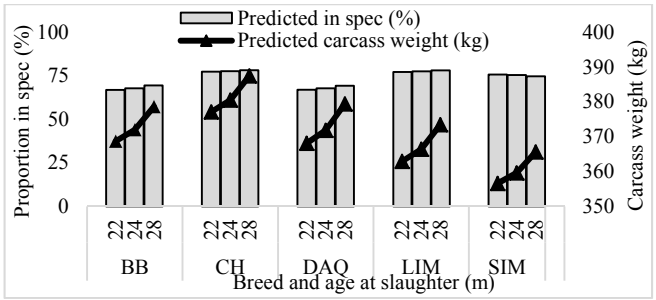

Figure 1 Predicted proportion of steers of specified continental beef breeds achieving market specification and predicted carcass weight (kg) of at selected age

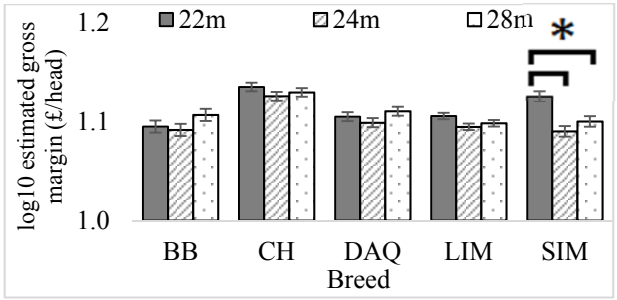

Figure 2 log10 Gross margin (£/head) when slaughtering steers of specified continental beef breeds at selected age at slaughter. Brackets denote significant difference ($P<0.05$), error bars show estimated standard error

Conclusion Slaughtering cattle earlier reduced carcass weight but did not reduce margins significantly, with higher margins achieved finishing SIM at 22m than 24 or 28m due to the reduced production cost. This suggests that producers can increase production efficiency by finishing earlier and reducing the costs of production and increasing throughput on farm.

Acknowledgements The authors gratefully acknowledge the participating BovIS abattoirs and funding from DAERA NI.

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039

Lowering dietary crude protein in pig diets: ammonia, odour and slurry production from finishing pigs

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Application Reducing crude protein (CP) in finishing pig diets from 180 to 130 g/kg can significantly reduce the volume of slurry produced and ammonia emitted by 49%, provided amino acids (AAs) are adequately supplied. This finding will support the sustainability of pig farming, and inform policy makers and regulators on the impact of protein reduction.

Introduction Currently, the pig industry is under intense scrutiny due to levels of ammonia and odour emissions. A reduction in dietary CP will result in less nitrogen excreted, and thus a reduced potential for ammonia creation (Sajeev *et al*., 2017), provided digestible AAs are adequately supplied, and the diet is formulated to ensure production performance is maintained. However, the relationship between ammonia and odour is ambiguous, and the effect on slurry output is unclear (Morazan *et al*., 2015). Dietary CP has been reduced in recent years, but the quantitative combined effect of this reduction on ammonia, odour, and slurry output is not yet known. The objective was to investigate ammonia and odour emissions of finisher pigs offered high (traditional), medium or low dietary CP, and subsequent slurry production.

Material and methods Thirty boar pigs were individually housed in batches of six, from 10 weeks of age (30±3.0kg) and offered diet 1: 185g/kg CP, 15.0MJ/kg digestible energy (DE) between 10 week of age and 45±3.0kg, followed by diet 2: 165g/kg CP and 14.3MJ/kg DE to 75±1.5kg. Pigs were then assigned to one of three treatment diets; 1) 180g/kg CP, 1.10 lysine (High CP), 2) 150g/kg CP, 1.13 lysine (Medium CP), and 3) 130g/kg CP, 0.90 lysine (Low CP). Diets were formulated by J Thompson and Sons to the same DE (14.0MJ/kg) and balanced for AAs. After three weeks on the experimental diets, six pigs were moved, on a weekly basis, to individual calorimetry chambers to measure ammonia and odour emissions. After ~24 h in the chambers, the analysers began recording ammonia production for a total of ~73 h. At ~28 h of recording, odour offensiveness was measured using dynamic olfactometry (BSEN13725:2003). At the end of the recording period, the pigs were removed from the chamber, weighed and their feed disappearance recorded to calculate dry matter intake (DMI). The slurry in each chamber was collected, weighed and stored for future analysis. Data were analysed using a general analysis of variance (ANOVA) in Genstat 16.0, with DMI used as a co-variate.

Results The effect of diet on water intake, and ammonia, odour and slurry output are shown in Table 1. The reduction of CP in the diet from 180 to 150g/kg resulted in a 20% reduction in ammonia emissions, and from 180 to 130g/kg resulted in a 49% reduction (P=0.045). No significant difference was observed between treatments for ammonia excretion as a proportion of nitrogen intake. There was no significant effect of reducing CP on odour offensiveness but using the data from all 30 boars, there was a positive relationship between odour and ammonia (Linear: R^2=0.25, P=0.005, Quadratic: R^2=0.26, P=0.002). Lowering CP to either 150 or 130g/kg reduced water intake (P=0.013) and slurry excreted per day (P<0.001).

Table 1 The effect of reducing dietary crude protein on water intake and ammonia, odour and slurry output

Measure	High CP	Medium CP	Low CP	S.E.M	P-value
Ammonia (mg/h)	430[b]	378[a,b]	223[a]	58.3	0.045
Nitrogen intake (g)	325[b]	270[a,b]	238[a]	2.2	<0.001
Ammonia excretion:nitrogen intake	1.44	1.56	0.94	0.251	0.203
Odour emission (Ou_E/Sec)	2.18	1.87	1.76	0.319	0.630
Water intake (L/day)	6.4[b]	5.1[a]	4.8[a]	0.39	0.013
Slurry output (L/day)	3.4[b]	2.1[a]	2.1[a]	0.21	<0.001

[a,b,c] Within each measure, mean values that do not share a common superscript are significantly different (P<0.05)

Conclusion When comparing the relative differences between treatment diets, lowering dietary CP reduced water intake, ammonia emissions, and slurry output. Although not significant, odour offensiveness was 19% lower in pigs fed lower CP diets. When using all the data, there was a positive relationship between ammonia and odour, with odour significantly reducing as ammonia reduced. Performance trials are currently being conducted as it is important to ensure that production performance is maintained across the dietary CP levels.

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040

Sensitivity of growth performance and crude protein conversion ratio of finisher pigs to dietary protein and essential amino acids

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Application Reducing dietary crude protein levels whilst meeting essential amino acid requirements has great opportunity to increase nitrogen use efficiency and thus reduce environmental footprint in finishing pigs.

Introduction Pure amino acids (AA) assist the least cost formulation of pig diets that are formulated to meet essential AA requirements at reduced crude protein (CP) levels. The resulting increased N use efficiency compared to high CP diets also reduces N excretion and thus environmental footprint. This was demonstrated using pure lysine, methionine, threonine and tryptophan (Bunger *et al*., 2015), though associated with poorer feed conversion ratio. Since pure isoleucine and valine have now become economically available, we hypothesised that reducing CP levels whilst meeting essential AA requirements does not penalise pig performance but improves CP conversion ratio, here used as a proxy for N use efficiency.

Material and methods A total of 72 90-d-old pigs (Danish Duroc × (Large White × Landrace)) were put into pens of 3 males or 3 females, with averaged body weight of 40.5±5.7 kg. Pigs were fed *ad libitum* a standard grower ration for four weeks as an adaptation period, during which males and females grew 1,299 and 1,157 g/d, respectively (s.e.d. 38 g/d; P<0.001). Pigs were then fed *ad libitum* one of three iso-energetic diets for 25 days: high CP (HP), low CP (LP), or LP with added AA (LP+AA) to the same level of standardised ileal digestible essential AA as in HP. Resulting CP levels were 167, 149 and 151 g/kg for HP, LP and LP+AA, respectively from d 118 to d 132 (NE: 9.4 MJ/kg), and 159, 140 and 143 g/kg, respectively from d 132 to 143 (NE: 9.3 MJ/kg). Diets HP and LP+AA met finisher pig AA requirements (BSAS, 2003), whilst the AA to CP ratio in HP and LP was constant. The CP reduction was done by reducing wheat and soya oil and increasing starch and soya hulls, whilst required AA levels were achieved through the use of pure AA. Feed intake and body weights were measured weekly until d 143 of age. Averaged daily feed intake (FI), body weight gain (WG), feed conversion ratio (FCR = FI/WG), CP intake (CPI) and CP conversion ratio (CPCR = CPI/WG) were calculated over d0 to d25. Data were analysed using a 3×2 factorial ANOVA, accounting for the effect of diet, sex and their interaction. Adaptation WG was a covariate for trial WG, whilst end of adaptation body weight was a covariate for trial FI, FCR, CPI and CPCR. This work was approved by SRUC's Animal Welfare and Ethical Review Body (ED AE 05-2018).

Results Table 1 shows significant effect of diets on most performance parameters measured. LP pigs ate less than HP and LP+AA pigs, which was most pronounced in males (P=0.017 for diet × sex interaction; data not shown). This resulted in a greater CP intake of LP+AA compared to LP pigs, with greatest CP intake for HP pigs. Across sex, LP+AA pigs grew faster than HP pigs, whilst LP pigs grew the slowest (Table 1). Feeding treatment did not significantly affect FCR, although LP+AA pigs tended to result in the best feed efficiency (P=0.087). LP and LP+AA grew at smaller CPCR than HP pigs. Males grew faster than females (1621 vs 1387 g/d; s.e.d. 37 g/d), with greater intake (3820 vs 3613 g/d; s.e.d. 70 g/d; P=0.002) at a lower FCR (2.346 vs 2.621; s.e.d. 0.079; P=0.004) and CPCR (0.353 vs 0.362; s.e.d. 0.012; P=0.003).

Table 1 Daily feed intake (FI), weight gain (WG), feed conversion ratio (FCR), crude protein intake (CPI) and CP conversion ratio (CPCR) of pigs on high protein (HP), low protein (LP) or LP diets with amino acids as in HP (LP+AA).

Dietary treatments	Parameters				
	FI (g/d)	WG (g/d)	FCR (g/g)	CPI (g/d)	CPCR (g/g)
HP	3,873	1,498	2.580	633	0.413
LP	3,567	1,469	2.447	515	0.354
LP+AA	3,710	1,546	2.423	545	0.357
s.e.d.	77	34	0.09	11	0.01
Probabilities	0.004	0.009	0.175	0.001	0.001

Conclusion The greater weight gain of the LP+AA pigs compared to the HP pigs concurred with reduced CP intake to weight gain at slightly better FCR. Further analysis will quantify total tract N digestibility and lean tissue growth in these pigs, but assuming that this additional weight gain between LP+AA and HP pigs is largely lean, and that total tract N digestibility is similar between the treatments, this data would support the view that ensuring appropriate levels of essential amino acid levels in reduced protein diets would concur with a reduction in N excretion and improved performance.

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Microbiological survey of liquid feed for finisher pigs on eight commercial pig farms

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Application The microbial quality of liquid feed varies from farm to farm. A common finding across farms is spontaneous fermentation within liquid feed. This may help to explain the variability in growth performance seen in the literature relating to liquid feeding of finisher pigs.

Introduction Feed accounts for ~70% of pig production costs (Teagasc, 2017). Optimising the microbial quality of liquid feed to encourage feed intake and decrease wastage is vital to achieve optimal growth and feed efficiency. By mixing feed and water, naturally occurring lactic acid bacteria (LAB) and yeasts proliferate which results in a reduced pH due to the production of lactic and acetic acids (Canibe and Jensen, 2012). The aim of this experiment was to investigate the microbial quality of liquid feed for finisher pigs sampled from commercial pig units. The hypothesis was that feed microbial quality will vary between farms and that within farm spontaneous fermentation will occur during feed preparation and feeding.

Material and methods A total of seven liquid feed samples were collected from three sampling locations in the finisher section from each of eight Irish pig production units; one from the mixing tank after the agitation process (Mix Tank), three samples of feed freshly delivered to each of three different troughs (Fresh) and three samples of liquid feed remaining in each of three different troughs just prior to feeding (Stale). Counts of LAB, *Enterobacteriaceae, E. coli,* yeast and mould were obtained from feed samples following serial dilution and pour/spread plating on selective media and log-transformed. The pH and temperature of each liquid feed sample was recorded on-farm. Feeding and sanitation practices on each farm were surveyed. Data from each of the eight farms were averaged for Mix Tank, Fresh and Stale and analysed using the MIXED procedure of SAS 9.4. Sampling location was included as a fixed effect and farm was included as a random effect. The experimental unit was farm.

Results Counts of LAB and yeast increased from Mix tank to Fresh and again to Stale (P <0.001), while pH was reduced from Fresh to Stale (P<0.001; Figure 1). Counts of *E. coli* increased (P <0.001) from Fresh to Stale while *Enterobacteriaceae* and mould counts did not differ by sampling location (Figure 1). Liquid co-product (pot-ale syrup and whey) inclusion in the liquid feed reduced counts of LAB, *E. coli*, and mould, increased counts of yeast and reduced sample pH (P<0.001).

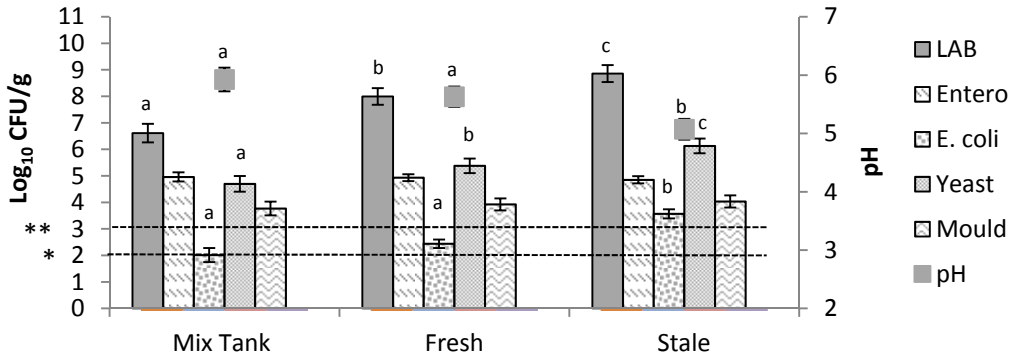

Figure 1 Microbial counts and pH (± SEM) of liquid feed sampled from the mixing tank and troughs from eight commercial pig production units. Detection limit for *LAB, *Enterobacteriaceae*, *E. coli* and **yeast and mould. Bars of the same colour that do not share a common superscript are significantly different.

Conclusion Spontaneous fermentation occurs in liquid feed troughs. This is supported by both the increase in LAB and the pH reduction in liquid feed samples. However, dwell time in the trough was not sufficient to reduce *Enterobacteriaceae* counts (Canibe and Jensen, 2012). Moreover, *E. coli* counts increased in the trough over time, probably due to faecal contamination. An increase in yeast count due to dwell time in the trough may indicate undesirable spontaneous fermentation. Including liquid co-products in the liquid feed helps to improve microbial quality.

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Nutritional evaluation of *Calopogonium mucunoides* as feed resource for grower pigs

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Application Replacing 15% of pig feed concentrates with fresh chopped *Calopogonium mucunoides* where abundantly available may help farmers produce pig meat at reduced costs.

Introduction The relatively high cost of pig production in Nigeria due to competition for conventional feed ingredients (soya bean and groundnut cake) may be solved through the use of abundance forage legume such as *Calopogonium mucunoides*. It is, however, well known that monogastric animals do not digest fibre effectively (Akinmutimi, 2004). Gastrointestinal tracts of pigs have been found to contain some microbes that are found in rumen of ruminants, linked to fibre digestion (Bach-knudsen *et al*. (2011). The aim of this study was to determine the optimum dietary level of inclusion of *Calopogonium mucunoides* forage in the diet of grower pigs.

Material and methods Thirty Landrace x Large White pigs of average initial weight (18kg) were randomly allotted to five diets with two pigs per replicate and replicated thrice. The dietary treatments were: diet 1 (0% *Calopogonium mucunoides),* diet 2 (5% chopped *Calopogonium mucunoides* mixed with 95% concentrate), diet 3 (10% chopped *Calopogonium mucunoides* mixed with 90% concentrate) diet 4 (15% chopped *Calopogonium mucunoides* mixed with 85% concentrate) and diet 5 (20% chopped *Calopogonium mucunoides* mixed with 80% concentrate). The experiment was carried out in a completely randomized design and lasted for 63 days. Growth performance, carcass and organ weights were evaluated as described by Abaza *et al.* (2008) and economics of diet was evaluated as described by Akpodiete and Inoni (2000). All data collected were subjected to Analysis of Variance using SPSS Base for Windows (2016) and Means with significant difference were separated using Duncan New Multiple Range Test of the same package.

Results Final weight, weight gain, and daily weight gain showed significant ($P<0.05$) differences while the best feed conversion ratio occurred in diet 4 (Table 1). Carcass and organ weights showed favourable dressed weight, carcass length and reduction in back fat thickness while there was general increase in the weights of all the organs of pigs fed the legume diets. The economics of the diet showed that diet 4 was more economically viable than others with the least cost/kg weight gain (Table 2).

Table 1 Growth performance of pigs fed with different levels of fresh *Calopogonium mucunoides*

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	SEM
Initial weight	16.00	16.50	17.00	15.00	16.50	0.17
Final weight	34.00^{b}	35.00^{b}	38.00^{a}	38.00^{a}	38.50^{a}	0.71
Daily weight gain	0.308^{b}	0.306^{b}	0.349^{b}	0.371^{a}	0.350^{a}	0.003
Daily feed intake	1.08	1.08	1.07	1.06	1.05	0.04
Feed conversion ration	3.40	3.48	3.33	2.77	3.03	0.11

a-b means along the same row with different superscript are significantly ($p<0.05$) different. SEM= Standard Error of Mean

Table 2 carcass, organ and economics of diet of pigs fed fresh *Calopogonium mucunoides*

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	SEM
Live weight (kg)	30.00^{ab}	29.00^{ab}	26.00^{c}	28.00^{b}	32.00^{a}	2.59
% Dressed weight	56.67^{ab}	55.13^{c}	53.80^{d}	71.42	40.63^{c}	2.67
Carcass length (cm)	65.00	70.00	65.00	70.00	69.00	0.86
Ham weight	19.00	19.00	18.46	18.50	18.50	0.25
Intestine (%)	12.20^{b}	14.51^{a}	15.36^{a}	15.71^{a}	15.45^{a}	0.37
Liver (%)	2.00^{b}	5.16^{a}	5.60^{a}	5.13^{a}	5.15^{a}	0.15
Kidney (%)	0.42^{c}	0.49^{bc}	0.60^{b}	0.77^{a}	0.86^{a}	0.04
Cost/kg weight gain (~~N~~)	282.10	273.77	248.65	195.35	201.13	7.35

a-c means along the same row with different superscript are significantly ($p>0.05$) different. SEM= Standard Error of Mean

Conclusion The use of 15% fresh chopped *Calopogonium mucunoides* in diet of grower pigs resulted in better feed conversion ratio, percentage dressed weight, comparable carcass quality and organ weight, normal blood constituents parameters and had least cost/kg weight gain and hence recommended.

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The effect of oil type and energy regimen during lactation on litter performance to weaning

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Application Lactation diets with salmon oil did not influence litter weight or growth to weaning when compared to diets with soya oil. A 7.9% increase in energy intake (from 1745KJ) during lactation also had no effect on litter performance.

Introduction In separate studies, substituting soya oil for salmon oil and increasing the energy density of the lactation diet have been suggested to improve the growth of suckling piglets and litter performance (Craig *et al*., 2017; Rooke *et al*., 2001). The objective of this study was to examine the combined effect of soya or salmon oil in lactation diets and the impact of using these oil types to increase the energy density of the diet in late lactation on litter growth performance to weaning.

Material and methods This study was carried out under the regulations of the Department of Health, Social Services and Public Safety (DHSSPS) of Northern Ireland in accordance with the Animals (Scientific Procedures) Act 1986. In this study 100 crossbred (Large White X Landrace) multiparous sows were randomly assigned to treatments on day 105 of gestation. A 2 x 2 factorial arrangement compared oil type (soya or salmon oil) and energy regimen ('Flat' (14.5 MJ DE/kg diet offered until weaning) or 'Phased' (14.5 MJ DE/kg diet offered until day 14 of lactation followed by a second diet containing 15.5 MJ DE/kg offered from day 15 until weaning)). Over the 28-day lactation sow feed intake was recorded weekly and energy intake subsequently calculated. Litter weight was recorded at birth, day 1, 14 and at weaning. Litter average daily gain (ADG) and the coefficient of variation (CV) for litter weight were calculated. Piglet mortality was also recorded. Data was analysed using GenStat 16th edition and applying generalized linear mixed models. Sow or litter was considered the statistical unit.

Results No interaction effects were observed on sow feed or energy intake during lactation or litter growth parameters measured (P>0.05). Sows offered diets containing salmon oil had higher feed intake on week 3 compared to sows offered diets containing soya oil (58.1 vs. 61.5 kg, respectively; P<0.05) but overall lactation feed intake (day 1 to 28) did not differ between treatments (av. 202.6 kg SEM= 3.63) (P>0.05). As expected, sows fed a 'Phased' regimen had higher energy intake from day 15 to 28 compared to sows fed a flat regimen (1940 vs. 1745 MJ DE, P=0.002) as well as a higher overall energy intake (3115 vs. 2887; P=0.004). Mean total born and born alive were 15.7 and 14.1, respectively. There was no effect (P>0.05) of treatment on litter size at weaning which averaged 12.2. Litters reared on sows offered salmon oil had increased ADG during week 2 and week 4 (Table 1), but there was no overall effect on litter weight or CV at any time point (P>0.05, respectively) or litter ADG between day 1 and 28 (Table 1). Average litter CV at day 1, 14 and 28 was 20.5±0.63, 19.4±0.75, and 17.5±0.62%, respectively. There was a tendency for reduced litter mortality in sows offered a diet containing salmon oil compared to that of sows offered a diet containing soya oil (9.9 vs 13.4%, P=0.06). Energy regimen had no influence on litter growth performance to weaning (Table 1).

Table 1 Effect oil type and energy regimen on litter weight and average daily gain (ADG) from birth to weaning

	Oil type				Energy regimen			
Variable	Soya	Salmon	SEM	*P-value*	Flat	Phased	SEM	*P-value*
Litter weight, kg								
Birth	20.89	21.65	0.425	0.209	-	-	-	-
Live-born	19.18	20.03	0.542	0.269	-	-	-	-
day 1	19.53	20.44	0.484	0.19	-	-	-	-
day 14	54.72	57.51	1.442	0.174	-	-	-	-
day 21	78.76	82.06	1.989	0.244	79.16	81.36	1.989	0.518
day 28	102.5	105.5	1.884	0.275	102.4	105.5	1.867	0.254
Litter ADG, kg/day								
Week 1	1.74	1.49	0.162	0.278	-	-	-	-
Week 2	3.33	3.81	0.116	0.004	-	-	-	-
Week 3	3.41	3.53	0.120	0.493	3.40	3.55	0.120	0.380
Week 4	3.15	3.56	0.128	0.024	3.28	3.44	0.127	0.372
day 1-28	2.94	3.03	0.061	0.301	2.94	3.02	0.060	0.387

Conclusion Increasing energy density from day 14 resulted in higher sow energy intake at the end of lactation but this did not translate into higher litter weight at weaning. Replacing soya oil with salmon oil in the lactation diet had little influence on litter ADG or piglet survival and no overall effect on litter weight. Litter wean weights were already high in the current study but the 7.9% increase in energy, offered especially in the last 14 days, appears to have been ineffective in raising them further. Lastly, this study would not support the use of salmon oil over soya oil in lactation diets.

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044

Supplementation of lactating sow diets with Lysolecithin improves litter growth and uniformity across seven studies

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Application Piglets from sows supplemented throughout lactation with lysolecithin had increased growth and reduced mortality until weaning, while sows had increased feed efficiency and reduced backfat loss.

Introduction During lactation, sows enter a negative energy balance, and very often feed intake is not enough to cover nutrient requirements. By improving nutrient absorption and availability, trials with lysolecithin have shown an improvement of piglet and litter weight and litter uniformity at weaning, when supplemented to gestating and lactating sows (Papadopolous *et al*., 2016). The aim of this work was to evaluate the consistency and magnitude of the effect of lysolecithin on sow and piglet performance.

Material and methods Seven separate experiments were conducted globally, as shown in Table 1. In total 230 sows were used in the experiments. The sows were equally allocated in two treatments according to their parity: a control treatment with sows fed standard diets, and a standard diet supplemented with lysolecithin (LYSOFORTE®, Kemin Animal Nutrition and Health). Each trial started approximately at day 90 of gestation and ended at weaning. All trials were conducted in line with local welfare regulations, and following approval of the Kemin Ethics Committee.

Table 1 Summary of trials assessing the efficacy of lysolecithin in gestating and lactating sows

Trial	Year	Country	Lysolecithin Inclusion	Sows/treatment	Lactation length (days)
1	2013	Italy	500 g/t	32	25
2	2007	China	750 g/t	12	21
3	2015	Greece	750 g/t	30	28
4	2016	South Korea	500 g/t	10	21
5	2017	France	600 g/t	12	21
6	2016	China	500 g/t	14	21
7	2017	France	600 g/t	6	21

Piglet performance parameters were recorded in all trials: piglets born/born alive per litter, litter weight at birth and weaning, piglets weaned per litter, mortality, piglet weight gain during lactation, and coefficient of variation of piglet weight at birth and at weaning. Sows' individual feed intake was registered daily; sow output was calculated as kg of sow feed intake per kg of piglet weight gain. Data were analysed using the REML method; the model considered treatment as a main effect, parity was considered a covariate, and trial code was included as a random effect. Means separation was achieved using Tukey's HSD in the Fit Model platform of JMP 14, and significance was determined at $P<0.05$.

Results Sows fed gestation and lactation diets that contained lysolecithin had higher feed intakes than sows fed standard diets, leading to reduced average backfat loss during lactation (4.65 mm control vs 3.75 mm lysolecithin), though these differences were not significant. However, sow output was substantially improved on average in supplemented sows, who required 2.23 kg of feed per kg of piglet gain, compared to control sows who ate 2.48 kg of feed per kg of piglet gain. This improvement in efficiency was driven both by increased weight gain in piglets from sows supplemented with lysolecithin, but also by numerically reduced pre-weaning mortality (14.63% control vs 12.85% lysolecithin). Piglets from supplemented sows grew faster, with average daily gains of 223.92 g/day and weaning weights of 6.57 kg, compared to unsupplemented litters where average daily gain was 212.70 g/day and weaning weights average 6.30 kg (ADG $P=0.0327$; piglet weaning weight $P=0.0812$). Overall, faster growth, improved uniformity (17.66 % CV control vs 15.00% CV lysolecithin) and reductions in mortality resulted in an extra 5.44 kg per litter at weaning ($P=0.0025$). The changes in average daily gain and litter weaning weight in piglets from lysolecithin supplemented sows were consistently positive across all trials; the extent of improvement varied from 26.57% and 24.51% in ADG and mortality, respectively, to 1.78 and 2.23%.

Conclusion These results show that lysolecithin applied on top of commercial sow diets can increase sow feed intake and improve condition at weaning. This improvement in sow condition leads to subsequent improvements in piglet growth rate until weaning, as well as reductions in mortality and variability in weaning weight. These results demonstrate that lysolecithin can consistently improve sow and piglet performance, across husbandry and dietary regimes.

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045

Growth response of low and average birthweight pigs to sow lactation feed intake

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Application Growth performance of low birthweight (BW) pigs increased significantly (12.4%) in response to a 24% increase in sow lactation feed intake. This work demonstrates that compromised piglets have the potential to achieve an acceptable wean weight if effective intervention strategies are employed.

Introduction Increased litter sizes currently present in modern commercial sow herds have resulted in elevated numbers of low BW pigs with higher pre-weaning mortality, lower weaning weights and reduced lifetime performance (Fix *et al*, 2010). Furthermore, differences in weaning weight often increase further throughout the growing and finishing periods (Williams, 2003). Therefore development of intervention strategies which maximise weaning weight and lifetime performance of compromised pigs are important to enhance overall herd performance and profitability. This work aimed to assess the growth response of low and average birth weight piglets to different levels of lactation sow feed intake.

Material and methods A two (birth weight) x two (lactation feed allowance) factorial design study employing 32 litters (448 pigs) across 8 replicates was undertaken at AFBI Hillsborough**.** In each replicate four sows, balanced for parity and body condition, acted as foster mothers. Within 24 hours of farrowing, two litters of 14 low BW pigs (<1kg) and two litters of 14 average BW pigs (1.25kg-1.75kg) were randomly assigned to the foster mothers. Lactation feed allowance was offered at either a high (HFA) or a low (LFA), albeit commercially standard, level. The low level allowance (LFA) offered 3kg at farrowing with increments of 0.3kg/day and was capped at 7.5kg/day whereas the high allowance (HFA) offered 3kg on the day of farrowing, increasing by 0.5kg/day up to maximum of 11kg/day. Weaning was undertaken at 28 days. At farrowing and weaning, sow back fat depth at the P_2 position was quantified using an ultrasound scanner. Piglets had individual health, vitality and liveweight recorded throughout lactation. Suckling behaviour was also monitored over a 24 hr period at day 7. Relative growth was calculated by dividing weight gain to weaning by birth weight.

Results There were no significant interactions (P>0.05) between treatments on any of the health or performance parameters recorded for sows or piglets (Table 1). Average feed intake of sows offered the HFA was 217kg whilst sows offered the LFA consumed an average of 174kg representing a difference of 24.7%. As expected, at weaning average BW pigs were heavier than low BW piglets but they had a lower relative growth rate (Table 1). Litters of low BW piglets had a higher mortality rate and were fewer in number at weaning as a result compared with litters of average birth weight piglets. Sows rearing litters of average BW lost more back fat. A HFA increased piglet wean weight and litter gain as well as relative growth rate but had no effect on litter mortality or back fat loss during lactation (Table 1). Analysis comparing the individual treatments found that there was no significant difference in weaning weight or litter gain between low BW litters offered a HFA and average BW litters offered a LFA. Pre-wean mortality was significantly higher for low BW litters offered a LFA compared to all other treatment groups (P=0.012). The back fat loss of sows rearing average BW litters and offered a LFA was significantly higher than that for all other treatments (P= 0.02).

Table 1 Effect of piglet BW and sow feed allowance on litter and sow performance

	Low BW		Average BW			Significance (P Value)	
	LFA	HFA	LFA	HFA	SED	Birth weight	Feed allowance
Piglet wean wt (kg)	7.0	7.9	7.9	8.6	0.36	0.003	0.005
Pig relative growth (kg/kg)	6.5	7.5	4.3	4.7	0.24	<0.001	<0.001
Litter size weaned	10.9	12.4	13.1	13.1	0.49	0.006	0.144
Total litter gain (kg)	62.7	83.4	84.5	92.1	4.9	0.009	0.005
CoV of litter wean weights	0.21	0.18	0.18	0.16	0.019	0.215	0.198
Pre-wean mortality (%)	22.3	11.6	6.3	6.3	3.53	0.006	0.144
Sow P_2 loss	2.0	1.7	4.3	2.7	0.57	0.009	0.122

Conclusion The performance of sows and piglets on the low allowance feeding regimen was reflective of commercial practice. However, this work demonstrated that sows were capable of enhanced intakes when offered a higher lactation feed allowance. This allowed compromised piglets to express a weaning weight matching that of average BW pigs reared under commercial like conditions and record a significantly reduced pre-wean mortality. Overall it is concluded that low BW piglets have a higher potential to grow, relative to their birth weight and can respond positively when provided with an increased milk allowance from the sow.

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046

Investigating the association between temperature and prevalence of respiratory conditions detected during meat inspection in pigs in England and Wales

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Application Prevalence of respiratory conditions in slaughtered pigs showed seasonal variation, with the highest levels in late winter/early spring. Associations with temperature varied by county, with evidence of an association between daily maximum temperature and prevalence of respiratory conditions in several counties.

Introduction Climate change is leading to more unpredictable and extreme weather events, as well as changing general weather patterns, which is likely to affect future disease risk/burden in livestock. Every pig slaughtered for human consumption in the UK is inspected *post mortem* for the presence/absence of specified conditions, with the primary purpose ensuring meat is fit for human consumption. However, meat inspection data may also be used for animal health monitoring purposes. Respiratory conditions are associated with a reduction in performance and increased production costs, as well as being a welfare issue, in pig production. A seasonal effect has been observed in the prevalence of respiratory conditions in pigs, but currently we do not have a good understanding of whether and how weather factors are involved in this seasonal effect. The aim of this this study was to investigate the association between temperature and prevalence of respiratory conditions in the Collection and Communication of Inspection Results (CCIR) data collected by the Food Standards Agency (FSA).

Material and methods We analysed respiratory conditions recorded in the CCIR dataset, which covers all English abattoirs, from Jan 2010 to Dec 2015. Daily maximum ambient temperature from the Meteorological Office (MET Office) was aggregated at the weekly level by averaging daily records at both national and county levels. Farm-level postcodes in the CCIR dataset were used to link pig origin to the Met Office data at the county level. The prevalence of the respiratory conditions was aggregated at the weekly level and calculated both at the national and county levels. Time-series of the weekly prevalence of respiratory conditions was assessed graphically and in relation to maximum ambient temperature, adjusting for seasonal patterns. Day-of-week effects were controlled for by performing the analysis at the weekly level. Seasonality was controlled for in the temperature analysis by using flexible spline functions. The metric considered was maximum temperature lagged by up to 10 weeks. The best fitting model at the national was chosen based on the model deviance outcomes. Based on the results of the national level analyses, we assumed the best fitting model at the county level analyses was the same as the national level. Temporal analysis of these data were performed using Stata 15.1.

Results A total of 4,916,898 records over 312 weeks were analysed at the national level and 51 counties were analysed at the county level. Prevalence of respiratory conditions showed cyclic patterns over time in both national and county level. The temperature model averaging lags between week 0 to week 5 showed the best fit, with the lowest deviance at the national dataset. In the averaged lag over 0 – 5 weeks model, there was a risk ratio of 0.991 (95% CI 0.809, 1.213; p = 0.927) per one-degree decrease in temperature below this threshold. In the county level analysis, the pooled effects of all counties had a risk ratio of 0.986 (95% CI 0.986, 0.986) per one-degree decrease in temperature below 15°C, which was more precise in county-level than in national level.

Conclusion We found seasonal trends in the prevalence of respiratory conditions, both at the national and county level. This is in agreement with previous results from analysis of pig health monitoring data (Correia-Gomes *et al*., 2017) We also found that there was some evidence of an association between daily maximum temperature and prevalence of respiratory conditions in several counties, but not at the national level. Not all counties showed this association and this may be because weekly prevalence was not based on the onset of disease, but rather on the diagnosis of disease. Other weather factors, such as rainfall, relative humidty and air frost, may be associated with the prevalence of respiratory disease in pigs.

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047

The effect of oil type and energy regimen during lactation on the fatty acid content of piglet blood plasma and adipose tissue at weaning

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Application The profile of fatty acids in piglet plasma and adipose tissue at weaning reflected the changes in the lactation diet (i.e. soya to salmon oil at low and high levels), demonstrating highly effective transfer of fatty acids from feed to sow blood, milk, piglet blood and lastly tissue. Salmon oil increased the proportion of n-3 fatty acids

Introduction Inclusion of fish oil, which contains a high level of n-3 fatty acids (FA), in diets for sows has been found to influence the proportion of fatty acids in piglet tissues (Rooke *et al*., 2001). N-3 fatty acids are important for foetal cognitive development and may influence piglet viability at birth to weaning. In addition, increasing the energy density of the lactation diet has been suggested to improve litter performance (Craig *et al*., 2017). The objective of this study was to examine the use of soya and salmon oil in lactation diets within a flat of phased energy regimen on piglet fatty acid profile at weaning.

Material and methods This study was carried out under the regulations of the Department of Health, Social Services and Public Safety (DHSSPS) of Northern Ireland in accordance with the Animals (Scientific Procedures) Act 1986. In this study 100 crossbred (Large White X Landrace) multiparous sows were randomly assigned to treatments on day 105 of gestation. A 2 x 2 factorial arrangement compared oil type (soya or salmon oil) and energy regimen ('Flat' (14.5 MJ DE/kg diet offered until weaning) or 'Phased' (14.5 MJ DE/kg diet offered until day 14 of lactation followed by a second diet containing 15.5 MJ DE/kg offered from day 15 until weaning)) over a 28-day lactation. At weaning 40 piglets balanced by litter and sex were selected for dissection to determine FA levels in blood plasma, and adipose tissue. Data was analysed using GenStat 16th edition and applying generalized linear mixed models and when analysing FA levels piglet was considered to be the statistical unit.

Results The FA composition of piglet blood plasma and adipose tissue are presented in Table 1. Piglets from sows offered the diet containing soya oil and phased regimen treatment had higher n-6 FA content in blood plasma and adipose tissue and also had a higher PUFA content in adipose tissue than the other groups (all $P < 0.05$). The proportion of n-6 FA content was greater in the blood plasma of piglets from sows offered diets containing soya oil ($P<0.01$), but total MUFA ($P<0.05$) and n-3 FA ($P<0.01$) was increased in the plasma of piglets from salmon oil sows. Salmon oil increased the saturated ($P<0.05$), MUFA, PUFA and n-3 FA content but decreased the n-6 FA content of piglet adipose tissue compared to soya oil ($P<0.001$). Offering sows a phased energy regimen increased the MUFA content of piglet blood plasma ($P<0.01$), whereas piglets from sows offered a flat energy regimen had greater MUFA content in adipose tissue ($P<0.01$). Total PUFA ($P<0.001$), n-3 ($P<0.01$) and n-6 ($P<0.001$) FA content in piglet adipose tissue was greater for progeny from sows offered the phased energy regimen compared to the flat energy regimen.

Table 1 Treatment effect (oil type and energy level) on fatty acid composition (g/100g total fatty acids) of piglet blood plasma and adipose tissue collected at weaning (day 28, 10 piglets/treatment)

	Soya Oil		Salmon Oil		SEM	P-value		
	'Flat'	'Phased'	'Flat'	'Phased'		Oil	Energy	Oil x Energy
Blood plasma								
Saturated	42.6	41.4	41.36	45.3	1.38	0.348	0.295	0.073
MUFA	23.7	19.8	24.5	23.0	0.81	0.018	0.002	0.145
PUFA	33.5	38.4	33.7	31.3	1.84	0.069	0.539	0.055
n-3	2.75	3.19	4.49	4.39	0.48	0.005	0.734	0.577
n-6	30.8[a]	35.2[b]	29.2[a]	26.9[a]	1.43	0.002	0.495	0.025
Adipose tissue								
Saturated	35.0	34.2	36.2	35.5	0.59	0.044	0.226	0.930
MUFA	43.0	39.2	44.2	43.1	0.69	<0.001	0.001	0.065
PUFA	21.8[a]	26.3[b]	19.3[c]	21.2[a]	0.41	<0.001	<0.001	0.002
n-3	2.15	2.42	2.47	3.11	0.13	<0.001	0.001	0.165
n-6	19.6[a]	23.9[b]	16.8[c]	18.0[c]	0.45	<0.001	<0.001	0.001

Conclusion Maternal nutrition during lactation can influence the FA content of piglet blood plasma and tissues at weaning. Soya oil and a phased energy regimen increased n-6 FA content of piglets. Salmon oil increased the n-3 FA content of piglets' blood and adipose tissue and as a consequence decreased the n-6 FA content, while a higher oil content in the phased energy regimen increased the total PUFA, n-3 and n-6 FA content in piglet adipose tissue at weaning.

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048

The effect of keeping gilts on an indoor or outdoor production system, during gestation and lactation, on litter and piglet performance to weaning

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Application Gilts of an outdoor genotype have the potential for greater reproductive performance and so more research is needed in order to make sure this is optimised.

Introduction Outdoor production systems make up 40 % of the UK pig industry (AHDB, 2018). A previous study found that when sows of a similar genotype were kept indoors throughout gestation and then farrowed either indoors or outdoors, the number of piglets born was the same, however, the number of piglets weaned outdoors was lower than indoors. This study also found piglets reared outdoors had higher pre-weaning growth rates when compared with piglets reared indoors (Miller *et al*, 2007). The type of production system gilts are kept in throughout gestation may also impact the litter. The aim of this study was to determine whether keeping gilts on indoor or outdoor production systems, throughout gestation and lactation, affected their litter and piglet performance to wean.

Material and methods Twenty three (outdoor genotype = Large White × Landrace × Duroc) gilts were either kept indoors or outdoors across two batches. Those housed indoors (n=13), were kept in straw yards from service until day 108 of gestation, when they were moved into the farrowing house and kept in conventional farrowing crates, within individual farrowing pens measuring 4.2m^2. Each pen had a creep area at the front with a heat lamp. Those kept outdoors (n=10) were in group outdoor paddocks from service until day 108 of gestation, when they were moved into individual farrowing pens with access to a straw bedded arc with a fender attached to the front. All gilts were fed the same diets throughout gestation and lactation that met all nutrient requirements (NRC, 2012). Piglets were weighed and ear tagged for identification within 24 hours of birth and weighed again on days 7, 21 and weaning. Fenders were removed from outdoor arcs on day 14. Data were analysed using the GLM procedure of SPSS (version 22) with environment and batch as main effects and litter sizes as a covariate. The gilt was the experimental unit. This study was approved by the University of Leeds Ethical Committee.

Results Gilts housed indoors had larger observed litter sizes at birth (+ 5.95 piglets) compared with gilts kept outdoors (P<0.001). Litter sizes indoors ranged from 13 to 18 piglets, compared with 6 to 14 outdoors. Production system did not influence average piglet birth weight (P=0.954). Piglets reared outdoors tended to be heavier on days 21 and weaning (+ 810 g at weaning) compared with piglets reared indoors (P<0.1); however, indoor gilts weaned more piglets (11.97 vs. 8.52).

Table 1 Effect of production system on litter and piglet performance to weaning

	Production system			
	Indoor	Outdoor	SEM	*P*-value
Number of piglets alive	15.09	9.24	0.636	< 0.001
Number of piglets weaned	11.97	8.52	0.634	0.002
Average piglet weights (kg)				
Birth	1.40	1.40	0.077	0.954
Day 7	2.40	2.66	0.110	0.169
Day 21	5.28	6.12	0.245	0.045
Wean	6.30	7.11	0.284	0.093
Overall ADG (g)	190	225	10.9	0.061

Conclusion This preliminary study suggests that outdoor genotype gilts are more productive when housed on an indoor production system and this affected numbers born as well as numbers weaned. Future work is needed to confirm this observation and determine why reproductive performance appears to have been compromised in gilts kept outdoors during gestation and lactation.

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049

The impact of an Oregano based Eubiotic on the health and performance of sows and their progeny

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Application Oregano essential oil, included in sow diets may help support sow reproductive performance and help to reduce morbidity in piglets.

Introduction With increasing pressure on the pig industry to reduce the use of antimicrobials whilst improving animal performance and welfare, there is a growing interest in sustainable alternatives. Oregano (*Origanum vulgare*) contains the compounds carvacrol, thymol, *y*-terpinene and *p*-cymene, which have been shown to have antimicrobial and anti-oxidant activities. Previous findings have shown that dietary supplementation of sows with oregano essential oil decreases oxidative stress markers in late gestation and early lactation, and showed improved piglet's performances (Tan *et al*., 2015). In order to reduce the reliance on antimicrobials at weaning such as zinc oxide, we must aim to wean more robust piglets, therefore the nursing phase represents a critical period of opportunity to develop piglet health and resilience to ensure long-term optimal performance. The present study evaluates the effects of a natural oregano essential oil (Orego-Stim©) in sow lactation and piglet creep diets on health and performance pre- and post-weaning.

Material and methods Sixty-two multiparous sows across two weekly batches were randomly allocated to treatment or control balancing for parity. Treatment allocation was blinded during the trial. Baseline parameters including litter size and sow body condition scores showed no significant differences at the start of the trial. Sows in the treatment group received oregano essential oil supplementation (OS) at an equivalent rate of 500g/t. Control (CON) sows received blank carrier. Both treatments were top dressed to sow diets daily from seven days prior to farrowing until weaning (~26 days). All piglets were ear-tagged at birth and any cross-fostering was carried out within treatment. At two weeks of age, piglets from all treatment groups were offered creep feed containing OS at 1kg/t. Sow feed intake, body condition score (BCS) and piglet weekly weight, mortality, medication and creep feed intake were recorded. The effect of OS on performance data was analysed using a linear mixed model in IBM SPSS Statistics (v24) (with treatment as fixed factor) and included sow, room and gender as random factors. Statistical analysis of body condition scores was performed using Chi-Square for trend.

Results Sow feed intake during lactation was not significantly affected by treatment, however sows on the OS treatment had a higher BCS at weaning (p=0.034). Piglet weights at birth were similar across treatments (Table 1). Piglets from the OS treatment had significantly improved average daily weight gain and body weight in the first week of lactation when no supplementary creep feed was available (Table.1). Health records showed that piglets from OS litters had a tendency towards lower incidence of morbidity (Table 1), resulting in a 4.2% reduction in therapeutic treatment and reduced pre-weaning mortality from 14.3% to 10.9%.

Table 2 Piglet pre-weaning performance

	CON	OS	SEM	p-value
Number of sows (n)	31	31		
Total born alive	441	428	-	-
Birth weight (kg)	1.363	1.383	0.02	0.374
Weight Week 1 (kg)	2.107	2.233	0.03	0.006
Weight Week 2 (kg)	3.465	3.540	0.05	0.292
Weight Week 3 (kg)	5.44	5.54	0.05	0.302
Weight Week 4 (kg) (weaning)	7.374	7.554	0.05	0.156
ADG Week 1 (kg)	0.141	0.163	0.004	0.045
Overall ADG (kg)	0.230	0.235	0.003	0.079
Morbidity	51/441 (7.9%)	34/428 (11.6%)	-	0.072

Conclusion The inclusion of OS maintained body condition score of sows during lactation. Piglets from sows receiving OS treatment showed a positive improvement in weight gain in the first week of life and showed a reduced incidence of morbidity and mortality with a lower usage of medication. This study highlights the potential benefits of using Oregano essential oil in lactation as a sustainable tool to improve sow and progeny health and performance.

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050

Developmental programming of porcine muscle progenitor cell fate by foetal growth restriction

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Application To develop new management strategies for preventing and treating runt piglets, knowledge of the biological basis on muscle development is required. This is expected to enable runt piglets to maximise their growth at different stages of life.

Introduction Selection for high-prolificacy in pigs has brought a significant increase in the frequency of naturally occurring foetal growth restriction, with negative consequences for the pork industry (Pardo *et al.,* 2013). FGR piglets are significantly smaller than their littermates and show reduced neonatal survival. A key feature of FGR littermates is reduced muscle mass associated with smaller numbers of fibres formed prenatally, and a tendency to accumulate fat in different body stores during post-natal growth. This results in poor growth and reduced carcass quality, with lower percentages of lean tissue (Wu *et al.,* 2006, Yates *et al.,* 2014).

Material and methods Two male foetuses, normal (N) and FGR, were collected from each of 4 Landrace X Large White litters at gestational day 90 (total n=8). In each litter, FGR foetuses were identified based on body weight below 2 standard deviations below the mean litter weight. Mononuclear progenitor cell fractions were obtained by enzymatic digestion of semitendinosus muscle samples and were expanded in DMEM media supplemented with FBS and bFGF. Cells were differentiated under myogenic (serum-free) or adipogenic (media supplemented with rabbit serum, Dexamethasone, 3-isobutyl-1-methylxanthine and insulin) conditions, followed by analyses of lineage markers using immunochemistry and PCR. In addition, paired muscle samples from N and FGR foetuses from all 4 litters were submitted for mRNA-sequencing, and differentially expressed transcripts were identified (FDR<0.1) and were analysed using Reactome Pathway Database. All statistical analyses were performed using Minitab 17 the normality of the distribution of the data was assessed by an Anderson-Darling test. Log10 transformations were carried out to achieve normality of the distribution of the data where required. ANOVA with a post hoc Tukey test was performed, with a block for gilt to account for the common maternal environment.

Results Results showed longer doubling times for cells from FGR than N foetuses (16.3 vs 11.5 hours, respectively; $P<0.05$). Moreover, cells from FGR foetuses had reduced myogenic capacity in culture, indicated by reduced fusion index (14% vs 26% in FGR and N foetuses, $P<0.05$) and significantly reduced expression of the skeletal muscle genes, MYH2 (110.0-fold) and MYH3 (4.9-fold). In contrast, cells from FGR foetuses had an increased ability to undergo adipogenic differentiation relative to N foetuses resulting in increased ($P<0.05$) levels (79.3-fold) of the adipogenic transcript, PPARγ, after a 14-day differentiation period. In addition, RNA-sequencing revealed changes (≥2-fold; FDR<0.1) in a total of 64 genes between foetuses, involving upregulation of 56 and 8 transcripts in muscle from FGR and N foetuses, respectively. Pathway analysis of differentially expressed transcripts revealed significant enrichment ($P<0.05$) of GO terms for metabolic, inflammation and immunity, and organ development processes.

Conclusion In conclusion, porcine foetal progenitor cell populations in culture are able to replicate the FGR muscle phenotype, characterised by reduced myogenic capacity and increased adipogenic capacity, demonstrating developmental programming of these progenitor populations in-utero. This will provide a powerful system to elucidate the mechanisms involved in the FGR phenotype.

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051

Whole genome sequencing gives n-ewe insights into the role of *Dichelobacter nodosus* in the pathogenesis of ovine footrot

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Application Widely endemic in the UK, footrot can lead to severe lameness, loss of condition and reduced productivity, thus having a great economic impact with costs up to £80 million per annum. So understanding the involvement of *Dichelobacter nodosus* in the progression of footrot is a key topic in the sheep industry.

Introduction Footrot, primarily caused by *Dichelobacter nodosus*, is responsible for approximately 70% of foot lesions in sheep in the UK. There are two clinical presentations of footrot: interdigital dermatitis (ID), an inflammation of the skin between the digits, and severe footrot (SFR) where hoof horn separates from the underlying sensitive tissue. Several virulence factors have been identified in *D. nodosus*, e.g. *fimA* (used to classify the 10 current serogroups), acidic proteases, virulence-associated regions/loci and outer membrane proteins (*OMPs*). However, current evidence has not found virulence factors to correlate with the presence of severe disease. *D. nodosus* exists in a community of multiple strains (metapopulation) and one hypothesis is that disease severity is dependent on several strains co-existing to cause disease, rather than one 'virulent strain'. Kennan & Gilhuus *et al.* (2014) analysed 103 *D. nodosus* isolates (prepared according to Illumina paired end sequencing on either Illumina GAIIx or a MiSeq instrument) from various countries and, from their analyses of the 31,627 core SNPs, identified two distinct clades. One clade deemed virulent (presence of *acidic protease V2* gene) and the other deemed benign (presence of *acidic protease B2* gene only). Eleven other genes scattered throughout the genome with SNPs correlating with the clade differentiation were identified, but in six of these genes did these differences result in an amino acid substitution in the encoded gene. Their analyses also indicated recombination between virulent and benign isolates however, they only had one isolate from the UK. Blanchard *et al.* (2018) analysed the isolates from Kennan *et al.* (2014) plus a further 68 *D. nodosus* isolates from the UK. From 171 *D. nodosus* isolates, 115 strain types were identified which were independent from serogroup and acidic protease type. The aim was to gain a deeper understanding of the *D. nodosus* community, investigate possible virulence factors and possible links with disease severity, from a much larger number of *D. nodosus* isolates than studied previously.

Material and methods More than 700 *D. nodosus* isolates were submitted for whole genome sequencing (Illumina paired end HiSeq x10) to undergo computational analysis. The *D. nodosus* isolates sequenced in Kennan *et al.* (2014) and Blanchard *et al.* (2018) were re-analysed through the Wellcome Sanger Institute pipeline, yielding 151 isolates of sufficient quality identified as *D. nodosus*. The pseudogenome of all the SNPs of the 151 isolates was calculated using maximum likelihood clustering (RAxML). The pangenome of just the core SNPs was calculated using Roary and RAxML. Gubbins was used to check for recombination. Mapping was used to analyse isolates by country, date, disease state, serogroup and acidic protease type.

Results There was no distinct clustering of the 151 *D. nodosus* isolates however those containing the *aprB2* (benign) gene only were predominantly clustered together distinct from isolates containing the *aprV2* (virulent) gene. A total of 990 core genes were identified from the 151 *D. nodosus* isolates. Again, those containing the aprB2 gene only were predominantly clustered together distinct from isolates containing the *aprV2* gene. In contrast to mapping all SNPs, the core SNPs showed three clusters; one predominantly comprised isolates containing *aprB2* mostly from Norway and Sweden, another comprised isolates mostly from the UK, and a third comprised isolates mostly from Australia. Considerable recombination was identified with significant peaks for *fimA*, *fimB*, *OMP1E* and *OMP1D*.

Conclusion These preliminary analyses show isolates diverge by country, also by acidic protease type as in Kennan *et al.* (2014). Both *fimA* (used to classify the serogroups) and *OMP* genes have been associated with virulence and, being highly recombinant, are worth further investigation when analysing all *D. nodosus* isolates being sequenced.

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Variation in lamb performance under a targeted selective anthelminthic treatment regime is not underpinned by between-individual differences

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Application Sustainable control of livestock disease requires the development of strategies to slow the development of drug resistance in parasites, and the monitoring of animal performance under such strategies.

Introduction In temperate regions, gastrointestinal strongyle nematodes (predominantly *Teladorsagia circumcincta* and *Trichostrongylus* spp.) are the most important parasites affecting the health and productivity of domestic sheep. Treatment has largely relied upon the frequent administration of a suite of anthelminthic drugs, but the development of nematode drug resistance has necessitated the design of more sustainable treatment regimens which will slow the evolution of resistance in the parasite population. Targeted selective treatment (TST) strategies aim to monitor one or more aspects of animal performance and treat only those individuals which require it, based on a pre-determined treatment decision threshold (Kenyon and Jackson 2012). However, as well as identifying which individuals require treatment, it is essential to determine how individuals vary in their response to treatment and their performance under TST strategies- such individual variation could underpin genetic variation, forming the basis of selection for high performance under TST in the future.

Material and methods Data were collected from Blackface-cross lambs from ~7 weeks of age in each of 2006-2011 (N = 248) (Kenyon *et al*. 2013). Lambs were grazed May-October with their dams on replicated paddocks naturally contaminated with gastro-intestinal parasites. In each year, lambs were subjected to a TST regime, as follows. Anthelminthic (invermectin, Oramec, Merial at manufacturers recommended dose rate) was administered to ewes upon entry to the paddocks on day 0. An additional treatment was given to lambs on day 28 control *N. battus* infection. From day 56, animals were weighed every two weeks and their expected weight gain calculated using the Happy Factor™ decision support model, which takes into account factors including feed availability, climate and maturity (Greer *et al* 2009). Animals which failed to meet their expected weight gain received ivermectin, while those that met their weight gain target remained untreated. In addition to data on weight gain, we also collected strongyle FEC data at each two-week interval.

Our main phenotype of interest was 'weight difference', calculated as an individual's weight at measurement minus their target weight. Thus, animals with positive weight difference scores achieved growth rates in excess of the treatment threshold suggested under TST and thus more positive scores could be a potential target trait for selection.

Results Generalized linear mixed-effects models (GLMMs) showed that there was zero between-individual variation for weight difference (χ^2=0.00, P=0.999). We found that weight difference became less positive across the course of the study, suggesting that animals became less likely to achieve their target weight as the study progressed (linear date estimate=-0.01±0.00SE, χ^2=33.58, P<0.001), and that animals treated at the previous assessment had a more positive weight difference (treated versus non-treated estimate=1.15±0.10, χ^2=139.88, P<0.001). Weight difference was also influenced by an interaction between strongyle FEC and treatment (χ^2=4.28, P=0.039): weight difference was negatively associated with FEC in individuals not treated in the previous month, but not correlated with FEC in individuals which were treated.

Conclusion The weight difference phenotype assessed here would not be a suitable target for selection of animals performing well under TST. In addition the results suggest that, even in a TST framework where the treatment decision is made based on body weight, individuals with higher FEC benefit most from treatment in terms of their performance.

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Effects of sub-optimal mobility on production performance of pasture-based dairy cows

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Application Sub-optimal mobility negatively effects production performance in pasture-based dairy cows.

Introduction Sub-optimal mobility has been identified as the third most important health-related economic loss, after fertility and mastitis (Bruijnis *et al*., 2010, Alawneh *et al*., 2011, Huxley, 2013). It is well known that severe forms of sub-optimal mobility cause losses in terms of milk yield (Enting *et al*., 1997); however, less is known about the effects of mild forms of sub-optimal mobility on milk yield and other production performance parameters. Therefore, the objective of this study was to investigate the effect of sub-optimal mobility on production performance in pasture-based dairy cows.

Material and methods Data from 8,921 cows from 66 pasture-based dairy herds located in the Munster region of Southern Ireland were collected as part of a larger research project. Cows were mobility scored (using a four point scale ranging from 0 to 3, where 0 describes a cow with optimal mobility and 3 describes a cow with very poor mobility), and body condition scored (BCS) (using a five point scale ranging from 1 to 5, with 0.25 increments) once in early lactation.
A linear mixed model was used to evaluate the effect of mobility score on 305-day milk, fat, and protein production, and somatic cell count (SCC). As the SCC distribution was right skewed, a log10 transformation was applied to normalize the data (Ali and Shook, 1980). Four models were run in total, each with different output variables; 1) 305-day milk yield, 2) 305-day fat yield, 3) 305-day protein yield, and 4) log SCC. Fixed effect variables were: mobility score, BCS (< 3, = 3, > 3), cow parity (1, 2, and 3+), calving date (day of year from 1 through 365), and the economic breeding index (EBI) sub-indices; milk (model 1 and 4), fat (model 2), or protein (model 3), and cow health (model 4). Herd was included as a random effect variable in each model. The EBI is the breeding index used to identify genetically superior animals to increase profitability within Irish dairy herds (Veerkamp *et al*., 2002). EBI sub-indices values (milk, fat, protein, or health) for all the cows were also included in the analysis as fixed effects for the genetic transmitting ability of certain traits. Descriptive statistics and modelling statistics were performed using the R statistical software (R Core Team, 2013), using the function 'lmer' for linear mixed effects analyses.

Results Cows with mobility score ≥ 2 had a reduced 305-day milk yield (-146 litres and -356 litres for mobility score 2 and 3 cows, respectively) when compared to the reference value (mobility score 0), while mobility score 1 had no effect on 305-day milk yield. Similarly, cows with a mobility score ≥2 had a reduced 305-day fat and protein yield, when compared to the reference value (mobility score 0), while cows with mobility score 1 showed no effect on 305-day fat or protein yield. Cows with any form of sub-optimal mobility (mobility score ≥ 1) had significantly higher SCC. BCS had no significant effect on 305-day milk, fat or protein yield, or SCC, while cow parity, EBI sub-indices (milk, fat, or protein), and calving date had significant effects in all the models.

Conclusion Cows with moderate and severe sub-optimal mobility (mobility score 2 and 3) have reduced 305-day milk, fat, and protein yield, and cows with any form of sub-optimal mobility (mobility score ≥1) have increased SCC.

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A survey of management practices prior to and at lambing which may influence lamb mortality on Irish sheep farms

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Application Increased use of known best practices prior to and during lambing may reduce the incidence of lamb mortality.

Introduction Average lamb mortality in Irish sheep flocks is currently 8.4% (NFS). Shiels *et al*. (2018) reported that 51.6 and 21.5% of neonatal lamb mortality occurs at birth and within 24 hours of birth, respectively. Shiels *et al*. (2018) also reported that the main causes of lamb mortality during the neonatal period were infection, dystocia, accident and other causes. The aim of this paper is to present results of a survey undertaken to establish farm management practices on sheep farms prior to and during lambing which may influence lamb mortality.

Material and methods The survey was undertaken with sheep farmers participating in the Teagasc National Farm Survey (NFS). The NFS is part of the Farm Accountancy Data Network (FADN) of the EU and is the Irish equivalent of the UK Farm Business Survey. The NFS uses a random representative sample of approximately 1,000 Irish farms which is selected annually in conjunction with Ireland's Central Statistics Office (CSO). The NFS sample represents a farming population of approx. 90,000 farms. A supplementary survey relating to the prevalence of on farm practises that carry high and low risks for lamb mortality, and farmer opinions of what management factors carry high and low risk on their farm was conducted as an additional section to the regular 2017 Teagasc NFS. A total of 183 NFS respondents who farmed sheep completed the additional survey. These farms represent a total of 18,284 Irish sheep farms. Only farmers (178) with a sheep enterprise consisting of more than 20 breeding ewes were included in the final analysis. The surveys were completed on farm by a team of trained NFS recorders. The supplementary survey contained 12 multiple part questions and was designed to create a profile of on-farm practices used by each individual farmer. The questions were predominantly "closed-ended" and designed for the specific aim of getting the required response in the most efficient and easily understood manner. Some "open-ended" questions were also included. On completion of data collection the dataset was cleaned and screened for anomalies. Any anomalies were checked and corrected. Descriptive statistics were compiled and preliminary analysis conducted using Microsoft Excel.

Results Of the 183 survey responses, 178 (97%) were usable. The mean (range) number of ewes and number of lambs reared per ewe joined were 135 (20-1,427) ewes/ha and 1.34 (0.23-2.05) lambs per ewe joined, respectively. Fifty six percent of respondents raddled rams prior to joining them with ewes. Sixty eight percent of farmers had their sheep scanned, of these 18% scanned >1.8 lambs per ewe joined and 3% scanned <1.2 lambs per ewe joined. Seventy six percent of farmers used individual lambing pens. Of those 51%, 15% and 10% cleaned and disinfected, cleaned only, and disinfected only individual lambing pens after each ewe, respectively. Twenty three percent of farmers did not clean or disinfect individual lambing pens. Eighty percent of farmers applied iodine to the navels of all lambs, 9% to some lambs and 11% did not apply iodine to the navels of any lambs. Eighteen percent of farmers vaccinated all lambs against orf, 8% vaccinated some lambs, while 74% of farmers did not vaccinate any lambs. Nine and half percent of farmers administered antibiotics to all lambs in order to treat and/or prevent diseases (scours and/or joint ill), 46.5% treated some lambs with antibiotics, while 44% didn't administer antibiotics to any lambs. Sixty four percent of respondents tail docked every lamb, 17% tail docked some lambs and 19% did not tail dock any lambs. Male lambs were reared entire on 64% of farms. Only 27% of farmers castrated all male lambs while 9% castrated some male lambs. Eighty six percent of farmers vaccinated their ewes. Seventy nine percent of farmers vaccinated their lambs. Vaccinations against clostridial and/or pasteurella diseases were the most common vaccines used on lambs (79%) and ewes (68%). Twenty percent of farmers vaccinated their ewes against abortion agents (toxoplasmosis and/or EAE). Seventy eight percent of farmers assisted lambs to suck at birth, 68% used artificial colostrum on their farm, while 46% gave fresh colostrum from another ewe. Nine percent of all farmers used artificial colostrum as their only source of colostrum at lambing. Thirty percent of farmers recorded lamb deaths. Diseases, predators and abnormal birthweight were ranked by farmers as the three main causes of live born lamb mortality in their flock.

Conclusion Many farms do not implement best practices on their farms prior to lambing. Of the 76% of producers who have lambing pens only 51% clean and disinfect after each ewe which may increase antibiotic usage. Farmers understand diseases/infection to be the main cause of lamb mortality.

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Udder health indicators in low-input dairy goat herds

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Application Daily milk yield, presence of udder abscess and fibrosis, age of goat and lactation stage can be used as predictors for on-farm assessment of udder health status facilitating mastitis diagnosis and prevention.

Introduction Intramammary infections are associated with decreased milk yield, poor milk quality and low health and welfare status, resulting in considerable economic losses (Leitner *et al*., 2004; Gelasakis *et al*., 2016). On-farm udder health assessment is a challenging task due to limited diagnostic tools (Bergonier *et al.*, 2003). The objective of the study was to assess the reliability of physiological and phenotypic traits as on-farm indicators of udder health status in dairy goats.

Material and methods A total of 1,196 dairy goats were randomly selected from seven flocks, representative of low-input pastoral farming systems in Greece (Gelasakis *et al*., 2017). Individual milk yield records, milk quality data and udder assessments were collected monthly for two consecutive milking periods. Udder assessment was done with observation and palpation to detect abscesses, fibrosis and/or asymmetry. Milk samples were analysed to determine somatic cell counts (SCC) and colony-forming units (CFU). The presence of both SCC>1,000,000/ml and CFU>20,000/ml was set as threshold indicative of compromised udder health status. Data analyses were performed using R version 3.5.1 and package "lme4". Generalised mixed linear models based on the maximum likelihood were built to assess fixed effects of daily milk yield, presence of udder abscess, fibrosis and asymmetry, age of goats and lactation stage on udder health. Random effects of goat and farm were estimated. For the analyses, daily milk yield records were distributed into four levels. Respectively, five lactation stages were distinguished, representing months post-weaning.

Results In total, 7,294 records were subjected to data analysis; about 1,775 cases (24.3%) of compromised udder health status were revealed. Udder asymmetry and fibrosis were observed in high frequencies; 29.8% (2,175 records) and 39.4% (2,873 records), respectively. However, frequency of udder abscesses was low; just 3.0% (222 records). Udder health was significantly affected by the majority of parameters tested ($P<0.01$); the exception was udder asymmetry. Goats with udder fibrosis and abscess had 1.65 ($P<0.001$) and 2.08 ($P<0.01$) times higher probability of compromised udder health status, respectively. Susceptibility to such problems also increased with age. The probability of compromised udder health was 2.93 to 10.37 times higher for aged goats compared to young ones; one year old ($P<0.05$). In advanced lactation stages udder health risk was higher. From 2nd to 5th month post-weaning, goats were 2.15 to 4.00 times more prone to udder health problems than in the 1st month ($P<0.001$). Low milk production was also indicative of compromised udder health. Goats producing less than 0.6 kilograms of milk daily were 2.40 to 6.95 times more likely to have compromised udder health status compared to goats of higher productivity ($P<0.001$).

Conclusion Combined information of daily milk yield, udder health clinical traits, age of goat and lactation stage can help identify goats with higher probability of compromised udder health. The use of such indicators for udder health assessment provides a quick, easy and cost-effective practical tool. The latter can facilitate epidemiological assessment of udder health problems and at the same time facilitate sampling of milk for laboratory confirmation and evidence-based control measures for mastitis prevention.

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The effect of the mycotoxin deoxynivalenol on the function and metabolism of bovine kidney epithelial cells *in vitro*

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Application Deoxynivalenol (DON) is a mycotoxin known to reduce performance in cattle. Investigation of the impact of this mycotoxin at the cellular level is necessary to inform the development of non-invasive tests for biomarkers of mycotoxicosis.

Introduction The presence of high levels of the trichothecene mycotoxin DON in maize silage has been associated with liver, nervous system, digestive and reproductive disorders in cattle. These manifest as a range of symptoms, including depressed feed intake and ketosis, that can adversely affect animal health, performance and milk yield in dairy cattle. These effects have been well documented at the level of the whole animal and at high concentrations, but the effect of lower concentrations on performance is not well understood. The aim of this work was to evaluate the toxicity of DON at the cellular level *in vitro* and to determine its effects on cellular metabolism. The present study was part of a larger study to better understand the impacts that apparently subclinical concentrations might have on animal health and rumen function, and to identify potential bovine biomarkers of low-level DON intoxication.

Material and methods Madin-Darby bovine kidney (MDBK) epithelial cells were treated with a range of concentrations of DON (0.01-20□g/ml). Following 24 hours of culture, supernatants were harvested, and the cytotoxic effect of mycotoxins quantified using a Cytotox 96 non-radioactive cytotoxicity assay kit. Metabolic activity was determined by MTT (3-(4,5-dimethylthiazoyl-2)-2, 5-diphenyltetrazolium bromide) assay. To analyse cell proliferation, cells were labelled with bromodeoxyuridine (BrdU). After 24 hours of culture, BrdU incorporation was quantified using the cell proliferation biotrack ELISA system. Data were analysed by one-way ANOVA with a Tukey post-hoc test. *De novo* protein synthesis was quantified using a Click-iT HPG Alexa Fluor Protein Synthesis Assay. Fluorescence was captured on a Leica DMIRE2 microscope equipped with a Hamamatsu ORCA-R2 camera. Ten fields of view per well at 200x magnification were digitised using Leica MM AF software. Mean fluorescence intensity in the cytoplasm and nuclei was determined using ImageJ software (http://rsb.info.nih.gov/ij). Data were analysed by two-way ANOVA with a Sidak's multiple comparisons test.
For metabolic profiles, cells were treated with DON (1□g/ml; concentration selected as below the level which induced significant cytotoxicity). Following culture, the medium was removed, and cells were washed twice with PBS before quenching with ice-cold methanol. Metabolites were analysed using a 600 MHz Bruker Avance III spectrometer. ^{1}H NMR spectra were acquired using a standard (1D) pulse sequence, using the first increment of the NOE pulse sequence for water suppression. Raw spectra were phased, baseline corrected and calibrated to TSP using Topspin 3.2 (Bruker Biospin). The spectra were then imported into MATLAB (Version R2014a; Mathworks Inc., USA) for further processing, namely removal of redundant peaks and manual alignment using in-house MATLAB scripts. The resulting spectra were then analysed for clustering using principal component analysis. Orthogonal partial least squares-discriminant analysis (OPLS-DA) was employed to parse out peaks associated with DON exposure, relative to controls.

Results Increased epithelial cell death was seen at concentrations of DON equal to or greater than 2.25□g/ml ($p<0.01$). However, overall metabolic activity was not significantly reduced at this concentration of DON. A reduction in MDBK proliferation was observed at concentrations of DON equal to or greater than 0.16□g/ml ($p<0.01$). Cells exposed to DON showed reduced levels of protein synthesis with a 44% decrease in newly synthesised protein seen in the cytoplasm ($p<0.0001$). The effect of this perturbed protein synthesis was investigated further using metabolic profiling. DON was found to induce metabolic perturbations to MDBK cells. DON exposure increased cellular alpha amino acids (alanine, glutamine, isoleucine, leucine, valine and tyrosine), glycerophosphocholine, lactate, 2-oxoglutarate, 3-hydroxybutyrate and UDP-*N*-acetylglycosamine and decreased □-alanine, choline, creatine, taurine and *myo*-inositol ($p=0.001$).

Conclusion At non-cytotoxic concentrations, DON exposure both inhibited epithelial cell proliferation and caused a sharp decrease in protein synthesis resulting in an increased pool of cellular free alpha amino acids. The biomarkers identified by metabonomic analysis suggest that DON was inducing hypoxic, hypertonic and ribotoxic stresses in cells. This suggests that even at low concentrations, DON could influence the function of the rumen epithelium and reduce both cellular function and epithelial renewal. It may be that although these effects would not induce clinically-observable disease, they could contribute to a decline in animal performance. Analysis of the combination of these metabolites induced upon DON exposure suggests that they might have utility as biomarkers for low-concentration DON exposure in cattle, and this should be investigated further for clinical application.

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Effects of mycotoxins and binder/deactivating agent on ruminal microbial digestion and metabolism *in vitro*

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Application Mycotoxins may reduce performance, through effects on metabolism and manifestation of disease. Effects of mycotoxin and the response to the addition of a 'binder' requires investigation to develop diagnostic tools of the disease.

Introduction The impact of mycotoxins on ruminant livestock is hard to determine due to the lack of a diagnostic tool for mycotoxicosis. Not all molds that grow on animal feeds produce toxic secondary metabolites, but those that do can cause chronic health problems and reduced productivity. Mycotoxicosis in cattle can remain undetected due to the absence of specific signs and concurrent disease such as acidosis. The most common clinical approach relies on the addition of a 'binder' to the diet. Here the impact of common mycotoxins on rumen function and microbial populations *in vitro* was determined with and without the addition of a 'binder', with the ultimate aim of identifying a biomarker for mycotoxicosis.

Material and methods Rumen contents were collected into a CO_2 flushed container from five cattle immediately after slaughter, which acted as the biological replication (n = 5). Rumen solids (24 g FW) were stomached with 200 mL of McDougall's artificial saliva. This was combined with 200 mL of the rumen liquor and used as the inoculum. Samples of freeze dried and ground substrate (4.8 mg grass silage + 3.2 mg dairy concentrate; Mole Valley Farmers Ltd.) were weighed into 150 flasks. Five treatments were prepared with 25 flasks per treatment: Deoxynivalenol (DON) 4 mg/kg; Zearalenone (ZON) 2 mg/kg; DON+ZON (4+2 mg/kg); DON+ZON (4+2 mg/kg) plus 3.2 mg binder (mycotoxin deactivator; Micron Bio-Systems Ltd) (DON+ZON+BIN); Control (CT) and CT+BIN (3.2 mg). All treatments had 16 uL of DMSO to solubilise the mycotoxin or as a control. Each treatment was incubated with the prepared inoculum anaerobically at 39°C and destructively harvested at (0, 0.5, 1, 3 and 6 h). At harvesting, samples of filtered liquor were taken for assessment of pH, volatile fatty acids (VFA), microbial profiling and ^{1}H NMR spectroscopy-based metabonomic analysis. Abundances of targeted components of the ruminal microbiome were measured by qPCR using species-specific primers. Residue was assessed for dry matter (DM) and neutral detergent fibre (NDF) loss. Nutritional parameters were analysed by a repeated measure ANOVA (Genstat 17th Edition). Metabolic data were analysed using a combination of unsupervised (principal components analysis [PCA]) and supervised (projection to latent structures-discriminant analysis [PLS-DA]) multivariate statistical analysis techniques. Changes in key rumen microbial populations were analysed by general linear models using both log10 transformed abundance data and factors derived from unsupervised PCA (R 3.5.1).

Results All treatments showed similar patterns for pH decline DM and NDF loss, reflecting a successful incubation. Total and individual VFA showed no differences across treatments except for butyrate in DON+ZON which was higher than CT ($P<0.05$). Key rumen microbial species were identified including: *Prevotella spp.; Fibrobacter succinogens; Streptococcus bovis; Ruminococcus flavefaciens* but with no difference in abundance across treatments. Figure 1 shows the scores plot from a PCA model generated on all the ^{1}H NMR spectral profiles. This indicates that DON and ZON alter the metabolic activity of the incubations compared to CT. A pairwise PLS-DA model was constructed to compare the metabolic signatures of the CT and DON cultures (Figure 2). This model showed that DON exposure prevented the production of methanol by the ruminal microbiota and resulted in the accumulation of dimethylamine (DMA). This effect was prevented following the addition of the binder (DON+BIN), with methanol production restored and DMA reduced.

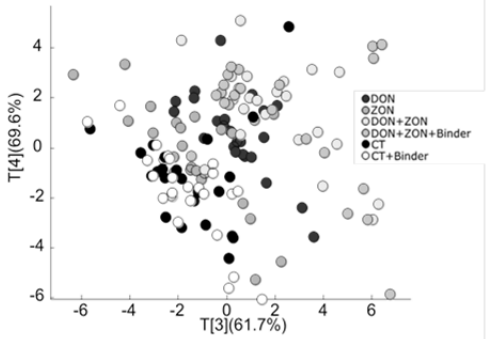

Figure 1 Cluster analysis H NMR outputs

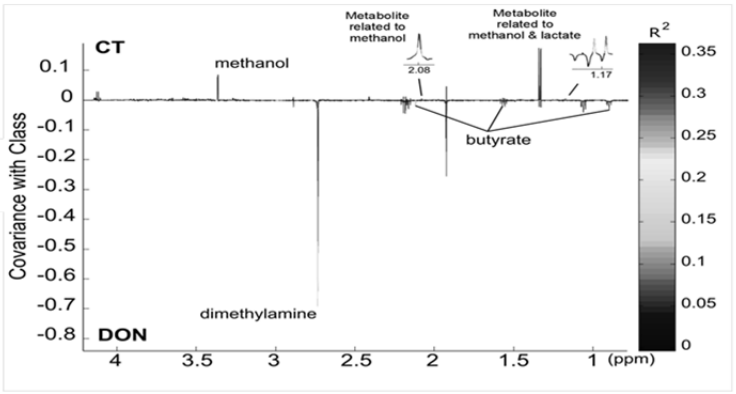

Figure 2 Temporal metabolic evolution of DON and CT

Conclusion There were minimal effects of mycotoxins on nutritional or bacterial rumen parameters. However, DON and ZON reduced the conversion of DMA to methanol in the batch cultures compared to CT. Addition of the binder restored methanol production at the expense of DMA, which shows potential for a diagnostic biomarker.

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Identification of *Staphylococcal* species from clinical isolated from hard to treat cases of bovine mastitis using conventional diagnostic techniques and Matrix Assisted Laser Desorption Ionisation – Time of Flight Mass Spectrometry (MALDI-TOF)

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Application This study utilised Matrix Assisted Laser Desorption Ionisation – Time of Flight Mass Spectrometry (MALDI-TOF) to determine the species-level identity of *Staphylococcus aureus* isolates from hard to treat clinical cases of bovine mastitis in Australia. The potential utility of this technology in mastitis disease outbreaks will be discussed.

Introduction *Staphylococcus aureus* forms part of the normal flora, that is ubiquitous, of the skin and mucus membranes but can also cause both clinical and subclinical mastitis in dairy cattle. *S. aureus* is a Gram positive, catalase and coagulase positive, haemolytic bacteria which produces toxic products causing hard to treat infections. As well as *S. aureus*, a number of other streptococcal species are implicated in bovine mastitis including opportunistic and / or environmental pathogens such as *S. agalactiae, S. dysgalactiae and S. uberis.* The outcome from the treatment of *S. aureus* mastitis is variable and the cure rates often low. Studies have shown that rates can vary between 4% and 92% for infections caused by *S. aureus* specifically (Apparao *et al*., 2009; Barkema *et al*., 2006; Baskaran *et al*., 2009) with significant implications therefore for development of antimicrobial resistance in this species. It is possible that misidentification of staphylococcal strains and therefore incorrect treatment. To address this issue, we compared standard morphological and biochemical identification of 56 isolates from clinical cases of bovine mastitis to compare with genus and strain identification using Matrix Assisted Laser Desorption Ionisation – Time of Flight Mass Spectrometry (MALDI-TOF) (Dubois *et al*, 2010).

Material and methods Bacteria were isolated from infected milk samples after aseptic collection of samples directly from infected cows. Bacterial isolates were compared using standard microbiological identification techniques and then subjected to Matrix Assisted Laser Desorption Ionisation – Time of Flight Mass Spectrometry using a Bruker Ultraflextreme MALDI-TOF/TOF-MS instrument. Spectra were recorded using linear positive mode at a laser frequency of 1000 Hz and within the mass range 2,000 to 20,000 Da. Data was compared to known pathogen standard library for genus and species identification.

Results MALDI-ToF confirmed the identification of 31 *S. aureus* isolates as defined by standard morphological and biochemical protocols. Of the further 12 *Staphylococcus* species that could only be determined to a genus level, MALDI-FoF confirmed identification of 2 isolates as *S. chromogenes*, 2 isolates as *S. haemolyticus*, 4 isolates as *S. vitulinus* and 3 as *S. warneri*. A further two isolates that had been previously identified as *S. epidermis* were confirmed to be *S. pseudintermedius*. Two isolates were confirmed as *Enterococcus faecium* and one that had been previously identified as Staphylococcus sp. but without strain identification was confirmed to be *Micrococcus luteus*. Only one isolate could not be identified by either method. Antimicrobial testing identified multiple resistant strains including MRSA.

Conclusion Together these results indicate that traditional methods of microbial identification may not be sufficient to determine species identify for hard to type bacteria such as less common *Staphylococcus* species. Misidentification may be misrepresenting antimicrobial resistance or risking this effect where suboptimal antibiotic regmines might therefore be implemented. Use of MALDI-ToF identification for bovine mastitis pathogens can assist in providing clinicians and researchers with a more accurate picture of the major pathogens involved in subclinical and clinical mastitis and assist in better antimicrobial stewardship in the future.

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Nickel nanoparticles induced testicular toxicity in male Sprague Dawley rats assessed by histopathology

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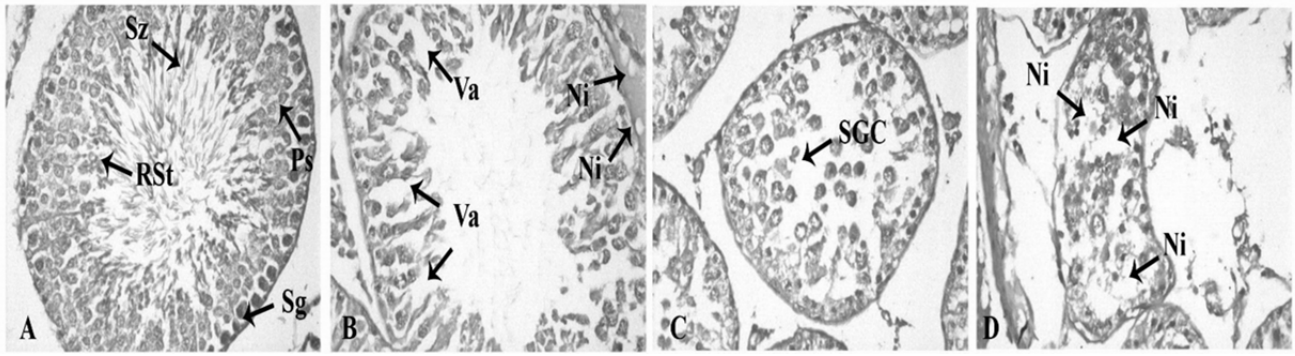
Application This study provided an insight into the toxicity of nickel nanoparticles (Ni-NPs) in Sprague Dawley rats. It may help policy makers to suggest preventive measures against the potential toxicity of NPs in living organisms.

Introduction Metallic nanoparticles such as nickel nanoparticles (Ni-NPs) are widely used in various applications but limited toxicological data and safety measure are available upon the wide use of Ni-NPs in various applications (Zhao and Wang, 2012). Ni-NPs cause infertility by producing oxidative stress, DNA damage at cellular level and histological alterations in different tissues of living organisms. Using Ni-NPs can cause various diseases and toxicity involving testes, spleen, lung, liver, heart, and gonads in human beings. Therefore, this study used male Sprague Dawley rats to modulate the toxic impacts of Ni-NPs on gonads.

Material and methods Twenty five healthy post weaning male Sprague Dawley rats of similar weights (225-250g) were procured from the animal house of Government College University Faisalabad (GCUF) after the approval of ethical committee on animal experimentation of GCUF. These rats were housed in to steel wire cages under standard laboratory conditions. The rats were given free access to water and a commercial feed. After acclimatization to cages & feeds for one week, these rats were divided in to five groups (n=5 per group) as control (without any treatment), placebo (treated with normal saline solution) and three treated groups (i.e., Ni-NPs @ 15 or 30 or 45 mg/kg body wt) to assess the Ni-NPs induced toxicity in the gonads of these rats. The rats received intraperitoneal injections of selected doses for twenty eight days on alternate day. At the end of the experimental period, the rats were fasted overnight before being anaesthetized by administering ketamine hydrochloride (30 mg/kg BW) and sacrificed. The gonads of these rats were then collected and treated by using standard histological tools. The samples were first fixed in sera (60ml Absolute alcohol+30ml Formaldehyde+10ml Glacial acetic acid) and then dehydrated by using different grades of ethanol (70, 80, 90, 95, and 100%). After dehydration, the samples were cleared in two changes of xylene. The samples were then embedded in paraffin wax which was then blocked out. The tissue sections (3–4 µm) were cut by a microtome (SLEE Rotary Microtome CUT5062 by Nikon Instruments Europe) and stained with haematoxylin–eosin (HE) standard staining method. The stained sections from the control and treated rats were observed under an optical microscope (Nikon Eclipse E200 POL) and photographed to observe alterations in testicular histology.

Results The microscopic examination of stained sections revealed that the Ni-NPs treatments induced histological alterations in the rat gonads in a dose dependent fashion (Figure. 1). Intensity of histological alterations was quantified as no histological (h) alterations (normal histological architecture), mild h alterations (10%); moderated h alterations (20%); severe h alterations (30%) and very severe h alterations (40%). Normal histology of gonads included Spermatogonia (Sg), Primary spermatocytes (Ps), Spermatozoa (Sz) and Round spermatids (RSt) while histological alterations in gonads included vacuation (Va), necrosis (Ni) with vacuole formation and either absence of Spectrum germ cell (SGC) or detachment of SGC. There were significant differences in the histological structures among treated groups ($P<0.05$).



A= control (0 Ni- NPs) B - 15 mg Ni- NPs /kg C - 30 mg Ni- NPs /kg D - 45 mg Ni- NPs /kg

Figure 1 Microphotograph of rat testes in control and treated groups showing normal or histological alterations (H&E, X400).

Conclusion The Ni-NPs exposure can induce toxicity as reflected by histological changes in gonads of male Sprague Dawley rats. This study implies that the Ni-NPs exposure could cause infertility and risk to the human health and also the environment.

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Nutritional Geometry: examining the critical roles of specific appetites in animal and human nutrition

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Application Nutrient specific appetites play a central role in driving food selection, nutrient intake, health and life history responses such as lifespan, growth and reproduction (Raubenheimer and Simpson 2018). Models centred on specific appetites and their interactions therefore provide a powerful means for understanding, predicting and managing nutrition (Simpson and Raubenheimer 2012). They also provide a framework for integrating across biological levels - from physiology to behaviour, life history and evolutionary analysis – and thus for structuring inter-disciplinary nutrition research (Raubenheimer and Simpson 2016).

Introduction In recent years, nutrient specific appetites have emerged as a powerful unifying theme for understanding the interactions of animals with their nutritional environments (Raubenheimer *et al*. 2009). Where possible, such appetites cooperate to help achieve a balanced diet. However, in imbalanced nutritional environments these appetites can compete, each expressing regulatory priorities for a different nutrient. The outcome of this competition determines cumulative intake of nutrients and other substances. These interact as mixtures within the gut and, once digested and absorbed, with systemic physiology to influence growth, health and life history. Nutritional geometry is framework for modelling appetites and their interactions, and examining how they influence animals in different environments and circumstances (Simpson and Raubenheimer 2012).

Material and methods After introducing the basic concepts in nutritional geometry, I will present a number of case studies that illustrate the framework in action in tightly controlled laboratory settings using animal models. I will then present studies that demonstrate that the findings from lab experiments generalise to more complex, but more realistic, settings in the field. These studies, involving wild primates, provide the backdrop for the final part of the talk, in which I use nutritional geometry to examine the nutritional ecology of our own species in modern environments.

Results and Conclusions The study of nutrient specific appetites and their interactions is a powerful approach for examining animal and human nutrition. Nutritional geometry provides a simple and effective framework for studying these interactions. It can help explain and predict patterns of foraging, food choice, nutrient intake and its consequences in lab and field studies, and link these responses to physiological mechanisms. This integrative approach to nutrition can provide new insight into pressing applied problems, such as the human obesity epidemic.

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061

Investigating the use of Quietwean's and concentrate feed level on the performance and behaviour of suckler calves weaned indoors

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Application Use of Quietweans (QW) reduced standing and increased lying time for two days after weaning compared to abrupt weaning (AW). The use of QW's had no effect on performance compared to AW at either concentrate level. This is of particular use as a weaning method that reduces stress at weaning without reducing performance.

Introduction At weaning calves undergo changes in diet, loss of maternal contact as well as being thrust into a new social environment. This causes stress on the animals which could reduce performance and increase the risk respiratory disease. The use of QW (a nose piece device which prevents calves from suckling their dams) has been shown to reduce the behaviours that are typically seen at weaning (Vocalisation and pacing) (Haley at al., 2005). However, there is conflicting information from Enríquez *et al*. 2010 who reported reduced performance in the period from QW insertion until weaning, hence indicating the behaviour difference may just occur earlier with the QW, in this two-step weaning process. The aim of this study was to assess the effects of Quietwean against traditional abrupt weaning for suckler calves offered different concentrate feeding levels on calf performance and behaviour.

Material and methods The experiment involved a total of 80 suckler beef calves, consisting of 32 Stabiliser heifers, 24 Stabiliser steers, and 24 Charolais steers. The cows and calves where housed indoors in a slatted shed with the calves having access to a creep area. All cows and calves were offered *ad libitum* grass silage. The calves were also offered 1 kg/head/day of concentrate in the creep area prior to the beginning of the study. Animals were allocated to a 2 (weaning method) x 2 (concentrate level) factorial design study. Treatments were balanced for calf age and weight. The weaning treatment included either an abrupt weaning or a two-step weaning using Quietweans (QW). The two step weaning involved a nose piece device (which prevented suckling) being inserted to the calves 7 days prior to weaning. The calf concentrate level was 1kg or 2kg, with the higher level being offered from day 0 onwards. This study was conducted in 2 batches, with equal numbers of animals on each treatment. Behaviour was monitored using IceQube pedometers which were attached to both the cows and calves on day 0 to record lying time lying bouts, standing time and standing bouts. QW's were inserted at day 7; weaning was undertaken at day 14 and the all pedometers removed on day 27. At weaning all calves were moved to a new shed. This data was automatically downloaded every 120 seconds using the CowAlert system. At each of these time points all calves were weighed to monitor performance. All data was analysed using Genstat. Performance data was analysed using REML mixed model analysis with date of birth, calf weight day 0, weaning allocation and concentrate allocation and weaning concentrate allocations interactions as fixed effects. Behaviour was analysed using REML mixed model analysis and generalized linear mixed model analysis with day, weaning allocation, concentrate allocation and interactions as fixed periods.

Results There were no significant interactions between weaning method and concentrate supplementation level. Experimental treatment had no significant (P>0.05) effect on overall calf performance during this study, which averaged 0.96 kg/day. There were no significant (P>0.05) behavioural differences observed with the insertion of the QWs. Behaviour differences (standing time and lying time) were significantly (P<0.001) different for the calves on days 15 and 16 (i.e. for 48 hours post weaning) with the calves on the AW treatment standing for a greater duration than the QW calves (Fig. 1 & 2).

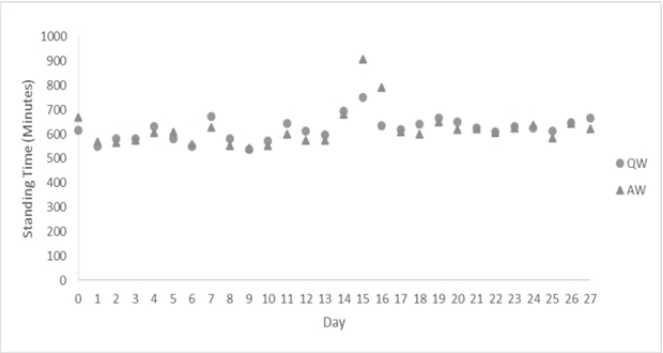

Figure 1 Effect of weaning method on calf standing time

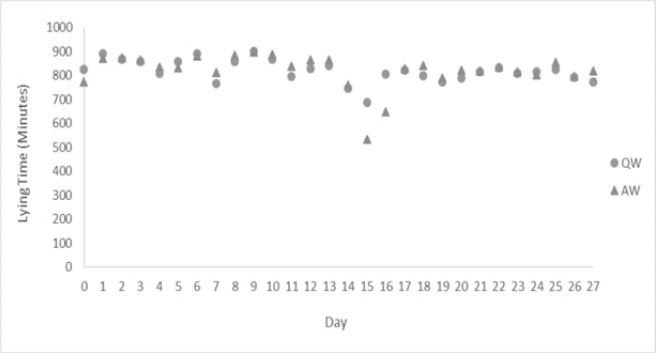

Figure 2 Effect of weaning method on calf lying time

Conclusion The use QWs reduced abnormal calf behaviour post weaning but did not influence calf performance.

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Intake, growth, carcass and selected meat quality traits of steers offered grass silage and supplementary concentrates containing maize or wheat dried distillers grains

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Application Under the conditions of this experiment, maize (MD) or wheat (WD) dried distillers grains with solubles had a feeding value comparable to rolled barley/soya bean meal, implying that farmers can use either depending on relative price.

Introduction Due to increased production of biofuels globally there is a greater supply of associated protein rich by-products such as distillers dried grains available for animal feed (Erickson *et al*., 2012). The two most common sources of distillers dried grains imported into Ireland at present are MD and, to a much lesser extent, WD. Relatively little evaluation of MD, and particularly WD, as feed ingredients for beef cattle especially when offered as a supplement to grass silage, has been carried out. The objective of this experiment was to evaluate the partial replacement of barley and complete replacement of soyabean meal in a barley-soya ration with MD or WD on intake, growth, carcass and selected meat quality traits of finishing beef cattle offered grass silage.

Material and methods Late-maturing breed steers (initial live weight, 441 kg, SD 37.4) were blocked by sire breed and weight and from within block randomly assigned to one of three (n=12) concentrate treatments. The control concentrate (BARS) comprised of 862 g rolled barley, 60 g soya bean meal, 50 g molasses, and 28 g minerals and vitamins per kg fresh weight. In the other two concentrates, barley and all the soya bean meal was replaced with either 800 g MD (crude protein (CP) 279, and Oil B 85, g/kg dry matter (DM)) or 800 g WD (CP 334, and Oil B 72, g/kg DM) per kg fresh weight. Concentrates were prepared as coarse mixtures. Steers were individually offered 4.0 kg DM of the respective concentrates, in two feeds daily, as a supplement to grass silage (DM digestibility, 713 g/kg; CP 102 g/kg DM) offered *ad libitum* during a 134 day finishing experiment. Animals were weighed at the beginning and end of the study, and every 14 days throughout. Ultrasonic fat and muscle depth were measured at the beginning and end of the study. Post-slaughter, carcass weight,, carcass conformation and carcass fat score were determined. At 48 h *post-mortem*, the lightness (L*), redness (a*) and yellowness (b*) of subcutaneous fat were recorded. After 72 h *post-mortem* pH, drip loss and L*, a*, b* colour (after 1 h bloom) of the *longissimus thoracis* muscle were recorded. Data were statistically analysed using ANOVA with fixed effects for treatment and block in the model.

Results Silage and total DM intake were lower (P<0.05) for MD and WD, which did not differ, compared to BARS. Inclusion of MD or WD in the concentrate supplement had no effect (P>0.05) on average daily live weight gain, feed conversion ratio, final live or carcass weight, kill-out proportion, carcass conformation and fat scores (Table 1) or ultrasonic measures of body muscle and lumber and rump fat. Ultrasonic rib fat depth was lower for MD and WD (3.5 and 3.8 vs. 4.3 mm, P<0.05) compared to BARS. Muscle and subcutaneous fat 'L*', 'a*', 'b*', saturation or hue angle did not differ (P>0.05) between treatments. There was no difference (P>0.05) between treatments in muscle pH and drip loss.

Table 1 Effect of maize (MD) or wheat (WD) dried distillers grains with solubles inclusion in a barley/soyabean meal-based (BARS) concentrate on dry matter (DM) intake, average daily live weight gain (ADG), feed conversion ratio (FCR) and carcass traits of finishing steers offered grass silage

	BARS	MD	WD	s.e.m.	P-value
Silage DM intake (kg/day)	5.3	4.8	4.8	0.14	0.028
ADG (kg)	1.07	1.05	1.03	0.055	n.s.
FCR (kg DM/ kg ADG)	9.0	8.4	8.7	0.39	n.s.
Carcass weight (kg)	328	326	328	6.4	n.s.
Kill-out proportion (g/kg)	562	561	567	7.2	n.s.
Carcass conformation score (1-15)	9.0	8.9	8.9	0.50	n.s.
Carcass fat score (1-15)	7.9	7.5	7.5	0.32	n.s.

Conclusion Rolled barley/soya bean meal can be replaced with 800 g/kg fresh weight MD or WD in a concentrate supplement to high-digestibility grass silage without negatively affecting animal performance or selected meat quality traits.

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The effect of floor type on the lying and standing behaviour of finishing beef cattle

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Application Fully slatted concrete floors are labour efficient, but do not allow beef cattle to fully express the same lying and standing behaviours as cattle which are accommodated on straw-bedded floor systems.

Introduction There is a perception that accommodating beef cattle on solid floors bedded with straw is higher welfare than a fully slatted concrete floor and differences in lying behaviour between cattle on these floor types have been observed. Furthermore Brscic *et al* (2015) suggested that if bulls lay with outstretched legs it was a strategy to get relief in their carpal and tarsal joints. The objective of the current study is to compare lying and standing behaviours of finishing bulls accommodated on fully slatted concrete floors compared to those accommodated on solid floors bedded with straw.

Material and methods Forty suckler-origin bulls, with a mean starting live weight of 296 (s.d. 41.1) kg and mean age of 257 (s.d.28.0) days, were blocked according to live weight into 20 blocks, each of two animals. Cattle within each block were randomly assigned to one of two treatments and balanced as far as possible for breed. Four animals were accommodated per pen and thus there were five pens of animals per treatment. The two treatments were either accommodating bulls on a fully slatted concrete floor at a stocking density of 2.25m^2/ animal or on a solid floor bedded with straw at a stocking density of 4.41m^2/ animal. Prior to the study the bulls were grazed outdoors. At the start of the study the bulls were initially offered grass silage *ad libitum* supplemented with 2kg concentrate/ head /day. Concentrate levels were increased by 1kg /week until *ad libitum* concentrate feeding was achieved. At this stage the diet was supplemented with chopped barley straw. Bulls were slaughtered at a mean of 15.1 months of age, balanced for treatments. The mean duration of the experimental period was 201 days. Behaviour of each individual animal was recorded by direct observation for an eight minute period on days 3 and 4 and then every three weeks thereafter. The ethogram of behaviours included leg positions while lying and differentiation of standing into active (whereby animals were observed to be eating or performing another behaviour at the same time) or non-active standing. Twenty cattle were observed per day in a pre-determined random order, balanced for treatments. Recordings of the direct observations were made using the 'JWatcher' programme downloaded onto a Microsoft Surface Pro tablet. IceQube® accelerometers (IceRobotics Ltd, Edinburgh, UK) were also fitted to all bulls from week 5 to the end of the study. Direct observation data were meaned at the pen level for each three weekly recording. The resultant variables were analysed as a linear mixed model with repeated measures with pen as the subject factor and a factorial arrangement of floor type and week as fixed effects. A mean value for each animal was calculated for two week time periods for each variable from the accelerometers. The resultant variables were analysed as a linear mixed model with repeated measures with animal as the subject factor and a factorial arrangement of floor and week as fixed effects. Pen was fitted as an additional random effect. The correlation between weeks was accounted for by using an autoregressive model of order 1.

Results Bulls accommodated on straw-bedded floors had a significantly higher number of lying bouts per day (18.5 v 9.9), lower lying (52 v 106 minutes) and standing (35 v 65 minutes) bout durations and took a higher number of steps per day (599 v 161) than those accommodated on fully slatted concrete floors (P<0.001), as measured using accelerometers. The percentage time spent carrying out lying and standing behaviours as recorded by direct observation are presented in Table 1.

Table 1 The main effects of floor type on percentage time spent on lying and standing behaviours

	Floor type			
	Concrete slats	Straw bedding	s.e.d	P
Lying (%)	52.9	44.6	4.14	0.056
Lying front legs out (%)	2.5	4.9	1.32	0.062
Lying back legs out (%)	4.2	10.6	2.49	0.019
Standing (%)	46.9	54.9	4.10	0.060
Active whilst standing (%)	43.4	49.2	3.49	0.091

Conclusion Finishing bulls accommodated on fully slatted concrete floors got up and down less often and spent less time lying with outstretched limbs than those accommodated on solid floors bedded with straw.

Acknowledgements The authors gratefully acknowledge funding from DAERA.

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064

Effect of pre-grazing herbage mass on performance of early- and late-maturing suckler bred steers

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Application Offering a pre-grazing herbage mass (PGHM) of 1500 kg DM/ha compared to 2000 kg DM/ha restricted growth of both early-maturing (EM) and late-maturing (LM) breed steers from the suckler herd.

Introduction Maximising cattle performance from low-cost grazed grass can increase farm profitability. Irish suckler beef production is largely pasture-based and comprises predominantly of LM breeds (Drennan and McGee, 2009). Compared to LM breed types, EM genotypes may be more suitable for grazing systems due to their greater subcutaneous fat deposition; additionally, there is evidence that they have superior live weight gain while grazing pasture (Regan *et al.,* 2018). Increasing regrowth interval and consequently PGHM is associated with substantially greater (and cheaper) annual grass herbage production (O'Riordan, 1997), but results of studies comparing the performance of beef cattle grazing contrasting PGHM are conflicting (Humphreys and O'Riordan, 2000; Boland *et al.*, 2013). The objective of this study was to examine the effect of PGHM on performance of suckler-bred EM and LM steers over a full grazing season.

Material and methods Spring-born, EM (Aberdeen Angus and Hereford, n=54) and LM (Charolais and Limousin, n=54) male 'weanlings' were purchased at ca. 8 months old, castrated 3 weeks after arrival, housed and offered grass silage *ad-libitum* for the 'first' winter. In mid-March steers were assigned based on weight within breed to a PGHM (> 4cm) of either 1500 or 2000 kg DM/ha. There were 3 replicates (grazing groups) of each PGHM within breed maturity, resulting in 12 groups each containing 9 cattle. The total grazing area was split into four equal farmlets comprising of paddocks. The steers rotationally grazed *Lolium perenne*-dominant swards to a compressed post-grazing sward height of 4 cm (measured using a rising plate meter). Herbage in excess of grazing requirements was removed by harvesting as silage. Stocking rate increased from 2035 kg live-weight/ha at turn-out in spring to 3110 kg live-weight/ha in mid-September before additional land (silage harvesting area) was incorporated into the grazing rotation. Duration of the grazing season was 232 days. Animals were weighed prior to turnout, at approximately 3 weekly intervals during the grazing season and 10 days post-housing (early-November) to account for variance in gut fill. Data were subjected to analysis of variance using the GLM procedure in SAS; the model had fixed effects for PGHM, breed and their interaction. The experimental unit was grazing group.

Results Mean (S.D.) (n = 295) PGHM during the grazing season was 1435 (509.8) and 2038 (604.8) kg DM/ha for the low and high PGHM, respectively. There were no interactions (P>0.05) between breed and PGHM for animal live-weight or live-weight gain. Compared to EM steers, LM were heavier (P<0.001) at turn-out to pasture in spring. Early-maturing steers had a higher (P<0.05) live-weight gain than LM during the grazing season, but LM were still heavier (P<0.01) at the end of the grazing season. Steers offered 2000 kg DM/ha had a higher (P<0.05) live-weight gain (+13 kg) over the grazing season than those offered 1500 kg DM/ha, resulting in a higher (P<0.01) live-weight at housing.

Table 1 Effect of breed maturity and pre-grazing herbage mass (PGHM) on performance of steers at pasture

	Breed		PGHM (kg DM/ha)			P-value	
	Early	Late	1500	2000	s.e.m.	Breed	PGHM
Turnout-weight (kg)	333	357	344	346	0.74	<0.001	n.s.
Housing weight (kg)	540	551	539	553	2.29	0.008	0.003
Live-weight gain (kg)	207	194	194	207	2.72	0.012	0.012

Conclusion Grazing the lower PGHM restricted steer growth at pasture. Although EM cattle had a higher live-weight gain at pasture, they were still lighter at the end of the grazing season. Whether these differences carry onto slaughter is being examined.

Acknowledgements The authors gratefully acknowledge funding from Teagasc.

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065

Intake, live weight gain, feed efficiency, ultrasonic and body measurements of 'yearling' Charolais and Holstein-Friesian steers offered a high-concentrate diet

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Application Holstein-Friesian (HF) steers consumed proportionately 0.34 more feed dry matter relative to weight than suckler-bred Charolais (CH) steers.

Introduction Feed efficient cattle are central to the economic and environmental sustainability of beef production enterprises (Kenny *et al.*, 2018). Due to the abolition of milk quotas in the European Union, the subsequent expansion of the Irish dairy herd has meant that proportionately more beef is derived from dairy-bred compared to suckler-bred animals. The objective of this study was to determine intake, growth, feed efficiency, ultrasonic and body measurements of CH compared to HF steers offered a high-concentrate diet.

Material and methods Three-quarter bred or greater CH (n=99) and HF (n=97) spring-born steers sourced directly from commercial Irish farms in autumn were used. Steers were housed indoors in two slatted floor sheds balanced for breed. Following a dietary adaption period of 24 days, they were individually offered a barley-based concentrate to appetite with restricted grass silage (3 kg fresh weight daily) for 71 days. Individual dry matter intake (DMI) was recorded daily. Animals were weighed on consecutive days at the beginning and end of the experiment and at 14 d intervals throughout. Average daily live weight gain (ADG) of each steer was computed as the coefficient of the linear regression of live weight on time (days). Ultrasonic fat and muscle depths and, skeletal measures were determined at the beginning and end of the experiment. Blood samples were obtained pre-feeding on two occasions and a rumen fluid (stomach tube) sample was obtained 2-4 hours post-feeding on one occasion during the study. Data were statistically analysed using the GLM procedure of SAS; the model contained the fixed effect of breed and shed.

Results The HF steers were 24 days older (282 vs. 306 days, $P < 0.001$) than CH, which reflects the mean calving dates of the national dairy and beef cow herds in Ireland. Despite their older age, HF steers were 98 kg lighter (mid-test, 341 vs. 439 kg, $P<0.001$) than CH, but had greater ($P<0.01$) ADG and a higher DMI on an absolute basis ($P<0.01$) and relative to live weight ($P<0.001$). Ultrasonically-assessed muscle depth and all measures of fatness were lower ($P<0.001$) for HF compared to CH. In terms of body measurements, HF had a similar ($P>0.05$) back length but were taller, narrower and had deeper chests but reduced chest circumference ($P<0.001$) than CH. Compared to HF, concentrations of blood creatinine, albumin and urea were higher ($P<0.001$), and beta-hydroxybutyrate ($P<0.01$), globulin ($P<0.05$) and glucose ($P<0.001$) were lower for CH. Rumen pH was lower for HF (5.65 vs. 5.85, $P<0.001$) compared to CH.

Table 1 Dry matter intake (DMI), daily live weight gain, feed conversion efficiency (FCE) and ultrasonically assessed body composition of Charolais and Holstein-Friesian steers offered a high-concentrate diet

		Charolais	Holstein-Friesian	s.e.m.	P-value
Total DMI	(kg)	8.39	8.74	0.084	0.004
	(g/kg live weight)	19.2	25.7	0.19	<0.0001
Initial live weight (kg)		396	295	3.9	<0.0001
Final live weight (kg)		485	392	4.2	<0.0001
Daily live weight gain (kg)		1.30	1.41	0.024	0.002
FCE (kg live weight/kg DMI)		0.155	0.161	0.0024	0.06
Ultrasound measurements (mm) -	Rib fat thickness	2.46	1.89	0.027	<0.0001
	Loin fat thickness	2.22	1.94	0.032	<0.0001
	Rump fat thickness	2.61	2.26	0.052	<0.0001
	Muscle depth	67.4	43.1	0.45	<0.0001

Conclusion Under the conditions of this experiment, the taller, narrower, leaner and proportionately 0.22 lighter HF steers consumed 0.04 more feed on an absolute basis and 0.34 more feed relative to weight, but they had a higher ADG, than CH. The higher ADG of HF compared to CH is likely attributed to compensatory growth.

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Antimicrobial resistance from beef cattle production

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Antimicrobial resistance (AMR) is a significant present-day challenge and poses a great threat to human and animal health. Although AMR is a natural phenomenon, the anthropomorphic use of antimicrobials has created heightened selective pressure that has led to an increased presence of antimicrobial-resistant bacteria in agriculture, aquaculture, and hospital environments. Concerns over the emergence of antimicrobial-resistant bacteria that threaten human health has prompted the retail and fast food industries to promote meat and milk produced from livestock that are raised without the use of antimicrobials. As an integral component of current intensive livestock production, antimicrobials are used to treat (therapeutic use) and prevent (prophylactic, metaphylactic) infectious disease and promote growth (subtherapeutic). There is epidemiological evidence showing that agricultural management practices have contributed to resistance in veterinary pathogens. While there is also evidence suggesting a link between the emergence and spread of antimicrobial-resistant bacteria in humans to agricultural antimicrobial use, the relationship is difficult to quantify. As livestock husbandry practices and antimicrobial use vary by sector, studies should be structured with a One Health approach to fully understand and implement AMR mitigation strategies. Following a general introduction to antimicrobial resistance and the Canadian beef system, this presentation will first present findings describing AMR in bovine respiratory pathogens, and the significance to animal health. Second, results from metagenomics studies investigating the prevalence of resistance genes in cattle feces, catch basins, manure-amended soil, and wastewater at a municipal treatment plant will be discussed. The main findings are that AMR in respiratory pathogens has increased over the last ten years, with major pathogens being detected that harbor multidrug resistance on mobile elements. While the abundance of resistance genes in cattle feces was greater than other environmental sources tested, the majority of resistance elements in feces were associated with antimicrobials used during production. The diversity and prevalence of genes conferring resistance to highly-important antimicrobials was greatest in the municipal treatment plant. Further studies detailing AMR from animal, environmental, and human perspectives will be useful in developing best management practices for livestock production.

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AMR – the human perspective

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Application Antimicrobial use is a major driver of AMR in humans. Without effective antimicrobials, the practice of modern medicine such as transplantation, cancer chemotherapy and complex surgery will become too risky. Interventions to reduce inappropriate antimicrobial use needs to healthcare professionals and the public.

Introduction As part of the global response to growing AMR, the WHO requested that all countries develop a national action plan for AMR for human and animal health (one health) to identify the scale of the problem and address local

Material and methods The last UK AMR Strategy (2013-8) focused on improving antibiotic prescribing, infection prevention and control, improving professional education & training and public engagement, better access to and use of AMR and consumption surveillance data, improved evidence through research, developing new treatments, diagnostics, vaccines and treatments, and strengthening international collaboration. New targets were set part way through the AMRS in response to the final O'Neill AMR Review to reduced inappropriate prescribing and healthcare associated Gram negative bloodstream infections by 50% by 2021.
The three devolved nations each developed their own local AMR strategy to their own needs. Research was completed to identify the level of inappropriate prescribing. In England, this was used through clinical quality improvement incentives to improve AMR surveillance and antibiotic consumption data, and to drive improvements in primary care and hospitals to reduce the consumption of antibacterials and the level of Gram negative bloodstream infections. Improved education of healthcare professionals and antimicrobial stewardship activity plus a national campaign was run to keep antibiotics working. The WHO essential medicines categories for antibiotics (AWaRE) were adapted for English AMR patterns.

Results There is now open access data in England for antimicrobial consumption and stewardship, AMR, healthcare associated infections, infection prevention and control for primary care and hospitals. Antibiotic consumption has decreased in primary by 13% and broad spectrum antibiotics to below 9% of the total. In hospitals, the rate of growth reduced to 2% in 5 years from almost 12% for the previous period. AMR was generally stable, except for co-amoxiclav in E.coli and azithromycin resistance in N.gonorrhoea. However, colonisation with carbapenem resistant Enterobacteriaceae is increasing, but not clinical infections. The burden of Gram negative bloodstream infections has increased by around 35% over the 5 years. Whilst the reduction in Gram negative bloodstream infections is likely to be met, the 50% reduction target for inappropriate antimicrobial prescribing should be met.

Conclusion An incentive driven approach can be effective in reducing and improving antibiotic prescribing and decreasing bloodstream infections.

Acknowledgements Public Health England, Dept of Health Advisory Committee of Antimicrobial Prescribing Resistance and HCAI.

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Effect of dietary supplementation of calves with essential oils on faecal bacterial count and abundance of antibiotic resistant bacteria

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Application Gaining more insight into the effect of essential oil on gut bacteria as well as abundance of antibiotic resistant bacteria would create opportunities to develop strategies that would improve animal health without increasing the likelihood of developing AMR on livestock farms.

Introduction Antimicrobial resistance (AMR) is a global human health concern with various bacteria developing the ability to grow in the presence of an antimicrobial drug designed to prevent or limit their growth (O'Neill, 2016). Antimicrobial use in animals is considered a leading factor in the worldwide increase of AMR (Landers *et al*., 2012). Calves routinely receive antibiotics for disease treatment and also via waste milk. Following therapeutic antibiotic treatment or waste milk feeding a very low concentration of antibiotics reach the gut and this may facilitates the emergence and spreading of AMR in the complex gut microbial community. Considerable efforts have recently been made to reduce on-farm antibiotic use including the use of essential oils (EO) as alternatives to antibiotics (Yang *et al*., 2015). Even though EO are used to improve animal health, whether or how EO influence AMR in the animal gut remains unexplored. Therefore, this project aimed to determine the dynamics of AMR in the gut of calves fed waste milk containing antibiotic residues with and without EO supplementation.

Material and methods Ten Holstein calves were divided into 2 groups (5 calves/group) and assigned to one of two dietary treatments: control (fed waste milk with antibiotic residues) and Oregano Essential Oil (Orego-Stim Liquid, Anpario plc, UK; EO; fed waste milk with Orego-Stim Liquid @ 10 mL/calf/day for the first 10 d of the study) within 48 h after birth (day 0). Average body weight of calves in control and EO was 43.5 and 44 kg, respectively. Each calf was bottle fed 2.5 L of milk twice a day and 5 mL of Orego-Stim was added to milk immediately before each feed for each calf. Starter feed was also offered to all calves. Calves were housed and fed individually during the supplementation period. Calves did not receive any antibiotics and did not exhibit signs of clinical disease during the entire study. Supplementation of waste milk with EO was the only difference between two groups of calves. After 10 d EO supplementation all calves received the same diet and were exposed to the same housing and management conditions. Faecal grab samples were collected on day 0, 3, 7, 10, 14 and 21 and then at weaning. Faecal samples were diluted in sterile phosphate-buffered saline solution and plated on MacConkey and Bile Esculin Azide agar, respectively, to count *E. coli* and *Enterococcus* colonies. Replica plating technique was used to determine the proportion of *E. coli* colonies resistant to different antibiotics: amoxicillin, oxytetracycline, streptomycin, tylosin and cefquinome (penicillin, tetracycline, aminoglycoside, macrolide and 4th generation cephalosporin class of antibiotics). Data were checked for normality and bacterial count was log transformed to achieve normality. Data (bacterial count, prevalence of resistant bacteria) were subjected to ANOVA using a General Linear Model (Minitab). The model included treatment and day, and their interaction as fixed effects and calves nested within treatment as a random effect. The *P* values <0.05 indicated statistical significance while 0.05<*P*=0.10 represented a tendency.

Results Faecal counts of Gram-negative bacteria (i.e. *E. coli*) tended to decline more in calves fed EO compared with unsupplemented calves, fed waste milk containing antibiotic residues (8.31 vs 8.79; $P = 0.10$). However, faecal count of Gram-positive bacteria *(i.e. Enterococcus*) was not influenced by EO supplementation. The proportions of total *E. coli* colonies that were resistant to penicillin, tetracycline, aminoglycoside and macrolide classes of antibiotics were not affected by treatment. However, supplementation with EO delayed the emergence of resistance to 4th generation cephalosporin (day 7 rather than day 3) and the proportion of *E. coli* colonies resistant to 4th generation cephalosporin was lower in the faeces of EO supplemented calves compared with control calves (12.6 vs 41.2%; $P < 0.001$). As calves grew, faecal counts of both total and resistant *E. coli* declined in both groups.

Conclusion Supplementation of calves' diet with EO tended to reduce the faecal count of the opportunistic pathogen *E. coli*. Supplementation of calf diets with a high dose of EO for a short period did not lead to an increased AMR in *E. coli*. Rather, EO supplementation reduced the faecal prevalence of *E. coli* resistant to 4th generation cephalosporin.

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069

Pasture management practices are associated with the prevalence of antimicrobial resistance in grazing cattle

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Application Improved pasture management practices such as rotational grazing may help to reduce the prevalence of antimicrobial resistance in grazing cattle.

Introduction Brazil is the second largest producer of beef in the world, with approximately 223 million head of cattle. It is also one of the largest consumers of antimicrobials, ranked third in the world in 2010 and accounting for 9% of total global consumption of antimicrobials by farm animals (van Boeckel *et al*., 2015) despite the relatively extensive nature of Brazilian beef production. There are many factors which may affect the prevalence of antimicrobial resistance (AMR) in animals including host age and the amount of interaction between the animal and microbiomes in the environment such as soil. Cattle that are set stocked may graze sparser pasture and have a greater consumption of soil (and soil microbiome) than those cattle that rotationally graze a denser sward. The objective of this study was to determine the prevalence of AMR in the faecal microbiome of Brazilian beef cattle kept either in set stocking or rotational grazing systems.

Material and methods Six beef farms that typically buy in weaned calves (150 kg, 7-8 months old) and rear them to 300 kg (approximately 24 months old) were selected. All farms were visited within one month in July, 2018. Samples of faeces were collected from ten Nellore or Nellore cross cattle at each farm, five from yearlings and five from cattle aged approximately 24 months old and weighing ca 300 kg. Samples were mixed in nutrient broth (5 ml) and this suspension (100 µl) was then spread onto plates containing either MacConkey agar (to isolate coliforms) or Bile Esculin Azide agar (for the isolation of *Enterococcus*) and incubated for 16 h at 37 °C. Pink colonies (presumed to be *E. coli*) from MacConkey agar and black colonies (presumed to be *Enterococcus* spp) from Bile Esculin Azide agar were then picked with a sterile loop and mixed with sterile saline until the turbidity in the tube matched that of McFarland 0.5. A sterile swab was then dipped in the suspension and streaked uniformly over a plate containing Mueller Hinton agar. Discs containing antibiotics (ampicillin 10 µg, ceftiofur 30 µg, streptomycin 10 µg for *E. coli,* 300 µg for *Enterocoocus*, ciprofloxacin 5 µg, tetracycline 30 µg, erythromycin 15 µg) were placed on each plate, and the zone of inhibition for each antibiotic was measured after 16 h incubation at 35 °C. Data were compared with EUCAST (2018) to determine whether bacteria were resistant, moderately sensitive or sensitive to the antibiotic. Associations between antibiotic sensitivity, age of animal and grazing system were determined using the Chi square test.

Results There was no association between host age and bacterial resistance to tested antibiotics. Both *E. coli* and *Enterococcus* were sensitive to streptomycin, tetracycline and ampicillin. *Enterococcus* was sensitive to ceftiofur, but cattle that were set stocked had greater numbers of *E. coli* that were resistant to ceftiofur compared with cattle that were rotationally grazed ($P<0.001$, Figure 1). *E. coli* was sensitive to ciprofloxacin (100%) and erythromycin (67%). *Enterococcus* was more likely to be moderately sensitive (rather than resistant) to ciprofloxacin and erythromycin ($P<0.05$) in cattle that were set stocked rather than rotationally grazed.

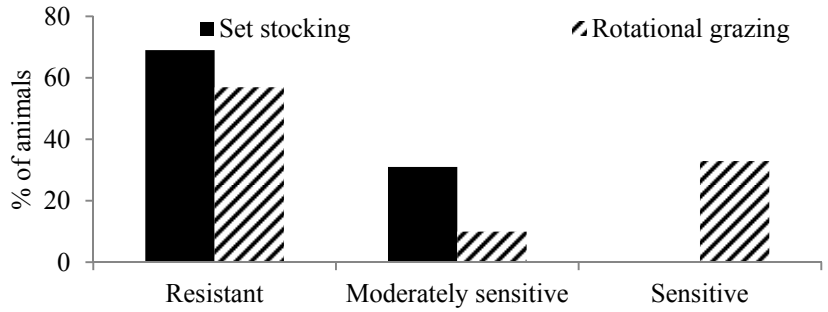

Figure 1 Effect of grazing system on *E coli* resistance to ceftiofur

Conclusion Rotational grazing of cattle, rather than set stocking, is associated with a reduced resistance to 3rd generation cephalosporins in sentinel Gram negative bacteria such as *E. coli.*

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Effect of pH on the abundance of antimicrobial resistance genes in manure

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Application Understanding the mechanisms underlying effect of manure management practices on antimicrobial resistance genes could allow development of effective mitigation strategies to reduce antimicrobial resistance in livestock manure.

Introduction We have previously shown that even after therapeutic antibiotic treatment antibiotic residues reach the gut and thus could contribute to the emergence and dissemination of antimicrobial resistant bacteria (ARB) and antimicrobial resistance genes (ARG). Therefore, reducing antimicrobial usage only may not be sufficient to reduce the emergence and spreading of ARB and ARG from livestock farms. Several manure management strategies (e.g. storage, composting, and lime treatment) have been used to kill pathogens. However, their effectiveness in reducing ARG in manure remained unexplored. Since underlying mechanisms of these manure management strategies rely on various factors including pH, this project aimed to investigate how various pH could influence ARG in cattle manure.

Material and methods Faeces and urine were collected from four groups of lactating cows (12 cows/group) receiving: no antibiotic, macrolide, 1st and 3rd generation cephalosporin antibiotics. Faeces and urine were pooled separately within each group before collecting representative faecal and urine samples. Faeces and urine were mixed with sterile water to achieve manure of 2% final solid concentration. Manure was prepared in 400 mL glass beakers and exposed to one of following four treatments: single initial pH shock of pH 5, 7, 9 and 12 (1 M HCl was used for pH 5 and 1 M NaOH for pH 9 and 12). Manure was incubated in duplicates at 25°C under aerobic condition. Samples were collected on day 0 (immediately after pH shock), 3, 7 and 28. Abundance of 16S rRNA genes and antimicrobial resistance genes (*cfxA*, *mefA* and *tetW)* were determined using qPCR (Aminov *et al*., 2001; Daly *et al*., 2004; Iwahara *et al*., 2006). All statistical analyses were performed in R software version 3.0.2 (R Foundation for Statistical Computing, Vienna, Austria). The data were not normally distributed even after transformation. Therefore, the data were aligned and rank transformed and subjected to a nonparametric ANOVA. The ANOVA on aligned rank transformed data was conducted with the package "ARTool" (Wobbrock *et al*., 2011). The statistical model included pH, days and their interaction (pH*days).

Results The abundance of *cfx*A gene in manure as a proportion of initial abundance was influenced by pH (P<0.001) and days of incubation (P<0.001). The abundance of *cfx*A was lower in acidic and neutral pH (pH 5 and 7) compared to alkaline pH (pH 9 and 12). Irrespective of initial pH shock, abundance of *cfx*A as a proportion of initial abundance increased with time. Relative abundance of *cfx*A in manure following initial pH shock followed trends similar to that observed for absolute abundance of *cfx*A. The abundance of *mef*A as a proportion of initial abundance was higher in alkaline pH (pH 9 and 12) compared to acidic or neutral pH (pH 5 and 7) (P<0.05). Initial increase in the abundance of *mef*A as a proportion of day 0 abundance decreased after 28 days of incubation (P<0.001). The abundance of *tet*W as a proportion of initial abundance decreased when manure received either acidic or alkaline pH shock. Following initial pH shock *tet*W abundance increased until day 7 and then decreased. However, relative abundance of *tet*W as a proportion of initial abundance remained elevated at the end of the incubation.

Conclusion Abundance of certain ARG in manure was reduced by acidic pH while other ARG were reduced under alkaline conditions. In addition, abundance of certain ARG decreased with time. Therefore, pH as well as time should be considered while developing or selecting manure management strategies to reduce or remove ARG from manure before land application.

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071

The effect of pasture allowance on the performance of in-calf Holstein heifers in their second grazing season

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Application This study informs decisions regarding the grazing of in-calf heifers, detailing what heifer and pasture performance can be expected from rotational grazing management with differing pasture allowances and stocking rates.

Introduction Several authors agree that grazed grass remains the cheapest source of high quality feed in ruminant livestock systems (Shalloo *et al*., 2004). Pasture allowance (PA) has long been recognised as a key factor in animal production due to its effect on herbage intake (Mayne, 1996). Limited research has examined the grazing management factors that influence heifer performance. The aim of this study was to investigate the optimal pasture allowance, balancing in-calf heifer performance with its effect upon pasture production, utilisation and quality.

Material and methods The study was carried out at AFBI Hillsborough. Holstein heifers (n = 54) were assigned to three PA treatments at 1.8%, 2.4% and 3.0% live weight (LW) allowance of grazed grass d^{-1}. Paddock area was flexible and calculated based on the kg DM demand for the heifers. Treatment groups were setup in triplicate, with groups comprising six heifers. Replicates were split into seven blocks and further subdivided into paddocks specific to treatment. Heifers were balanced on their reproductive status, their weight and their age. Average age at commencement was eighteen months old with an average weight of 426 kg. The study commenced on 23rd April 2018 and ran for 92 days, with a rotation length of twenty five days (three and a half day paddock residency). A rotational nitrogen application programme was carried out, with no additional operations carried out within the paddocks. Heifer LW and body condition score (BCS) were recorded fortnightly using a manually operated and calibrated weighbridge (Tru Test Ltd, UK). Compressed sward heights were measured with a rising plate meter (Jenquip, New Zealand) and recorded on animal entry and exit to each paddock. Herbage mass was calculated using a predetermined equation calibrated at AFBI Hillsborough (Dale, 2010) and validated weekly by taking grass clippings (Bosch, UK) of 0.2 m x 1 m across five random plots within each paddock (total 1.0 m^2) cut above 4 cm. Samples collected were weighed fresh and submitted for laboratory analysis to determine the oven DM (dried at 60^{o}C for 72 h). Water soluble carbohydrate (WSC), crude protein (CP), acid detergent fibre (ADF) and metabolisable energy (ME) were determined via near infrared spectrometry (0.2 m^2 above 4 cm). GenStat (VSN International, 2015) was used for data analysis. Data were analysed using repeated measures and by analysis of variance (ANOVA).

Results Increasing PA from 1.8% to 3.0% resulted in a significant increase in daily live weight gain from 0.72 kg/d to 0.91 kg/d respectively ($p<0.024$). Average DM intake increased by 1.65kg DM from lowest to highest PA ($p < 0.001$). Increasing PA resulted in an increase in herbage production from 1473 kg DM/ha grown per rotation to 1745 kg DM/ha ($p < 0.001$). Pasture utilisation reduced significantly from 84% to 60% with increasing PA ($p < 0.001$) resulting in the area required for the grazing of the heifers on the greatest PA being 40% greater across the season ($p < 0.001$).

Table 1 Effect of pasture allowance on animal and pasture performance

	Treatment				
	1.80%	2.40%	3.00%	SED	P-value
Av. live weight gain (kg)	0.72	0.79	0.91	0.068	p<0.05
Pasture utilisation (%)	83.73	68.67	60.21	1.428	p<0.001
Av. Pre grazing cover (Kg DM/ha)	3215	3637	3879	56.23	p<0.001
Pasture production (kg DM rotation)	1473	1640	1745	51.74	P<0.002
Paddock Area (ha)	0.093	0.11	0.131	0.00272	p<0.001

Conclusion At a PA of 2.4% these in-calf Holstein heifers could achieve their live weight performance target prior to calving, whilst a PA of 1.8% was insufficient to achieve the 0.75 – 0.80 kg/d growth target required. For 1 ha of land the lower allocation could graze nine heifers across the season, compared to just six at the highest allowance, coupled with a 14% reduction in pasture utilisation. Performance recording of heifers at grass is imperative, evaluating whether they are ahead of or behind their target weight will dictate the efficiency of the pasture which should be aimed to be achieved.

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072

Prediction of dairy cow nitrogen intake over 305 days of lactation using long-term production data

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Application Nitrogen (N) intake of dairy cows during the lactation period (305 d) can be accurately predicted from annual milk yield, live weight and dietary N concentration.

Introduction Annual N excretions and associated ammonia emissions from dairy production systems are often predicted from annual N intakes, with the latter estimated from feed intake using energy rationing systems. An alternative approach is to estimate annual N intake directly from cows' performance. The objective of the present study was to evaluate if there was a significant relationship between annual N intake and annual milk yield and live weight (LW) of dairy cows, and then develop prediction equations for annual N intake using animal and dietary factors.

Material and methods Dairy cow data (n = 476) used were collated from 8 full lactation production studies undertaken at the Agri-Food and Biosciences Institute between 2006 and 2013. Cows (286 Holstein, 161 Jersey-Holstein crossbred and 29 Swedish Red-Jersey-Holstein crossbred) were either totally confined throughout the experimental period (n = 89), or confined in early lactation and late lactation, and grazed in mid lactation (n = 387). Diets offered comprised predominantly grass silage, grazed grass and concentrates. Feed intake, LW and milk production were recorded throughout experimental periods, except for intake of grazed grass which was estimated using energy rationing models within 'Feed into Milk' (Agnew *et al*., 2004). Data were collated or calculated for individual cows on a daily basis, with experimental periods ranging from 250 to 390 d (mean 306, s.d. 27.7 d). Data for individual cows were then scaled to a 305 d basis, assuming a lactation cycle of 365 d (305 d lactation, 60 d dry period). These data were used to develop prediction equations for N intake (kg/305 d) using energy-corrected milk yield (ECMY, kg/305 d), mean LW and dietary N concentration. The REML procedure was used to develop these relationships, with the effects of experiment, cow breed/genotype, parity, management regime and dietary forage type and proportion being removed.

Results The current dataset contains a large range in dietary CP concentration (0.123 to 0.224 (mean 0.175, s.d. 0.0179) kg/kg DM), LW (379 to 769 (men 533, s.d. 69.6) kg), ECMY (3621 to 13224 (mean 7415, s.d. 1593.8) kg/305d) and N intake (76 to 210 (mean 143, s.d. 24.4) kg/305d lactation). These data were used to develop prediction equations (all significant, $P < 0.001$) for N intake (Table 1 and Figure 1). Compared to ECMY only (Eq. 1), adding LW (Eq. 2), and LW and dietary N concentration (Eq. 3) to the relationship between N intake and ECMY increased the R^2 values from 0.763 to 0.797 and 0.806, respectively. These equations were then evaluated through an internal validation procedure. The validation indicated that N intake could be accurately predicted from ECMY, with the mean predicted N intake close to actual intake (144.8 vs. 142.0 kg/305d) and a low mean square prediction error (MPE, 0.130). The prediction accuracy was improved (MPE = 0.104, and predicted – actual N intake = 1.9 kg/305d) when N intake was predicted from ECMY, LW and dietary N concentration.

Table 1 Prediction equations for N intake (NI) in lactation (kg/305d) of dairy cows

	Equations	R^2	Eq. No
NI =	$0.010_{(0.001)}$ ECMY + $64.9_{(9.5)}$	0.763	1
	$0.009_{(0.001)}$ ECMY + $0.104_{(0.010)}$ LW + $20.6_{(9.4)}$	0.797	2
	$0.009_{(0.001)}$ ECMY + $0.103_{(0.009)}$ LW + $3.475_{(0.292)}$ Ncont - $78.8_{(11.9)}$	0.806	3

ECMY - energy-corrected milk yield (kg/y), LW - live weight (kg), Ncont - diet N content (g/kg DM)

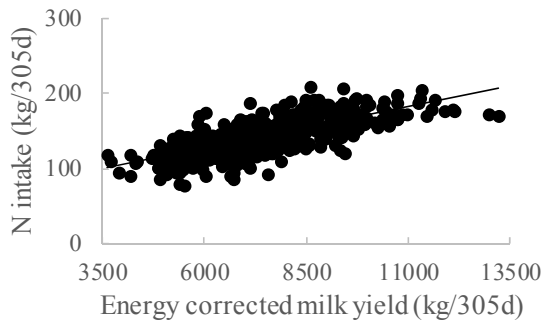

Figure 1 Milk yield vs N intake

Conclusion The N intake of dairy cows over 305 d lactation can be accurately predicted from annual milk yield, LW and dietary N concentration. This provides an alternative measure to quantify annual N excretion and associated ammonia emissions in dairy production systems.

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The effect of grazing season length and stocking rate on milk production and supplementary feed requirements within spring calving dairy systems in the north-east of Ireland

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Application Significant potential exists to increase productivity from pasture by increasing stocking rate and extending grazing season length on dairy farms in the north-east region of Ireland.

Introduction In comparison with other regions of Ireland, dairy production systems in the north-east are characterised by lower stocking rates (SR), a shorter grazing season (GS) and reduced farm profitability (Lapple *et al*., 2012; Ramsbottom *et al*., 2015). The objective of this study was to quantify the impacts of alternative SR and GS length combinations on animal and pasture productivity on a wetland soil in the northeastern region.

Material and methods This study was carried out at Ballyhaise Agricultural College (54° 015'N, 07° 031'W) during 2017. The experimental site is comprised of a variety of different soil types including alluvial, brown earth, gley and brown podzolic soils while the topography ranges from alluvial flatlands to drumlins with steep slopes and U-shaped valleys. 120 spring calving dairy cows were randomly assigned pre-calving based on breed, parity, calving date and previous lactation milk yield to one of four grazing systems comprised of 2 GS lengths: average (AGS; 205 days; 15 March to 20 October) and extended (EGS; 270 days, 15 February to 20 November) and 2 SR treatments: medium (MSR; 2.5 cows/ha) and high (HSR; 2.9 cows/ha). Each experimental group had its own farmlet. While indoors, both AGS groups were fed a grass silage and concentrate diet. Weekly milk production was derived from individual milk yields recorded at each milking. Milk fat, protein and lactose concentrations were determined once weekly from successive morning and evening milk samples while individual body weight (BW) and body condition score (BCS) was recorded on a bi-weekly basis. Least squares means for GS and SR were estimated using linear mixed models.

Results The effect of GS and SR on animal performance is displayed in Table 1. Grazing season length varied from 209 days for both AGS treatments to 262 and 259 days for the MSR EGS and HSR EGS treatments, respectively. Neither SR nor GS had a significant effect on individual animal performance in terms of milk yield, milk composition, average BW or average BCS. Higher SR resulted in significantly increased milk and milk fat plus protein production per hectare. As both AGS treatments were indoors for an additional 60 days between February and November, significantly more concentrate and silage were required during lactation compared with the EGS treatments.

Table 1 Effect of Stocking rate and Grazing Season length on animal performance and supplementary feed requirements.

Grazing season length	Average		Extended			P value		
Stocking rate	Medium	High	Medium	High	s.e.d.	SR	GS	SR*GS
Milk yield (kg/cow)	5,224	5,154	5,056	5,287	113.6	0.47	0.87	0.18
Milk yield (kg/ha)	13,074	14,935	12,636	15,311	300.2	0.001	0.91	0.16
Fat plus protein yield (kg/cow)	452	452	454	470	10.5	0.45	0.34	0.46
Fat plus protein yield (kg/ha)	1,132	1,311	1,136	1,360	28.3	0.001	0.34	0.41
Grazed grass utilisation (t DM/ha)	9.6	10.4	10.7	11.6	0.76	0.27	0.15	0.88
Concentrate fed (t DM/ha)	1.4	1.6	1.1	1.3	0.04	0.001	0.001	0.78
Silage fed (t DM/ha)	2.3	2.5	0.9	1.4	0.12	0.01	0.001	0.22

Conclusion The results of this study show the potential of both extended grazing and higher SR to increase productivity and reduce supplementary feed requirements. Extending the GS resulted in similar milk production and a reduced requirement for supplementary feeds during lactation. Increasing SR resulted in similar milk production per cow and significantly increased milk output per hectare. A full economic appraisal of the production systems must be undertaken.

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074

Relationships between blood metabolites and energy balance in early lactation dairy cows offered grass silage based diets: a meta-analysis

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Application Robust relationships that could be integrated into cow health management tools were identified between blood metabolites and energy balance (EB) during early lactation.

Introduction An altered metabolic state is common in high yielding dairy cows during early lactation. While blood metabolites such as beta-hydroxy butyrate (BHB), glucose, and non-esterified fatty acids (NEFA) are frequently suggested as indicators of energy status, relationships between blood metabolites and metabolic status is often poor within individual experiments. The objective of this study was to identify if relationships exist between blood metabolites and energy status, based on a meta-analysis of data from experiments undertaken at the Agri-Food and Biosciences Institute (AFBI).

Material and methods A meta-analysis of individual cow data collected from 10 experiments (representing 27 treatments and 332 cows, 90.8% of which were Holstein Friesian) conducted at AFBI Hillsborough, Northern Ireland, was undertaken. Perennial ryegrass silage was the predominant forage source in all experiments. The concentrate component of the diets was offered either mixed with the forages (partial mixed ration), separate from the forages (via in-parlour of out-of-parlour feeders), or via a combination of these practices. The mean forage-to-concentrate ratio (DM basis) of the diets offered was 52:48, with all diets offered *ad libitum*. For inclusion in the analysis, data on feed intake (daily), live weight (LW, weekly), milk yield (daily) and milk composition (at least fortnightly), had to be available for each cow, together with detailed information on the composition of the diets offered. Daily EB (MJ of ME/d) was calculated for each individual cow according to equations described within Feed into Milk. The metabolisable energy (ME) content of concentrates offered was calculated from the ME content of each individual ingredient, based on UK feed tables (FeedByte® - SAC Consulting), while the ME content of forages offered were determined either via NIRS predictions (2 studies), or based on values from sheep offered the silages at maintenance level (8 studies). Blood samples were normally taken between 1 and 2 hours prior to feeding, while the frequency of blood sampling (for BHB, glucose, and NEFA) varied between studies (normally one sample every 14 – 28 days). Mean EB values were calculated for the seven day period around the date that each blood sample was collected. Data was split into three time periods (1–4, 5–8 and 9–12 weeks post calving). The data was analysed using a Linear Mixed Model (REML estimation method). Study and cow within study were fitted as random effects into the model. Statistical analyses were performed using GenStat® (18th edition).

Results Both BHB and NEFA were negatively related to EB whereas there was a positive relationship with glucose. Relationships were most robust during weeks 1-4 and 5-8, with relationships during these periods having a higher R^2 than the relationship over the 12 week period.

Table 1 Linear relationships (EB = A + BX) between blood metabolites and energy balance (MJ of ME/d) in dairy cows during early lactation, based on a meta-analysis of data from 10 experiments

Metabolite, X	Lactation Week	n	A	s.e.	B	s.e.	P-value	R^2	RMSE	AIC
BHB (mmol/L)	1–4	770	-28.9	4.24	-13.2	2.68	<0.001	0.85	0.807	7563
	5–8	894	-11.8	5.03	-12.5	2.71	<0.001	0.84	0.671	8554
	9–12	421	5.9	6.41	-21.0	6.92	0.003	0.77	1.052	3985
	1–12	2085	-12.2	4.29	-17.9	1.90	<0.001	0.61	0.584	20317
Glucose (mmol/L)	1–4	770	-118.3	10.07	26.1	3.10	<0.001	0.84	0.811	7523
	5–8	894	-57.9	10.89	11.8	3.08	<0.001	0.83	0.680	8560
	9–12	422	-42.5	15.34	11.1	4.47	0.013	0.77	1.055	4003
	1–12	2086	-93.2	7.68	21.9	2.04	<0.001	0.61	0.587	20306
NEFA (mEq/L)	1–4	769	-28.3	4.72	-23.9	3.53	<0.001	0.84	0.810	7534
	5–8	894	-15.3	5.06	-15.7	3.32	<0.001	0.83	0.672	8552
	9–12	422	-7.4	5.52	2.4	3.84	0.531	0.80	1.033	4009
	1–12	2085	-16.8	4.66	-22.1	2.15	<0.001	0.62	0.583	20303

A = intercept; B = regression coefficient; s.e. = standard error; X= variable; RMSE = root mean square error; AIC = Akaike's information criterion.

Conclusion Models developed displayed good statistical fit, and it may be possible to integrate them with other management and performance data to help develop improved estimates of EB in early lactation.

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Dietary starch level alters rumen pH and copper metabolism in lactating Holstein-Friesian dairy cows receiving added dietary sulphur and molybdenum

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Application Diets containing high levels of starch that reduce rumen pH result in a higher copper (Cu) availability than those containing low levels. The starch content of the diet should be taken into consideration when supplementing with Cu.

Introduction Copper is an essential trace element and its supply can affect dairy cow health and performance (Suttle, 2010). Sulphur (S) has been shown to react with dietary molybdenum (Mo) in the rumen to form insoluble thiomolybdate complexes with Cu, which can prevent Cu absorption and/or metabolism (Suttle, 2010). Previous work has identified a greater effect of S and Mo on reducing Cu status in dairy cows when fed grass silage compared to maize silage based rations (Sinclair *et al*., 2017). It was hypothesised that this may have been due to rumen pH altering thiomolybdate formation and/or hydrogen sulphide production in the rumen (Sinclair *et al.*, 2017). The aim of the present study was to alter rumen pH through dietary starch level and assess the effects on Cu metabolism in the presence of additional S and Mo.

Material and methods Sixty Holstein-Friesian dairy cows (48 multiparous and 12 primiparous) that were 33 (SE ±2.5) days post-calving and yielding 41 (± 0.9) kg/d were blocked and randomly allocated to 1 of 4 dietary treatments in a 2 x 2 factorial design based on parity (multiparous or primiparous), and milk yield in the week prior to allocation. Cows remained on study for 98 days. The four diets were formulated to contain approximately 15 mg of Cu/kg of dry matter (DM), were isoenergetic and isonitrogenous, and had a grass silage-to-maize silage ratio of 1:1 (DM basis). The diets were formulated to contain starch levels of either 231 g/kg DM (HS) or 103 g/kg DM (LS), and were either unsupplemented (-) or supplemented (+) with 1.2 g of S/kg DM, and 4.1 mg of Mo/kg DM. The four diets were therefore: LS- [103 g/kg of DM dietary starch, no additional antagonists]; LS+ [103 g/kg of DM dietary starch, with additional S and Mo]; HS- [231 g/kg of DM dietary starch, no additional antagonists]; HS+ [231 g/kg of DM dietary starch, with additional S and Mo]. Dietary ingredients were fed as a total mixed ration through roughage intake feeders (Insetec, Marknesse, Netherlands), fitted with an automatic weighing and animal identification system calibrated to ± 0.1 kg. Reticular pH boluses (eCow Ltd, Devon, UK) that recorded pH every 15 mins were administered prior to commencing the study. Liver biopsy samples were collected during weeks 0 and 14 of the study via the 11th intercostal space, were immediately snap frozen in liquid nitrogen and stored at –80 ^{o}C prior to digestion at 60^{o}C in concentrated nitric acid and analysed for Cu by ICP-MS (Perkin Elmer, UK) as described by Sinclair *et al.*, (2017). Performance parameters were analysed as a 2x2 factorial design using a repeated measures ANOVA, with main effects of starch level (S), Cu antagonists (A) and their interaction (SxA) using Genstat (v18). Hepatic Cu change was analysed as a 2 x 2 factorial by ANOVA.

Results Reticular pH was highest immediately prior to feeding, with a subsequent decline across all treatments thereafter, with mean values 0.2 lower ($P < 0.05$) in cows offered the high starch diets (Table 1). The addition of S and Mo reduced ($P < 0.001$) mean DM intake by 1.9 kg/d, but had no effect ($P > 0.05$) on milk yield. The inclusion of S and Mo reduced hepatic Cu concentrations by 1.1 mg/kg DM/d compared to unsupplemented animals, whilst the higher dietary starch concentration improved hepatic Cu concentrations by 0.58 mg/kg DM compared to those fed the lower dietary starch level.

Table 1 Dietary starch and copper antagonist effects on performance and hepatic copper status

	Diet					P-value		
	LS-	LS+	HS-	HS+	s.e.d	S	A	S x A
Mean reticular pH	6.35	6.41	6.24	6.22	0.079	0.022	0.755	0.487
Dry matter intake, kg/d	21.7	20.6	22.4	19.8	0.67	0.983	<0.001	0.107
Milk yield, kg/d	38.5	36.9	37.3	36.0	0.98	0.292	0.158	0.906
Δ Hepatic Cu, mg/kg DM/d[1]	0.72	-0.65	1.02	0.20	0.349	0.019	<0.001	0.262

[1]over the 14 week study period

Conclusion Increasing dietary starch level can decrease rumen pH which is associated with a reduction in the antagonistic effects of dietary S and Mo on Cu status. These results highlight the need to take account of dietary effects on rumen pH when deciding on appropriate Cu supplementation levels. The mechanisms by which rumen pH alters Cu availability are not clear and require further investigation.

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Effect of altering the frequency of fresh pasture allocation on grass utilisation and the performance of lactating dairy cows

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Application Preliminary results indicate that reducing the frequency of grazing allocation from 12H allocations to 24H or 36h allocations has the potential to improve milk fat plus protein yield.

Introduction The economic benefit of improving milk from forage has been highlighted, however currently there are limited novel grazing management strategies that allow high production dairy cattle to sustain high milk yields while maintaining high levels of pasture utilisation. Previously research has found daily allocations of fresh pasture increased milk and milk fat plus protein yield compared to a four day pasture allocation (Abrahamse *et al*., 2008), however to date research has not investigate the closely aligned times of 12, 24 and 36hour allocation that are commonly practiced on dairy farms. Reducing the frequency of pasture allocation offers a potential labour saving benefit. The aim of this experiment was to examine the effect of altering the frequency of fresh pasture allocation on animal performance and grass utilisation.

Material and methods The experiment was conducted at the Agri-Food and Biosciences Institute (AFBI), Hillsborough. The experiment was split into two experimental periods both lasting 61 days each. Period 1 (P1 - 11/05/18 – 10/07/18) which involved 90 spring calving Holstein-Friesian dairy cows (63 multiparous and 27 primiparous) and period 2 (P2 - 12/08/18 – 11/10/18) which involved 87 (60 multiparous and 27 primiparous) spring calving Holstein-Friesian dairy cows. Dairy cows were balanced and assigned to one of three grazing strategies offering fresh pasture at either (1) 12hour (12H), (2) 24hour (24H) or (3) 36hour (36H) frequencies. Concentrate allocation was 4.4 and 5.72kg DM/cow/day for primiparous and multiparous animals, respectively. Six primary blocks of perennial ryegrass (*Lolium perenne L.*) were established, each block consisting of six 12H (0.14ha), three 24H (0.28ha) and two 36H (0.36ha) paddocks. Additional areas were sought in low grass situations. Pre- and post- grazing compressed sward heights were determined using a rising plate meter. Herbage compositional quality was analysed twice weekly using NIRS. Total herbage utilisation was determined as the difference between available (>4cm) and consumed herbage. Individual animal milk yields, daily liveweight, weekly milk composition and fortnightly body condition score (BCS) was recorded. Individual animal lying time (IceRobotics, Edinburgh) and ruminating behaviour (ITIN+HOCH, Switzerland) was monitored during each period.

Results Treatment had no effect (P>0.05) on grass utilisation, however numerically the 36H treatment had the highest pasture utilisation (Table 1). Herbage compositional quality did not significantly differ between treatments with a mean DM of 20.0% for P1 and 16.0% for P2. The mean ME of all treatments was 11.5 and 11.0g/kg DM for P1 and P2, respectively. Frequency of pasture allocation had no significant effect on milk yield which averaged 28.8 and 22.2kg/cow for P1 and P2, respectively. However, the 12H treatment displayed a tendency for the lowest milk fat plus protein yield in P1 (P<0.067) in addition this effect was significant in P2 (P<0.001). The 24H treatment displayed a greater liveweight loss during P1 (P<0.05) however this treatment effect was not displayed in P2.

Table 1 Effect of altering frequency of pasture allocation on grass and animal performance

	Period 1					Period 2				
	12H	24H	36H	SED	Sig	12H	24H	36H	SED	Sig
Pre-grazing height (cm)	12	11.7	11.1	0.58	NS	11.2	11.4	11.2	0.36	NS
Post-grazing height (cm)	5.5	5.3	4.7	0.34	NS	5.2	5.3	5.2	0.23	NS
Utilisation (%)	83.5	84.5	88.3	2.45	NS	85.2	83.7	85.8	3.36	NS
Milk fat + protein yield (kg cow^{-1} day^{-1})	2.12	2.24	2.19	0.077	0.067	1.81^{a}	1.90^{b}	1.92^{b}	0.026	**
Change in liveweight (kg cow^{-1})	-8.5^{ab}	-13.8^{a}	-3.2^{b}	4.07	*	0.4	-6.8	1.0	5.02	NS

Conclusion Preliminary results indicate that reducing the frequency of grazing allocation from 12hour allocations to 24 or 36hour allocations has the potential to improve milk fat plus protein yield. Reducing the frequency of pasture allocation on farm offers potential labour saving benefits to farmers.

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Effect of dairy management system on phytoestrogen concentrations of retail milk

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Application Consumption of organic milk can increase the intakes of potentially beneficial phytoestrogens, but any implications on consumer health, as a result of these differences, cannot be drawn by the present work.

Introduction In addition to the widely studied milk nutrients (e.g. profiles of fatty acids, minerals, vitamins, antioxidants) milk also contains phytoestrogens, which are plant secondary metabolites involved in plant's growth and survival. These are mainly lignans (e.g. secoisolariciresinol, matairesinol, lariciresinol, hydroxymatairesinol, enterolactone, enterodiol), isoflavones (e.g. daidzein, genistein, glycitein, formononetin, naringenin, equol) and coumestans (e.g. coumestrol) (Kuhnle *et al*., 2008). Milk phytoestrogens originate either from the plant or from the transformation of plant phytoestrogens by rumen microbiome (Njastad, *et al*., 2014). Potential benefits from the consumption of phytoestrogen-rich foods include reduction of risk of cardiovascular disease, type-2 diabetes, osteoporosis, menopausal symptoms and hormone-dependent cancers; however, existing evidence is limited and not sufficient for advice on consumption (Leitzmann, 2016; Fardet, 2010). Phytoestrogens are found in animal feed, and dietary intake, as well as dairy management system, can influence milk phytoestrogens contents; in previous work, organic milk in Nordic countries contained more secoisolariciresinol, enterolactone, enterodiol, daidzein, genistein, formononetin, and equol than conventional milk (Adler,*et al*. 2015; Hoikalla *et al*. 2007). However, the phytoestrogen profile of UK milk is still unknown. The aim of this study was therefore to assess the effect of dairy management system and month on the concentrations of lignans, isoflavones and coumestans in retail milk in the UK. We hypothesise that phytoestrogen concentrations will differ between conventional, organic and free-range milk, mainly because of the differences in cow diets (e.g. pasture, forage and clover intakes) between these production systems.

Material and methods Milk of 4 conventional, 4 organic and 2 free-range brands was purchased monthly, over 12 months, from retail outlets in Reading, UK (n=120). Milk phytoestrogen were quantified using LC-MS/MS, microLC 200 series from Eksigent/AB Sciex and QTrap 5500 MS from ABSciex, using calibration curves and internal standards. Analysis of variance by linear mixed models used management system (conventional, organic, free-range) and month (March 2016 – February 2017) as fixed factors and milk ID as random factor.

Results The effect of management system was significant for milk concentrations of secoisolariciresinol, matairesinol, lariciresinol, coumestrol, daidzein, genistein, formononetin, naringenin, coumestrol, and sum of lignans and isoflavones, which were all higher in organic milk than in conventional and free-range milk. Differences may be explained by the higher intakes of pasture and clover (either grazed or ensiled) in organic dairy herds, because they would increase dietary intakes of phytoestrogens. These would either directly be transferred to milk or provide the substrate for the synthesis of mammalian phytoestrogens in the rumen, which are then absorbed and transferred to milk. Differences between conventional and free-range milk were not statistically significant.

Table 1 Relative differences in milk phytoestrogen concentrations (µg/L compared with conventional milk)

Lignans				**Isoflavones**			
	Organic (n=48)	**Free-Range** (n=24)	**ANOVA P-value**		**Organic** (n=48)	**Free-Range** (n=24)	**ANOVA P-value**
Plant				**Plant**			
Secoisolariciresinol	**+0.06**	+0.02	***	Daidzein	**+1.74**	+0.01	***
Matairesinol	**+0.05**	+0.02	*	Genistein	**+1.49**	+0.01	***
Lariciresinol	**+0.14**	+0.00	**	Glycitein	+0.27	-0.09	ns
Hydroxymatairesinol	+0.00	+0.05	ns	Formononetin	**+1.01**	+0.00	***
Mammalian				Naringenin	**+0.13**	+0.01	**
Enterolactone	+0.52	-2.65	ns	**Mammalian**			
Enterodiol	+0.01	-0.01	ns	Equol	**+347.45**	+2.74	***
Total	+0.78	-2.57	ns	**Total**	**+352.08**	+2.68	***
Coumestans							
Coumestrol	**+0.35**	-0.02	***				

Significant differences against conventional milk are shown in bold case. ***, P<0.001; *, P<0.05; ns, P≥0.05.

Conclusion Organic milk had higher concentrations of individual phytoestrogens, and sum of lignans, isoflavones and coumestans, than conventional and free-range milk, potentially due to the higher dietary supply of fresh grass and clover.

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Silage making practices on Northern Ireland dairy farms, and factors perceived by farmers to influence silage quality

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Application Silage making practices are extremely variable in Northern Ireland. Farmers perceive many factors to impact on the quality of the silage that they produce, some, but not all of which are outside of their control.

Introduction While grass silage remains a key component within Northern Ireland (NI) dairy systems, the quality of silage produced on many dairy farms remains moderate. This study was designed to obtain information on silage making practices within NI, and to identify factors that farmers believe impact on the quality of silage that they produce.

Material and methods A survey, which comprised a short questionnaire, was conducted during a two-day (24 and 25 January 2018) Dairy Open Day at Greenmount Agricultural College in NI. The survey was designed to obtain information on silage making practices, and to quantify the perceived impact ('none', 'some', 'moderate' (Mod.), 'large' and 'very large') of a number of factors on the quality of the silage made on local farms. On completion of the open day tour, visitors were approached at random and, if they were active dairy farmers within NI, were asked to participate in the survey. The survey was conducted by AFBI staff (five staff each day), with 174 questionnaires completed.

Results 22% of farmers take two cuts of silage, 65% take three cuts and 13% take four or five cuts. A self-propelled forage harvester was used on 63% of farms, a trailed harvester on 17% of farms, a forage wagon on 13% of farms, while big bales were used on 7% of farms. Almost two thirds of farmers (62%) normally use a contractor, 29% never use a contractor, while the remaining 9% of farmers sometimes use a contractor. Additives are normally used by 47% of farmers, sometimes used by 18% of farmers, while 35% of farmers never use an additive. Of farmers who use a contractor, 89% are charged per acre, 7% per bale, 2.4% per hour, while one farmer was charged using a yield-based system. If contractors were to offer an alternative yield based charging system, 64% of farmers said that this might encourage them to cut earlier, while 36% of farmers said it would not. Weather related issues and their impact on timing of silage making, were identified as having the largest impact on silage quality (Table 1). However, 34% of farmers indicated that delaying cutting to allow the crop to 'bulk-up' to reduce contractor costs was having an adverse effect (moderate to very large) on silage quality. The availability of the contractor when needed was not a major issue on the majority of farms. Ensiling grass that grew in the late autumn/winter, along with first cut silage the following spring, was identified as having either a large or very large effect on silage quality on approximately 30% of farms. The impact of poor quality swards was acknowledged as being an issue, with this a particular problem on land rented on a short term basis. Contamination of herbage with either slurry residues or soil was identified as having a large to very large effect on silage quality on just under 25% of farms. While weather related issues are largely outside of the farmers control, many other factors which farmers perceived to impact on silage quality can be controlled or changed by better management.

Table 1 Farmer perceptions of the impact of a range of issues relating to the quality of silage produced on their farms (% of farmers within each category)

	Impact on silage quality (% of farmers)				
	None	Some	Mod.	Large	Very large
Delaying cutting due to poor weather or poor ground conditions	2	6	24	33	35
Delaying cutting to allow herbage nitrogen levels to fall	36	21	22	14	7
Delaying cutting due to the contractor not being available	44	20	11	15	10
Delaying cutting to allow swards to 'bulk-up' to reduce harvesting costs	42	23	11	12	12
Grass not being allowed to wilt for long enough	13	18	36	24	9
Delaying 'lifting' due to poor weather or poor ground conditions	13	11	23	32	21
Ensiling grass which grows in late autumn/winter along with 1st cut silage	37	13	21	18	11
Ensiling poor quality grass harvested from conacre ground	31	13	16	28	12
Ensiling poor quality grass harvested from owned ground	39	17	17	19	8
Ensiling slurry residues along with grass	54	15	9	11	11
Soil contamination of grass during raking up	34	26	16	13	11
Inadequate compaction of herbage due to the silo being filled too quickly	44	20	17	12	7
Insufficient labour being available when making silage	42	24	16	13	5

Conclusion A wide range of silage making practices are adopted on NI dairy farms. While weather related issues were identified as having a significant impact in silage quality, farmers identified many other management practices that were within their control and which if addressed, could result in an improvement in the quality of silage produced.

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Autumn feed budgeting and grazing strategies impact on animal performance and pasture productivity of intensive grass-based spring dairy cow production systems

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Application Increased Average Farm Cover (AFC) and higher stocking rates (SR), supported by increased grazing intensity and concentrate supplementation, can be effective strategies to maintain animal performance and the reliance on grass in autumn.

Introduction Stocking rate, defined as the number of animals per unit area of land used during a specified defined period of time (cows/ha), is acknowledged as the main driver of productivity in pasture-based systems through increased grazed grass utilisation (McCarthy *et al*., 2011). Higher SR will place added pressure on available feed resources on farms in spring and therefore, the development of appropriate autumn grazing management practices to allow higher SR on farms to continue to harness the benefits of a predominantly grass-based diet at this time of year. The objective of this study was to quantify the impact of alternate autumn feed budgeting and grazing strategies on animal and pasture productivity.

Material and methods 140 spring-calving dairy cows were randomly allocated to one of three AFC treatments (high, HFC; medium, MFC; and low LFC farm covers) during autumn 2017. Within each AFC, the experimental animals were further divided into two grazing intensities (GI): a medium grazing intensity (MGI; 2.75 cows/ha, target post grazing intensity of 40mm) and a high grazing intensity (HGI; 3.25 cows/ha, target post grazing intensity of 35mm). The HGI groups also received an additional 2kg of concentrate per cow/day compared to MGI. The 3 AFC treatments were established by extending rotation length from late summer to achieve peak autumn AFCs of 1350, 1100 and 870 kg DM/ha. All treatments were balanced for breed, parity, genetic merit, bodyweight and body condition score. Milk yield was recorded daily and milk constituents weekly, while grazing measurements were undertaken according to the methods of Delaby and Peyraud (1998). Least squares means for AFC and GI were estimated using linear mixed models.

Results Average pre-grazing and post-grazing available biomass was significantly influenced by AFC treatment but resulted in no significant impact on milk or fat plus protein yield. In contrast, GI had no significant impact on pre-grazing available biomass, however the combination of increased SR and increased concentrate supplementation within the HGI treatment resulted in reduced post-grazing biomass, similar milk yield and increased fat plus protein production compared to MGI (Table 1).

Table 1 Effect of Average Farm Cover (AFC) and Grazing Intensity (GI) on milk production

Average Farm Cover	Low		Medium		High			P value		
Grazing System	MGI	HGI	MGI	HGI	MGI	HGI	s.e.d.	AFC	GI	AFC x GI
Pre-grazing biomass (kg DM/ha)	1,536	1,696	1,722	1,865	2,328	2,349	100.0	<0.001	0.19	0.26
|Pre-grazing sward height (kg DM/ha)	10.0	10.1	10.4	10.3	11.9	12.0	0.30	<0.001	0.85	0.94
Post-grazing sward height (kg DM/ha)	3.59	3.49	3.83	3.58	4.08	3.74	0.09	0.001	0.003	0.42
Milk yield (l/cow/d)	16.0	16.6	15.6	16.2	15.7	16.0	0.42	0.44	0.11	0.84
Fat plus protein (kg/cow/d)	1.51	1.56	1.49	1.57	1.49	1.51	0.035	0.517	0.04	0.57

Conclusion Increasing AFC resulted in increased pre-grazing biomass yields but had no impact on animal performance, and can therefore, be an effective strategy to maintain reliance on grazing during autumn. Equally, the combination of reduced post-grazing residuals and increased concentrate supplementation can increase animal performance within higher SR systems.

Acknowledgements The authors gratefully acknowledge the financial support of Teagasc, INRA and Irish Dairy Levy.

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080

The impact of supplemental UV lighting, and a dietary additive, on the vitamin D content of bovine milk

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Application The provision of supplemental UV lighting to housed dairy cows provides an opportunity to significantly increase the vitamin D content of bovine milk. A dietary additive did not significantly increase milk vitamin D concentrations.

Introduction Vitamin D deficiency is well recognised as a public health issue, with recent research (Cashman *et al*., 2016) suggesting that 40.4% of the EU population is deficient. Good naturally occurring sources of vitamin D such as oily fish are not widely consumed and individuals living at more northerly latitudes have limited opportunity for endogenous dermal vitamin D synthesis. Consequently, there is interest in increasing the vitamin D content of commonly consumed foods. This study investigated the effect of UV lighting and a dietary additive on the vitamin D content of bovine milk.

Material and methods Four treatments were examined in a continuous design (2 x 2 factorial) 12-week experiment involving 32 Holstein Friesian dairy cows. Factors examined comprised two levels of UV light supplementation (No UV-B vs. UV-B) and two dietary additive treatments (No additive vs. Additive). Cows were housed in two separate pens (16 cows per pen), fitted with cubicles and a 'head locking' feed barrier. One pen was fitted with two parallel rows of UV bulbs above the cow feeding area. Cows in both groups were restrained at the feed barrier each morning, and offered grass silage. The lighting system, which was suspended on a pulley system, was then lowered to approximately 1.2 m from the cows back, and cows exposed to the UV bulbs for 30 minutes. All cows were offered 7.0 kg concentrate/day (3.5 kg at each milking). The concentrate offered to half of the cows in each group contained a dietary additive designed to enhance the vitamin D concentrations of the milk produced, while that offered to the remaining cows in each group contained no additive. Milk samples were taken from all cows each week during two consecutive milkings, bulked in proportion to milk yield, and subsequently analysed for concentrations of vitamin D3, vitamin D2, 25-hydroxyvitamin D3 (25-(OH)-D3) and 25-hydroxyvitamin D2 (25-(OH)-D2).

Results UV-B significantly increased vitamin D3 and 25-(OH)-D3 ($P<0.001$) concentrations in milk (Figure 1 A and B). Week had a significant effect on vitamin D3, vitamin D2 and 25-(OH)-D2 ($P<0.001$) but not 25-(OH)-D3 ($P=0.079$). There was a significant week x Additive ($P=0.021$) and week x UV light supplementation ($P<0.004$) interaction for vitamin D3. Additive had no effect on the concentration of any of the vitamin D compounds investigated.

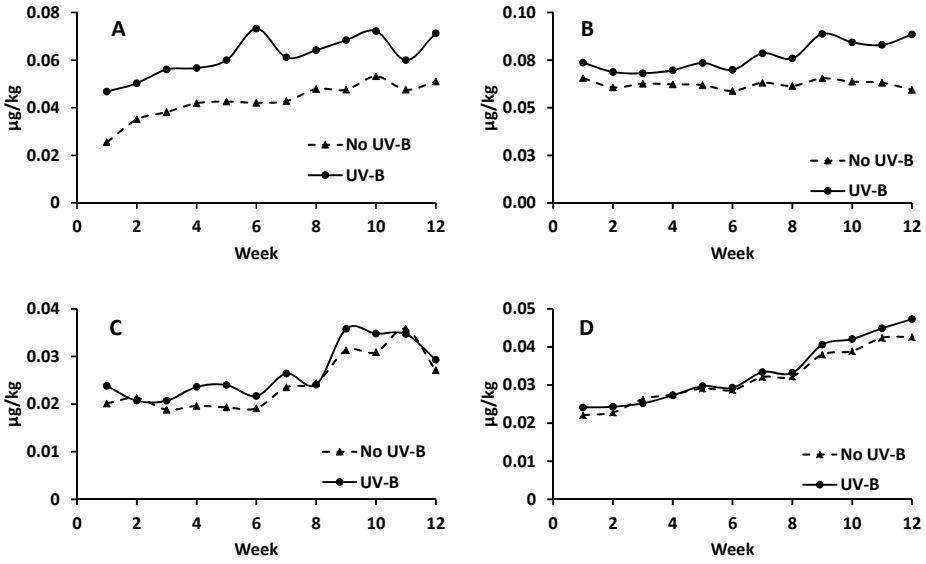

Figure 1 Effect of UV-B lighting on vitamin D3 (A), 25-(OH)-D3 (B), vitamin D2 (C) and 25-(OH)-D2 (D) content of milk

Conclusion UV-B lighting significantly increased the concentrations of vitamin D3 (by 43%) and 25-(OH)-D3 (by 23%) in bovine milk. A dietary additive did not significantly increase milk vitamin D concentrations.

Acknowledgements This study was co-funded by the Agri-Food Quest Competence Centre (AFQCC) and carried out in partnership with Devenish Nutrition, AFBI, Thompsons, Dale Farm, Karro, CAFRE and NICHE, Ulster University.

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081

Effect of dietary cobalt supplementation on the intake, performance and whole tract digestibility in dairy cows fed tropical forages

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Application Supplementation of cobalt to dairy cows fed tropical forages increases dry matter intake but does not affect milk performance or whole tract digestibility.

Introduction Cobalt (Co) is an essential micro mineral that is required by the microbes in the rumen for the synthesis of vitamin B_{12} (McDowell, 2000). Vitamin B_{12} plays a major role in glucose and methionine synthesis in dairy cattle, and a deficiency of Co has been associated with a reduction in dry matter (DM) intake, whole-tract digestibility, and milk production (McDowell, 2000). The recommended dietary concentration of Co is 0.11 mg/kg DM (NRC, 2001), but many forages, particularly tropical forages that are available in Sri Lanka, are deficient in Co. Most research studies have evaluated Co metabolism in dairy cows fed temperate forages (Weerathilake *et al*., 2018)), and information on the effects of Co supplementation on the intake and performance of dairy cows fed tropical forages is lacking. The objectives of the study were to determine the effects of dietary supplementation of Co on the intake, milk performance and whole-tract digestibility of dairy cows fed tropical forages in Sri Lanka.

Material and methods Fifteen Jersey dairy cows (11 primiparous and 4 multiparous) weighing 283 (± 30.9 kg) were fed one of three dietary treatments in a 3 x 3 Latin square design with 3 periods, each of 4 weeks duration. Each period consisted of a 21 d adaptation period followed by 7 d of sampling. The dietary treatments were: no additional Co (Control), an additional 0.2 mg Co/kg DM (Low) or an additional 0.4 mg Co/kg DM (High). The cows were fed a basal forage mix (75% Guinea grass (*Panicum* maximum) and 25% CO3 (*Pennesitum purpureum*): DM basis) *ad libitum* that contained 0.03 mg Co/kg DM, and were supplemented with 1.8 kg/d of a concentrate that contained 0.04 mg Co/kg DM. Additional Co was supplied as $CoSO_4$. Animals were fed individually and machine milked at 0600 and 1600 h, and had free access to drinking water. During the final 7 d of each period, feed intake was recorded daily, with milk yield recorded at each milking and samples collected at the morning and evening milking on two days for subsequent analysis of fat and protein content. Faecal samples were collected at two time points (0900 and 1300 h) during the final 5 d of the collection period. Feed and faecal samples were analysed for DM, neutral detergent fibre (NDF) and acid detergent fibre (ADF). Acid insoluble ash was also analysed in feed and faecal samples to estimate whole tract digestibility. Data was analysed as a Latin square design using Minitab v.18

Results Dry matter intake increased ($P < 0.05$) with increasing dietary concentration of Co (Table 1). In contrast, there was no effect ($P > 0.05$) of dietary treatment on milk yield, milk fat or protein content, with mean values of 4.07 kg/d, 41.3 and 36.0 g/kg respectively. Similarly, there was no effect ($P > 0.05$) of dietary treatment on whole tract digestibility of DM, NDF or ADF, with mean values of 0.60, 0.72 and 0.42 kg/kg respectively.

Table 1 Effect of cobalt supplementation on the performance and whole tract digestibility of dairy cows

	Control	Low	High	s.e.d	Significance
Total intake, kg DM/d	8.59[a]	8.83[b]	9.05[c]	0.170	<0.001
Milk yield, kg/d	3.99	4.03	4.20	1.227	0.882
Milk fat, g/kg	42.1	38.9	42.9	12.33	0.636
Milk protein, g/kg	36.9	34.7	36.3	3.360	0.184
DM digestibility, kg/kg	0.60	0.59	0.60	0.030	0.779
NDF digestibility, kg/kg	0.72	0.71	0.72	0.021	0.767
ADF digestibility, kg/kg	0.42	0.41	0.43	0.044	0.767

[a,b,c]Means with different superscripts within a row differ ($P<0.05$)

Conclusions It is concluded that the addition of Co to the diet increases intake but does not affect performance or whole tract digestibility in dairy cows that are managed and fed under tropical conditions.

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082

Effect of the supplementation level of concentrate on milk and methane production in crossbreed tropical grazing dairy cows

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Application The use of native grasses can reduce the production of greenhouse gases.

Introduction The predominant greenhouse gases (GHG) emitted by livestock are methane (CH4), nitrous oxide (N2O) and carbon dioxide (CO2) (IPCC, 2006). According to FAO (2010) as the production of fat and protein corrected milk decreases worldwide, GHG emissions per kg increase. However, in developing countries, milk production per cow is low and information regarding GHG emissions are limited. One of the alternatives for GHG reduction is the use of local resources available for animal food (Gard *et al*., 2016). Therefore, the objective of this study was to evaluate the level of supplementation of concentrate in dairy cows grazing in native pastures, and estimate CH4, N2O and CO2 emissions.

Material and methods The study included 12 crossbred F1 dairy cows (½ *Bos taurus* - ½ *Bos indicus*) over 60 days of lactation. Cattle grazed tropical grasses (28% native grasses: *Paspalum spp.*, *Axonopus spp.*, and 72% *Brachiaria spp.* and *Cynodon neumfluensis),* supplemented with 0, 150, 300 and 450 g of concentrate (g DM / kg daily milk production) in three periods of 15 days each one in a crossover design (all animals received all treatments). Pasture and concentrate samples were collected, which were analyzed for dry matter (DM), crude protein (CP), Neutral Detergent Fiber (NDF), and Acid Detergent Fiber (ADF) (AOAC, 2002). Milk production (kg/d) was recorded and corrected to 3.5% fat = (kg milk * 0.432) + [(kg fat / d-1) * 16.23. Total digestible nutrients (TDN) = 88.9 - (ADF * 0.779), ADF content (g / kg DM), Nitrous oxide (N2O) emissions from excreta were calculated (IPCC, 2006). N excreted (Nex) = (g CP intake / 6.25) * (1 – (DMD / 100)).
The quantity of N excreted was calculated based on the intake of crude protein (g CP intake/d) and the digestibility of the dry matter (DMD), and daily CH_4 production (kg • head^{-1} • day-1), (IPCC, 2006). EF = [GE * (Y_m / 100)] / 55.65, and Y_m = 0.0038 * DE^2 + 0.4178 * DE - 4.3133, where EF: CH_4 emission factor (kg • head^{-1} • day-1) GE: gross energy intake (MJ • head-1 • day-1), Y_m: Fraction of gross energy converted to methane, and 55.65 (MJ/ kg CH_4 $^{-1}$) represented the energy content of methane, Digestible Energy (DE) = GE * energetic digestibility.
Data were analyzed with the SAS MIXED procedure and means subjected to a trend analysis using orthogonal polynomials.

Results There were no differences (p >0.0001) for LW and Milk yield between treatments. The supplementation with concentrate in tropical dairy cows did not increase milk yield (Table 1) but increased CH_4 and N_2O (p <0.0001) excretion per cow.

Table 1 Dry matter intake, milk production and CH_4, N_2O and CO_2 production in F1 crossbred dairy cows in pasture supplemented with different levels of concentrate in humid tropics

	Treatment[1]				SEM	P Value		
Variables	0.00	0.15	0.30	0.45		Tretament	Linear	Quadratic
LW $^{0.75}$	108.5	107.60	109.1	109.9	0.39	0.7403	0.5910	0.7401
DMI kg/d	12.78	12.57	12.35	13.43	0.12	0.2113	0.5523	0.0911
GE Intake (MJ/d)	212.7^{b}	217.2^{b}	219.3^{b}	251.9^{a}	2.86	0.0001	0.0093	0.0682
Milk yield kg, 3.5%	7.3	8.6	8.8	8.7	0.94	0.1575	0.7316	0.0702
CH_4 g/cow /d	390.5^{b}	398.7^{b}	402.5^{b}	462.5^{a}	5.25	0.0001	0.0093	0.0682
CH_4 g /kg Milk ,3.5%	46.7	51.7	59.4	50.1	4.09	0.1815	0.1861	0.0888
CH_4 g / kg DM Intake	30.6^{d}	31.7^{c}	32.6^{b}	34.4^{a}	0.19	0.0001	0.0001	0.1104
N_2O g/ cow / d	61.1^{c}	67.4^{bc}	69.3^{b}	82.6^{a}	1.23	0.0001	0.0004	0.0628

[1] kg of concentrate (kg DM / kg daily milk yield)

Conclusion The use of concentrates in crossbreed F1 dairy cows fed with local tropical pastures negatively affects the emission of GHG, producing more CH_4 and N_2O per cow per day, however cow supplemented presented a greater concentrate intake, which means more gross energy intake and higher DMI, but not showing more milk yield production.

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083

Effects of breeding-herd management strategies on carbon footprints of pasture-based beef production systems calculated using measured emission factors

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Application The Intergovernmental Panel on Climate Change is placing increased emphasis on reducing greenhouse gas (GHG) emissions from livestock sectors. This study identifies effective on-farm strategies to achieve this goal.

Introduction Carbon footprints (CF) estimated under the life cycle assessment (LCA) framework have become a standard metric to evaluate system-wide contributions of a commodity to global warming. This study calculates a cradle-to-farmgate CF of pasture-based beef production under site-specific emission factors. A range of scenario and sensitivity analyses are carried out to determine approaches to mitigate GHG emissions.

Material and methods The study was carried out at the permanent pasture (PP) beef enterprise on the North Wyke Farm Platform (NWFP), a BBSRC National Capability grazing trial in Devon, UK (Orr *et al*., 2016), across 2015 and 2016 grazing seasons. Each year, 30 Charolais × Hereford-Friesian finishing cattle were sourced from a nearby breeding herd, also on permanent pasture. The system boundary for the present study included both breeding and finishing herds. A functional unit was set as 1 kg liveweight (LW) departing the farmgate. On-farm emissions were calculated using a modified IPCC Tier 2 approach (McAuliffe *et al*., 2018). As a globally novel contribution to current literature, emission factors (EF) for enteric fermentation of methane (CH_4) and direct nitrous oxide (N_2O) emissions from pasture were both derived from field trials conducted at the NWFP to remove a high level of uncertainty associated IPCC default values. Correlations between CFs and their potential determinants were investigated through Pearson's correlation coefficient using GenStat 18.1. Following baseline estimation for all 60 animals, four sensitivity tests and two scenario analyses were carried out on the best (least polluting), median and worst (most polluting) animals. The sensitivity tests considered the effect of adopting site-specific emission factors, whilst the scenario analyses quantified the effect of changes to breeding-herd management.

Results Cradle-to-farmgate CFs were estimated to be 24.2 and 25.1 kg CO_2-eq/kg LW in 2015 and 2016, respectively. Intra-system differences in environmental performance were largely explained by livestock performance, with average daily gains post-weaning showing strong and negative correlations with global warming potential ($r = -0.81$, $p < 0.001$). Use of IPCC EFs, particularly those pertaining to CH_4, was shown to cause considerable biases to resultant CFs (Figure 1, items 2-3). Increasing the stocking rate and the parity number were both shown to hold considerable potential to reduce CF of pasture-based beef production systems **(**Figure 1, items 6-7). Other results of the sensitivity and scenario analyses are presented in Figure 1.

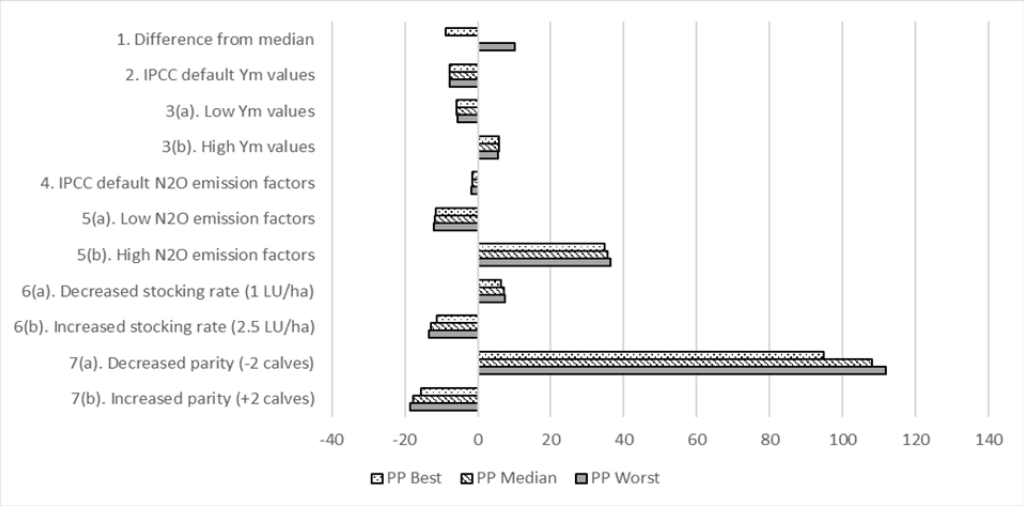

Figure 1 Results of scenario and sensitivity analyses carried out for the best, median and worst animals on the PP system. Apart from differences from the median animal (item 1), values are percentage differences from the baseline results for the same animals.

Conclusion: The above results suggest that, within the perimeter of commercial farming, there is no trade-off between economic profitability and environmental burdens. Efficient use of pasture and breeding stock contributes to both causes.

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084

Circadian rhythm in enteric methane emission among temperate grassland beef cattle offered three typical grass silage diets

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Application In temperate grassland beef cattle, several factors including diet quality and circadian rhythm affect enteric methane emission. Dietary interventions and a shift in the diurnal cycle may prove to be promising strategies to reduce livestock emissions.

Introduction Livestock production systems are a significant source of agricultural greenhouse gas (GHG) emissions (Herrero *et al*., 2016). However, grassland beef production can act as a carbon source and/or sink in temperate regions. Although many studies have assessed the impact of diet on cattle enteric methane emissions, few if any have conducted measurements over the longer term. Here we present results of measurements from growing beef cattle over an entire winter housing period, assessing the impact of forage silage diet and characterising the diurnal pattern in emissions.

Material and methods We used ninety beef cattle at the North Wyke Farm Platform (NWFP, Rothamsted Research, Devon, UK) for CH_4 and CO_2 measurements for 161 days using the GreenFeed emission monitoring system (GEM, Huhtanen *et al*., 2014) to make individual animal measurements across the whole period. The NWFP consists of three 'farmlets', each of approximately 22 ha with three contrasting pasture forages: 1) permanent pasture (PP); 2) reseeded pasture with a monoculture high-sugar grass variety (HS); 3) reseeded pasture with a mixture of high-sugar grass and white clover (WC, see Takahashi *et al*., 2018 for more information). We fed silage made from these swards to 30 growing beef cattle on each farmlet (balanced for breed and gender) during the winter housing period (average live weight = 336.7 ± 62.21 kg). All the experimental procedures were approved by Animal Ethics Committee at Rothamsted Research, North Wyke, UK. Drinking water and silage was offered *ad lib.* Data were analysed using linear mixed effect models in R (version 3.4.1) with period (6 equal intervals from 0.00 to 24.00) and forage type as fixed effects. Individual animals were fitted as random effects.

Results Both CH_4 (Fig. 1) and CO_2 emissions varied significantly with diet and time of day ($p < 0.05$). Clover fed animals had lower emissions ($p < 0.05$). Emissions were low during morning hours ($p < 0.05$).

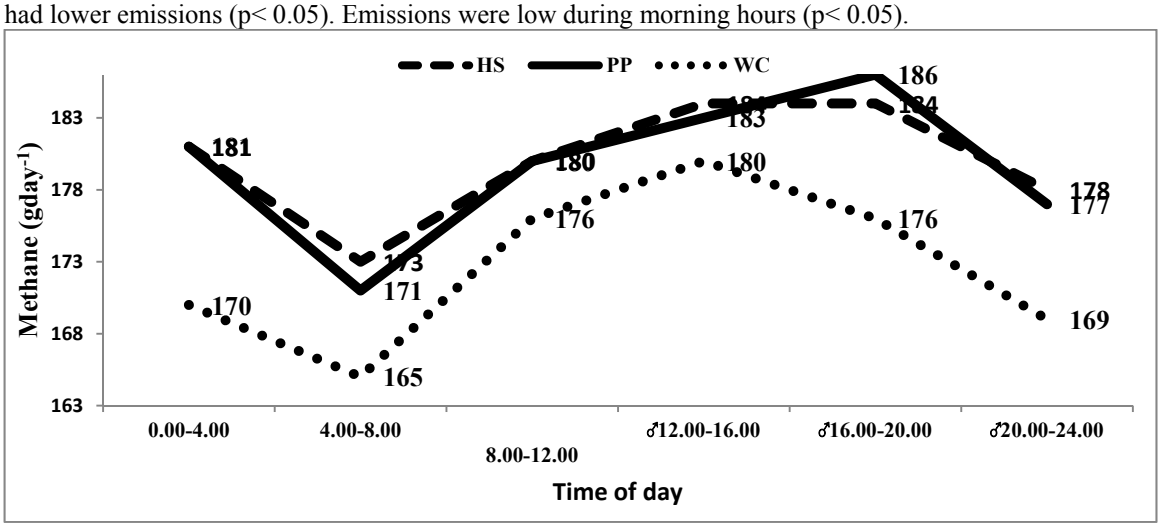

Figure 1 Diurnal and diet effects on enteric methane emissions from beef cattle

Conclusion Our long term measurements have shown a clear diurnal pattern in emission from growing beef cattle across all forage types. Further work could determine if this could be exploited to reduce enteric emissions through changing the feeding regime.

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085

Effect of antibiotic treatments on dairy cow methane production, milk yield and dry matter intake

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Application Assessing the milk yield and methane production, from healthy and antibiotic treated dairy cows using a laser methane detector (LMD).

Introduction Enteric methane (CH_4) in dairy cows is a result of the fermentation of rumen contents and can be affected by the amount and quality of the feed (Moss eta al., 2000). The use of antibiotics to treat diseases such as lameness and mastitis are generally given as an injection and will affect the microbiology of the rumen (Russell & Strobel, 1989) and potentially the efficiency of the rumen (Jewell *et al*., 2015). Nonintrusive estimates of enteric CH_4 can be obtained using a LMD and has been used as a proxy for rumen function (Chagunda *et al*, 2009). The aims of this study were to assess the production of enteric methane from cows treated with antibiotics and to compare CH_4, dry matter (DM) intakes and milk production from treated cows with a paired group of healthy cows.

Material and methods One group of 15 high performance housed dairy cows, milked 3 times a day and treated with prescribed antibiotics, as part of regular veterinary treatment for lameness or mastitis, were paired with a group of healthy untreated cows. The cows were paired on days in milk, parity, genetic merit and feed type. Diet was either High Energy or Standard Energy, designed to supply 11.3 MJ/kg DM or 12.2 MJ/kg DM respectively. Milk yield (MY) was recorded at every milking and feed intake recorded for three consecutive days out of 6, from HOKO feed bins. CH_4 emissions were estimated using a LMD, taking two CH_4 readings per second, for approximately 4 minutes for each animal after midday milking four days per week for 8 weeks after antibiotic injections, using a procedure described by Chagunda *et al*. (2013). Liveweights were taken daily with body condition scores recorded fortnightly CH_4 readings per animal, grouped by week of experiment and reading day, were log transformed to attain normality of the data, with zero readings excluded. Linear mixed effects models were fitted in R using lmer and Anova packages at a 5% significance level.

Results Average daily MY over the 8 week period after antibiotic treatments for the untreated and treated groups were 30.8 kg and 33.8 kg, respectively. Week 1 gave the largest mean difference in MY (9.8 kg) intake between the untreated and treated cows, with this reduced to 1.8 kg by Week 4 and the remaining weeks gave very similar MY (mean of 0.01 kg). The mean DM intakes over the 8 weeks were 23.0 kg/cow/day for the untreated group and 22.0 kg/cow/day for the treated group. The largest difference in DM intake was in Week 2 with the untreated group consuming on average 3.2 kg DM/cow/day more than the treated group. The enteric CH_4 measurements were greater for the untreated group over the 8 weeks at 33.1 ppm compared to the treated group (32.3 ppm) (Figure 1).

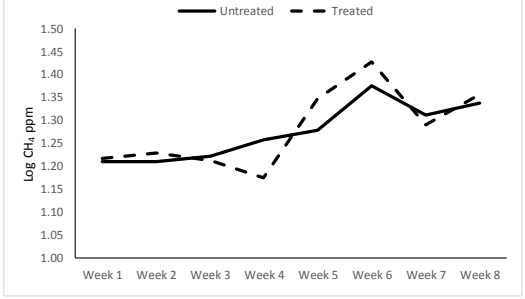

Figure 1 Mean weekly group CH_4 measurements

Conclusion The use of routine antibiotics reduced the milk yield, however, enteric methane emissions were reduced at the start of the monitoring period for both the treated and untreated groups. The DM intake was similar for both groups throughout the whole of the 8 weeks. The initial reduction could be a result of the animals' response to the monitoring, although the treated group methane emissions remained depressed for a week longer than the untreated.

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086

Archaea and members of the family, *Lachnospiraceae*, are altered in the rumen microbiome of cattle divergent in methane yield grazing perennial ryegrass swards with and without white clover

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Application The inclusion of white clover in the grazing sward altered the rumen microbiome of dairy cows. Treatment associated differences in the rumen microbiome may have led to the reduction in methane yield.

Introduction Agriculture will be required to feed a global population in excess of 9 billion people by the year 2050 (UN, 2017). It is estimated that 40% of agriculture greenhouse gas emissions arise from enteric fermentation of which 18% comes from dairy cattle production (Tubiello *et al*., 2014). Reductions in emissions from agriculture will be required to feed the global population in a sustainable manner. In dairy cows, the inclusion of white clover in the grazing sward has previously been shown to reduce methane (CH_4) yield without any negative impact on milk production (Enriquez-Hidalgo *et al*., 2014). The objective of the study was to investigate if variation in the CH_4 yield of dairy cows grazing perennial ryegrass swards with and without the inclusion of white clover was associated with changes in the rumen microbiome.

Material and methods Spring calving dairy cows (n=40), balanced by breed and productive traits, rotationally grazed swards containing either perennial ryegrass only (GO; n=20) or swards containing perennial ryegrass and white clover (GWc; n=20). A daily herbage allowance (HA) of 16 kg of DM was targeted with cows allocated a supplementation of 1 kg of concentrate/cow per day. Enteric CH_4 emissions were estimated using the sulphur hexafluoride (SF_6) method over a 6-day period when GWc clover content was 0.24 (± 0.031). Concurrent measurements were made of daily milk production and individual dry matter intakes (DMI) using the *n-alkane* technique as described in Enriquez-Hidalgo *et al*. (2014). Individual rumen samples were collected via stomach tubing and microbial DNA was extracted using the repeated bead beating method (Yu and Morrison 2004). A total of 39 amplicon libraries, targeting the V4 region of the 16S rRNA gene, were generated using the 515F/806R primers (Caporaso *et al*., 2011) and subjected to sequencing on the Illumina MiSeq. Amplicon sequences were processed in R (version 3.4.2) using the DADA2 package (version 1.9.0). PERMANOVA analysis was carried using the Vegan package (version 2.5.2) to investigate if differences in microbial community structure associated with treatment were obtained. A Wilcoxon rank sum test, with Benjamini Hochberg correction (FDR=0.05) was implemented for identification of treatment differences in relative abundance of taxa with Spearman's rank correlation coefficient used to determine relationships between the abundance of microbes and animal performance.

Results Animal performance has been previously reported by Enriquez-Hidalgo *et al*. (2014). Briefly, CH_4 yield (g/kg of DMI) was significantly lower in the GWc group (21.5 vs. 24.5 g/kg of DMI; $P<0.05$). Diet was deemed to have significantly altered microbial community structure based on the PERMANOVA analysis results ($P = 0.026$). Cattle grazing the GWc sward had a reduced abundance of archaea (1.48 vs. 1.88%; $P<0.03$) and a tendency for a reduced relative abundance of *Methanobrevibacter* (1.128 vs. 1.543%; adj $P = 0.059$). Several genera belonging to the family *Lachnospiraceae* had relative abundances that differed between groups including a reduced abundance of *Pseudobutyrivibrio* (0.806 vs. 1.376%; adj $P<0.001$) and increased abundance of *Lachnospira* (0.227 vs. 0.039%; adj $P<0.001$) in GWc compared to GO cattle. Both the abundance of *Pseudobutyrivibrio* (0.34; $P<0.04$) and *Lachnospira* (-0.36; $P<0.03$) were correlated with methane yield. In addition both *Pseudobutyrivibrio* (0.43; $P<0.01$) and *Lachnospira* (-0.37; $P<0.03$) were observed to be correlated with *Methanobrevibacter*.

Conclusion White clover inclusion in the grazing sward significantly reduced CH_4 yield and altered the rumen microbiome of dairy cows when compared to animals grazing GO swards. A reduction in the abundance of archaea in the GWc animals was accompanied by variation in the abundance of members of the family *Lachnospiraceae* amongst treatment groups. Microbial community differences between groups, most likely influenced the reduction in CH_4 yield seen in the GWc cows.

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Effect of the alkaline ammonia treatment of wheat grain on *in vitro* rumen fluid pH, gas production and potential supply of amino acids into the abomasum

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Application New alkaline ammonia treatments of wheat grain increased rumen fluid pH and the amount of total amino acid (AA) in the residual material following incubation and, following appropriate *in vivo* validation, this approach has the potential to increase potential milk and meat yield.

Introduction Fast growing animals and higher yielding dairy cattle are likely to be offered greater amounts of dietary cereals, which typically depresses rumen pH (Humer. 2017). Such animals may benefit from dietary strategies to maintain or increase the pH of rumen digesta.This in turn can increase postruminal protein and AA supply, thus productivity and feed conversion efficency. The aim was to assess the effect of a novel alkaline ammonia treatment of wheat on rumen fluid pH, feed degradation rate and post-ruminal AA supply.

Materials and methods A total of fifteen samples (5 replicates / treatment) of dried and ground (1 mm) wheat grain (W) with; 0, 3 or 6 % alkaline ammonia (ALKA) treatment (0, 8 and 16 g/kg FM of potential ammonia) were incubated with a grass; maize and cereal silages, with cereal and soya blend (45:25:25:5 on a DM basis) partial mixed ration (PMR). Five bottles were included as blanks and all bottles had buffered mineral solution added, were flushed with CO_2 and incubated for 24 h at 39^{o}C. The *in vitro* production of gas was measured, using the Ankom-RFS system. Chemical analysis of feed and post incubation residual material was completed and total AA concentration was measured using gas liquid chromatography. Treatment means were analysed using a general linear model in Minitab, applying alkaline application rate as a fixed effect and individual bottle as random effect, using a 0.95 confidence interval and significant differences using Tukey's test.

Results The rumen fluid pH was greater throughout the 24 h incubation, when 3 (P=0.014) and 6 % (P <0.001) ALKA was applied (Fig 1), but did not differ between 3 and 6% application rate. There was no effect of ALKA treatment on gas production rate and total gas produced (Table 1). The application of 3 % ALKA increased propionic acid concentrations though CP concentration was not affected. Addition of 6 % ALKA increased the amount of total AA in the post incubation residual material and thus potentially supplied to the abomasum.

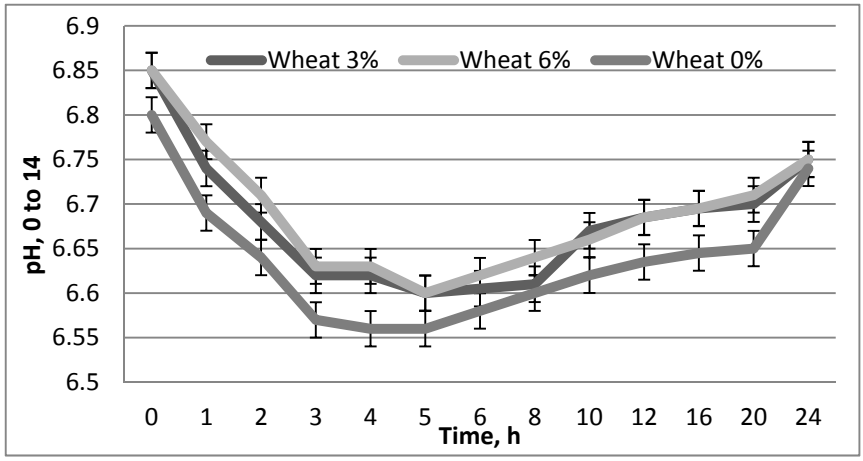

Figure 1 Incubation fluid pH of wheat grain with 0, 3 and 6 % ALKA

Table 1 Effect of novel alkaline (ALKA) treatment of wheat on mean gas production and concentrations of volatile fatty acids, CP and AA

	W 0 % ALKA	W 3 % ALKA	W 6 % ALKA	SEM	P value
Total gas, psi (a+b)	9.40	8.73	9.90	0.323	0.123
Gas production rate, psi (c)	0.42	0.45	0.42	0.015	0.382
Acetic, mmol/L	22.18	23.05	22.31	0.536	0.492
Propionic, mmol/L	13.75 [b]	14.91 [a]	14.24 [a, b]	0.267	0.040
n-butyric, mmol/L	8.02	8.47	7.84	0.442	0.619
Post incubation residual material					
CP, g/kg	415.9	434.0	442.2	8.81	0.122
Total amino acids, g/kg	19.32 [b]	20.30 [a, b]	21.08 [a]	0.400	0.032

[a, b, c] - Means in rows with different superscript letters differ significantly at P<0.05

Conclusions Rumen fluid pH was greater throughout the 24 h incubation period, when 3 or 6 % ALKA treatment was applied to wheat grain. This did not affect the rate or total production of gas. The application of ALKA at 3 % increased propionic acid concentrations. While ALKA application had no effect on the CP concentrations of post incubation residual material, the total amino acid concentration was greater when 6% ALKA was applied.

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088

Developing a rapid high throughput screening method for the estimation of rumen degradability of ruminant feedstuffs

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Application A simple and rapid microplate method could be used as alternative to the conventional gas production methods to rank ruminant feedstuffs according to their degradability.

Introduction Although the gas production technique has been widely used to determine fermentation kinetics of ruminant feedstuffs, it is not feasible when testing many samples. Here we have adapted a technique originally developed to assess soil microbial activity (Microresp™) to study dry matter degradability of ruminant feedstuff using a 96-well microplate.

Material and methods Twenty rice straw cultivars from the Philippines were selected based on their silica content. To estimate their rumen degradability, *in vitro* incubations using rumen fluid from four sheep diluted 1:2 with buffer were carried out. Aliquots of 10 mL were incubated with 0.1 g of straw (4 replicates) under CO_2 and at 39°C and gas production was measured up to 96 h. Cumulative gas production data were fitted to the model of Ørskov and McDonald (1979): $p = a+b\ (1e^{-ct})$, where p is the volume of gas produced at time t, a and b are the gas production from the immediately soluble fraction and insoluble but slowly fermenting fraction, respectively, and c is the gas production rate constant for the insoluble fraction. Effective degradability (ED) of dry matter (DM) was calculated as ED = a + ((b*c)/(k + c)) (Ørskov and McDonald, 1979) with k (food passage rate through the rumen, %/h) considered as 5%. In addition, the Microresp™ system (Campbell *et al*., 2003) was adapted to estimate DM degradability of those cultivars. Aliquots of 0.3 mL of diluted rumen fluid (1:9) were dispensed in to a deep 96-well plate, each well containing 3 mg of straw (4 replicates) and flushed with N_2. Instantaneous gas production was recorded over 15 or 30 min at 6 to 24 and 36 to 96 h, respectively, as described by Campbell *et al*. (2003), and pH was measured at 96 h. Multiple regressions of the ED from the gas production technique against the pH values and the instantaneous gas values obtained from the Microsresp™ were carried out using Genstat.

Results Rice straw samples differing in silica content also differed in ED (P<0.001). The relationship between ED and the fitted instantaneous gas production data from Microresp™ was significant (P=0.040), with the predictive model explaining 60% of the variance. A significant relationship was also obtained between ED and final pH values (P<0.001), the percentage of variance accounting for 62.7%. Plotting predicted ED values obtained from pH or Microresp™ instantaneous gas measurements against the ED estimated from the gas production technique resulted in R^2 of 0.647 and 0.831, respectively.

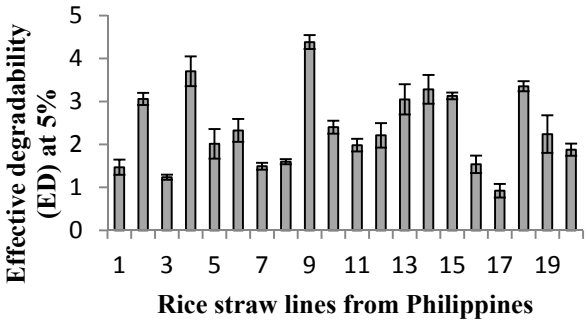

Figure 1 Effective degradability of DM of rice straw lines.

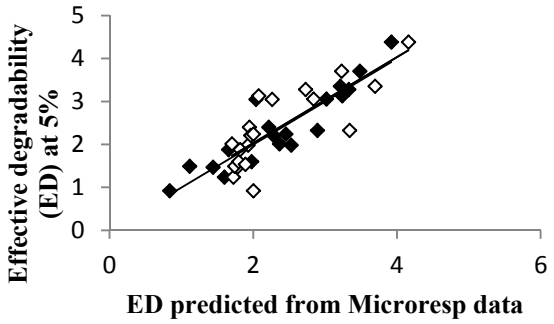

Figure 2 Relationship between ED and the ED predicted from final pH (white rhombus) or instantaneous gas production from the Microresp™ (black rhombus).

Conclusion The use of an adapted microplate method (Microresp™) allowed the ranking of rice straw cultivars in terms of their ED, based on instantaneous gas production measurements. A single measurement of the pH at the end of the incubation also predicted ED, being a most rapid and cost-effective approach.

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089

The effect of lactic acid bacteria inoculation or molasses on the fermentation quality and nutritive value of amaranth (*amaranthus hypochondriacus*) (var.maria) silage

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Application The chemical composition, particularly CP, ash, and ADL, nitrate, oxalic acid, and *in vitro* disappearance suggest that ensiled amaranth (var. Maria) made with or without the use of additives has potential as a ruminant feedstuff.

Introduction Crops adapted to water scarcity such as Amaranth (*Amaranthus hypochondriacus*) can be useful as feedstuffs for ruminants in low rainfall areas. Amaranth yields up to 85 t fresh weight/ha and compared to corn silage (CS), has a greater CP concentration, a lower lignin content, with a moderate to high OM disappearance (Rezaei *et al*., 2014). Replacing CS with ensiled amaranth (EA) has been found to be practical in fattening lambs (Rezaei *et al*., 2014), and in lactating cows (Rezaei *et al*., 2015). *A. hypochondriacus* var. Maria has a high grain yield and is a dual purpose crop (grain and forage) compared to other varieties (Jacobsen, 2014). This study assessed the effects of LAB inoculant and/or molasses on the chemical composition, silage fermentation parameters and OMD of amaranth silage var. Maria.

Material and methods Amaranth was sown in a randomized complete block design with 6 replicates on the 24th of July (2016). It was harvested, after 85 d, by cutting the whole plants to a 5-cm stubble height, and chopped into fragments of 2 to 4 cm in lengths before ensilage. Six treatments were as follows: 1) fresh amaranth forage (FAF), 2) ensiled amaranth without additive (EA), 3) EA inoculated with LAB (EAB), 4) EA + 5% of molasses on a fresh basis (EAM), and 5) EA with LAB + 5% of molasses (EABM). Plant material in the ensiled treatments containing lactobacillus were inoculated using 0.313 g of LAB diluted in 240 mL of distilled water and then kept for 4 h before being sprayed onto 100 kg of fresh material. The homogeneous mixtures for silage were packed into 10-kg plastic bags (total 36 bags) and sealed for 45 d, after which representative 3-kg samples were taken from each bag for later analyses and measurements.

Results Compared with FAF, EA had lower values of water soluble carbohydrates (WSC) and nitrate. The EA had lower OMD compared with FAF. Adding molasses to EA resulted in increased ash and lactate concentrations and decreased ammonia-N, but had no effect on OMD.

Table 1 Chemical composition, nitrate, oxalic acid (g/kg of DM or as stated), silage fermentation parameters, and OMD of fresh amaranth and ensiled amaranth without or with molasses, *Lactobacillus plantarum* or their combination.

	Treatments						*P*-value	
Entries	FAF	EA	EAB	EAM	EABM	SEM	FAF vs. EA	Among silages
DM, g/kg of fresh wt.	233	250^{b}	258^{b}	303^{a}	304^{a}	4.45	0.90	0.01
CP	187	171	168	170	173	3.54	0.80	0.88
NDF	420	400	402	398	395	6.14	0.03	0.77
lignin	44.6	43.0	45.0	41.4	41.5	0.26	0.70	0.60
WSC	62.5	19.7	19.6	21.0	21.0	1.06	0.02	0.70
Ash	145	170^{b}	171^{b}	188^{a}	189^{a}	2.35	0.01	0.01
ME, MJ/kg of DM	8.4	7.5	7.9	7.5	7.6	0.19	0.01	0.52
Anti-quality compounds								
Nitrate	3.30	0.21	0.24	0.20	0.20	0.02	0.01	0.40
Oxalic acid	7.61	7.50	7.94	7.31	7.47	0.63	0.50	0.90
Silage fermentation parameters								
pH	-	4.49^{a}	4.63^{a}	3.90^{b}	0.70^{b}	0.03	-	0.01
Ammonia-N (g/kg of total N)	-	54.3^{a}	53.2^{a}	51.0^{b}	51.8^{b}	0.50	-	0.01
Lactic acid	-	57.0^{b}	55.0^{b}	70.0^{a}	69.2^{a}	0.41	-	0.01
Acetate	-	17.1	17.0	17.3	17.9	0.32	-	0.90
Propionate	-	0.30	0.31	0.30	0.28	0.02	-	0.05
Butyrate	-	0.30	0.40	0.34	0.36	0.01	-	0.60
OMD (g/kg of OM)	662	617	615	603	602	5.69	0.001	0.24

Conclusion Fresh amaranth var. Maria can be preserved as a valuable silage to feed ruminants. Ensiling amaranth var. Maria decreased the anti-quality compounds, and molasses addition improved the fermentation quality of the silage.

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090

Effect of the alkaline ammonia treatment of oat feed on *in vitro* gas production, rumen fluid pH and potential supply of protein and amino acids for ruminants

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Application Novel alkaline ammonia feed treatment applied to oat feed (6 % or 16 g/kg ammonia) increased gas production, rumen fluid pH and the amount of post-incubation feed residue crude protein (10 % or 16 g/kg ammonia) and amino acid (AA) concentrations, which, following *in vivo* validation, could increase the feeding value of OF.

Introduction Growing animals and higher yielding dairy cattle benefit from greater diet digestibility along with the maintenance of higher rumen fluid pH, which may increase postruminal protein and AA supply, thus increasing feed conversion efficency. This research aimed to assess oat feed treated with one of three different quantities of alkaline ammonia on *in vitro* gas production / feed degradation, pH of incubation fluid and residual protein supply.

Materials and methods A total of fifteen samples (5 replicates / treatment) of dried and ground (1 mm) oat feed (OF) with; 0, 6 or 10 % alkaline ammonia (ALKA) (0, 16 and 27 g/kg FM of potential ammonia) treatment were incubated with the addition of a grass; maize and cereal silages, with cereal and soya blend (45:25:25:5 on a DM basis) partial mixed ration (PMR). Five bottles were included as blanks, all had buffered mineral solution added, were flushed with CO_2 and incubated for 24 h at 39^{o}C. The *in vitro* production of gas was measured, using the Ankom-RFS system. Chemical analysis of feed and post incubation residual material was completed and total AA concentration was measured using gas liquid chromatography. Treatment means were analysed using a general linear model in Minitab, applying alkaline application rate as a fixed effect and all other factors as random effects, using a 0.95 confidence interval and significant differences using Tukey's test.

Results The gas production rate and total gas production was greatest from the incubation of OF with 6% and 10 % ALKA (Table 1). The incubation fluid pH, over the 24 h incubation period, was greater when 6 (P=0.016) and 10 % (P=0.012) ALKA was applied to OF (Fig 1). The residual feed CP concentration was greater when 10 % ALKA was applied and total AA concentration was greatest when either 6 or 10 % ALKA was added (Table 1).

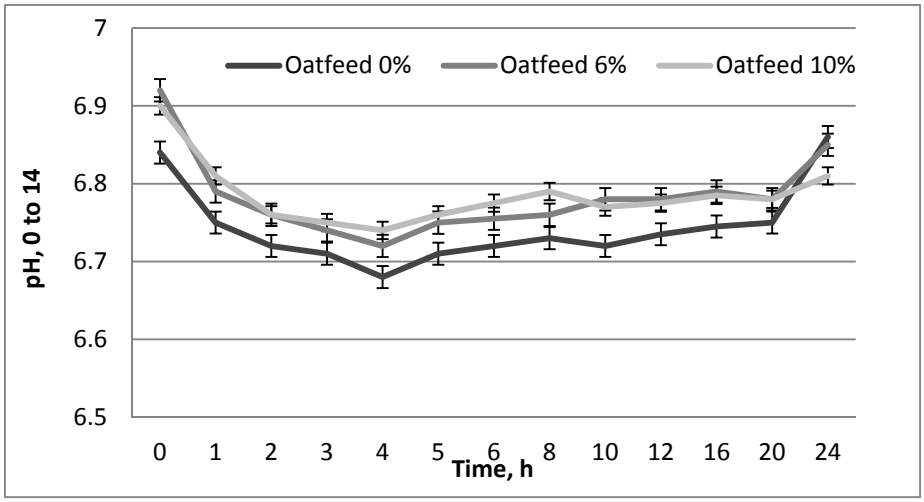

Figure 1 pH of rumen fluid incubated with OF and ALKA for 24 h

Table 1 Mean gas production and post incubation protein and amino acid concentration of the residual material following *in vitro* incubation of oat feed (OF) treated with 0, 6 or 10 % alkaline ammonia (ALKA)

	0 % ALKA	6 % ALKA	10 % ALKA	SEM	P value
Gas production, psi (b)	1.81 ^{b}	4.09 ^{a}	2.73 ^{b}	0.263	0.003
Total gas produced, psi (a+b)	2.69 ^{b,}	4.55 ^{a}	3.49 ^{b}	0.213	0.003
Production rate, psi (c)	0.12 ^{b}	0.20 ^{a}	0.15 ^{b}	0.009	0.003
Post incubation residual material					
CP, g/kg	113.0 ^{b}	140.3 $^{a, b}$	167.6 ^{a}	9.46	0.009
Lysine (LYS), g/kg	6.33	6.66	7.08	0.448	0.517
Methionine (MET), g/kg	3.15	3.62	3.64	0.235	0.298
Total amino acids, g/kg	6.85 ^{b}	9.66 ^{a}	10.28 ^{a}	0.611	0.007

$^{a, b, c}$ - Means in rows with different superscript letters differ significantly at P<0.05

Conclusions The gas produced from OF feed degradation was greatest when OF was treated with 6% ALKA. The application of 6 or 10 % ALKA increased incubation fluid pH. The post incubation material, which could, potentially, be supplied to the abomasum, had greater CP concentrations when ALKA was applied to OF at 10 %, while the total AA concentrations were greater when 6 and 10 % ALKA was applied.

Acknowledgements Five Alka Ltd. and H J Lea Oakes for supporting this research.

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Assessment of ruminal fluid pH evolution across the weaning period in Holstein calves under field conditions

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Application Under field conditions, the ruminal function peri-weaning differs among calves because it is associated with farm weaning strategies.

Introduction Several studies have investigated the effect of different diet, housing and weaning strategies on calves' performance and gastrointestinal development. Ruminal fluid pH value (pH_{rf}) is considered a significant indicator of proper ruminal function. However, data regarding the biological intra- and inter-herd variability of rumen parameters during the weaning period, under field conditions, are lacking. The aims of this study were: a) to identify pH_{rf} evolution patterns peri-weaning and b) to assess factors that affect pH_{rf} at weaning (pH_{rf}_day0) and the week after (pH_{rf}_day7) in Holstein calves.

Material and methods A total of 129 calves from 4 commercial dairy farms (A: n=28; B: n=35; C: n=30; D: n=36) were enrolled in the study. At days -7, 0 and +7 relative to the day of weaning, each calf was clinically examined and all findings recorded; live bodyweight (BW) was estimated from heart girth measurement. At each study-day, samples of ruminal fluid were collected via an oro-ruminal probe attached in a manual suction pump, 1-2 h post-feeding. The pH_{rf} was measured on site with a portable device. A hierarchical cluster analysis was performed to identify the number of clusters based on pH_{rf} evolution in the weaning period. A two-step cluster analysis was used to establish the pH_{rf} patterns. The proportion of calves of each cluster within farms was compared with Fisher's exact test. Age and BW at weaning among clusters and farms were compared with Kruskal-Wallis. Additionally, the potential effect of several factors (i.e. age and BW at weaning, clinical afflictions, previous pH_{rf} measurements, overall effect of farm) on pH_{rf}_day0 and pH_{rf}_day7 was assessed with univariate regressions using general linear models (IBM SPSS v.25). Non-significant effects at the 0.05 level were excluded from the models.

Results Four distinct clusters regarding pH_{rf} evolution patterns were obtained (Table 1). Calves in C1 and C2 had constantly pH_{rf} >6.0; C2 values increased through days of study, while C1 reached a plateau at day 0. Calves in C3 had pH_{rf} <6.0 at days -7 and 0 and increased >6.0 afterwards, while C4 had constantly pH_{rf} <6.0. The distribution of clusters among herds differed significantly at P<0.001 (Table 2). There were no differences in age and BW at weaning among clusters. However, there were differences in age and BW at weaning among farms at the 0.05 level. The pH_{rf}_day0 was significantly affected by age at weaning, pH_{rf}_day-7 and farm ($_{adj}R^2$=0.323). The pH_{rf}_day7 was significantly affected by age and BW at weaning, pH_{rf}_day0 and farm ($_{adj}R^2$=0.178). Adding the effect of respiratory afflictions at day 0 in the model slightly improved the model's fit but was removed as there was only a tendency for significance (P=0.082).

Table 1 Centroids of clusters regarding ruminal fluid pH evolution during the weaning period in Holstein calves

Cluster	N	Mean (±SD) ruminal fluid pH		
		Day -7	Day 0	Day 7
C1	39	6.50 (±0.34)	6.58 (±0.30)	6.25 (±0.34)
C2	55	6.48 (±0.56)	6.85 (±0.40)	6.97 (±0.24)
C3	15	5.65 (±0.34)	5.57 (±0.32)	6.96 (±0.40)
C4	20	5.56 (±0.25)	5.72 (±0.50)	5.73 (±0.28)

Table 2 Distribution (%) of ruminal fluid pH clusters among farms and comparisons for age and bodyweight (BW) at weaning

Farm	Clusters				Age (days)	BW (kg)
	C1	C2	C3	C4	median (range)	median (range)
A	28.2^{ab}	23.7^{ab}	0^{1}	20.0^{ab}	67^{a} (61-83)	86.9^{a} (60.9-126.4)
B	12.8^{b}	12.7^{a}	66.7^{a}	65.0^{a}	55^{b} (45-77)	67.0^{bc} (46.9-93.4)
C	15.4^{ab}	32.7^{b}	20.0^{ab}	15.0^{b}	81^{c} (67-122)	73.5^{bd} (48.5-96.2)
D	43.6^{a}	30.9^{ab}	13.3^{b}	0^{1}	61^{a} (56-89)	64.9^{c} (46.9-83.1)

^{a,b,c,d} Values with different superscripts within the same column differ significantly at the 0.05 level. [1]Not used in comparison.

Conclusion There are different patterns of ruminal fluid pH evolution around weaning period. The significant effect of farm means that ruminal pH of weaned calves is related to herd-level management of the pre-weaning period and weaning decision protocols. Hence, further analysis of the multifactorial weaning process for a successful transition is required.

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Evaluation of the stress effects of oesophageal intubation for rumen sampling from sheep

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Application Oesophageal intubation for rumen sampling is considered to be a less invasive technique compared to surgical fistulation, but stress effects are unknown. Here we demonstrate in sheep that intubation induces a mild stress response compared to a known stressor: uncomfortable individual restraint, thus addressing the 3Rs aspect of refinement.

Introduction Studies on nutrition and metabolism frequently use animals fitted with cannulas that cause pain and stress to the animals (Silberberg *et al*., 2015). Increasing societal concern over the welfare of experimental animals must lead to the development of alternative, less painful and stressful techniques. Oesophageal intubation for rumen sampling has been developed to address this ethical point, though no study has verified that it is less invasive. Variation in cortisol, glucose and indicators of fat mobilisation in blood can be used to reveal stress in animals. This study was performed to assess the stress response to intubation compared to the response induced by a known stressful practice, individual restraint.

Material and methods As part of a larger project, 48 female Romane lambs were separated into two equal groups (N=24): Animals submitted to chronic unpredictable stress (S group) or not (NT group). All lambs had been habituated prior to sampling: On several occasions they were placed in the appropriate posture and had their mouths opened to insert a wooden guide. As part of the stressor regime, five weeks into the study (7 mo. of age), S lambs were individually contained using a Gambrel restrainer for 20min. Blood samples (10ml/an.) were taken once the restrainer was removed to assess stress biomarkers. S and NT animals were intubated for rumen sampling (50ml/ an.) six weeks into the study. All equipment was adapted to the animals' age & size. Intubation lasted less than 5 min. Pre-intubation and 20 min post-intubation, blood plasma was sampled for stress biomarkers. Cortisol concentration was assessed using a sheep specific ELISA. Glucose, non-esterified fatty acids (NEFA) and β-hydroxybutyrate (β-OH) concentrations were determined via spectrophotometry. Comparisons for Pre and Post Intubation, as well as Post intubation and Individual Restraint (S lambs) were performed using non- parametric Mann-Whitney U tests (no covariables) on Genstat (VSN International, 2011).

Results Pre and Post intubation comparisons: Oesophageal intubation induced a stress response in both treatment groups as both S and NT animals had higher cortisol values post intubation (P<0.001). NEFA concentrations also rose (NT, P=0.003, S, P<0.001). No differences were observed between treatments. Post-Intubation and Restraint comparison for S group (Figure 1): All plasma concentrations were significantly higher for Restraint: Cortisol, P=0.046, Glucose, P=0.042, NEFA & β-OH, P<0.001. The difference between Restraint and Intubation may be due to the habituation procedures followed for the later. Restraint and the duration of the overall aversive event were also shorter during intubation.

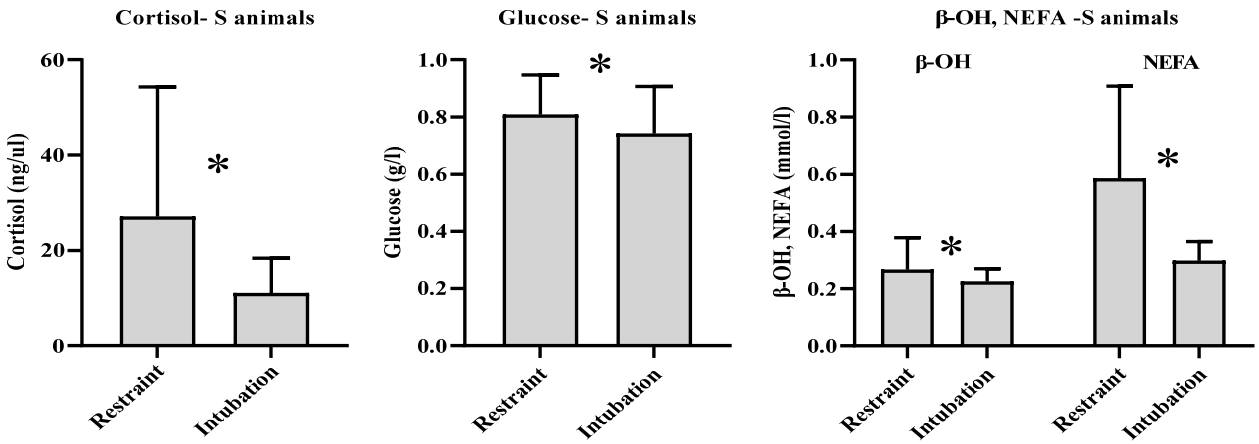

Figure 1 Restraint and Post Intubation levels of stress biomarkers for S animals

Conclusion Despite being a mildly invasive event, oesophageal intubation induces a less pronounced stress response in sheep compared to individual restraint. Further work would be needed to preclude pain effects.

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Does birth order have an effect on blood gas, acid-base, and glucose status at birth in triplet-born lambs?

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Application Birth order has no effect on blood gas, acid-base and glucose levels at birth in triplet-born lambs.

Introduction Lamb vigour is important to enable the lamb to stand and find the udder to secure colostrum intake, and thus survival. However, prolonged birth may lead to hypoxia and depletion of blood glucose in the lamb and may affect lamb vigour. Triplet lambs are particularly vulnerable to high neonatal mortality and the delay of delivery of the second- and third born in a set of triplet lambs may affect the blood oxygen and glucose status of the lamb. The objective of this study was to investigate the relationship between birth order, blood gas, acid-base, and glucose status and lamb vigour within 5 minutes of birth. We hypothesized that the first-born lamb is less hypoxic and has greater glucose status compared to the second and third born lambs and hence will be more vigorous.

Material and methods Eight naturally-mated multiparous triplet-bearing composite ewes of 3 to 5 years of age were selected from a commercial flock at 65 ± 5 days of gestation. At day 84 of gestation, the ewes were acclimatised to indoor housing in individual pens of 1.1 m × 3 m^2. The ewes were fed twice daily a dried chopped lucerne diet with 30% barley grain to meet 100% of the protein and energy requirements for triplet bearing ewes (AFRC 1993), with fresh water available *ad libitum*. Lambing interventions were provided when required and birth ease scored according to Dwyer and Morgan (2006). Within 1-4 minutes of birth, a jugular venepuncture blood sample was collected into EDTA vacutainers from each lamb. A subsample was used to analyse blood gas-, acid-base values and glucose levels using an i-STAT portable clinical analyser (Abbott Laboratories, Chicago, IL, USA). At five minutes post-birth, lamb vigour was scored according to Matheson *et al.* (2012). Two hours after birth, each lamb was weighed and whether suckling assistance was required was assessed. Partial CO_2 (pCO_2) and O_2 (pO_2), oxygen saturation (sO_2), pH, base excess (BEecf), bicarbonate (HCO_3), total CO_2 (TCO2) and glucose were analysed using a mixed model with birth order, birth ease, gender, birth interval between lambs and birthweight as fixed effects and the ewe as random factor. To achieve a normal distribution of residuals, pO_2, sO_2 and glucose were log^{10} transformed. Values for glucose and pCO_2 that were above or below detection limits for the i-STAT analyser were given a random value from 0-20 for glucose and pCO_2 the detection limit value 130 mmHg, to be able to include all animals in the statistical analysis.

Results Ewes lambed with minimal interventions. One lamb was delivered manually. Average time of birth between first and second lamb was 1 hour ± 13 minutes, while time of birth between second and third lamb averaged 17 ± 4 minutes. Birth order had no significant effect on any of the blood gas, acid-base, and glucose measures, nor did time of birth between lambs, birthweight and gender.

Table 1 Mean ± standard errors blood gas, acid-base and glucose levels in first-, second- and third born lambs

	First	Second	Third
n	8	8	8
pO_2 (mmHg)	21.6 ± 3.05	15.4 ± 1.08	16.25 ± 1.87
pCO_2 (mmHg)	89.9 ± 9.02	99.5 ± 2.50	106.6 ± 6.19
sO_2 (%)	15.0 ± 4.08	9.6 ± 1.28	11.3 ± 2.45
pH	6.963 ± 0.0781	6.989 ± 0.0209	6.934 ± 0.0384
BEecf (mmol/L)	-8.6 ± 1.84	-7.5 ± 1.30	-9.7 ± 2.49
HCO_3 (mmol/L)	22.2 ± 1.60	24.0 ± 1.01	22.5 ± 1.88
TCO_2 (mmol/L)	24.6 ± 1.74	27.1 ± 1.01	38.6 ± 13.2
Glucose (mg/dL)	36.1 ± 9.49	30.3 ± 2.64	34.9 ± 3.45

Conclusion These results indicate birth order has no effect on blood gas, acid-base, and glucose levels at birth in triplet-born lambs and indicate that factors other than birth order are likely to contribute to poor survival of triplet-born lambs. These results are to our knowledge the first blood-gas, acid-base, and glucose records from new-born lambs.

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Comparative performance of Holstein-Friesian dairy cows of Elite and National Average EBI on contrasting feeding treatments during the early lactation

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Application Future proofing the genetic improvement of the national dairy breeding programme.

Introduction The Economic Breeding Index (EBI) has been used in Ireland since 2001 (Veerkamp *et al*., 2002) to identify genetically superior animals within Irish dairy herds. The performance of Holstein-Friesian dairy cows of divergent EBI on contrasting feeding treatments during early lactation has not been examined previously.

Material and methods Data was generated over a two year period (2017-2018). Cows were representative of two genotypes (GG) of Holstein-Friesian dairy cows; ELITE represented cows in the top 1% nationally (mean EBI €203, Milk SI €57) and NAT AV representative of the mean EBI nationally (EBI €104, Milk SI €37). Over the two years, a total of 170 animals with 242 records were used. The breakdown of parity was 26% parity 1, 22% parity 2 and 52% parity 3 or greater. Mean calving date for the ELITE and NAT AV was the February 14 (±19days) and February 22 (±21days). Animals were randomised to feeding treatments pre-calving. The feeding treatments (FT) were; Control (CTL), Lower Grass Allowance (LGA) and High Concentrate (HC), with a target post-grazing sward heights of 4.5-5, 3.5-4 and 4.5-5cm, and daily concentrate supplementation of 3kg, 3kg and 7kg, respectively. Treatments were imposed until the end of April (up to18 weeks). Milk Yield was recorded daily and milk fat and protein concentrations were determined weekly from one successive p.m. and a.m. milk samples. Bodyweight was determined weekly using a calibrated electronic scale (Dairymaster, Causeway, Co. Kerry). Body condition score (BCS) was recorded fortnightly on a 1 to 5 scale. Statistical analysis was conducted using PROC MIXED of SAS. The model included GG, FT, year, calving day of year, parity and GG*FT.

Results Daily MY was lower for ELITE compared to NAT AV. Fat and protein content as greater and daily milk solids yield, consequently, tended to be higher for ELITE. BCS was consistently different between ELITE and NAT AV. There was no difference between the GG for BCS change and bodyweight. GG*FT interaction was observed for daily MY with ELITE outperforming NAT AV in LGA and NAT AV outperforming ELITE in CTL and HC.

Table 1 Milk Production, BCS & Body Weight across Genotype and Feeding Treatments

	Genotype			Feeding Treatments				Pr>F		
	Elite	Nat Av	SEM	LGA	CTL	HC	SEM	Geno	Feed	G*F
Daily MY[1] (kg)	20.0	24.3	0.234	22.3	23.9	26.2	0.287	0.3886	<.0001	0.0499
Fat (g/kg)	4.64	4.46	0.038	4.55	4.62	4.47	0.049	0.0013	0.1043	0.1644
Protein (g/kg)	3.42	3.35	0.014	3.33	3.40	3.46	0.018	0.0014	<.0001	0.9441
Daily MS[2] (kg)	1.93	1.88	0.018	1.75	1.90	2.06	0.021	0.0746	<.0001	0.1873
PC BCS[3]	3.30	3.13	0.023	3.22	3.20	3.22	0.030	<.0001	0.8053	0.6033
Δ BCS[4]	-0.36	-0.36	0.025	-0.43	-0.32	-0.32	0.031	0.9107	0.0107	0.4203
ET BCS[5]	2.92	2.80	0.022	2.79	2.82	2.95	0.028	0.0002	<.0001	0.2000
BW (kg)[6]	501	502	3.766	491	502	510	4.829	0.8837	0.0185	0.9556

[1]Daily Milk Yield, [2]Daily Milk Solids, [3]Pre-Calving BCS, [4]Change in BCS from pre-calving to end of treatments, [5]End of Treatment BCS, [6]Body Weight.

Conclusion Selection for EBI results in genetics capable of higher milk yield and higher BCS irrespective of the early lactation feeding treatments. However the level of feeding during the early lactation influences milk production, BCS period and body weight performance.

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Using commercial farm data to demonstrate the value of the national dairy selection index of Australia

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Application Using lifetime performance data captures the benefit of selection on farm productivity and profitability better than using data from only a "snap shot" or portion of an animal's life.

Introduction To improve the uptake of national selection indexes and maximise genetic progress, there is a need to clearly show the link between farm productivity, profitability and genetic merit. A powerful approach is to analyse productivity and financial data from commercial dairy farms. While this can be used to produce regionally focused results, the power of such an analysis could be reduced by incomplete recording. The Balanced Performance Index (BPI) is the Australian dairy industry's main selection index and is designed to maximise farm profit. Half of the weighting in the BPI goes on milk production EBVs; the relative weighting of other traits is as follows: 12% fertility, 10% somatic cell count, 11% type, 6% workability, 8% residual survival and 2% Feed Saved EBVs (Byrne *et al*. 2016). The aim of this study was to compare the value of using a snapshot of 2-years of data versus lifetime data from commercial dairy herds, to demonstrate the link between farm productivity, profitability and genetic merit.

Material and methods Cow performance, pedigree and EBV records were extracted for 30 dairy herds (n= 12,931) for the 2016 and 2017 financial years, and from 2008-2016 for a subset of 5 herds (n = 2,125) from the national database housed by DataGene. Farm financial and physical data was collected by trained consultants. Two analyses were performed to compare differences in the contribution to farm profit (Cow$) of cows of high and low genetic merit over; 1) a 2-yr period and 2) their lifetime. Cow$ was calculated as: *Cow$ = milk + cull + calf - (feed + repro + replace*). Cow performance data was multiplied by average within-herd monetary values to calculate: milk income (milk), feed costs (feed), calf sales (calf) and reproduction costs (repro). Cows that left the herd were assigned the average within-herd salvage value (cull) or $0 if recorded as dead. In Analysis 1 (2-yr period), only cows which exited the herd during the 2-year period were assigned a breed specific replacement cost (replace). In the lifetime study (analysis 2) all cows were assigned a replace cost to reflect that all cows exited the herd over the study period. Using parent average derived EBVs from multi-breed models enabled a within-herd, but across-breed analysis. Within each herd, each cow was classified into one of two sub-herds, either low or high BPI based on whether her BPI was below or above the median BPI for her contemporary group: herd and year of first calving. Lifetime results were annualised to account for differences in productive life. A linear model was used to test for differences in Cow$, and its components.

Results Although high BPI cows made a greater contribution to profit over both time periods (analysis 1 and 2), a higher percentage of herds had significant ($p<0.05$) results when lifetime data was used (analysis 2). High BPI cows had lower cull cow income and saved replacement costs, significant ($p<0.05$) in one third of herds and 60% of herd in analysis 1 and 2 respectively, as fertility, health and survival traits are included in the index. High BPI cows remain in the herd for longer. Despite reproduction having 12% of BPI weighting, only small differences in reproduction costs were seen across both analyses. This is expected due to small differences in reproduction EBVs (not shown) between high and low BPI sub-herds.

Table 1 Mean difference (mean, s.e.) in cow contribution to profit (Cow$) and its components, and percentage of herds where difference was significant (% sig, $p<0.05$), comparing high and low BPI cows over a 2-year period and cow lifetime.

	Difference over 2 years (no. herds = 30)								Annualised differences from lifetime data (no. herds = 5)							
	BPI	Cow	Income over 2 yrs ($)			Costs over 2 yrs ($)			BPI	Cow	Lifetime income ($/yr)			Lifetime costs ($/yr)		
	($/yr)	($)	milk	cull	calf	feed	replace	repro	($/yr)	($)	milk	cull	calf	feed	replace	repro
Mean	81	261	370	-59	8	130	-80	10	80	201	201	-60	-4	45	-114	1
(s.e)	(6)	(155)	(239)	(50)	(10)	(95)	(73)	(9)	(5)	(57)	(75)	(28)	(5)	(27)	(51)	(6)
% sig	100	43	40	33	13	37	33	28	100	80	80	60	0	60	60	0

Conclusion Comparing the performance of cows of high and low genetic merit over a short period of time, instead of entire productive life, reduces the ability to detect differences, especially for non-production traits included in modern selection indexes. Lifetime data is more useful for clearly demonstrating the link between farm profitability and genetic merit.

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Methods for the elicitation of preference in breeding goals: a systematic review

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Application The use of methods for the elicitation of preference towards appropriate genetic improvement programs is growing in popularity. Increasing interest in decomposing overall utility of an agricultural commodity into separate utilities for its constituent characteristics (following Lancaster, 1966), has resulted in the application of a number of methods over the past three decades. However, there is no comprehensive, systematic review of methods, meaning inconsistencies in the framework of analysis persist. The current paper addresses this substantial knowledge gap, together with presenting aggregate ranks of traits for agricultural commodities under evaluation.

Introduction The elicitation of preference for breeding goal traits is becoming more popular (Nielsen *et al*., 2014). In countries with well-structured agricultural industries, breeding goals are often derived at the national level; however, increasing attention is being paid to the needs of the user (Byrne *et al*., 2016). Attempts to elicit user-preference in the formulation of practical breeding objectives not only seek to increase user-ship, and so increase the rate of genetic gain, but also to understand what traits and trait-types may become more important in changing production circumstances, towards more resilient, future-proof agricultural systems. The absence of key stakeholders in the derivation of breeding objectives risks genetic improvement programs becoming unsuitable or inappropriate (Nielson *et al*., 2014). Thus, in the context of this issue, the current paper seeks to present and critique methods for the derivation of practical breeding objectives. This review represents the first comprehensive, systematic review of this rapidly developing, important field.

Material and methods A systematic review was undertaken to compile literature using various methods to elicit preference for breeding goal traits, following a Rapid Evidence Assessment protocol (Khangura *et al*., 2012). The review captured literature from both animal and plant breeding, as the primary interest was in methods. Data was then extracted from the papers, which included details of the method, objective, sample size, sample population, geographic location of study, statistical analysis, and numerous additional data points. Furthermore, the results of each individual study - the rank of traits for the commodity being studied - were also recorded, which allowed the derivation of aggregate ranks of traits for commodities, both in terms of individual traits and trait-categories, according to study characteristics (such as location).

Results A total of 77 studies were compiled. As some studies contained more than one rank, this resulted in approximately 200 ranks of traits. The subject of studies included llamas, peanuts and bees, amongst 15 more familiar agricultural commodities. Livestock were the focus of more than 80% of the studies, with the most common subject being cattle. Sample size of studies ranges from 10 to 1221, with a median of 101. Although the majority of studies were based in low income countries, studies from high income countries were responsible for the most sophisticated and scientifically robust methodological approaches. Discussion of relative merit of methodological approaches is accompanied by aggregated ranks of commodities under evaluation.

Conclusion Rank aggregation can reveal trends in preferable trait-types, for example highlighting increasing recognition of the importance of adaptation traits in a changing production system. However, few studies recognise the importance of consumer preference for traits, which may be a key aspect of sustainable agricultural systems in future. Future research in the field must adopt a consistent framework in order that opportunities to characterise respondent preference towards the derivation of appropriate genetic improvement programs are not underexploited with insufficient and inefficient methodological approaches.

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The impact of including genotyped cows in the Single-Step genomic evaluation of bovine tuberculosis in Holstein dairy cattle in the United Kingdom

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Application Inclusion of genotyped cows in addition to bulls in Single-Step genomic evaluation (ssGBLUP) resulted in 70 percent increase in genomic accuracy and hence can assist in a higher rate of genetic gain using genomics

Introduction Bovine tuberculosis (bTB) is a chronic bacterial disease of cattle caused by *Mycobacterium bovis* infection primarily involving the respiratory tract. The Department for Environment, Food and Rural Affairs lists bTB as one of the four most important livestock diseases globally, incurring annual costs of about £175 million in the UK. Routine genetic evaluation for resistance to bovine tuberculosis (bTB) has been implemented in the UK since January 2016. Infected animals were classified as those with a positive skin test, or negative skin test but with a positive post–mortem examination result. It is a trait with low heritability (0.09) (Banos *et. al*., 2017), thus only about 22% of sires evaluated had a reliability of at least 50%. Genotypic data has been incorporated in the bTB evaluations in an attempt to increase the accuracy of evaluations. Currently the genomic model for bTB uses only bull genotypes and de-regressed proofs (DRP) in a two-stage procedure giving an accuracy of prediction of 0.27. Recently genotyping of cows with records was undertaken. A Single-Step BLUP (ssGBLUP) that utilizes all phenotypic and pedigree data while incorporating genomic data through the combined relationship matrix ($\mathbf{H}^{-1}$) matrix might be more appropriate to increase accuracy of bTB. This study therefore examines the impact of using ssGBLUP on the accuracy of genomic predictions for bTB including all available genotypes on bulls and cows.

Material and methods Data used consisted of 1,009,562 Holstein cows with 2,996,993 bTB records and a pedigree consisting of 9,118,885 animals. The details of the model used for the bTB evaluation has been presented by Banos *et al* (2017). The fixed effects consisted of breakdown interval, year and month interaction of breakdown onset; lactation number and covariates included age, breakdown duration and heterosis and recombination for crosses of Holstein with other breeds. The random effects were animal and permanent environmental effect. The genotypic data consisted of 6,822 bulls and 5,028 cows genotyped with the 50K Illumina chip. After the usual edits, 43,134 SNPs were used for the analysis. Analyses were undertaken with ssGBLUP with genomic matrix for genotyped animals ($\mathbf{G}_{22}$) of $\mathbf{H}^{-1}$ computed from only genotyped bulls or cows or both bulls and cows. The validation set was 277 genotyped bulls born after 2011 and the 39,860 observations for their daughters were set as missing. The accuracy of evaluations was computed as the correlation between the genomic breeding values (GEBVs) of the validation bulls and the mean of the bull individual daughter deviations (IDD) or DRP. IDD refers to the yield of daughters corrected for all effects include half of dam breeding value.

Results In all analysis, DRP consistently gave lower estimates of correlations and regressions compared to IDD. This could be due to the associated inaccuracies in de-regressing a low heritability trait. Compared to using the **A** matrix, the use of only genotyped bulls and cows resulted in slightly higher accuracy with DRP but the using both bulls and cows increased accuracy by almost 300%. Using IDD, there was no advantage of including genomic data using either only bulls or cows. However, there was an increase of 77% in accuracy when both bulls and cows were used**.**

Table 1 Estimates of correlations and regressions between GEBV and IDD or DRP in validation set

	Animal model		ssGBLUP					
			Bulls Only		Cows only		Bulls and Cows	
Estimates	IDD	DRP	IDD	DRP	IDD	DRP	IDD	DRP
Regression	0.45	0.22	0.30	0.24	0.41	0.22	0.54	0.54
Correlation	0.39	0.13	0.36	0.19	0.40	0.15	0.69	0.48

Conclusion The accuracy of bTB genomic predictions showed marked improvement with the inclusion of both genotyped bulls and cows in the model using ssGBLUP approach

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Genetic parameters for live weight traits in purebred Irish Texel, Suffolk and Charollais lambs

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Application Different levels of genetic variation exist in different breeds of sheep for lamb live weight traits in the Irish sheep production system. Genetic evaluation on a per-breed basis could improve accuracy and rates of genetic gain compared to the current genetic evaluation system.

Introduction Lamb live weight and the rate at which the animal grows have been defined as the key drivers of profitability in Irish (Byrne *et al.,* 2010) and international (Conington *et al.,* 2004) sheep production systems. Previous research has shown considerable variability in pre and post weaning lamb growth rates not only at a phenotypic (Dixit *et al.,* 2001) but also at a genetic level (Safari *et al.,* 2005). To date, current genetic parameters and evaluations have been calculated within a multibreed population context. The objective of the present study was to estimate and compare genetic parameters and genetic evaluations for a range of lamb live weight traits within three breeds commonly recorded in Ireland namely Texel, Suffolk and Charollais.

Material and methods A total of 94,484 live weight records from 33,721 lambs collected from 364 purebred flocks across the three breeds were extracted from Sheep Ireland, the Irish national database (http://www.sheep.ie). Records pertained to years 2010 to 2017, inclusive. In Ireland lamb live weights are recorded at three time points post lambing by Irish producers using weigh-scales: pre weaning (20-65 days), weaning (66-120 days) and post weaning (121-180 days). Following all edits, 33,721 pre weaning weight records, 32,623 weaning weight records and 28,140 post weaning weight records remained. Variance components were estimated for each trait and breed using the following linear mixed animal model:

$$Y = CG + AFL + Parity + Gender * Age + Birth\ type * Rearing\ type + Animal + Dam + DamPE + Litter + e$$

Where Y = lamb live weight, CG = contemporary group (breed-by-flock-by-week of weighing), AFL = age at first lambing, Parity = parity of the dam, Gender*Age = the interaction between the gender and age of the lamb, Birth type*Rearing type = the interaction between the birth type and rearing type of the lamb, Animal = random animal direct additive genetic effect, Dam = random maternal genetic effect, DamPE = random maternal permanent environmental effect, Litter = random maternal common environmental effect, and e = random residual effect. Within-breed genetic correlations were estimated among all the live weight traits using the model previously described in a series of bivariate analyses. Estimated breeding values were calculated for each live weight trait and genetic trends were produced from these results.

Results Heritability estimates are shown in Table 1. Significant positive genetic correlations between the direct additive genetic effects among pre weaning, weaning and post weaning traits were calculated. Negative correlations were seen between the direct additive and maternal genetic effects within trait indicating that animals with a genetically superior direct additive genetic effect are expected to be maternally inferior. Genetic trends ranged from 0.023-0.171kg/year across different traits and breeds.

Table 1 Direct heritability (h^2_d), maternal heritability (h^2_m), maternal repeatability (R_m) and maternal common environmental effect (C^2_m) for pre weaning, weaning and post weaning weight across breed.

Trait	Breed	h²d	h²m	C²m	Rm
Pre weaning	Texel	0.16*	0.06*	0.30*	0.12*
	Suffolk	0.22*	0.05*	0.31*	0.06*
	Charollais	0.14*	0.02	0.35*	0.03
Weaning	Texel	0.27*	0.04*	0.26*	0.06*
	Suffolk	0.17*	0.03	0.27*	0.04
	Charollais	0.23*	0.03*	0.24*	0.04*
Post weaning	Texel	0.27*	0.04*	0.21*	0.05*
	Suffolk	0.15*	0.00	0.23*	0.03
	Charollais	0.17*	0.01	0.23*	0.01

*Estimates significantly different ($P < 0.05$) from zero. SE ranged from 0.01 – 0.03.

Conclusion Considerable differences in genetic parameters and evaluations were found between the Texel, Suffolk and Charollais breeds for each of the three traits examined in the present study. Variability was seen in both heritability and trait correlation estimates suggesting that current genetic improvement systems may benefit by considering these breeds separately in future genetic evaluations.

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Effects of age at first joining and ewe genotype on performance of ewes from 2 to 6 years of age

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Application Use of prolific ewe genotypes and lambing at 1 year of age results in an extra lifetime output of at least 2 lambs reared per ewe joined.

Introduction The cost of rearing a replacement ewe to first joining at ~19 months equates to approximately 25% of the value of the lamb carcass output produced during her lifetime (Keady 2014). Replacement cost may be reduced by lambing at 1 year of age and using prolific genotypes. Keady and Hanrahan (2014) reported that Belclare (B), B×Suffolk (B×S) and >75% S replacements joined at ~7 months reared 1.34, 1.03 and 0.93 lambs per ewe lambing. Lambing at one year of age had no negative effect on ewe reproductive performance or progeny performance when lambing at 2 years (Keady and Hanrahan 2016). The aim of the current study was to evaluate the effects of age at joining (~7 or 19 months) and ewe genotype on the performance of ewes up to 6 years of age, and the performance of their lambs.

Material and methods A total of 424 ewes [157 B, 114 B×S, 153 >75%S; 2 cohorts] were joined, annually, with Charollais rams, starting at 19 months of age. A random 50% of each genetic group had been joined at ~7 months and 85% had produced lambs at 1 year of age. Ewes left the flock when culled for natural reasons (e.g., udder and mouth issues) or when they died. All ewes were shorn at housing (group pens of ~ 40) in early December and offered grass silage *ad libitum* until lambing. During the last 7 weeks pre lambing ewes were offered concentrate supplement; the level depended on forage feed value and expected litter size (ultrasonic scanning). Ewes rearing singles or twins received no concentrate supplementation post lambing while those rearing triplets received concentrate (0.5 kg/d) for 5 weeks post lambing, and their lambs had access to concentrate (up to 300 g/head daily) until weaning. All lambs were managed as one flock between weaning and slaughter and offered grazed grass as the sole diet. All lambs were slaughtered prior to the end of the grazing season. The data were analysed using the MIXED, GENMOD or LIFETEST procedures of SAS, as appropriate.

Results The effects of age at first joining and ewe genotype on animal performance between 2 and 6 years of age are presented in Table 1. There were no age-at-first-joining by ewe-genotype interactions (P > 0.05). Ewes that lambed as 1-year olds had lower lamb mortality (P<0.001) at subsequent lambings. The >75%S ewes had a lower litter size (P<0.001) and reared fewer lambs per ewe joined (P<0.001). Lambs born to B×S ewes tended to have lower mortality (P=0.075) than lambs from the other genotypes. The effect of ewe genotype on ewe survivability is shown in Figure 1. The differences among the survival curves were relatively minor; a higher proportion of B×S ewes survived to joining at 6.5 years of age than the mean for B and >75%S (P=0.08; Table 1). Ewes joined at 1 year of age but that did not lamb reared fewer lambs per ewe joined (0.17, s.e. 0.11) and had lower survival (13% *v* 30% joined at 6.5 years; P < 0.05) than those that lambed at 1 year.

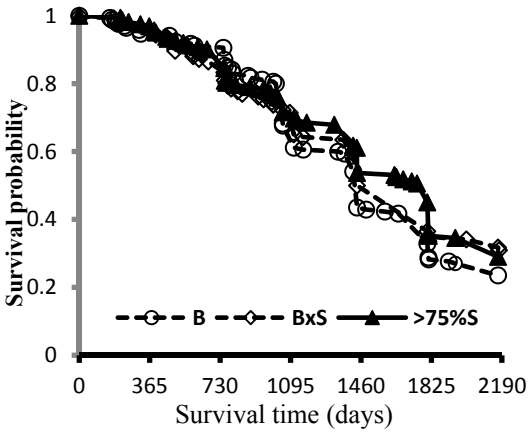

Figure 1 Effect of genotype on ewe survival

Table 1 Effects of age at first joining and ewe genotype on ewe and lamb performance

	First joining (FJ)			Ewe genotype (G)				Sig.	
	7 month[§]	19 month	s.e.	B	B×S	>75%S	s.e.	FJ	G
Ewe weight at lambing (kg)	73.9	72.4	0.61	71.7	74.1	74.5	0.84	NS	**
Litter size	1.98	2.00	0.036	2.11	2.04	1.78	0.050	NS	***
Lambs reared/ewe joined	1.66	1.57	0.042	1.63	1.70	1.35	0.056	P<0.1	***
Lamb mortality (%; twin basis)	5.9	8.8	-	7.4	5.9	8.5	-	***	P=0.1
Ewes joined at 6.5 years (%)	29.7	25.4	-	16.8	26.8	22.2	-	NS	P=0.09

[§]Represents ewes that actually lambed at 1 year of age

Conclusion Age at first joining (7 or 19 months) had no adverse effect on the performance of ewes between 2 to 6 years of age. Belclare and B×S ewes reared 0.28 and 0.35 extra lambs annually per ewe joined compared with >75% S ewes.

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Genetic parameters of faecal egg and oocyst counts, dag scores, live weight and immunological traits in Scottish Blackface sheep

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Application Implementation of breeding programmes that include disease traits such as faecal egg counts is a promising method to control important parasites responsible for gastrointestinal parasitic infections affecting sheep.

Introduction Gastrointestinal parasitism is an important contributor for economic losses in sheep production, posing a threat to the development and productivity of the host. The development of breeds selected for enhanced resistance to parasites is a promising method to control parasitism. The aim of this study was to assess genetic parameters of disease, productivity and immune traits, and investigate the feasibility of selecting sheep for increased resistance to parasites.

Material and methods Data were collected for a total of 3,951 animals from an SRUC experimental hill farm flock. Animals were faecal sampled at approximately 3 months of age. Faecal count data was obtained for strongyles (FEC_S) which may contain various genera within the strongyle population (Bishop *et al*., 2004), *Nematodirus* (FEC_N), with eggs easily distinguishable from strongyle eggs (Morris *et al*., 2004), and coccidian faecal oocysts (FOC_C), a protozoan parasite. Eggs and oocysts were quantified using the McMaster technique (per gram of faeces). Live weight (LWT) and 5-point faecal soiling scores (DAG) were recorded at the time of faecal sampling. Genetic parameters (heritability and correlations) were estimated using the software ASReml v3.0 (Gilmour *et al*., 2009). FEC, FOC and DAG data were log-transformed to approximate normal distribution. Heritabilities were estimated using univariate analyses. Genetic and phenotypic correlations between traits were estimated with bivariate statistical analyses based on the following model: $Y = X\beta + Za + e$, where β is a vector of fixed effects, a is a vector of additive genetic effects including animal pedigree, e is the vector of residual effects, and X and Z are the design matrices relating records to fixed or random effects. Only significant fixed effects were considered for each of the analyses, which included lamb gender, lab, year, birth-rearing rank, lamb age, grazing locations, dam age (at parturition), genetic line and significant interactions, when appropriate. Blood samples were collected from lambs at roughly 2 months of age (i.e. one month prior to the first faecal count). Whole blood stimulation assays were used to characterise the adaptive immune response. Blood was stimulated with either pokeweed mitogen (PWM), a family of lectins that non-specifically activate lymphocytes irrespective of their antigen specificity, and *Teladorsagia circumcincta* (T-ci) larval antigen to activate parasite-specific lymphocytes. The type of adaptive immune response was determined by quantifying the cytokines interferon-gamma (IFN-γ), interleukin (IL)-4, and IL-10, which relate to T-helper type 1 (Th1), Th2 and regulatory T cell (Treg) responses, respectively. Heritabilities were estimated for cytokine release data with a model similar to the above.

Results Heritability and correlations between disease and production traits are highlighted in Table 1. A strong positive genetic correlation was found between FEC_S and FEC_N and a moderate correlation between FEC_S and FEC_C. DAG was negatively (favourably) correlated with LWT at a genetic level. Phenotypic correlations were generally lower than their genetic counterparts. FEC_S and FEC_N had weak negative (favourable) correlations with LWT. DAG was negatively correlated with FOC_C and with LWT. Heritabilities of cytokine expression (Table 2) varied from low (0.14±0.06) to very high (0.77±0.09) and were always significantly greater than zero (P<0.05).

Table 1 Heritabilities (diagonal) of disease and productivity traits; genetic and phenotypic correlations below and above the diagonal, respectively (s.e.)

Traits	FEC_S	FEC_N	FOC_C	LWT	DAG
FEC_S	0.14(0.03)*	0.22(0.02)*	0.13(0.02)*	-0.09(0.02)*	0.02(0.02)
FEC_N	0.74(0.09)*	0.17(0.03)*	0.09(0.02)*	-0.06(0.02)*	0.00(0.02)
FOC_C	0.39(0.15)*	0.23(0.16)	0.09(0.03)*	0.02(0.02)	-0.06(0.02)*
LWT	-0.01(0.13)	-0.08(0.12)	0.25(0.15)	0.33(0.15)*	-0.19(0.02)*
DAG	0.08(0.18)	0.02(0.18)	0.03(0.21)	-0.33(0.15)*	0.09(0.03)*

*Estimates are significant (P<0.05).

Table 2 Heritabilities of cytokine expression (s.e.)

Immune traits	h^2
IFN-γ PWM	0.33(0.10)*
IL-4 PWM	0.77(0.09)*
IL-10 PWM	0.16(0.07)*
IFN-γ T-ci	0.27(0.06)*
IL-4 T-ci	0.14(0.06)*
IL-10 T-ci	0.22(0.08)*

*Estimates are significant (P<0.05).

Conclusion There is enough genetic variation among individuals in disease traits to underpin a breeding programme aiming to enhance animal resistance to infection. Selecting animals for an increased resistance to FEC_S will also enhance their resistance to both FEC_N and FOC_C. A breeding programme aimed at improving resistance to these parasites is feasible and will not affect live body weight. Results from cytokine expression have also shown enough genetic variation. Correlating immune traits with disease traits might give an insight to the immune function of Scottish Blackface sheep against gastrointestinal parasites.

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Bayesian estimation of genetic parameters for piglet survival and birth weight at piglet and sow level using a population kept under outdoor conditions

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Application Genetic improvement of survivability and birth weight of piglets using a model at piglet level is expected to be more successful than at sow level to enhance the sustainability and welfare of pigs reared outdoors .

Introduction Improvement of piglet survival is challenging because it is a binary trait (alive and dead) controlled by piglet genes related to vitality, health, etc. (direct effects) and dam genes related to milk yield, mothering ability, etc. (maternal effects). In addition, traits such as litter size and variation of birth weight within litter have an impact on piglet survival due to their undesirable genetic correlations (Matheson *et al*., 2018). In this project, the objectives are the Bayesian estimation of genetic parameters and identification of the genetic impact of birth weight, its variation and litter size on piglet survival.

Material and methods The data are from a 2-generation selection experiment comprising of 22,481 piglets kept under outdoor conditions (Roehe *et al*., 2010). Two datasets were analysed; the first contained performance at individual piglet level including survival at birth (SVB), survival at weaning (SVNP) and individual birth weight (IBW). The second dataset contained performance at sow level (per litter): number born piglets (NB), average piglet birth weight (ABW), standard deviation of piglet birth weight (SDBW), survival ratio at birth (SVBL) and at weaning (SVNPL). Data at piglet level were analysed by a Bayesian multivariate threshold model, which considered farm-unit-year-month-parity, gestation length, sex and fostering as fixed effects and direct and maternal genetic, common environmental litter as random effects. At sow level, a Bayesian multivariate linear model was fitted for five traits with farm-unit-year-month-parity, gestation length and generation as fixed effects, and sow additive genetic and sow permanent environment as random effects.

Results At piglet level, direct and maternal heritabilities of IBW were substantially larger than for survival traits. Significant (P<0.05) genetic correlations between survival traits and IBW were low but positive, whereas the correlations between ABW and survival traits were non-significant (Table 1). Not shown in Table 1, NB was significantly (P<0.05) correlated with SDBW and SVNPL at 0.38 and -0.36 respectively, but non-significantly with SVBL (-0.37). SDBW was negatively correlated with SVBL and SVNPL at -0.43 and -0.02 respectively, but non-significant due to large SE.

Table 1 Heritabilities and genetic correlations of reproduction traits (95% highest posterior density interval in parentheses)

Piglet level					Sow level		
Effect	Trait	Heritability	Correlation Direct IBW	Correlation Maternal IBW	Trait	Heritability	Correlation with ABW
Direct	SVB	0.18* (0.13 0.23)	0.23* (0.11 0.35)	0.12 ^{ns} (-0.00 0.24)	NB	0.22* (0.16 0.30)	-0.39* (-0.59 -0.17)
	SVNP	0.18* (0.13 0.24)	0.25* (0.13 0.37)	0.14* (0.01 0.26)	ABW	0.22* (0.13 0.32)	
	IBW	0.36* (0.32 0.40)		-0.05 ^{ns} (-0.14 0.05)	SDBW	0.11* (0.06 0.17)	0.68* (0.48 0.85)
Maternal	SVB	0.14* (0.12 0.17)	0.16* (0.04 0.29)	0.17* (0.06 0.29)	SVBL	0.06* (0.02 0.12)	-0.17 ^{ns} (-0.64 0.29)
	SVNP	0.12* (0.09 0.14)	0.15* (0.03 0.27)	0.28* (0.18 0.38)	SVNPL	0.13* (0.06 0.19)	0.31^{ns} (-0.04 0.65)
	IBW	0.29* (0.26 0.32)	-0.05^{ns} (-0.14 0.05)				

*: significant ^{ns}: not significant

Conclusion All traits showed significant heritabilities indicating the potential for improvement of piglet survival and birth weight through selection. The positive genetic correlations between SVB, SVNP and IBW suggest that selection for birth weight will improve piglet survival, and vice versa. Increased SDBW showed a tendency to negatively influence survival at birth. Selection for survival is necessary because NB was negatively genetically correlated with ABW and SVNPL.

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3D cameras can alert farmers to problem behaviours in pigs

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Application The unpredictable and damaging nature of tail biting means it is a persistent problem for farmers and a health and welfare concern. However recent evidence shows that pigs lower their tails before a tail-biting outbreak. 3D camera technology can automatically detect differences in tail posture and could alert farmers to heightened risk in pens thus allowing mitigation strategies.

Introduction Tail biting is a major welfare and economic problem. Tail biting results in pain and sickness for bitten pigs. Infections from tail wounds can lead to economic losses from carcass condemnation (Harley *et al*.2012), there are negative impacts on growth (Harley *et al* 2014) and considerable on-farm labour and veterinary costs (D'Eath *et al*. 2016). Tail docking of piglets is partly effective at reducing tail biting in later life, but is seen as an undesirable mutilation and its routine use is banned in the EU (by Council Directive 2008/120/EC). Tail biting outbreaks can be unpredictable but new research suggests that changes in tail posture could be an early warning sign (Lahrmann *et al*. 2017; D'Eath *et al*. 2018). Taking a precision livestock farming approach, we used Time-of-flight (TOF) 3D cameras, processing data with machine vision algorithms, to determine if we could automate the measurement of pig tail posture.

Material and methods The subjects of this study were 667 weaner/grower pigs with intact-tails (JSR Genetics Large White x Landrace x Hampshire). Both sexes (entire males and females) were studied and housed in groups of 29 pigs per pen (average). 3D (TOF) cameras were placed above feeders to automatically measure whether pig tails were up and curly, or held down. 2D CCTV cameras were used for validation work. 23 groups were monitored with 3D and 2D cameras and regularly tail-scored for injury (0 to 4 with increasing damage). The work was regulated by the UK Home Office and ethical approval was obtained from SRUC's Animal Experiments Committee (ED AE 27-2016). The animals were closely monitored and tail biting was stopped as soon as an outbreak was detected. 3D and 2D video images were watched simultaneously to validate 3D data 'by eye" and analysed using a chi-squared test for association. Linear Mixed Models were fitted in Genstat to determine the relationship between 3D and injury scoring data.

Results 15 groups had tail biting outbreaks, following which enrichment was added to pens and biters and/or victims were removed and treated. 926 automatic 3D tail detections were checked by eye and described as curled, high loose, low loose or tucked. Tails which were visually identified as not being tucked (n=624) were accurately identified as not being low ("3D high") 66.8% of the time (417/624 true negative rate; specificity). There was a significant association between tucked and "3D low" (Fig 1. $\chi^2 = 248.5$, $p<0.001$). Thus the overall accuracy of the algorithm (correct classifications 684 / total 926) was 73.9%. When there are fewer low tails (3D 0) there are many pigs with uninjured tails (Damage score 0) or slightly injured tails (1 or 2) (i.e. negative coefficients of effect). More low tails were predictive of a greater proportion of damaged tails (score 3 or 4) (i.e. positive coefficient of effect – Table 1).

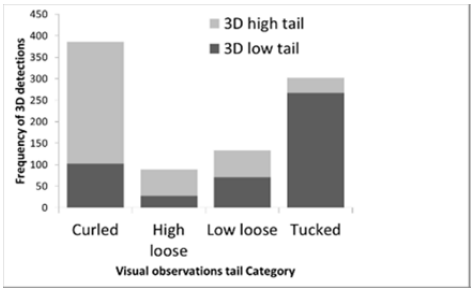

Figure 1 Bar graph of 3D data validation by human observer

Table 1 Relationship between tail damage scores and 3D low tails data. Data shown are the coefficient of effect (± standard error) for a series of Linear Mixed Models

Prop[n] of pigs with Tail Injury Score	3D 0 Low tails
Damage 0	-0.703 ± 0.094***
Damage 1	-0.083 ± 0.032*
Damage 2	-0.210 ± 0.034***
Damage 3	0.100 ± 0.040*
Damage 4	0.831 ± 0.097***

Conclusion Pigs lower their tails prior to an outbreak. There is potential for a 3D machine vision system to automate tail posture detection and provide early warning of tail biting on farm. Validating these precision livestock tools on commercial farms is an important next step to realising their potential.

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Developing sustainable livestock systems through participatory farmer research

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In pursuit of sustainable farming systems, there is an urgent need to build resilience in agriculture against the dual challenges of climate change and food security. To address this need requires change, adaptation and the implementation of innovation across the industry, using an approach that empowers farmers to develop the practical tools they need to address the current and future challenges facing their businesses.

Linking research to commercial development farms, and developing farmer networks to encourage uptake, an 'impact model' has been developed, with an overarching aim of ensuring the continuity of economically-viable livestock systems. A key feature of this 'impact model' approach is that the work is industry-led, to ensure it is of direct benefit and has the greatest value to the end-user. Scientific evaluations of innovative strategies that require either: further validation of their efficacy prior to uptake on the commercial farms; or multiple options tested at one site; or more detailed data collection than can be practically achieved on farm (e.g. feed response in individual animals) are then undertaken by the science team linked to the project. Key project messages are disseminated through a farmer-to-farmer dissemination network, with support for open events provided by an agricultural extension team. This parallel approach between industry and research allows the innovation at a farm level to be tested under scientific replication at research sites, providing statistical rigour to validate the innovations tested on farms. The outputs from participatory projects are varied, ranging from farmer-friendly technical case studies, articles on Knowledge-Based Innovation (Marley *et al*., 2011), publications on the scientific experiments (Crotty *et al*., 2015; Detheridge *et al*., 2015; Crotty *et al*., 2016) through to outputs on the social science aspects of the project (Crotty *et al*., 2018), thus providing varied routes through which to create impact.

This paper will discuss the approach, the lessons learnt and the benefits of this research approach using examples of participatory farmer projects (e.g. Sustainable Forage Protein (EFBS project), PROSOILplus, SUREROOT) on sustainable livestock systems. This approach has proven to be a method to increase the impact of the science, whilst ensuring that the research conducted is of direct relevance to the end-user and to stakeholders across the agricultural industry.

Acknowledgements The PROSOILplus project has received funding through the Welsh Government Rural Communities - Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government. The EFBS project was funded through a joint initiative between partners: Dalehead Foods Ltd., Dovecote Park, Müller Milk & Ingredients, Coombe Farm, Waitrose, Germinal, Bangor University and Aberystwyth University. The project was funded by the industry partners and co-funded by Innovate UK, the UK's innovation agency. The SUREROOT project is BBSRC and industry funded science developing improved rooting systems in grasses and clover for sustainable livestock systems and for ecosystem services. We gratefully acknowledge all the farmers involved in our participatory research projects.

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An investigation of the feasibility of running a mobile robot in a flock of broiler chickens and bird behavioural response

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Application A mobile robot was successfully run among a flock of fast-growing broiler chickens for an entire flock cycle with no apparent negative effects on bird behaviour or production.

Introduction In commercial broiler flocks, close monitoring of the bird environment is required to ensure good welfare and production. However, this is difficult in large houses and existing sensors are infrequent and often placed high above the litter. A mobile robot that can traverse through a flock at all bird ages collecting environmental data at bird level would allow for more accurate monitoring at a high grid density. This could improve welfare as areas of unsuitable temperature, humidity etc. could be identified and dealt with before birds are compromised. However, fast-growing broiler strains typically show reduced mobility later in the cycle and stocking densities can be as high as 39kg/m^2. A mobile robot must be able to overcome this challenge to safely operate among the flock at any age of bird. Precision livestock farming technologies that can automatically monitor animals are increasingly used in intensive animal systems (Berckmans 2014). Mobile robots have been developed for use among laying hens (Joffe and Usher 2017) and for behavioural studies on chicks (Gribovskiy *et al*. 2017) but there is no scientific research on using a similar robot among broiler flocks. The aim of this study was to investigate the feasibility of running a mobile robot among a small flock of fast-growing broilers from day 1 to slaughter, studying bird behavioural response.

Material and methods An experimental room (5.5m x 15m) was set-up to replicate a commercial environment with automatic pan feeders and nipple drinkers and sawdust litter. 1500 Ross 308 broiler chicks were housed in the room at 1-day of age. At 30 days of age, the flock was thinned by removing 400 individuals. This ensured that the maximum stocking density of 35kg/m2 was not exceeded. A stockman walked the flock to check for unwell or dead birds twice a day at 8:30 and 14:30. The robot was driven through the flock under manual remote control three times a day at 10:00, 13:00 and 16:00 Monday to Friday. The robot was driven along a set route (approximately 48 m long) each time. Bird behaviour was studied using camera footage. Behaviours studied included startling incidents, back-fill behind the robot, contact incidents with the front of the robot, blocking birds and activity levels (measured using an image analysis system). Additionally, mortality records were kept and weights were measured automatically throughout the cycle to keep track of bird growth. All work was carried out under Home Office Licence (PD4FD332A).

Results As this was a preliminary and novel trial using one flock, statistical testing was not appropriate. Summary statistics were instead produced to look at potential effects and trends in the results throughout the cycle. The birds showed minimal startling behaviour in response to the robot at all ages with a mean number of startle incidents per run of 4.21 (+/- 3.84). Group startles involving 3 or more birds occurred only once in the entire study. Birds came into contact with the front of the robot frequently. The mean number of these contact events across the whole cycle was 97.87 (+/- 43.54) per run. This increased throughout the cycle, peaking just before the birds were thinned at 30 days. Despite regular contact with the robot, there were only 17 incidents overall, where birds did not move out of the way of the robot and remedial action (such as reversing the robot or going around) had to be taken. Of these incidents, 15 were after day 24. Birds filled the area behind the robot well at all ages. Bird activity increased during both stockman walks and robot runs with the increase in activity appearing to be greater for stockman walks. Production and mortality figures were in line with commercial standards.

Conclusion The low levels of startling behaviour and good back-fill behind the robot indicate that the birds were not fearful of the robot, likely because they were habituated to it from day 1. Although many birds came into contact with the robot, very few were unable or refused to move out of the way completely and in these cases the robot was manoeuvred around these birds effectively without harming birds. The results show that running a robot safely in a flock is achievable and that bird behaviour did not appear to be negatively affected. The next step is to trial the robot on real commercial premises using control flocks to compare welfare measures.

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Impact of the introduction of the Nitrates Action Programme in Northern Ireland on the monthly concentrations of ammonia measured at three sites

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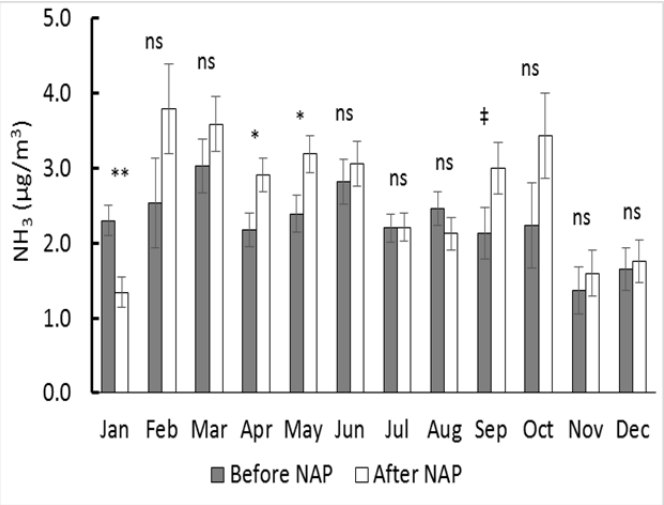
Application The introduction of the Nitrates Action Programme in Northern Ireland (NI) has reduced monthly atmospheric ammonia concentrations in winter and increased them in spring and autumn, with this likely a reflection of the introduction of closed periods for the application of organic and inorganic manures.

Introduction Ammonia emissions are currently a cause of concern within Northern Ireland (NI), with per capita emissions now approximately four times higher in NI than in the rest of the United Kingdom (UK). This reflects the importance of the agri-food sector to NI, and especially livestock based agricultural systems. A significant part of ammonia emissions is derived from the application of livestock manures and inorganic fertiliser to agricultural land. However, under the EU Nitrates Directive the whole of NI was designated a Nitrate Vulnerable Zone in 2006, and as a consequence a Nitrates Action Programme (NAP) was implemented in January 2007 to mitigate against nutrient losses from agriculture to waterways. This NAP prohibits the application of organic manures between 15 October and 1 February, while the application of inorganic manures is prohibited between 15 September and 1 February. This study examined the impact of the introduction of the NAP on monthly concentrations of ammonia gas.

Material and methods The National Ammonia Measurement Network (NAMN), which is part of the UK Eutrophying and Acidifying Pollutants (UKEAP) network, was established in 1996 to quantify temporal and spatial changes in air concentrations and deposition of gaseous ammonia and particulate ammonium on a long term basis. There are 72 NAMN sites (at January 2017) across the UK, three of which are in NI: Hillsborough (Co. Down), Aghadowey (Co. Londonderry) and Lough Navar (Co. Fermanagh). At these three sites gaseous ammonia deposition is sampled via a diffusion denuder tube in the sampler (DELTA - DEnuder for Long Term Atmospheric sampling). The tube and filter were replaced monthly, approximately, and the amount of captured gaseous ammonia, expressed as µg/m^3, was determined by the Centre for Ecology and Hydrology at Lancaster. Data relating to monthly ammonia deposition at each of the three NAMN sites in NI was obtained (Coleraine, January 2000 – December 2016 (omitting 2010); Lough Navar, January 1997 – December 2017; Hillsborough, January 1997 – December 2017 (omitting 2001)). Using the combined data from the three sites, the monthly pattern for the years before and after the implementation of the NAP, i.e. from 1997 to 2006 and from 2007 to 2016, was compared by testing the mean for each month for the two periods for significance with 2-tailed Student's t-test, assuming variances of the two samples under test at any time to be unequal, and considering 'year' as a replicate.



Results Following the introduction of the NAP in NI, ammonia concentrations (Figure 1) declined during January ($P<0.01$) and increased during April and May ($P<0.05$), with a tendency to increase during September ($P<0.1$). The lower concentrations post NAP in January are likely to be due to the absence of manure spreading at this time, while the higher concentrations during April and May post NAP likely reflect the spreading of manures at this time, rather than during the winter months, as was the situation pre NAP. The trend for higher concentrations in autumn is likely to reflect increased manure applications before the start of the closed period. Higher annual concentrations after than before introduction of NAP may be due to an increase in livestock numbers in areas around the detectors since 2007. Census data suggest pig and poultry numbers have increased in NI since 2007.

Figure 1 Comparison between mean monthly concentration of ammonia (recorded at the three NAMN samplers across NI) before (Before NAP) and after (After NAP) the introduction of the Nitrates Action Programme (Bars indicate SEM; ns = not significant; ‡ = $P< 0.1$; * = $P< 0.05$; ** = $P< 0.01$)

Conclusion Following the introduction of the NAP in NI in 2007, ammonia concentrations were lower during January, but higher during April and May, and tended to be higher in September. These differences are likely to reflect changes in spreading patterns throughout the year for manures, especially organic manure, due to the introduction of 'closed periods'.

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Modelling the potential performance improvement value in Scottish and English sheep and beef systems

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Application Scottish and English sheep and beef farms demonstrate a potential performance improvement in net pasture production per hectare, meat production per hectare and net profit.

Introduction The average Scottish and English sheep and beef farms do not achieve their potential pasture growth due to inefficient farm systems. Farm businesses are increasingly seeking opportunities to improve their pasture management practices to deliver higher production and profit from their farm assets, in a sustainable system. The aim of this study was to identify and quantify the potential performance improvement value in Scottish and English beef and sheep systems.

Material and methods A representative farm-system model was developed for each of Scotland and England. FARMAX Sheep, Beef and Deer UK (FARMAX) (Marshall, 1991*)* was used as the modelling tool to create these farm models.
For the English farm model, number of animals per farm at each animal age group was retrieved from 2017 Survey data (AHDB[1], 2018) and included number of mature breeding stock, mature non-breeding stock, one-two year old heifers or ewe hoggets, calves or lambs, and one-two year old male stock. Standard farm data including farm area, animal liveweight gain, mating percentages, feeding volumes and housing periods were also retrieved from 2017 survey data (AHDB[2], 2018). FARMAX was used to determine daily pasture intake volumes, potential pasture growth (5582kgDM/ha), pasture quality, net pasture yield, carcass weights and default crop yields.
For the Scottish farm model, animal numbers and standard farm data was also retrieved from 2017 survey data (AHDB[1], 2018). Specific data related to Scottish sheep and beef farm systems was used to refine average farm area and animal performance metrices (Scottish Government, 2018).
To develop the optimised models, stock policies of the farm system including mating dates, sales dates and animal performance were held constant. The total number of stock was scaled within the existing stock policy design until the farm system achieved a pasture cover below 2900kgDM/ha for the entire season on both cattle and sheep land areas. Potential pasture growth was fixed between average and optimised scenarios, and FARMAX delivered output data for forecasted change in pasture quality, loss of potential, and decay to determine net pasture yield realised. Farm financials were scaled using the same income prices in the sale of wool and meat, provided by the FARMAX model. Expenses were either fixed at per hectare prices or scaled per stock unit to recognise change in system costs associated with change in stock numbers. The standardised farm systems for each of English Average (EA), Scottish Average (SA), English Optimised (EO) and Scottish Optimised (SO) were then compared based on net pasture yield, meat production and profitability.

Results Scottish and English sheep and beef farms demonstrated a performance improvement potential of 139.7% and 143.1% in net pasture production and 168.1% and 173.5% in kg meat produced per hectare respectively. The net profit per hectare increased by £147 for Scottish farm and £78 for English farm.

Table 1 Annual farm system performance outputs

	Scottish Average	Scottish Optimised	English Average	English Optimised
Potential Pasture Production (kgDM/ha)	5453	5453	5540	5540
Net Pasture Production (kgDM/ha)	1348	3231	1320	3209
Kg meat per hectare	47.0	126.0	42.7	116.9
Gross Margin (£/ha)	64	214	46	129

Conclusion There is opportunity to improve farm performance in total pasture production, meat production and profitability in both Scottish and English farming systems. As stocking rate increases, pasture quality is controlled more effectively in the model and net pasture yeild achieved increases. Farm systems may be further optimised on these performance metrics by adjusting stocking policies and integrated practices including cropping and feeding to achieve further improvements.

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Effect of maize silage clamp density on aerobic stability and forage quality

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Application Consolidating fresh chopped maize to a minimum density for silage can help farmers and contractors improve feeding value.

Introduction Silage density results from extent to which silage has been compacted. Aerobic spoilage microorganisms are known to reduce silage quality in silages with low density and greater oxygen porosity (Pahlow *et al.,* 2003). Rêgo *et al.* (2016) reported highest clamp face temperatures towards the top and lowest towards the base (44.4˚C, 38.6˚C and 34.1˚C top, middle and bottom). Ashbell and Weinberg (1992) observed that the sidewalls were on average 3-4˚C warmer than measurements taken from the centre of the clamp. McDonald (1991) states that clamp density is one of the key factors influencing the nutritive value of silage. Aim to determine effect of silage density on clamp-face temp. and aerobic spoilage.

Material and methods Three maize silage clamps located on three dairy farms in the West Midlands, England were visited on four occasions between May and July 2016. At each visit, each silage clamp was sampled at nine sampling locations (3X3 matrix) on the silage clamp feed-out face. Temperature measurements were taken at each sampling point using a 0.2m and a 0.5m thermometer probe. Subsamples from each spatial location were removed using a corer attached to an electric drill. Sub-samples were weighed and the fresh matter density of each sample calculated. All sub-samples were vacuum packed and stored in a coolbox to await NIRS analysis (NIRS4Farm, Aunir), to predict the DM, pH, Lactic Acid, NDF, ADF, DM, ash, D-value and ME content. Results were analysed as a 3 x 4 x 9 factorial designed experiment using Genstat 18th edition.

Results Silage temperature at both 0.2 and 0.5m depths into the face of the clamp was found to increase as silage density decreased ($P<0.001$, Table 1). Silage temperatures at 0.2m from the clamp face were found to be more variable than those taken at 0.5m deep. Silage density values were found to differ on different farms and clamp type, however, no interaction ($P>0.05$) was observed for farm or spatial location. CP, lactic acid and starch values all linearly increased ($P<0.05$) with increased silage density. A negative linear relationship ($P<0.05$) was observed for ADF and Ash content as silage density increased. Regression analysis found clamp temperature (0.5m) lowest at 600kgFW/m^3 silage density ($P<0.001$; $R^2=0.575$).

Table 1 Effect of sampling location on mean maize silage density and nutritional values

	Horizontal location			Vertical location			Horiz	Horiz	Vert	Vert
	Left	Centre	Right	Top	Middle	Base	SED	P	SED	P
Density kg FW/m^3	501.2	790.3	512.9	501.9	614.3	688.2	22.49	<0.001	22.49	<0.001
Temp ^{o}C @ 0.2m	20.5	20.4	23.8	25.9	20.7	18.1	1.247	0.012	1.247	<0.001
Temp ^{o}C @ 0.5m	19.8	21.0	22.7	25.3	20.0	18.2	1.195	0.074	1.195	<0.001
DM g/kg	24.64	27.66	21.42	24.43	25.31	23.99	0.596	<0.001	0.596	0.087
Ash g/kgDM	4.411	4.560	4.594	4.589	4.522	4.455	0.033	<0.001	0.033	<0.001
pH	3.94	3.96	3.97	3.99	3.94	3.93	0.012	0.059	0.012	<0.001
LA g/kgDM	21.01	28.56	22.51	23.18	25.22	23.69	1.378	<0.001	1.378	0.315
CP g/kgDM	81.39	87.58	80.7	84.72	83.64	81.3	0.635	<0.001	0.635	<0.001
Starch g/kgDM	334.8	318.2	321.9	317.6	326.0	331.3	3.65	<0.001	3.65	0.002
NDF g/kgDM	396.5	393.0	415.2	408.2	398.9	397.6	3.70	<0.001	3.70	0.011
ADF g/kgDM	269.5	251.9	283.5	296.8	265.1	270.0	3.51	<0.001	3.51	0.302
D-value	0.710	0.714	0.701	0.699	0.712	0.712	0.366	0.004	0.366	<0.001
ME MJ/kgDM	11.44	11.4	11.2	11.2	11.4	11.4	0.059	0.004	0.059	<0.001

Nutrient values quoted relate to NIRS prediction

Conclusion Clamp density at ensiling effects silage quality. At ensiling, fresh chopped maize should be consolidated to achieve an absolute minimum crop density of 600kgFW/m^3 to avoid spoilage and nutrient loss.

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The effect of autumn management on perennial ryegrass sward quality and morphology in spring

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Application Altering autumn management of a perennial ryegrass sward affects the sward quality for spring opening.

Introduction Grazed grass is the cheapest feed available to support milk production in a pasture-based system in Ireland (Dillon *et al*. 2005). An acknowledged herbage deficit in this pasture-based system can be seen in the commencement of spring calving and results in supplementation with more expensive feeds. Autumn closing date can have a large influence on herbage accumulation over winter and the following spring. However, Lawrence *et al*. (2017) has shown that earlier closed swards have a large decline in sward quality the following spring. The decline in sward quality can be a result of increased leaf senescence (Hennessy *et al*., 2008), due to higher levels of herbage mass (HM) resulting in increased shading compared to later closed swards (Lawrence *et al*., 2017; Hennessy *et al*., 2008) . The objective of this study was to investigate the effect of the closing treatment in autumn on the sward quality the following spring.

Material and methods A study was undertaken at Teagasc, Moorepark, Fermoy, Co. Cork Ireland from 5th October 2017 to 25th January 2018, with 3 autumn closing managements: Early (September 25th –November 9th), Normal (October 10th – November 24th) and Late (October 25th – December 9th) on a total of 48 paddocks. As a subset of 9 paddocks (n=3) were closed, three 1m transects were chosen at random and mature individual perennial ryegrass (PRG) tillers were identified at 10 cm intervals and marked using coloured wire. Over the measurement period leaf senescence rate tiller/day (LSR) was calculated by measuring the change in the length of the green leaf tissue in the two oldest leaves per tiller over the measurement period. Prior to grazing on all paddocks (n=48) leaf, stem and dead proportions were determined by cutting to ground level. A subsample of 40g (> 3.5 cm) was separated into leaf, stem and dead proportions, weighed and dried at 90°C for 16 hours to determine the DM. Sward quality was estimated using the in-vitro neutral detergent cellulase method to measure organic matter digestibility (OMD) prior defoliation on all paddocks. Data were analysed using PROC MIXED in SAS 9.4. Fixed terms were treatment and the random term was paddock.

Results The closing treatments had a significant effect ($P<0.05$) on the monthly senescence rates with greater overall senescence from paddock closing to the end of January in the earlier closed paddocks compared to later closed paddocks (6.6 and 1.52 ± 0.61 mm tiller^{-1} day^{-1} respectively). In the grazing horizon (> 3.5 cm), leaf proportion was significantly ($P<0.05$) affected by treatment; The early closed treatment had a lower leaf proportion compared to the late (0.71 and 0.76 ± 0.016, g/kg DM, respectively) with the normal intermediate to both (0.72 ± 0.016, g/kg DM). Treatment did not have a significant effect on dead and stem proportions in the grazing horizon. Treatment had a significant effect ($P<0.05$) on sward OMD. The late closed treatment had a greater OMD compared to the early closed treatment (847 and 831 ± 4.4 g/kg DM, respectively) with the normal intermediate to both (833± 4.4 g/kg DM).

Conclusion The differences observed in the above study show that autumn closing treatment in a paddock system affects sward quality by increasing the amount of senescent material in the earlier closed paddocks (September-November) compared to late closed paddocks (October- December) the following spring. The OMD and proportion of green leaf are also significantly decreased in earlier closed paddocks which contribute to an overall reduction in quality. Later closed paddocks may provide a better quality feed in spring through a better green leaf proportion and higher OMD than early closed paddocks. However, ensuring that sufficient grass availability in the following spring and sward quality must be considered in autumn closing management for spring calving production systems.

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Impact of biostimulants on ryegrass silage quality, aerobic stability and animal performance

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Application Novel microbial-derived commercial products can be applied to the forage to help mitigate the negative effects of biotic and abiotic stress that may decrease yield, alter nutritional quality and make them susceptible to pathogen attacks.

Introduction A range of plant and microbial derivatives are currently used as biostimulants. The most recent definition of biostimulants can be summarised as ''*a substance or microorganism that stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield''* (European Commission, 2018). The main objective of the current study was to assess the effect of biostimulant-treated ryegrass on silage quality, aerobic stability and ultimately, animal feed intake. In the present study, the commercial biostimulants used were SOIL-SET™ Aid (SE) and IMPRO-GRAIN™ (Plant biostimulant, PB), both provided by Alltech Inc. (Sarney, Dunboyne, Ireland). The initial hypothesis was that the biostimulant application in-field would alter the nutritional value and aerobic stability of the subsequent ryegrass silage based on the results of a previous field-study (Christou, 2017).

Material and methods Experimental treatments consisted of an untreated hybrid ryegrass (*Lolium x hybridum*) control; ryegrass treated with SOIL-SET™ Aid (SE); ryegrass treated with IMPRO-GRAIN™(PB); ryegrass treated with a combination of the two products (SE+PB). At the time of harvest, treated ryegrass was ensiled to produce 24 silage bales. Before opening, core samples from the middle and side of each bale were used for an aerobic stability test, while the rest of the bales were fed to Suffolk Cross-Charolaise lambs over a 30-day feeding trial. The 48 sheep were females only and their weight ranged from 26.0 to 36.6 kg. The sheep were allocated in 4 groups based on the treatments. The baled silage was offered to the sheep twice a day *ad libitum* with a new bale opened every 5 days (4 bales, one of each treatment/5 days). The sheep were weighed prior to a new bale opening and refusals weighed prior to offering new feed. Upon opening, the bales were processed through a straw chopper. All data were analysed with analysis of variance (ANOVA) using the 19th version of GenStat Software (VSNI). Significance level was set at 95% ($P<0.05$) with trend indicated at ($P<0.1$).

Results The silage parameters are shown in Table 1. Following ensiling, the fibre (NDF) content of the PB treated ryegrass was significantly lower than the other treatments. The predicted ME content of PB and combination treatment were significantly higher than the other treatments. There was a trend that PB treatment was more aerobically stable than the other treatments.

Table 1 Chemical parameters and aerobic stability of ryegrass silage along with daily DMI of sheep

Parameters	Control	SE	PB	SE+PB	SED	P
DM g kg^{-1} FM	^{a}210	^{ab}218	^{b}230	^{ab}218	4.7	0.007
NDF g kg^{-1} DM	^{b}544	^{ab}517	^{a}509	^{ab}531	11.8	0.038
ME MJ kg^{-1} DM	^{a}11.5	^{ab}11.7	^{b}11.8	^{b}11.9	0.10	0.010
Aerobic Stability h	94.9	116	138	111	15.31	0.092
Average DMI / day g kg^{-1} DM	0.690	0.750	0.820	0.700	0.072	0.253

Conclusion The results of the present study suggest that a biostimulant treated sward improved the DM, decreased the fibre content and increased the energy content of subsequent its silage. The decreased fibre content may have resulted in a more digestible product. However, the improved silage composition did not affect significantly the average daily dry matter intake during the feeding trial. There was also a positive trend of the biostimulant treatment towards improved aerobic stability.

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Effect of feeding chitosan with different levels of crude protein on nitrogen intake, digestibility and utilisation in beef heifers fed total mixed ration

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Application Nitrogen excretion from ruminants represents an important environmental concern. Supplementing cattle diets with chitosan increased faecal N excretion, whereas, increasing CP intake resulted in higher urinary N excretion.

Introduction Chitosan (*N*-acetyl-D-glucosamine polymer) is a natural biopolymer (Belanche *et al*., 2016), which is the second most abundant organic compound on earth next to cellulose, found in lower plants and some arthropods and crustaceans (Dias *et al*., 2017). Studies show chitosan has the potential to increase DM, CP digestibility and reduce faecal nitrogen (N) excretion while having no effect on DMI, N intake and urinary N excretion in ruminants (Araujo *et al*., 2015; Mingoti *et al*., 2016). Therefore, the objective of this study was to evaluate the effects of chitosan with different levels of dietary CP on N intake and digestibility and utilisation in beef heifers fed grass silage (GS).

Material and methods Eight ruminally cannulated Belgian Blue/Holstein Friesian cross heifers (752 ± 52Kg BW) were allocated one of four dietary treatments in a 2 x 2 factorial Latin Square design (n=8). Diets were offered as total mixed ration (TMR) consisting of GS plus concentrate. Chitosan was included at 10 g kg^{-1} DMI and diets were offered once daily *ad libitum*. Dietary treatments were as follows: high CP (16%) +/- chitosan supplementation (**HP+)** or (**HP-**) and low CP (12%) +/- chitosan supplementation (**LP+**) or (**LP-**). Experimental periods were 25d in duration (14 d for dietary adaptation and 10 d for sampling). Total feed intake, urine output and faecal output was weighed and recorded daily in each period, over five consecutive days for N balance (**NB**) determination. Data was analysed using Proc Mixed procedure in SAS. Significant differences were considered when $P<0.05$.

Results There was no interaction between protein level and chitosan supplementation ($P>0.10$). Chitosan had no effect on N intake, urinary N excretion and NUE ($P>0.10$). However, chitosan had a negative effect on DMD ($P<0.001$) which resulted in more N excreted in the faeces, 101.2 compared to 93.64 g d^{-1} ($P<0.05$) with higher levels partitioned to the faeces ($P<0.01$).

Table 1 Effect of chitosan with different levels of crude protein on nitrogen intake, digestibility and utilisation

	Treatment[1]					P-value		
	HP	LP	CHI+	CHI-	SEM	Protein	Chitosan	Interaction
DMD (%)	68.6	68.1	67.2	69.2	0.37	0.379	<0.001	0.787
N intake *(g d^{-1})*	325.9	262.1	293.0	294.9	5.16	<0.0001	0.800	0.760
N output (g d^{-1})								
Faecal N	96.9	97.8	101.2	93.6	1.96	0.748	<0.05	0.831
Urine N	162.9	110.0	136.1	136.8	6.09	<0.0001	0.940	0.428
N recovery[2]								
Faeces	0.298	0.371	0.349	0.320	0.0063	<0.0001	<0.01	0.833
Urine	0.504	0.421	0.463	0.462	0.0204	<0.01	0.976	0.298
NUE (%)	19.6	20.7	18.7	21.6	1.95	0.712	0.304	0.306

[1]CHI = chitosan inclusion +/-; [2]N recovery = N out [faeces (g/d)]/N intake (g/d) & N out [urine (g/d)]/N intake (g/d)

Conclusion Supplementing TMR diet fed to beef heifers with chitosan reduces DMD, resulting in more N partitioned to faecal excretion. However, reducing the CP intake in beef animals will result in reduced amounts of N excreted in the urine and the amount of N partitioned to the urine and faeces.

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Effect of a live yeast strain of *Saccharomyces cerevisiae* supplementation on growth, carcass yield and meat quality of finishing feedlot cattle

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Application Feedlot cattle supplemented with Levucell SC20® had a higher average daily gain and a lower feed conversion ratio in the early finishing period.

Introduction Yeast additives in ruminant diets are popular because they favour growth of beneficial bacterial populations by modifying the ruminal environment and hence increasing feed efficiency (Wagner *et al*., 2016). The aim of this study was to assess the effect of a live yeast strain of *Saccharomyces cerevisiae* CNCM I-1077 (Levucell SC20®), supplemented in the diet of finishing feedlot cattle, on their growth rate, feed conversion efficiency, carcass yield and meat quality.

Material and methods A total of 192 bulls of different breeds from 3 feedlots (64 bulls per farm) were stratified by bodyweight (BW) and breed and randomly allocated to two equal groups: Control (C) and Yeast (Y), with 8 replicates (pens) per treatment and 4 bulls per pen in each farm. The experimental period was 6 months with an acclimatization period of *ca.* 3 weeks. Y bulls were supplemented with 1/ton of a wheat middlings based premix containing Levucell SC20® and C bulls with a placebo premix without yeast. Bulls in both groups were offered *ad libitum* concentrate and wheat straw. Bulls were individually weighed on a 3-week interval up to slaughter to calculate average daily gain (ADG). Feed refusals were collected and weighed weekly on a pen basis and average individual daily feed consumption (DFC) and feed conversion ratio (FCR) were calculated. At slaughter, carcass weight and killing out percentage were obtained for the assessment of carcass yield. A meat sample was obtained from the 13th rib of the left hand side of each carcass. Samples were vacuum-packaged and after an ageing period of 1 week at 5 ^{o}C, tenderness, pH and colour were measured. Tenderness analysis was performed with Stable Micro Systems TA.HD plus Texture Analyser; pH with the Multi-parameter analyser C1020 and meat colour traits (lightness, redness and yellowness) were measured with Chroma-Meter (KONICA MINOLTA). The effect of treatment on BW, ADG, DFC and FCR was assessed with repeated measures mixed models (SPSS v.25) accounting for random effects of farm, pen and animal. An autoregressive covariance matrix produced the best fit. Carcass yield and meat quality traits between the experimental groups were compared with independent samples *t*-tests. Homoscedasticity was assessed with Levene's test.

Results Initial and final BW did not differ between C and Y bulls. The overall effect of treatment and treatment×time interaction on BW, ADG, DFC and FCR was non-significant across the study. However, compared with C bulls, Y ones had a significantly higher mean ADG and a significantly lower mean FCR during the first 42 days of the experimental period (Table 1). Carcass yield did not differ between animals in C and Y groups. There were any significant differences in meat quality traits measured on samples obtained from carcasses of the two groups of bulls.

Table 1 Bodyweight, growth rate and feed efficiency parameters of control and Levucell SC20® supplemented bulls

	Control bulls (*n*=96)		Yeast bulls (*n*=96)		*P*-value
	mean	sd	mean	sd	
Initial BW *kg*	407.6	39.0	405.3	38.4	n.s.
Final BW *kg*	647.3	48.1	656.7	49.4	n.s.
DFC *kg*	10.32	1.89	10.32	1.92	n.s.
ADG Overall *g*	1,528.4	252.2	1,554.0	278.5	n.s.
ADG First 42 days *g*	1,749.9	337.0	1,916.0	473.8	0.006
FCR Overall	6.89	1.72	6.75	1.46	n.s.
FCR First 42 days	5.76	1.42	5.28	1.82	0.047

Conclusion The supplementation of Levucell SC20® resulted in better feed conversion efficiency and higher growth rates in the first 42 days of the finishing period; thus optimizing the transition of growing cattle to a high-concentrate diet.

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Intake, feed efficiency and growth-related performance of suckler-bred Charolais and Holstein-Friesian steers offered grass silage

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Application Holstein-Friesian (HF) steers consumed proportionately 0.31 more grass silage relative to weight than suckler-bred Charolais (CH) steers.

Introduction Due to the abolition of milk quotas in the European Union, the subsequent expansion of the Irish dairy herd has meant that proportionately more beef is derived from dairy-bred compared to suckler-bred animals. Feed efficient cattle are central to the economic and environmental sustainability of beef production enterprises (Kenny *et al.*, 2018). Grass silage is an inherent part of seasonal grass-based beef systems; there is increasing interest in developing beef production systems based on only high-nutritive value grass, either grazed or conserved (Regan *et al.*, 2018). The objective of this study was to evaluate the intake, feed efficiency and growth-related traits of CH and HF steers offered grass silage.

Material and methods Three-quarter bred or greater CH (n=94) and HF (n=91) spring-born steers sourced directly from commercial Irish farms were used. Prior to commencing the experiment they were adapted to and offered a high-concentrate diet for 95 days (McGee *et al.*, 2019). Steers were housed indoors in two slatted floor sheds balanced for breed. Following a dietary adaption period of 21 days, they were individually offered first-harvest, precision chop grass silage (DM, 290 g/kg; dry matter digestibility, 700g/kg) *ad libitum* for 70 days. A mineral-vitamin supplement was offered daily. Individual dry matter intake (DMI) was recorded each day. Animals were weighed on consecutive days at the beginning and end of the experiment and at 14 d intervals throughout. Average daily live weight gain (ADG) of each steer was computed as the coefficient of the linear regression of live weight on time (days). Ultrasonic fat and muscle depths and, skeletal measures were determined at the beginning and end of the experiment. Blood samples were obtained pre-feeding on two occasions and a rumen fluid (stomach tube) sample was obtained 2-4 hours post-feeding on one occasion during the study. Data were statistically analysed using the GLM procedure of SAS; the model contained the fixed effect of breed and shed.

Results The HF steers were 25 days older (373 vs. 398 days, $P < 0.001$) than CH, which reflects the mean calving dates of the national dairy and beef cow herds in Ireland. Despite their older age, HF steers were 83 kg lighter (mid-test, 414 vs. 497 kg, $P<0.001$) than CH, but had greater ($P<0.01$) ADG and a higher ($P<0.001$) DMI on an absolute basis and relative to live weight. Ultrasonically-assessed muscle depth (64.4 vs. 42.5 mm, $P<0.001$) and rib fat thickness (3.06 vs. 2.83 mm, $P<0.001$) were lower, and loin fat (2.82 vs. 2.96 mm, $P<0.05$) thickness was greater for HF compared to CH; rump fat thickness did not differ ($P>0.05$) between the breed types. The HF were taller, narrower and had deeper chests ($P<0.001$) than CH, but the breed types did not differ ($P>0.05$) in back length and chest circumference. Compared to HF, concentrations of blood creatinine and albumin were higher ($P<0.001$) for CH. Rumen pH did not differ (6.81 vs. 6.81, $P>0.05$) between the breed types.

Table 1 Dry matter intake (DMI), daily live weight gain and feed conversion efficiency (FCE) of Charolais and Holstein-Friesian steers offered grass silage

		Charolais	Holstein-Friesian	s.e.m.	P-value
Total DMI	(kg)	6.50	7.04	0.061	<0.0001
	(g/kg live weight)	13.1	17.1	0.12	<0.0001
Initial live weight (kg)		484	401	4.2	<0.0001
Final live weight (kg)		510	430	4.1	<0.0001
Daily live weight gain (kg)		0.424	0.495	0.0178	0.005
FCE (kg live weight/kg DMI)		0.065	0.071	0.0026	0.12

Conclusion Under the conditions of this experiment, the 0.17 lighter HF steers consumed 0.08 and 0.31 more silage on an absolute basis and relative to weight, respectively, but they had a higher ADG, than CH. The higher ADG of HF compared to CH is likely attributed to compensatory growth.

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Effect of low moisture feed block supplementation on the rumen microbial fermentation of hay: *in-vitro*

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Application Low moisture feed blocks (LMFB) are a popular supplement for extensively managed grazing ruminants, however little is known about their effect on microbial fermentation of forage in the rumen.

Introduction LMFB provide an additional source of nutrition to forage based diets when the nutritional quality of forage is insufficient. Research has shown supplementing grazing ruminants with LMFB to increase forage intake and have positive effects on animal performance compared to control animals (Cabiddu, *et al*. 2014, Greenwood, *et al*. 2000 and Titgemeyer, *et al*. 2004). It is thought LMFB positively affect the rumen microbial population increasing fibre fermentation. This study investigates the effect of supplementing hay with the commercial LMFB, Crystalyx® Extra High Energy.

Material and methods *In-vitro* gas production was measured over 24 hours to investigate the effect of supplementing hay (1.5 g DM) with Crystalyx® (108 mg) on fermentation and the solid associated microbial population (SAP) at 4 and 24 hours. Rumen fluid was collected from 4 sheep and used to inoculate 96 bottles with buffer solution at 1:10 ratio. Pressure from the bottle headspace was measured at 0, 1, 2, 4, 6, 8 and 24 hours to determine cumulative gas volume and fitted to the exponential model $Y= a + b(1–e^{(-ct)})$ (Ørskov and McDonald 1979). VFA and ammonia concentrations were measured from inoculum along with pH. RNA was extracted from residual forage, reverse transcribed and microbial abundance of total bacteria, methanogens, anaerobic fungi and protozoa quantified via q-PCR. Data was analysed via two-way ANOVA with blocking for individual sheep.

Results Supplementing hay with Crystalyx® had tendency for greater gas production, however in the absence of substrate supplementation had no effect on gas production (Figure.1 and Table.1). Supplementation increased total molar concentration of volatile fatty acids ($p<0.05$), in particular acetate ($p<0.05$). There was no effect of supplementation on molar concentration of ammonia. Supplementation had no effect on the microbial abundance of the SAP.

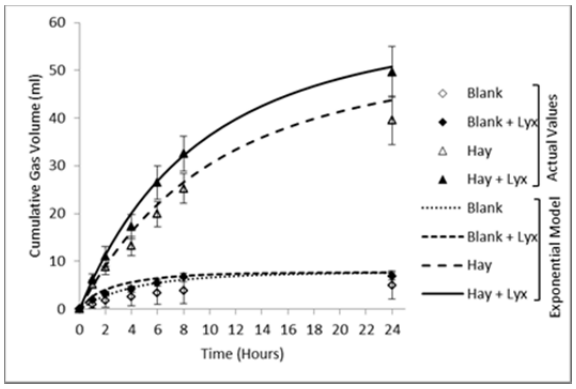

Figure 1 Cumulative Gas Volume

Table 1 Cumulative Gas Volume (ml) for Blank (B), Blank + Crystalyx® (B+C), Hay (H) and Hay + Crystalyx® (H+C) at 4 and 24 Hours

Treatment	B		B+C					
Time	4	24	4	24	s.e.d.	Treatment	Time	TxT
Cumulative Gas Volume (ml)	3.0	4.1	6.4	6.9	1.12	0.506	0.029	0.792
Treatment	H		H+C					
Time	4	24	4	24	s.e.d.	Treatment	Time	TxT
Cumulative Gas Volume (ml)	13.2	39.5	17.2	49.6	3.14	0.052	<0.001	0.357

Conclusion Crystalyx® enhanced the fermentation potential of the forage. Crystalyx® had no effect on the abundance of the solid associated microbial population, suggesting Crystalyx® stimulates microbial activity resulting in greater fermentation of forage.

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Nutritional evaluation of *Enterolobium cyclocarpum* plant parts as supplementary feed in ruminant production system

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Application *Enterolobium cyclocarpum* leaves, seeds, pods and stem bark has nutritional potentials as dry season feed supplements in ruminant production system.

Introduction Tropical trees and shrubs have received increasing attention in recent times, due to great potentials as feed resources in ruminant production. They serve as good quality green fodder and are associated with features such as abundance, accessibility, protein content and quality in terms of available energy, minerals and vitamins (Habib *et al.,* 2013). *Enterolobium cyclocarpum* is a tropical tree legume that is easily established and grows to maturity over a short period of time. They produce seeds, pods and whole fruit which if well harnessed can serve as a potential supplement in ruminant feeding. This study therefore aims to evaluate the nutritional properties of *Enterolobium cyclocarpum* plant parts as supplementary feedstuff in ruminant production system.

Material and methods Fresh matured leaves, seeds, pods and stem bark of *Enterolobium cyclocarpum* were harvested from different trees within the campus of the Federal University of Agriculture, Abeokuta, Nigeria. Samples for chemical and phytochemical analysis were ground using a hammer mill, sieved and analyzed for proximate composition according to the procedure of AOAC (2000). Crude protein was determined by Kjeldahl method. The fibre fraction namely neutral detergent fibre, acid detergent fibre and acid detergent lignin were determined with the procedure of Van Soest *et al,* (1991). Phytochemical screening was carried out following the methods described by Trease and Evans (1989). Data obtained were analysed using the analysis of variance (SAS, 2000) in a completely randomized design and means separated using Duncan's Multiple Range Test in the same package.

Results Significant differences ($p<0.05$) were observed in chemical composition of different plant parts of *Enterolobium cyclocarpum* (Table 1). Dry matter (DM) values ranged from 81.50% in the pod to 92.75% in the leaf. crude protein concentration of the plant parts varied between 12.84% to 16.74%. Variations were also observed across phytochemical constituents and followed similar trend with the stem bark and seeds recording the highest ($p<0.05$) and lowest contents, respectively.

Table 1 Chemical and phytochemical composition of *Enterolobium cyclocarpum* plant parts

Parameters	Plant Parts			
	Seed	Leaf	Pod	Stem bark
Dry matter	83.75±1.22^{b}	92.75±1.44^{a}	81.50±1.31^{b}	92.00±1.40^{a}
Crude protein	16.74± 0.38^{a}	15.14±0.30^{b}	14.48±0.29^{c}	12.84±0.36^{d}
Neutral detergent fibre	58.00±0.87^{a}	53.50±0.72^{b}	54.00±0.81^{b}	60.50±0.85^{a}
Acid detergent fibre	30.50±0.71^{b}	30.00± 0.69^{b}	31.00±0.73^{a}	36.00±0.71^{a}
Acid detergent lignin	7.01±0.37^{b}	7.23±0.35^{b}	9.01±0.45^{a}	9.40±0.41^{a}
Phytochemical constituents				
Oxalate	0.09±0.01^{c}	0.05±0.01^{d}	0.17±0.01^{b}	0.31±0.03^{a}
Tannin	0.99±0.27^{c}	0.60±0.22^{d}	2.13±0.31^{b}	3.44±0.34^{a}
Saponin	0.53±0.10^{d}	1.90±0.12^{a}	1.05±0.12^{b}	0.60±0.11^{c}
Phytate	0.51±0.08^{c}	0.34±0.06^{c}	1.00±0.07^{b}	1.30±1.01^{a}

^{abcd} Means in the same row with different superscripts are significantly different ($P<0.05$)

Conclusion *Enterolobium cyclocarpum* leaves, seeds, pods and stem bark contains appreciable nutrients that could be exploited as a potential supplementary dry season feed for ruminants especially in the tropics.

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Interaction of intestinal microbiome, health and nutrition for finfish production

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Introduction Aquaculture is globally one of the fastest growing food sectors and is expected to continue to expand substantially over the next 30 years. At present greater than 50% fish and shell fish consumed is derived from aquaculture worldwide. Within the UK the predominant species for fish farming is Atlantic salmon with production of ~170 - 180,000 tonnes per annum. The expansion of the industry has been constrained by a number of factors including fish health issues, licencing for new sites to increase tonnage and international competition. To help identify the research requirements that are required for improved and sustainable production UKRI (BBSRC and NERC) have jointly funded a 5 year aquaculture initiative program. A key component of this has been the generation of an aquaculture Network to develop academic, industrial and governmental interactions and define key priority areas for research. The Aquaculture Research Collaborative Hub (ARCH-UK) is composed of eight working groups including covering finfish and shellfish production and also other aspects including aquaculture related to human health, economics and environment. Full details of the ARCH UK can be found at https://www.aquaculturehub-uk.com/. Each of the working group organizes events mainly in the way of focussed workshops. An area with increasing research interest in the role of microbiomes in fish and shellfish health and aquaculture performance. This presentation will address several aspects of research being carried out intestinal health and microbiota in salmon, including nutrition and environmental rearing parameters that can impact microbiota.
Nutrition is the single largest cost in salmon aquaculture and the diets salmon are fed have changed dramatically in the last 20 years. The natural salmon diet is wild marine animals rich in marine proteins and oils, which was used during the early days of fish farming, however with the global expansion of aquaculture wild sourced fish meal and oil can no longer meet the demand. Diets have been developed that are rich in plant proteins and vegetable oils, however such changes can impact of the intestine of the fish due to co purification of antinutritional factors that have in the past been shown to induce inflammation (Krol *et al* 2015). Much research has been devoted to designing processing plant proteins that can be successfully used in salmon aquaculture. However, the relationship between microbial communities and intestinal health is only now being started to be studied. Part of this work also includes understanding how the microbiota change during different rearing conditions, to gain baseline information and understand species compositions and levels of diversity. Other research that will be presented includes the changes that occur during the parr-smolt transformation (Dehler *et al* 2017a&b), which is when salmon move from freshwater to salt water. During this life history event the fish are exposed to new microbial communities and also major changes in the chemistry of the intestinal lumen.
Other mucosal surfaces including skin and gill are also areas of current interest in relation to microbiome communities. Future work may involve manipulation of these microbial systems to improve health management and production.

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Dietary utilization of soybean meal and rapeseed meal for Zebrafish (*Danio rerio*)

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Application Soybean meal (SBM) and rapeseed meal (RSM) diets can replace fishmeal (FM) diets for zebrafish and other finfish to reduce cost and promote sustainability of aquaculture production.

Introduction There have been significant research efforts at improving dietary composition of feeds and maximising fish growth for sustainable aquaculture. This is achieved by identifying sustainable source of ingredients in order to reduce dependency on highly competitive and expensive fish by-products. The aim of the present study was to compare the acceptability and effect of SBM and RSM based diets with a commercial FM based diet, on growth and body composition through repeated but non-invasive measurements on zebrafish.

Material and methods The study was carried out under the approval of the Newcastle University's Animal Welfare Ethics Board (AWERB –ID 401). Two iso- nitrogenous (47% crude protein) and iso-calorific (11.8 MJ DE/kg) experimental diets were formulated and compared with a commercial diet for zebra fish This study was conducted according to a 3 x 2 factorial arrangement involving three diets at two stocking densities. The fish were fed three times daily for a period of eight weeks. Morphometric measurements, water quality and feed allowances were determined on weekly basis. After the experiment, fish were euthanized using tricaine methanesulphonate MS-222 (Sigma Aldrich) buffered to neutral pH with $NaHCO_3$ following Schedule 1 (Animal Scientific Procedures Act 1986). The euthanized fish were frozen at -20^{o}C and later freeze dried until processed for various chemical analysis. The length weight relationship, condition factor and growth parameters of the fish were determined. Samples of feeds and fish were analysed for proximate (AOAC 2000), minerals and fatty acids compositions. The minerals were analysed by using ICP-OES technology (Vista – MPX CCD Simultaneous ICP – OES, USA) following acid digestion while the fatty acid methyl esters were analysed by GC-MS (Agilent 5975C MSD, USA) after fat extraction (using modified method of Folch *et al*.,1957), methylation and esterification. Data were analysed using ANOVA and GLM. Tukey's *post-hoc* test was used to compare means to observe significance at $p < 0.05$.

Results The crude protein, nitrogen free extract and ash contents on dry matter basis were not different ($p<0.05$) for the fish fed any of these diets (Table 1). However, the ether extract of the fish fed SBM diet was lower compared to the others. Mean live-weight gain (WG), food conversion ratio (FCR) and protein intakes (PI) were higher ($p<0.05$) in the fish fed the commercial diet than the other diets. No differences were observed in the specific growth rate (SGR) food intake (FI) and protein efficiency ratio (PER) among the fish fed the three diets. Palmitic (C16), oleic and linoleic acids (C18:1n9) were prominent in all the fish. The total saturated and omega-6 fatty acids were highest in fish fed commercial diet (34.25 ±0.75, 14.57 ± 0.13 %) compared to the other diets. This is a reflection of the impact of the diets on the fish, however, there was no significant differences observed in the PUFA and Omega-3 fatty acids in the fish muscle's fed different diets. The Ca, K, Mg, Na and P contents were more prominent in all the fish, with Na found to be highest ($p<0.05$) in fish fed RSM diet (31.220 ± 3.63 mg/l) than those fed commercial diet (21.510 ± 2.81 mg/l) and SBM diet (22.380 ± 1.24 mg/l) respectively.

Table 1 Mean ± SE of the proximate composition, growth performance of zebrafish fed various diets

	Proximate composition (%)					Growth performance					
Parameters	DM	CP	EE	Ash	NFE	WG (g)	SGR(%)	FCR	FI (g)	PI (g)	PER
FFMD	25.92 ± 1.8	13.775 ± 0.99	8.464 ± 0.61^{a}	1.092 ± 0.32	3.054 ± 0.31	0.215 ± 0.01^{a}	1.027 ± 0.15	0.170 ± 0.12^{a}	1.396 ± 0.59	1.449 ± 0.11^{a}	0.218 ± 0.09
FSBMD	23.05 ± 1.66	13.157 ± 0.98	5.679 ± 0.50^{b}	1.203 ± 0.28	3.042 ± 0.28	0.120 ± 0.13^{b}	0.849 ± 0.10	0.118 ± 0.01^{b}	1.091 ± 0.21	1.081 ± 0.08^{b}	0.119 ± 0.02
FRSMD	26.53 ± 1.36	14.496 ± 0.76	7.345 ± 0.60^{a}	1.605 ± 0.22	2.949 ± 0.42	0.120 ± 0.02^{b}	0.788 ± 0.14	0.105 ± 0.01^{b}	1.137 ± 0.30	0.919 ± 0.09^{b}	0.143 ±0.03

Note: FFMD; fish fed fish meal commercial diet, FSBMD; fish fed SBM diet and FRSMD; fish fed RSM diet

Conclusion No adverse effects of the SBM or RSM based diets on fish in terms of the survival rates (>95%), chemical composition and growth were observed. The effect of the diet x stocking density on the growth and performance of the fish was not significant. Based on the results, the study showed that both SBM and RSM diets can potentially replace FM based commercial diet for zebra fish.

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Galacto-oligosaccharides: an investigation into dietary inclusion levels for rainbow trout (*Oncorhynchus mykiss*) for improved gut histomorphology

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Application The addition of galacto-oligosaccharides to diets for rainbow trout may help improve gut health by ameliorating the loss of supranuclear vacuolated surface area associated with the development of dietary induced enteritis.

Introduction Enhancing gut health through the optimisation of plant based diets for salmonid fish is a key factor in improving production performance. High inclusion of plant based materials in feeds is known to induce enteritis, resulting in morphological alterations to the structure of the mucosal fold, leading to loss of supranuclear vacuolated surface area (Urán *et al*., 2008). Galacto-oligosaccharides (GOS) confer prebiotic and direct health benefits in a range of species, including improved carcass characteristics and positive changes to the mucosal layer in salmonid fish (Hoseinifar *et al*., 2008; Miles *et al*., 2018). The aim of the present study was to evaluate the effects of gradient levels of dietary GOS inclusion on gut histomorphology of rainbow trout (*O.mykiss*), in balanced feed formulations.

Material and methods Experimental procedures were approved by Harper Adams University Research Ethics Committee. One thousand and two hundred juvenile rainbow trout (mean weight 19.53±0.75 g) were randomly assigned to one of four dietary treatments (in triplicate tanks) as detailed by Miles *et al*. (2018). Briefly, diets contained either 0.00 % (Control), 0.88 %, 1.75 % or 3.50 % of a commercial GOS product (Nutrabiotic®, Dairy Crest Limited). Hindgut samples were obtained from three fish per tank and fixed in 10 % neutral buffered formalin for histological analysis at weeks nine and 12 of the experiment. Fixed tissue samples were sectioned to 5 µm thick and one slide stained with Alcian blue/periodic acid–Schiff and a second section stained with haemotoxylin and eosin. Morphometric analyses were performed using opticial microscopy (Olympus CX31, equipped with an Olympus V-CMAD3 digital camera running Infinity Analyse software) and measurements were normalised to the diameter of the gut following the method of Dimitroglou *et al*. (2009) to assess absorptive surface area via internal circumference: outer circumference and surface length to outer diameter. Mucosal fold condition scoring (1-5 scale) was used to evaluate the status of the supranuclear vacuolated surface area and lamina propria in the method of Urán *et al*. (2008). Data were analysed by one-way analysis of variance blocked by sampling week in GenStat (18th edition), followed by Tukey test where significance (p=<0.05) was indicated.

Results Condition score was significantly (p<0.001) improved with the addition of GOS product irrespective of level, compared to the negative control (Table 1), whereby a higher score indicates an increasing loss of supranuclear vacuolated surface area. The addition of GOS tended (p=0.08) to reduce surface length: outer diameter but did not significantly (p=0.43) affect the absorptive surface via internal circumference: outer circumference that would indicate a greater mucosal fold surface length and/or number of mucosal folds within the lumen.

Table 1 Effects of increasing dietary GOS product on the hindgut histomorphology of rainbow trout (O. mykiss)

Metric	Control	GOS 0.88 %	GOS 1.75 %	GOS 3.50 %	SEM	p-value
Internal Circumference: Outer Circumference	4.50	4.23	4.10	4.46	0.198	0.427
Condition Score	2.21^{a}	1.48^{b}	1.58^{b}	1.50^{b}	0.1144	<0.001
Surface length: outer diameter	0.46	0.40	0.40	0.38	0.022	0.077

Superscripts within the same row are significantly different (p<0.05); SEM=pooled standard error of the mean

Conclusion The addition of GOS to diets for rainbow trout may help ameliorate the loss of supranuclear vacuolated surface area associated with the development of dietary induced enteritis. Further investigation is needed to fully assess the effects of GOS on gut health, including mucosal production and microbiome diversity.

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Optimising gene flow between parallel year groups to improve genomic prediction in Atlantic salmon breeding programmes

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Application Optimising gene flow between parallel breeding lines can improve the accuracy of genomic prediction, increase genetic variation within lines and enhance consistency between lines in Atlantic salmon breeding programmes**.**

Introduction Because of the reproductive biology of Atlantic salmon, farmed populations typically follow a breeding programme characterised by discrete generations with interval of three or four years. This results in the formation of up to four independent parallel lines within a breeding programme. Genomic selection (GS) allows simultaneous use of the information from parallel lines thereby increasing the size of the reference population. Even if all lines have a common origin and selection objective, their reproductive isolation could result in genetic differentiation, reducing the between line genetic relatedness. This could affect the accuracy of prediction, as selection candidates would be only distantly related to a large part of the reference population. Thus, GS might need to be implemented within each parallel line, leading to smaller reference populations and lower selection accuracy. Moving breeding fish from one line to another ('mixing') to connect the lines could improve GS accuracy. The aim of this study was to investigate the impact of various mixing strategies on the accuracy of prediction from genomic evaluation across lines.

Material and methods The effect of mixing between lines was tested by simulation. Simulation analysis were performed using in-house developed software. A salmon population was simulated assuming four parallel lines (500 fish/line) derived from a common ancestral population. One line reproduced each year in a rotational manner, so each line produced offspring every four years. In a given year, the next generation for a given line was created by randomly selecting four year old candidate parents from that line plus a proportion (from 0.0 to 0.5) of three year old candidate parents from a parallel line (100 parents in total for each line). Each selected candidate has two randomly assigned mates to produce two full sib families of equal size. Ten discrete generations were created by line. The genetic distance between individuals (within and across -consecutive and non-consecutive- lines) was calculated at each generation to study the impact of the mixing rate on genetic differentiation between lines. The accuracy of the breeding values from genomic evaluation was explored under three different scenarios: a) using only animals of the same population (within), b) using animals of one population to predict another population (between), and c) jointly using all the populations to predict a single population (combined). The relationship between the accuracy and degree of genetic distance between lines was quantified to determine the optimum mixing strategy to improve genetic prediction in farmed salmon.

Results With no mixing the genetic distance increased between populations and the genetic variation within population decreased (Figure 1C). There was no increase of accuracy by combining data across populations (Figure 1A). Even a small percentage of mixing decreased the genetic distance between populations and increased the genetic variation within population (Figure 1D). The higher the percentage of mixing the faster the lines became similar. The accuracy of prediction climbed as the percentage of mixing increased (Figure 1B). The increase in accuracy from the combined evaluation approach compared to the within evaluation approach was greater with an increased percentage of mixing (not shown).

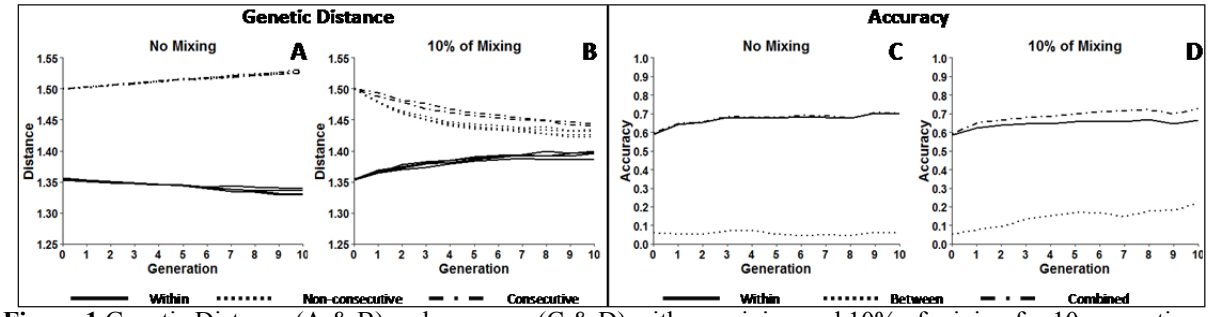

Figure 1 Genetic Distance (A & B) and accuracy (C & D) with no mixing and 10% of mixing for 10 generations.

Conclusion The commercial breeding cycle of salmon imposes a four year generation interval with four parallel breeding populations. If there is no gene flow between populations the lines drift apart and there is no value in combining information across populations for genomic breeding value prediction. Only a small amount of mixing between lines brings the lines closer together and facilitates the use of information across lines to improve breeding value prediction. Thus optimising gene flow between lines should be an integral part of salmon breeding programme design.

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The comparison of models of using chest girth to estimate live weight of Adilo, Horro and Bonga sheep in Ethiopia

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Application Live weight (LW) of Ethiopian sheep were accurately predicted using heart girth (HG) by simple linear models with transformed LW for production and marketing purposes.

Introduction A simple method of estimating sheep LW in Ethiopia is using linear models based on HG. These models were recommended based on R^2 value with no attention to residuals. Thus, it is not a surprise that these models are reported inaccurate by stakeholders. Therefore, this study aims to develop robust predictive equations to estimate LW in various sheep breeds and to validate published and recommended models of the respective sheep breeds that are currently in use.

Material and methods Live weight and HG of 310 heads of Adilo (4-144 months), 310 of Bonga (6-86 months) and 400 of Horro (4-96 months) breeds were recorded. The study did not contain any sick or pregnant sheep. All sheep were fed mainly on natural pasture and straws. The predictability of simple linear, simple linear with LW transformed, quadratic and allometeric models wasevaluated using R^2, the root mean square prediction error to standard deviation ratio (RSR), mean bias (MB), slope bias (SB) and the concordance correlation coefficient (CCC). The models with a prediction error (PE) ≤10, which is the accepted margin of error for production and marketing purposes (Goopy *et al.* 2017), were recommended. Three published models, generated using the same sheep populations of this study, were fitted to the data of this study.

Results Live weight (kg) of sheep was 16-60 in Adilo, 15-58 in Bonga and 15-44 in Horro. All published models had poor predictability (PE >20). All constructed models had satisfactory R^2 (>~0.6), RSR (<0.66), MB (<0.001), SB (<0.001) and CCC (>0.723). However, simple linear, quadratic and allometeric models had PE >10 and only simple linear models with transformed LW had PE ≤10.

Table 1 Performance of constructed and published models in predicting LW of Ethiopian sheep

Breed	Model	R^2	RSR	MB	SB	CCC	95th percentile PE
Adilo	Log(LW)= 0.408 + 0.015*HG	0.82	0.425	<0.001	<0.001	0.749	6.3
	Published models						
	Taye *et al.* 2016						21.2
	Berhe 2017						33.2
	Tadesse and Gebremariam 2010						32.5
Bonga	Log(LW)= -36.6 + 0.882*HG	0.59	0.632	<0.001	<0.001	0.723	7.27
	Published models						
	Edea *et al.* 2008						53.9
	Berhe 2017						23.6
	Tadesse and Gebremariam 2010						24.1
Horro	$LW^{0.5}$= -1.26 + 0.085*HG	0.81	0.435	<0.001	<0.001	0.881	10.1
	Published models						
	Edea *et al.* 2008						45.3
	Berhe 2017						25.4
	Tadesse and Gebremariam 2010						25.6

Conclusion The models produced in this study predicted LW of Adilo, Bonga and Horro sheep, using HG with PE less than 10 regardless of age and sex. Thus, these models can be used to estimate LW of these sheep for production and marketing purposes.

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Active dry yeast (*Saccharomyces cerevisiae*) supplementation boosts performance of growing lambs

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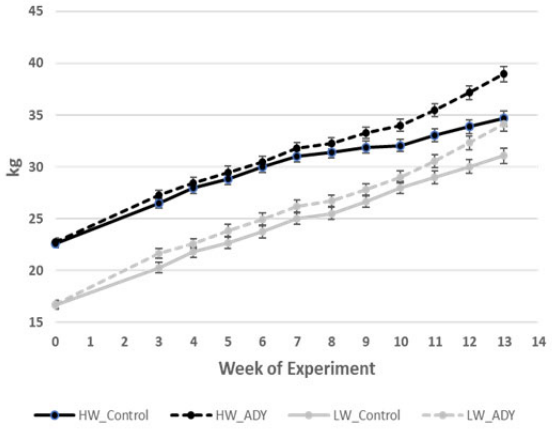
Application Supplementing growing lambs with a novel probiotic product (live yeast) has the potential to improve animal productivity and economical return.

Introduction Growing ruminant animals face numerous dietary challenges that can impair both their health and productivity. Dietary supplementation of active dry yeast (ADY) has been shown to mitigate such conditions in dairy (AlZahal *et al*., 2014) and beef cattle (Ovinge *et al*., 2018). However, information on the effect of ADY on the productivity of lambs is scarce. Growing lambs are often challenged with rapid dietary changes during the weaning process and, under some rearing systems, are often fed rations lacking in effective fibre; which in turn may predispose them to acute or subacute ruminal acidosis. The objective of this study was to evaluate the impact of a novel ADY on productivity of lambs under commercial conditions.

Material and methods One hundred and sixty-eight Assaf female lambs were blocked by live body weight (BW) into either light BW (LW, 16.7 ± 2.4 kg; ± STD) or heavy BW (HW, 22.7 ± 2.7 kg) blocks; then randomly assigned into one of two treatments, ADY (6 x10^9 colony forming unit/head/day; AB Vista, Marlborough, UK) or control. The lambs were housed in a shed on wood shavings bedding in a total of 4 groups with full access to feed bunks and water. The lambs were acclimatised for two weeks and followed by a 13 week period of testing period from March to June. Lambs were offered *ad libitum* alfalfa haylage and a fixed amount of concentrate mixture twice daily for the entire trial (maize and barley grains, sunflower expeller, vitamins and minerals; on average 0.473 and 0.595 kg/d for LW and HW, respectively). Rations were formulated to support an average daily gain (ADG) of approximately 0.180 kg per day. Diets contained 13.5% crude protein (CP) and 0.94 UFV/kg on dry matter (DM) basis. The treated animals received 10 g/head/day of wheat middlings containing 0.3 g of ADY. The control animals received 10 g/day of wheat middlings only. Individual BW of lambs were recorded weekly throughout the study. Offered feed intake for each group and amount of refusals were recorded once every week. Refusals contained 38% DM and 7% CP on DM basis. Weekly BW data and overall gain at Week 13 were analysed using the mixed model of SAS (9.4, SAS Inc.) using the fixed effects of treatment, block, and their interaction.
Group intake for each treatment by block was divided by final BW for each group to provide information about the level of feed conversion ratio.



Results Initial BW of lambs (Week 0) were not different (P = 0.84) between treatments. There was no interaction between treatment and block for any of the measured variables (P > 0.05). Lambs supplemented with ADY achieved a heavier BW by the end of the study (36.6 vs. 32.9 ± 0.5 kg, P < 0.001). Lambs in the HW block reached 39.0 and 34.2 ± 0.7 kg compared with 34.7 and 31.1 ± 0.7 kg of BW for the LW group (P < 0.001) for ADY and control; respectively (Figure 1). Average daily gain was greater for ADY supplemented lambs compared with control (main effect, 0.185 vs. 0.145 ± 0.005 kg/d, P < 0.001) and greater for LW compared HW (main effect, 0.175 vs. 0.155 ± 0.005 kg/d, P = 0.005). The overall daily dry matter intake achieved in this study was 1.33 and 1.30 kg/d for HW and 1.05 and 1.02 kg/d for the LW group for ADY and control, respectively. The corresponding feed conversion ratios were 6.7, 8.8, 4.9, and 5.8; respectively.

Figure 1 Average weekly body weight of lambs during the experimental period. HW= heavy body weigh block. LW=light body weight block. ADY= active dry yeast.

Conclusion Supplementing growing lambs with active dry yeast improved average daily gain and final body weight, and may have the potential to improved production efficiency.

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Effects of dietary replacement of maize with graded levels of melon husk on the performance of growing rabbits

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Application Rabbits fed diets containing 20% melon husk diets had better performance and nutrient digestibility. This can be exploited as an alternative feedstuff to rising cost of conventional feeds in rabbit production.

Introduction The source for non-conventional and cheaper feed resources by nutritionist as a substitute to reduce the high cost of conventional feed resources for livestock is now been advocated. Melon is a widely cultivated plant in Nigeria because of the seeds used as condiments in stew and soup. After harvesting, husks of melon are usually discarded or burnt after removal of the melon seeds (Ogbe and George, 2012). Harnessing crop residues such as melon husks which is not directly utilizable by man, can however, be a potential feed source in reducing feed cost in rabbit production. Therefore, this study aimed to investigate into the effects of dietary replacement of maize with graded levels of melon husk on the performance of growing rabbits.

Material and methods Twenty-four (24) Chinchilla mixed breed rabbits aged eight weeks with average initial live weight of 570g were randomly divided into three groups of eight rabbits. Each treatment was replicated four times with two rabbits per replicate based on weight equalization. The test ingredients; melon husk (MH) was sun dried, milled and included at 0%, 10% and 20% inclusion levels (DM basis) as a replacement to maize in rabbits' diets (g/kg) containing wheat offal 325, soya bean meal 160, bone meal 30, oyster shell 20, fish meal 10, premix and common salt at 2.5 fedat l00g per animal. Diets were weighed and offered on a daily basis, with the daily refusals collected to determine the intake. Rabbits were weighed at weekly intervals to determine weight changes and digestibility trials were carried out on the eighth week of the experiment. Samples of MH, experimental diet and pooled faeces samples were analyzed for proximate composition (AOAC, 1995). Data collected were analyzed using one-way analysis of variance (SAS, 1999) and significant means separated using the Duncan multiple range test in the same package.

Results Feed intake declined with the level of MH inclusion in the diet with no variation ($P>0.05$) observed in daily feed intake of rabbits fed MH diets (Table 1). The average weight gain (g/day) ranged from 10.70 to 12.14 and varied ($P<0.05$) across treatments. Weight gains in rabbits on the control treatment ranked the same ($P>0.05$) with rabbits on 20%MH. The least value (10.70) was recorded in rabbits fed 10%MH. Feed conversion ratio was best ($P<0.05$) in rabbits fed 20%MH. Significant ($P<0.05$) differences were observed on the dry matter (DM) and crude protein (CP) digestibility in rabbits fed the experimental diets. DM and CP digestibility increased ($P<0.05$) with increasing level of MH in the experimental diets.

Table 1 Performance and nutrient digestibility in growing rabbits fed melon husk-based diets

Parameters	0% MH	10% MH	20% MH	SEM
Feed intake/rabbit (g/d)	86.82 [a]	80.96[b]	80.39[b]	0.180
Initial weight (g)	570.00	568.00	571.00	0.764
Final weight (g)	1250.00	1168.00	1206.00	3.550
Average weight gain (g/d)	12.14[a]	10.70[b]	11.34[ab]	0.473
Feed conversion ratio	7.15[b]	7.56[a]	7.09[b]	0.351
Nutrient Digestibility (g/kg)				
Dry matter	756.53[a]	731.32[b]	760.50[a]	0.402
Crude protein	664.51[a]	638.91[b]	663.23[a]	0.381
Crude fibre	774.20[b]	790.34[ab]	794.62[a]	0.541

[abc] *means on the same row with different superscript are significantly different ($P<0.05$)*

Conclusion The improved performance of rabbits fed diets containing 20% melon husk diets in this study indicates its potential to help increase performance in rabbit production. This can be exploited as alternative source of feed in improving rabbit production.

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Effect of Neem (*Azadirachta indica*) leaf meal on the growth performance and carcass characteristics of female growing rabbits

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Application The replacement of wheat offal with neem leaf meal in the diet of a female grower rabbit above 100 g/kg adversely affected weight gain and carcass weight.

Introduction Due to scarcity of conventional feed resources which had been the main limitation in the production of livestock products to meet the animal protein requirements of rabbits, other available but neglected cheaper novel feed resources have been the focused areas of recent research (Mahmud *et al*., 2015). In the light of this, there is increased interest in rabbit farmers to substitute conventional feed ingredients with the non-conventional types, which one of such unconventional feed ingredients is leaf meal of ethno medical plant such as neem (Esonu *et al*., 2005).

Material and methods The experiment was carried out at Federal University of Agriculture, Abeokuta, Nigeria. Thirty-six female weaner rabbits of mixed breeds were purchased from reputable farms and were acclimatized for two weeks before they were distributed to four experimental groups of nine rabbits each. Neem (*Azadirachta indica)* leaf meal (NLM) was used to replace wheat offal in a diet containing (g/kg) Maize (400), wheat offal (150), rice husk (170), soyabean meal (230), oyster shell (15), bone meal (30), vitamin/premix (2.5) and salt (NaCl; 2.5) at 0, 50, 100 and 150 g/kg on an air-dry basis to produce four different diets. Feed was given *ad libitum* and adequate fresh water was supplied daily. The feeding trial lasted for thirteen weeks. Data on growth performance which included feed intake, weight and feed efficiency were taken on weekly basis and data on carcass indices gathered were subjected to a One-way ANOVA using the Minitab 16 statistical package. Means were also separated using the Tukey test of the same statistical package.

Results The effect of neem leaf meal on growth performance of female growing rabbit at different inclusion levels are shown in Table 1. Results showed that final weight, total weight gain and daily weight gain were lowest ($P<0.05$) while total feed intake, daily feed intake, and feed conversion ratio were not significantly ($P>0.05$) affected by the levels of neem leaf meal in the diets. The effect of NLM on carcass characteristics showed that dressing percentages were similar ($P>0.05$) across the treatments (Table 2)

Table 1 Effect of neem leaf meal on the growth performance of female growing rabbits

	Inclusion level of neem leaf meal (g/kg)			
Parameters	0	50	100	150
Initial weight (g)	583.3±9.62	577.8±11.11	577.8±11.11	566.7±0.00
Final weight (g)	1416.7±58.53^{a}	1461.1±20.03^{a}	1366.7±33.33^{a}	1161.1±56.38^{b}
Total weight gain (g)	833.3±50.00^{a}	833.3±25.46^{a}	788.9±29.40^{a}	594.4±56.38^{b}
Daily weight gain (g)	9.2±0.55^{a}	9.2±0.28^{a}	8.7±0.32^{a}	6.5±0.62^{b}
Total feed intake (g)	5383.3±285.99	5396.7±389.40	4905.6±102.89	4755.6±200.54
Daily feed intake (g)	59.16±3.14	59.3±4.28	53.2±1.13	52.3±2.20
Feed conversion ratio	6.5±0.47	6.1±0.54	6.2±0.21	8.3±1.21

^{a,b}: Means with different superscripts along the row were significantly ($P<0.05$) different. ±Standard error

Table 2 Effect of neem leaf meal on the carcass characteristics of female growing rabbits

Inclusion level of neem leaf meal (g/kg)				
Parameter	0	50	100	150
Live weight (g)	1568.33±38.43^{a}	1594.67±81.98^{a}	1368.67±38.68^{ab}	1115.00±12.87^{b}
Carcass weight (g)	1148.67±37.81^{a}	1123.00±1.64^{a}	975.00±56.04^{ab}	757.67±78.43^{b}
Dressing %	73.22±1.09	70.50±0.56	71.17±2.7	68.12±0.87

^{a,b}: Means with different superscripts along the row were significantly ($P<0.05$) different. ±Standard error

Conclusion Replacement of wheat offal with NLM should not exceed 100 g/kg in the diet of female growing rabbit to prevent poor weight gain and carcass weight.

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Healthy milk from healthy cows: a genetic analysis of quantity and trace element concentrations in the milk and serum of dairy cows

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Application Nutrient levels in milk and blood of dairy cows are significantly influenced by both diet type and genetics which can help inform industry solutions to improve these for the benefit of the cow and the value of milk for human health.

Introduction Nutrients are essential inorganic substances (i.e., not synthesised by living organisms) in the diet of all animals. Originating from the soil (intake comes from consumption of plants and animals) they are required in order to maintain normal body function and remain healthy (FAO and WHO, 2004). Dairy products contribute substantially to nutrient intake and are an important source of P, Ca, I and Mg (~ 60%, 60%, 55% and 10% of RNI respectively; Kliem and Givens, 2011). Here we aim to (1) determine the effect of genetic background and diet on circulating nutrient concentrations (conc.) in dairy cow milk and blood serum; and (2) carry out a genetic analysis of milk and serum nutrient conc.

Material and methods Holstein-Friesian dairy cows involved in this study (n=449) were from the Langhill pedigree herd and part of a long-term (on-going) selection experiment for genotype × environment following a 2 by 2 approach (Veerkamp *et al*., 1994). Cows were equally divided between 2 genetic lines (highest and average genetic merit for milk fat plus protein yield) and assigned a diet based on by-product (BP) or home-grown (HG) feeds. Between June 2012 and May 2016 a total of 946 milk and 754 whole blood samples were collected, microwave digested in nitric acid and then analysed using inductively-coupled plasma mass spectrometry. Additionally, cows were extensively monitored for productivity as part of routine recording. Data were analysed using a mixed linear animal model that accounted for genetics and management practices with genetic relationships between individuals accounted for by fitting a pedigree relationship matrix. Analyses were carried out using ASReml version 3 (Gilmour *et al*., 2009).

Results Genotype was found to have no impact on nutrient conc., however, significant differences (*P<0.001*) between diets were observed with higher levels seen in milk Ca (HG), Mg (BP), Mo (HG), P (HG), K (HG), Se (BP), and in serum Mo (HG), P (BP) and Se (BP). Univariate analyses yielded significant heritability (h^2) estimates for 7 milk and serum nutrients (Table 1). Among the significant estimates greater h^2 were observed in milk compared to serum (excluding Mo). From the multivariate analyses milk and serum K was found to have a significant positive genetic and phenotypic correlation (0.52 and 0.22 respectively), however, no other significant genetic relationships were observed between concurrent milk and serum traits. Significant phenotypic associations were noted between milk and serum Ca (0.16), Mo (0.16) and Na (-0.68). Regarding associations with milk yield (kg) significant negative genetic correlations were observed with milk Ca (-0.49), Mg (-0.35), P (-0.44) and Se (-0.46) with positive associations seen in serum Mo (0.38), P (0.34) and milk K (0.32). Contrary, but consistent, associations were observed for these traits with fat and protein (%).

Table 1 Results from genetic analysis. Milk and serum nutrient heritability with corresponding genetic correlation between milk and serum (significant values in **bold**).

Nutrient	h^2 *milk*	h^2 *serum*	r_a
Calcium (Ca, mg/L) [q]	**0.22 (0.04)**	**0.12 (0.05)**	*0.26 (0.23)*
Magnesium (Mg, mg/L) [q]	**0.30 (0.04)**	**0.14 (0.05)**	*0.18 (0.20)*
Molybdenum (Mo, µg/L) [t]	**0.19 (0.04)**	**0.23 (0.06)**	*-0.11 (0.19)*
Phosphorus (P, mg/L) [q]	**0.22 (0.04)**	**0.20 (0.05)**	*-0.01 (0.18)*
Potassium (K, mg/L) [q]	**0.27 (0.05)**	**0.18 (0.05)**	**0.52 (0.18)**
Selenium (Se, µg/L) [t]	**0.18 (0.04)**	**0.10 (0.05)**	*0.30 (0.26)*
Zinc (Zn, µg/L) [t]	**0.46 (0.04)**	**0.18 (0.06)**	*-0.31 (0.17)*

t Trace nutrient; q Quantity nutrient; h^2 heritability; r_a genetic correlation

Conclusion Results show that diet ration has a significant impact on circulating nutrient conc., especially in milk. Moreover, the genetic analysis provides evidence that nutrient conc. in milk and serum are heritable and exploitable genetic variation exists. Finally, the associations observed between quantity and trace nutrients with milk composition traits suggests that genetic selection for nutrient conc. could lead to a healthier product for human consumption.

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The genetics of tooth loss and longevity in Scottish Blackface hill ewes

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Application This preliminary study suggests potential for genetic selection to reduce tooth loss and improve the longevity of Scottish Blackface hill ewes.

Introduction Tooth loss is often identified as a significant reason for culling ewes from hill flocks and therefore influential in terms of ewe longevity. The premature culling of ewes can prove costly to farmers in terms of increased replacement costs, reduced genetic gain and reduced income from cast ewe sales, thus impacting on overall flock efficiency and greenhouse gas emissions. The aim of this study was to assess genetic control and relationships between teeth traits and the overall longevity of ewes in the flock.

Material and methods Data were available from 5,198 performance recorded Scottish Blackface ewes born between 1996 and 2011 in SRUC's hill research flocks, one based in the Western Highlands, near Crianlarich, the other in the Pentland Hills, near Edinburgh. The three traits investigated were longevity (LONG), defined as the age (in years) at the last recorded lambing event (2 to $\geq$ 6 years old, n = 4,054 ewes); age at tooth loss (LOSS), defined as the age (in years) when the ewes were culled for missing one of their four centre teeth (2 to $\geq$ 6 years old, n= 3,846); and the number of adult teeth present (TEETH) when the ewe was approximately 2.5 years old (2 to 8 adult teeth, n = 2,932 ewes). Only ewes that had at least one lambing event recorded were included in the analyses and teeth data were only available for ewes scored between 1998 and 2006.
Genetic parameters were estimated using univariate analyses in ASReml (Gilmour *et al.* 2009). The fixed effects fitted in the animal models used, for each trait, were all early life effects and included ewe birth year, flock, age of the ewe's dam, litter size the ewe was reared in, and an interaction term between ewe birth year and flock. Each fixed effect was significant for the majority of the traits, with those not significant retained to keep consistency across the analyses. Genetic and phenotypic correlations were estimated using multivariate analyses in ASReml (Gilmour *et al.* 2009). The pedigree file used contained sire and dam information for 45,616 animals.

Results The average age (s.d.) for LONG and LOSS was 4.38 years (1.09) and 5.05 years (0.93) respectively. The average number of adult teeth present (s.d.) for TEETH was 4.43 (0.92). Preliminary heritabilities for each trait, and the genetic and phenotypic correlations between the traits, are given in Table 1. Heritabilities estimated were low, ranging from 0.12 (LONG) to 0.24 (TEETH). Genetic and phenotypic correlations estimated between TEETH and both LONG and LOSS ranged from -0.04 to -0.10, and were not significantly different from zero (P>0.05). High genetic and phenotypic correlations were observed between LONG and LOSS (0.93 in both instances).

Table 1 Heritabilities (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations (with s.e.)

Trait	LONG	LOSS	TEETH
Longevity (LONG)	**0.12 (0.03)**	0.93 (0.02)	-0.10 (0.14)
Age at tooth loss (LOSS)	0.93 (0.002)	**0.23 (0.04)**	-0.09 (0.13)
No. of adult teeth at 2.5 years old (TEETH)	-0.04 (0.02)	-0.04 (0.02)	**0.24 (0.05)**

Conclusion These preliminary results demonstrate that both longevity and age at tooth loss are heritable and therefore could be incorporated into future breeding programmes. The higher heritability estimate for tooth loss suggests that greater genetic progress could be made through the inclusion of this trait in similar hill flocks. The correlation estimates indicate that the number of adult teeth present when the ewe is 2.5 years old cannot predict how long the ewe will retain her teeth in later life or remain in the flock.

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Introduction of a total merit index for dairy goats in Austria

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Application Since 2017, breeding values for dairy and fitness traits have been estimated for different goat breeds. Additionally, these breeding values are combined to a total merit index which is the mathematical definition of the breeding goal.

Introduction In 2016, 83,000 goats were kept in Austria, of which roughly 17,000 were breeding goats. The main breed is the Saanen goat, a dairy breed, with almost 10,000 breeding animals (ÖBSZ, 2017). To ensure a long-term sustainable development and to remain competitive, goat breeding organizations have focused on the revision of the breeding objectives and the establishment of a routine genetic evaluation during the recent years.

Material and methods Based on the recently developed routine genetic evaluations for dairy traits (milk, fat and protein yield) and fitness traits (number of kids born, number of kids born alive, somatic cell count, persistency), a total merit index was defined for four dairy goat breeds in Austria, Saanen, Gemsfärbige Gebirgsziege, Bunte Edelziege and Toggenburger. Genetic evaluations are performed by ZuchtData EDV-Dienstleistungen GmbH on a weekly basis. Economic values were mostly adopted from Fuerst-Waltl *et al*. (2018).

Results Milk, fat and protein yield have the highest economic importance (60 % relative economic weight for the dairy complex, Table 1). While the results of a routine genetic evaluation for fat and protein content are also published, these traits are not considered in the TMI. Among the fitness-related traits, somatic cell count received the highest weight with 16.3 %. The expected genetic gain is nearly 90 % for dairy traits. However, it is positive for all considered fitness traits as well.

Table 1 Relative economic weights in the total merit index and expected genetic gain for dairy goats in Austria

Traits		Economic weights (%)		Expected genetic gain (%)
		Single traits	Trait complex	
Dairy traits	Milk yield	20.6	60	88
	Fat yield	19.0		
	Protein yield	20.4		
Fitness traits	No. of kids born	5.9	40	12
	No. of kids born alive	2.8		
	Somatic cell count	16.3		
	Persistency	15.0		

Conclusion The current traits included in the genetic evaluations serve as a starting point for the establishment of a TMI that is economically feasible but also sustainable in the long-term. Further traits that may be additionally considered are e.g. longevity, milking speed and selected conformation traits.

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What advice would UK pig industry give to geneticists seeking to breed more disease resilient pigs?

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Application The pig industry would value more disease resilient pigs but there are a lot of caveats to this aspiration related to the specific production context, side-effects and subject to acceptance of processors, retailers and consumers. Practicalities mean disease resilience is difficult to identify in practice.

Introduction Disease resistance is a valuable attribute, increasingly so as pressure to reduce antibiotic use intensifies. Genetics is one possible route to achieve this (Bishop & Woolliams 2014). This research sought to ascertain how pig industry actors viewed the contribution of more disease resilient pigs to overall herd health and productivity. It forms part of a larger project aimed at identifying genomic contributions to disease resilience.

Material and methods This qualitative research consisted of 17 individual interviews and 5 focus groups conducted between March and October 2018 in England and Scotland. A total of 67 individuals contributed, including 49 pig producers, 10 vets and 20 advisors/other. Pig producers included indoor and outdoor units, large integrators, individual producers and small pedigree breeders. Data were analysed inductively based on observation, rather than testing a theory.

Results Disease is a major concern for pig producers However, a number of caveats regarding genetic selection were expressed as indicated in Table 1.

Table 1 What needs to be taken into account when breeding more disease resilient pigs?

Factor to be taken into account	Further explanation
Balance between disease resilience and overall productivity and meat quality	Overall productivity is key to economic performance and the value of disease resilience will depend on context.
Balance between disease resilience and behaviour.	Tail biting and aggressiveness are proving challenging to producers. Any increase in these characteristics would not be welcome.
Difficulty of evidencing effects of improved disease resilience.	Limited anecdotal evidence of breed and strain differences in disease resilience exist but have not been corroborated. Differences in pathogenicity, housing, location and management mean differences are difficult to substantiate.
What works in the lab, may not work in the field.	The example of E. Coli resistant pigs was given, as not always performing as expected in the field.
The 'dilution' effect of changing breeding stock supplier.	Producers reported how they experiment with different sources of semen, potentially reducing the disease resilience.
Collaborative decision-making	For major decisions, producers tend to consult with veterinarian and wider supply chain
Money saving?	Could only be realised if resilience was sufficient to obviate need for vaccination and save these costs.
Mitigation or elimination?	Specific disease resistance important if unit has the disease and cannot be controlled by depopulation/repopulation.
Resilience to improve vaccine responses.	Genetics also useful to improve response to vaccination.
Too weak a response and takes too long.	Benefits would be small and allow time for pathogens to mutate to overcome resilience. Removing action of one pathogen may open the door to another.

Disease resilience was viewed as potentially effective in reducing antibiotic use, particularly in the context of 'door keeper' diseases such as Porcine Reproductive and Respiratory Syndrome (PRRS) and Enzootic Pneumonia.

Conclusion The new context of emphasising reductions in antibiotic use increases the need for new disease control methods. However, attention needs to be paid to the whole context of production, disease and disease control measures.

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Genetic variation in animal resilience to weather changes in UK dairy goats

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Application Reaction norm analyses can be used to estimate changes in animal production as response to climatic variation. Individual animal slopes obtained from these analyses can be used to inform selection programmes for enhanced resilience.

Introduction Climate change can have a detrimental impact on the quality and quantity of food production. While most efforts have been directed to reduce greenhouse gas emissions (Moran *et al*. 2011), complementary strategies are necessary to control its effects on production. A potential strategy is to consider joint functions of production and environmental conditions to inform selection programmes (Mulder 2016), aiming for productive animals that are able to maintain production levels under environmental challenge and variation. The aims of the present study were to (i) develop animal resilience phenotypes reflecting production under changing weather conditions and (ii) estimate their genetic parameters.

Material and methods Animal milking records (average daily yield in kg for 10 consecutive days) were obtained from two dairy goat farms (animals kept in sheds without climate-controlled conditions). The dataset spanned the period July 2007 to June 2016 and consisted of 828,624 milk records of 16,168 goats. Pedigree data consisted of 42,639 animals over 17 generations. Weather data (temperature, humidity and temperature-humidity index computed following the National Research Council formula) were obtained from the nearest meteorological station (19 miles) and averaged for the 10 days corresponding to each milking record. Weather data ranges were min-max normalised to a range from -3 to 18 degrees Celsius for temperature, 65% to 98% for daily humidity and 30 to 66 for THI.
Reaction norm models were used to estimate individual and population changes in milk production due to weather variation. Legendre polynomials were used to fit the weather variable with the random effect of the animal. Fixed effects were farm, year-season of kidding, herd-test-day, lactation number and days in milk. Individual animal response curves where estimated and their corresponding slopes were computed. The slopes were considered as new resilience phenotypes, and their variance components, heritabilities and genetic correlations with total milk yield were estimated using mixed models.

Results Initial exploration of polynomials of varying order showed a relative linear behaviour of the data; therefore, first degree polynomials were used in the ensuing analyses. An overall increase in milk production was observed with increased temperatures and THI as expected (Figure 1). Change of milk production of individual animals varied considerably. Variance estimates of the new resilience phenotypes are summarised in Table 1 together with respective heritabilities.

Table 1 Phenotypic variance ($\mathbf{V_{PHEN}}$), additive genetic variance ($\mathbf{V_A}$), heritability ($\mathbf{h^2}$) and genetic correlation with total milk yield ($\mathbf{r_a}$) for estimates of animal resilience to temperature (**T**), temperature-humidity index (**THI**) and humidity (**H**).

	$\mathbf{V_{PHEN}}$	$\mathbf{V_A}$	$\mathbf{h^2}$	$\mathbf{r_a}$
T	3.13E-3 ± 4.67E-5 *	1.88E-4 ± 4.99E-5 *	0.060 ± 0.016 *	0.101 ± 0.121 NS
THI	1.03E-3 ± 1.54E-5 *	6.27E-5 ± 1.65E-5 *	0.061 ± 0.016 *	0.096 ± 0.120 NS
H	7.87E-4 ± 1.17E-5 *	3.44E-5 ± 1.02E-5 *	0.044 ± 0.013 *	0.239 ± 0.133 NS

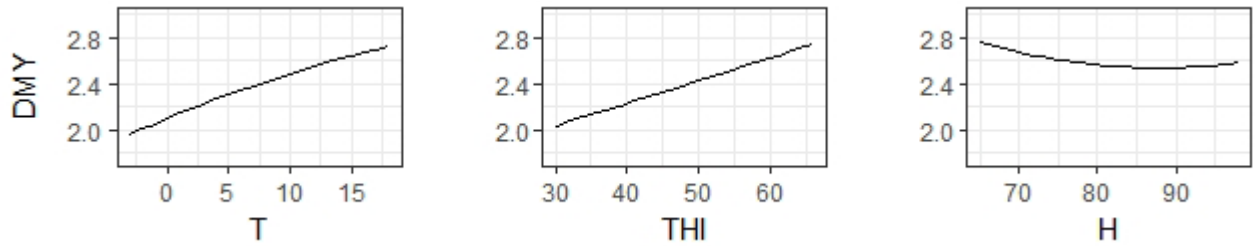

Figure 1 Reaction norm population curves of daily milk yield on temperature (left), THI (centre) and humidity (right).

Conclusion This study has quantified the genetic variability in new resilience phenotypes for dairy goats which can inform selection strategies to enhance stability of milk production in changing climatic conditions. Although no significant genetic correlations with total milk yield were detected, selection strategies should take into consideration potential antagonistic correlations with other traits in the breeding goal.

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Modelling crossbreeding strategies for Boran cattle in Ethiopia

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Application Our model allows the prediction of herd performance over time under a range of crossbreeding strategies for cattle farmers in Ethiopia as well as the potential of the model for use in other systems.

Introduction Crossbreeding has long been considered a good strategy to increase the productivity of cattle herds in Sub-Saharan Africa. A variety of crossing strategies are commonly used, including grading up towards 100% exotic genetics by using an imported sire every year, rotational strategies which rotate the sire type annually or strategies which use specific sire types on different cow genotypes (Cunningham and Syrstad, 1987). In order to select an optimal strategy, a prediction of the effect of these strategies on the performance of the whole herd over time is needed. Our aim is to predict the performance of a herd under varying crossing strategies, using a case study of an initial herd of Boran cattle in Ethiopia and the trait of annual milk yield.

Material and methods Two sire breed types, Boran and Holstein, are used over the initial herd of Borans, and subsequent generations, to produce a range of defined crossbred types and compare these with purebreds. Our deterministic herd model uses initial herd composition, survival and calving rates and sire breed type to predict herd composition in terms of crossbred types over 40 years. Genetic variation in calving rate is modelled with additive and non-additive genetic breed effects (Dickerson, 1973) for age at first calving and calving interval (Demeke *et al*., 2004) plus a deterministic model to predict calving rates for each crossbred type necessary for the herd model. The proportion of each crossbred type can then be combined with the predicted performance of that crossbred type for a given trait, in our case milk yield (Demeke *et al*., 2004b), to predict the whole herd performance, per cow in the herd, for that trait. We tested 4 crossing strategies where the sire used was: a) Boran, b) Holstein, c) Rotational Holstein and Boran d) Holstein but Boran over females with greater than 50% Holstein genetics ('specific sire').

Results All crossing strategies show potential to increase annual milk yield per cow compared to the yield from purebred Boran cows of 288kg (a) (Figure 1), due to increased expression of the large additive effect of the Holstein breed as the proportion of Holstein increases. Rotating between sire types annually (c) increased annual milk yield per cow to 1001kg after 20 years but this increase slowed and annual milk yield oscillated but on average continued to increase to 1123kg after 40 years. This strategy does not perform as well as the others as the average proportion of Holstein genetics in the herd does not exceed 50%. Using Holstein sires (b) increased the annual milk yield per cow to a maximum of 1512kg after 19 years; however this then dropped to 1346kg after 40 years. This decrease is due to decrease in average heterosis from around 0.7 to 0.3 (on a scale of 0-1, where F1s have a value of 1(Dickerson, 1973)). Heterosis has a significant effect on fertility traits so this reduction in annual milk yield per cow can be explained by the reduction in the number of cows in milk due to a poorer age at first calving and calving interval when less heterosis is expressed. The specific sire strategy (d) slightly reduces this loss in milk yield, resulting in an annual milk yield per cow of 1401kg after 40 years, by maintaining heterosis and therefore maintaining the high level of fertility and proportion of the herd in milk.

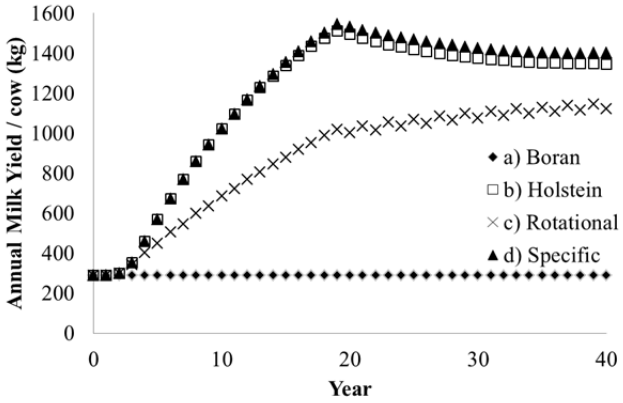

Figure 1 Milk yield per cow over 40 years under varying strategies

Conclusion Our model allowed the prediction of herd performance for a trait depending on varying long-term crossbreeding strategies. Combining the results of this model for multiple traits would allow for the prediction of herd profitability under varying crossing strategies, better allowing for prediction of the optimal strategy.

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Development of insect proteins and utilisation as a feed in Africa

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Application In African, poultry, pig and fish farming are among the fastest growing agri-businesses, but these sectors are constraint from realizing their full potential, due to the shortage and high cost of common animal-feed protein sources, leaving farmers with almost no profit margins.

Introduction Food insecurity and undernourishment are key developmental challenges that Africa has had to grapple with more than any other region in the world. The growing prevalence of hunger and undernourishment in the continent continues to fuel increasing demand for protein and efforts to tackle this problem have largely depended on enhancing crop and livestock productivity, which is unsustainable due to the dwindling land and water resources as well as impact of climate change. Thus, there is an urgent need to develop and promote alternative and sustainable protein sources for improving the productivity of livestock and aquaculture sectors. Insects are potentially one of these options to the expensive conventional protein sources (fishmeal and soybean). The aim of the present study was to catalogue edible insects, enhancing awareness, understand the perceptions and willingness to pay for insect protein-based feeds, adapting indigenous knowledge, mass production, wild harvesting, nutritional profiling, processing, marketing, post-harvest handling, safety and regulations.

Material and methods Extensive surveys, data mining of reports and publications were conducted to gather information on the current inventory of African edible insects. Questionnaires were used to collect information on knowledge, attitudes and practices of different communities at households and community levels. Contingent valuation survey design was used to assess consumer acceptance and willingness to pay for insect-based protein formulated feeds. Suitable rearing substrates were identified and their influence on quality control parameters of the insects evaluated under different rearing conditions. The nutritional and biosafety quality (heavy metals, pesticide residue levels, mycotoxins and toxins) of wild and processed insects was determined using various chromatographic and spectroscopic techniques including high performance liquid chromatography (HPLC), liquid chromatography (LC) coupled to mass spectrometry (MS), gas chromatography (GC) coupled to MS, ICP-mass spectrometry, Atomic Absorption Spectrometer (AAS), protocol described by Chauzat *et al*. (2006), and LC-triple quadruple MS. On-station assessment of formulated insect-based protein feeds was carried out to establish the effect on growth performance, feed conversion rate, palatability, carcass quality and blood profile of fish, pig and poultry.

Results Results revealed that edible insects played a significant role in food and nutrition security across the continent. More than 470 insect species were consumed in Africa by > 300 million people in 75% of African countries. Depending on the rearing substrates, insects were highly nutrient-rich in crude protein, fat contents, micronutrients (iron and zinc), essential amino acids (including high amounts of cereal-limiting amino acids like lysine, threonine and methionine) and high gross energy. No aflatoxin, pesticide residues and heavy metals were identified. Microbial contaminations were easily overcome after post-harvest treatment making them safe for use in animal feeds. On-station studies revealed that the influence of insect-based feeds on pig, poultry and fish was comparable or superior to conventional feeds. For instance, chicken layers fed on feeds with 20% replacement fishmeal resulted in 53% higher weekly egg production, an improved egg quality, a more sustained production and quality as well as higher cost benefit ratio and better return compared to conventional feed. Nile tilapia fish fed with insect-based feed were 23% heavier than those fed with conventional feed. Performance studies on African catfish also revealed a 37% higher growth rate, 23% higher weight gain and higher carcass crude protein when fed insect-based protein feeds. Insect-based feed was a good alternative protein source in growing and finisher pigs without adverse effects on growth, daily weight gain, feed conversion ratio and blood profile but with reduced predisposition to heart diseases, which is always associated with high total cholesterol and low-density lipoproteins. Socioeconomic studies showed that in Kenya 70% of commercial poultry farmers purchase feed, while in Uganda, 53.31% of poultry farmers mixed their own feed. Over 80, 72 and 68% of poultry, fish and pig farmers, respectively, used commercial feeds. Furthermore, over 70, 80 and 65% of poultry, fish and pig farmers, respectively, were aware that insect-based meal could form an integral part of livestock feed. Over 90% of the consumers were willing to pay for chicken meat derived from insect-based protein feeds. These findings were very instrumental in the development of the first standards and legislation that allowed the integration of high-quality insect-based protein ingredients in compounded animal feeds.

Conclusion Therefore, rolling-out insect-based protein feeds technologies would have a huge potential for improving poultry, pig and fish production, thus opening new markets and opportunities for commercialisation of insect-based protein feeds in Africa and beyond.

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Alternative protein sources; an Australasian perspective

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The major crude protein (CP) source for monogastrics world-wide has been soyabean meal (45-48% protein), and this will continue to be for some time. Canola or rapeseed meal (33-38% CP) with low glucosinolate levels is the second most popular protein, particularly in swine diets. Canola grows in a wider range of soils and climates compared to soyabean meal (SBM) and its quality and availability will continue to increase. Canola's use is gradually increasing in both pig and poultry diets, and whole canola seed is used up to 10% in broiler diets.

SBM is a high quality protein source, however more alternative protein sources are required due to concerns about the GMO status of this legume grain, potential trade restrictions, potential droughts in the Americas, biosecurity and environmental implications. There are other more traditional protein sources from other oilseed meals (eg sunflower and cottonseed meals) and legumes (Peas and lupins), however these crops find it hard to compete with Canola and Soyabean meals economically. In countries where meat meal and blood meal can still be used, levels and availability of these are reducing due to the growth of aquaculture and pet food where the animal protein meals have higher value.

The fermentation products from ethanol production (25-35% CP) or dried distillers grains (DDGS) are widely used in the Americas and Europe, however the quality and composition is variable although it has improved over the past 5 years. The high non-starch polysaccharide (NSP) levels restrict the amount of DDGS used, particularly in broiler diets. Formulating diets using net energy and standardised ileal digestibility of amino acids does improve general growth performance of pigs using high levels of DDGS (Kerr *et al*, 2015).

The use of DDGS in Australasia is very low due to a small ethanol industry, however the use of lupins, fabs beans, field peas, and feed grade chick peas and lentils is more common. The benefits of these legumes are the higher content of pectin and other functional NSP which can improve gut health through the production of volatile fatty acids (eg butyrate), create satiety and improve behaviour in breeder pigs (Pieper *et al*, 2015). Moving forward, higher value will be placed on alternative protein sources that also offer improved gut heath or other benefits that prove growth performance.

There are two potential protein sources that offer essential amino acids as well as higher health benefits. The first this single cell protein (SCP) from commercial amino acid or MSG production. Most SCP are non-GMO bacterial fermentation products and contain between 55%-70% CP, are highly digestible and also contain 8-12% nucleotides which are important to maximise performance in young monogastric and lactating sows (Zhang *et al*, 2013). As the demand for crystalline amino acids increase, the greater amounts of SCP that will be available on the market. Secondly, the insect protein meal supply will continue to grow, particularly from black soldier fly (BSF) production. The technology to enable higher yields of BSF on green and other human/agricultural waste is improving significantly. The protein levels vary from 30 to 40% depending of the food source, and once rendered or defatted protein levels increase as high as 65%, and there are health benefits from the high lauric acid content of the BSF, and producing equal to better growth than SBM (Moula *et al*, 2018).

In the future, there is a high potential that protein from SCP and insect meal production will become major alternatives to SBM.

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Rumen protected rapeseed expeller (NovaPro) as an alternative to soya bean meal in dairy cow diets

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Application Holstein Friesian dairy cows had higher milk yields when rumen protected rapeseed expeller (NovaPro) replaced soya bean meal in diets balanced for metabolisable energy and protein.

Introduction There are environmental, social and economic pressures to reduce the use of soya in ruminant diets and hence provide alternative forms of protein and digestible rumen undegraded protein (DUP). Rapeseed is the largest UK grown high protein feed. A protected form of industrial scale rapeseed expeller (NovaPro) provides similar quantities of DUP and metabolisable energy (ME) compared to soya. NovaPro is expelled rapeseed, heat-treated with a specific wood derived xylose to increase DUP. A rapeseed product that was heat-treated only was also evaluated; the lower ME of this product required additional fat to balance ME. The objective of this study was to test the hypothesis that soya meal could be replaced by this rumen-protected rapeseed in balanced diets for dairy cows without adversely affecting cow performance.

Material and methods Forty-four Holstein Friesian dairy cows were allocated to four groups of 11 cows balanced for parity, milk yield, days in milk and live weight. Groups were fed on four diets in a 4 x 4 Latin square design with four feeding periods of 28 days. Partial mixed rations (PMR) were formulated to provide 100% of ME and metabolisable protein (MP) requirements (FiM; Thomas, 2004) for Maintenance + 32 L of milk per day. A commercial compound was fed according to milk yield (+0.45 kg/L above 32 L/d) during robotic milking. All PMR contained 65% forage DM (grass, maize and cereal silages) and 35% concentrate DM. Concentrates were based on rolled-wheat, sugar beet pulp, protected fat, minerals and vitamins, plus varying protein sources. The main protein sources (% of PMR DM in brackets) were: Control – soya (10%); T1 – NovaPro (12%); T2 – Heat-treated rapeseed extract (12%); T3 – NovaPro (9%) and SoyPass (2%). Wheat DDGS, unprotected rapeseed extract and urea were used to balance rumen degradable protein across diets. Milk yield, milk composition, dry matter intake (DMI) and live weight were recorded daily for each cow in the last week of each feeding period. Intakes of ME, MP and metabolisable methionine (MMet) were compared with requirements for actual milk production (Thomas, 2004). Data were analysed using the Latin Square design of the ANOVA procedure in Genstat (18th Edition). The fixed effect was treatment diet, and the random effects were feeding period and individual cow.

Results Milk yield was higher when cows were fed on treatment diets than the control diet (Table 1). Concentrations of milk fat and protein reflected differences in milk yield, so there was no difference between treatments in yield of milk fat (1.46 kg/d) or protein (1.38 kg/d). Dry matter intake was higher when cows were fed on T1 and T3 than when they were fed on the control diet; DMI for T2 was intermediate. Mean ME and MP intakes matched 100 to 103% of requirements for observed performance according to FiM equations. The threshold value for MMet in FiM is 2.1 g/100g MP. The control diet was marginal for MMet and all other diets were above the threshold, suggesting a contribution of methionine to the milk yield response for diets containing protected rapeseed meal.

Table 1 Mean performance when cows were fed on soya (Control) or protected rapeseed products (T1 – T3)

	Treatment					
	Control	T1	T2	T3	sed	P
Milk yield (kg/d)	41.1a	42.8[b]	42.5[b]	42.7[b]	0.57	0.009
Milk fat (g/kg)	35.1	34.5	35.1	34.5	0.60	0.448
Milk Protein (g/kg)	32.9[a]	32.5[b]	32.7[ab]	32.5[b]	0.16	0.004
Dry matter intake (kg/d)	23.9[a]	25.1[b]	24.4[ab]	24.9[b]	0.39	0.012
MMet (g/100g MP)	2.13	2.26	2.26	2.22		

Conclusion Results confirm that soya meal can be replaced by protected rapeseed meal in balanced diets for dairy cows without adversely affecting cow performance. Improved milk production was most likely due to improved amino acid balance in protected rapeseed meals compared with soya meal. This is consistent with the review of Huhtanen *et al*. (2011).

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Removing the dependence on perishable feed ingredients in *Tenebrio molitor* (yellow mealworm) diet

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Application Water can replace carrot as a hydration source for *Tenebrio molitor* (yellow mealworm), thereby reducing production costs, with no effects on growth but increased crude protein and decreased fat density.

Introduction Alternative protein sources are urgently needed to replace the traditional sources for animal feeds, (e.g. soyabean meal). Insects, particularly *Tenebrio molitor* larvae (TM), could serve either as a partial or full replacement due to having a similar nutrient composition. Improvements in production methods are needed to scale up insect production for supply for animal feeds or as human food (Rumpold and Schlüter 2013). For example, the majority of commercial insect producers utilise vegetables (e.g. carrot) to supplement the feed (usually wheat bran based), presumably to act as a water source. This significantly increases production costs when compared to water alone. The aim of this study was to compare the effect of alternative wheat bran based feeds where carrot was replaced with water alone, or with added sucrose and beta-carotene on growth, feed consumption and nutritional composition of TM.

Methods TM (mini-form) were obtained from Monkfield nutrition Ltd and acclimatised on a wheat bran (WB) only diet for 3 days. At day 0, TM were transferred to plastic dishes (n=200/dish) and allocated to one of five feed groups (5 dishes per diet): Control (WB + carrot), WB (no carrot or water source), CW (WB + cotton wool (CW)), W (WB + CW+ water (W)) and BC+S (WB + CW + W + Beta Carotene (BC) + Sucrose(S)). Beta carotene and sucrose were mixed with wheat bran at concentrations of 13.81µg/g and 59.83mg/g respectively, to reflect intake from carrots. TM were fed *ab libitum* for 14 days and weighed and counted (with any dead TM being removed) on days 4, 7, 9 and 11, feed (WB only) and water (carrot or water) consumption were measured and refreshed each time. At day 14, final measurements were taken (any dead removed) and TM were killed by cold exposure and stored at -20ºC. Samples were freeze dried then analysed for crude protein (EA 1112 Elemental Analyser), total fat (Gerhardt Soextherm) and total energy (Bomb Calorimeter). Data were statistically analysed by one way ANOVA (Genstat-19th Edition) and when significant ($P<0.05$) a Bonferroni post hoc test carried out.

Results There were no significant differences in initial live weight (Table 1). There were significant decreases in final live weight, total feed intake and dry matter in those mealworms not provided a water source (WB and CW). Total feed intake was significantly increased in the water only (W) group compared to the Control group given carrot. In the 2 groups given water (W and BC+S) total fat content was significantly lower compared to the Control (carrot) group, but the total crude protein was higher in W, along with WB and CW. There was no difference in total energy between the groups.

Table 1 Effects of removing carrot and manipulating feed on growth and feed intake across the 14 days of treatment and the body composition of remaining live TM on day 14.

	Control	WB	CW	W	BC+S	SED	P
Initial Live Weight[1] (g)	13.90	13.80	14.09	13.96	14.32	0.37	0.680
Final Live Weight[1] (g)	17.27^{a}	10.50^{b}	10.53^{b}	16.90^{a}	17.02^{a}	0.72	<.001
Total Feed Intake[1] (g)	41.38^{a}	33.11^{b}	30.56^{b}	46.10^{c}	44.68^{ac}	1.18	<.001
Dry Matter[1] (g)	5.60^{a}	4.17^{b}	4.23^{b}	5.35^{a}	5.36^{a}	0.26	<.001
Total Crude Protein[2] (g/gDM)	0.545^{a}	0.574^{c}	0.578^{c}	0.563^{bc}	0.555^{ab}	0.0051	<.001
Total Fat[2] (g/gDM)	0.280^{a}	0.274^{a}	0.268^{a}	0.240^{b}	0.243^{b}	0.0077	<.001
Total Energy[2] (MJ/gDM)	0.0047	0.0052	0.0050	0.0048	0.0048	0.0012	0.995

[1]Mean values per dish, [2]Mean values

Conclusion When TM were fed the poor nutrient quality WB feed, they were able to grow without carrot, as long as there was a water source. The lack of a water source (or carrot) inhibited growth, presumably via dehydration, but caused an increase in protein. The control (carrot) diet appeared more feed efficient, but carrot intake was not included in total feed intake, so TM could simply be consuming carrot instead of WB. Compared to the control, the diet with a water source (W) produced the same dry matter, higher protein and lower fat content. This suggests that utilising alternative wheat bran based feeds can alter the metabolism of TM to reduce their fat content and increase protein density (on a DM basis). This would increase their value as an alternative protein source.

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Management of young farmed livestock: why it matters and what can be done to optimise development

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Application Youngstock are the future of the farm and optimising their management is crucial for future productivity and profitability. Consideration of the frequency and method of feeding, and how to allow social learning through the mother, or other animals, can improve their adaptation, growth and welfare.

Introduction The early life environment of a young animal can have a profound impact on its subsequent growth, development and responses in later life. In mammals, the newborn relies on its mother to provide nutrition, warmth, protection (both physical and immunological), security, comfort and opportunities for social learning. This relationship can influence a host of different systems including the subsequent stress responsiveness, learning abilities, food preferences, microbiota profiles, social and sexual preferences of the young animal into adulthood. In many farmed youngstock, however, these processes are truncated through earlier weaning than would naturally occur. In this paper how well we are able to provide the young animal with the optimal developmental environment, and the impact this can have on future productivity and welfare, will be discussed.

Early rearing environments Newborn livestock face a number of significant challenges on the day of birth as they adapt to the transition from the benign maternal uterus to the more hostile extra-uterine environment. A crucial component of this adaptation, and one which has a significant influence on the survival and development of young mammals, is the rapid intake of maternal colostrum. This provides immunoglobulins, as most neonatal livestock are immunologically naïve, nutrition for thermoregulation, growth factors to influence gut maturation and, in some species, plays a role in the recognition of mothers and their offspring. As livestock are relatively precocious at birth the responsibility for showing coordinated behavioural responses to find the udder and suckle is largely that of the neonate, with mothers showing a variety of cooperative responses to facilitate udder location. The ability of the young animal to perform these behaviours depends on the prenatal environment, the ease with which it has been delivered, and the challenges present in the early postnatal environment. Thereafter offspring may be reared either by the mother, or artificially. Mother-rearing allows the vertical transmission of social learning, and young animals generally learn about the environment from their interactions with the mother. This can be exploited to allow young animals to accept novel foods, to learn management routines and to become habituated to stimuli that they may otherwise find frightening. Separation of the young animal from its mother will disrupt these opportunities for learning, and has been shown in calves to be associated with slower growth, impaired learning and social skills and a more negative mood state that was similar to calves that had been dehorned. Sucking is also a strongly motivated behaviour for young animals, and management systems that prevent animals from meeting these behavioural needs (for example, feeding low volumes in a small number of feeds or abrupt removal of milk feeds at weaning) leads to an increase in abnormal behaviours such as inappropriate sucking. Inadequate supply of milk can also lead to hunger, and compromise growth, health, welfare and future productivity.

Weaning and beyond Weaning is often considered to be about the change in nutrition from milk to solid food. However, weaning is also about the disruption of the psychological bonds between the mother and offspring, and these are often not considered in management systems. Suckling and close contact between mothers and young causes increases in circulating oxytocin, and is associated with comfort and reassurance of the young which are separate from the nutritive value of suckling. When the offspring is separated from the mother it forms new social relationships with other animals, often peers, but these may not be sufficient to completely compensate for the loss of the mother. In natural weaning, generally it is the mother who weans her offspring, usually before the offspring is completely ready to be weaned. This is usually a gradual process where the mother restricts access to the udder, and may eventually refuse all contact with her offspring, or changes in the social requirements of the mother and her offspring may lead to separation. Abrupt weaning ends both psychological and nutritional contact between the mother and her young and appears to be associated with a greater growth check and stress responses in the offspring compared to fenceline or other form of gradual weaning. In dairy systems, gradual weaning encourages the calf to increase intake of solid feed and promotes the development of the rumen. Beyond weaning, the early life impacts of food preferences, learning abilities and social responses can persist throughout life.

Conclusion The early management of youngstock plays an important role in their growth, development, health, welfare and future productivity. Adopting systems that work with the behavioural biology of the young animal can help to optimise development, and may offer new opportunities to exploit the development of the young animal.

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Feeding behaviour and activity as early-indicators of disease in pre-weaned dairy calves

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Application Activity and feeding behaviour are important indicators of disease in calves, and can be utilised within early-warning systems to facilitate early intervention and optimised treatment.

Introduction Approximately 50% of UK beef production originates in the dairy herd. Calves are typically sourced from a large number of dairy farms before entering rearing units at a few days or weeks of age. Across the industry, there is large variation in health status of calves entering these units and as a result disease incidence and antibiotic use is high. Economic impacts of poor calf health include calf losses, veterinary treatment, increased labour and loss of productivity throughout life. Methods of early-detection of disease have not been widely explored within calf rearing units. This study aimed to determine whether changes in activity and feeding behaviour can be used as early-warning indicators of disease in calves.

Material and methods In total 100 pre-weaned male Holstein calves (age ~8-42 days) were used in the study. Calves were group-housed and provided with starter diet (ForFarmers Vitastart), straw bedding and *ad libitum* water. Calves were fed milk replacer *ad libitum* (ForFarmers Omega Gold: 15% concentration) through a computerised calf feeder (Holm and Laue) and each calf was fitted with an activity monitor (Axivity®) on the hind-leg. Each calf was assessed daily using a modified version of the 'Wisconsin Scoring System' which is the best practice method for detecting respiratory disease in calves and involves recording rectal temperature alongside coughing, nasal and ocular discharge. Calves were classed as diseased, intermediate or healthy based on their cumulative health score (diseased: cumulative score ≥5 and temperature score =3, intermediate: cumulative score ≥4 and temperature score ≤2, healthy: cumulative score ≤3). The peak day of the most extreme illness event was identified for each calf. Data from diseased and healthy calves were paired for analysis. The paired healthy calf had to be within 7 days of age and ± 10 kg body weight as the ill calf. Health was independently monitored by farm staff and treated as per normal farm practice. Daily activity and feeding behaviour variables were calculated for each calf and analysed using PROC MIXED (SAS, Version 9.3) with health status (healthy or diseased) and date as fixed effects. Effects of age, weight, and genetic line were tested and included where significant. Random effects included calf pair and pen. Differences between means were tested using a least square means comparison test.

Results The results showed that ill calves had fewer feeder visits (with intake), spent less time feeding each day and lay for longer compared to healthy calves. Changes in lying and feeding behaviour were also evident up to 2 days prior to illness.

Table 1 Effect of disease status on feeding behaviour and activity in pre-weaned calves (Total calf pairs = 22).

Variable	Diseased	Healthy	SEM	Significance
Total Visits (No.)	7.54	8.81	0.818	TE
Total Milk (Litres)	5.75	6.76	0.338	TE
Visits with intake (no.)	2.05	3.18	0.221	*
Visits without intake (no.)	5.50	5.23	0.804	NS
Total Feed Time (minutes)	19.30	22.84	1.037	*
Time with intake (minutes)	15.85	19.37	0.796	*
Time without intake (minutes)	3.44	3.47	0.564	NS
Average Visit Length (minutes)	4.36	3.30	0.369	TE
Average Visit Length with intake (minutes)	8.11	7.00	0.326	TE
Average Visit Length without intake (minutes)	0.46	0.68	0.073	TE
Milk Volume (litres)	2.99	2.50	0.161	NS
Drink Speed (litres/min)	0.369	0.371	0.014	NS
Lying Time (hours)	17.60	16.66	0.194	**
Lying Bouts (no.)	17.67	19.55	0.862	NS
Average Lying Bout Length (minutes)	74.84	55.96	5.64	TE

*<0.05, **<0.01, *** <0.001; TE = tendency (P<0.1); NS = not significant (P>0.1).

Conclusion This study demonstrated that feeding behaviour and activity parameters differed between healthy and diseased calves which were also evident prior to the development of clinical symptoms. Thus measurement of feeding and activity using precision technology within early-detection systems can facilitate early intervention and optimised treatment.

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Monitoring of activity and feeding behaviour for early detection of respiratory disease in pre-weaned calves

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Application This analysis shows the potential of close monitoring of feeding and activity behaviours for early detection of ill health, which will allow early intervention and optimised treatment.

Introduction Calf health problems throughout early life are not only a major source of calf and financial losses, but also impact heavily on calf survival and subsequent lifetime performance. In some treatment scenarios, when a few animals have been diagnosed with disease, a blanket treatment of antimicrobials is administered (metaphylaxis). This includes treatments of calves which have not contracted the disease, a practice that increases the probability of antibiotic resistance arising. Changes in feed intake and behaviour often precede clinical symptoms of disease; these can therefore be used as a means of identifying the early onset of disease. Early detection of disease can allow for targeted treatment of animals, therefore reducing the use of antimicrobials. The aim of this study was to develop and assess prediction models for the early detection of respiratory disease in pre-weaned dairy bred calves.

Material and methods Feeding behaviour and activity data was collected from 100 pre-weaned pure bred Holstein-Friesian bull calves from ~8 to 42 days of age. Calves were group housed and provided with starter diet (ForFarmers Vitastart), straw bedding, *ad libitum* water and *ad libitum* access to milk replacer (ForFarmers Omega Gold: 15% concentration) through computerised calf feeders (Holm and Laue). Activity behaviour was captured through an accelerometer (Axivity®) mounted to the hind-leg. The health status of individual calves was assessed daily using an adapted version of the Wisconsin Scoring System, which is best practice technique to identify respiratory disease in calves. This involved recording rectal temperature alongside coughing, nasal and ocular discharge. Continuous diseased days were classed as a single disease event, 4 healthy days had to be present between disease days for them to be classed as separate events. Health was independently monitored by farm staff and treated as per normal farm practice. Two prediction models were developed to predict disease; (i) deviation from the normal using rolling averages (RA) based on daily lying time and (ii) random forest (RF), a machine learning based technique, which used both feeding behaviour and activity variables. Within the RA model, lying time was predicted based on previous behaviour and the expected value for the current day (based on calf age). If the actual lying time increased by >9% of the predicted lying time, a disease day was predicted. Note that the RA model was not split into training and test datasets. Both feeding behaviour and activity variables were included within the RF model. Data was split into training (70% of the data) and test (30% of the data) datasets based on disease events, e.g. consecutive disease days were classified as one disease event and kept together. The RF model was built on the training dataset, and tested against the test dataset using the RandomForest package in RStudio. Outcomes from RA and RF prediction models were combined to give a third prediction model (COMB), based on the test dataset used in the RF model. To assess the accuracy of the RA, RF and COMB models, an adapted version of sensitivity and specificity was performed. If a positive disease prediction was in agreement with an actual disease event within a 3 day rolling window it was classified as a true positive. Note that disease events were used in this sensitivity specificity analysis rather than individual disease days.

Results In total, 88 respiratory disease events were identified (based on individual calves). Eighty events were used in the RA model (due to missing activity data around the time of a disease event), whilst 28 events were used in the RF and COMB models (due to data being split into training and test datasets). Sensitivity (the rate of how often the model correctly provided a disease prediction) and specificity (the rate of how often the model correctly provided a healthy prediction) were 0.41 and 0.97, and 0.48 and 0.98 for RA and RF models respectively. The COMB model had a sensitivity of 0.64 and specificity of 0.95 – see Table 1 for summary.

Table 1 Sensitivity and specificity analysis on three prediction models.

	Sensitivity	Specificity	Disease events used in model
RA	0.41	0.97	80
RF	0.48	0.98	28
COMB	0.64	0.95	28

RA – Rolling Average model; RF – Random Forest model, COMB – Combination of models.

Conclusion Close monitoring of feeding behaviour and activity can allow for early detection of respiratory disease in pre-weaned dairy bred calves, with moderate sensitivity (the ability of the model to correctly predict a disease event) and high specificity (the ability of the model to correctly identify healthy days) observed in the COMB model.

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Effect of environmental enrichment on feed intake and behaviour of dairy calves following milk consumption

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Application Environmental enrichment (EE), especially cereal straw offered directly following milk feeding, reduced harmful cross sucking and increased play behaviour, which contribute to improved welfare of artificially reared calves.

Introduction Individual calf rearing raises cognitive and welfare challenges, creating consumer concerns regarding dairy production practices. Cross-sucking most commonly occurs within the first twenty minutes following milk consumption (Margerison *et al.,* 2003) and is indicative of poor welfare (Boissy *et al*., 2007; Held and Špinka, 2011). Play behaviour increases the calves' ability to cope with stressors and novel situations (Jensen *et al.,* 1998; Gaillard *et al.,* 2014) potentially reducing stress. This study aimed to assess the effect of EE on cross sucking, feeding and play behaviour in milk fed calves.

Material and methods Calves (n=48; 24 pairs) were randomly selected at 5 weeks of age and allocated to one of four EE's, which were applied directly following milk feeding: No EE (Nothing); cereal straw in the morning (CS AM); cereal straw in the morning and afternoon (CS AM+PM); or manila rope for one hour. Data was assessed using Minitab (17.0) and normality distributed feed intake data was assessed using AVONA GLM, while not normally distributed feeding rate and behaviour data was assessed using Kruskal Wallis command, applying animal as a random and EE as a fixed effect in the models. Means and Medians were presented with P values > 0.05 stated at not significantly (NS) different (Table 1).

Results Offering CS, once and twice daily, reduced non-nutritive and cross sucking behaviour, while offering CS twice daily increased play, total nutritive and straw eating behaviour (Table 1), but did not affect starter intake.

Table 1 Feeding rate and post-milk feeding time spent in differing behaviours by calves offered: nothing, manila rope or cereal straw (CS) in the morning (AM) or morning and afternoon (AM+PM) as environmental enrichment

Behaviours	Nothing	Manilla rope	CS AM	CS AM+PM	P value
Mean milk intake, L/d	8.50	8.50	8.50	8.50	NS
Mean starter intake, kg/d	0.61	0.63	0.68	0.67	NS
Median time consuming milk, s/d[1]	354	343	329	357	NS
Median rate milk consumption, ml/s	12.9	12.5	12.0	13.0	NS
Median non-nutritive behaviour, s[2]	49.5 [a]	47.5 [a]	29.5 [b]	11.0 [b]	<0.001
Median cross-sucking behaviour, s [2]	20.0 [a]	19.5 [a]	0.0 [b]	0.0 [b]	<0.001
Median play behaviour, s[2]	0.0 [c]	6.5 [b]	7.0 [b]	27.0 [a]	<0.001
Median total nutritive behaviour, s[2]	0.0 [c]	0.0 [c]	34.5 [b]	195 [a]	<0.001
Median time spent eating straw, s[2]	0.0 [c]	0.0 [c]	34.5 [b]	195 [a]	<0.001

[a, b, c] Means that do not share a letter are significantly different at P<0.05
[1] Total time spent consuming milk daily, calculated by adding together time taken to consume milk meals twice daily
[2] Observed over two 20 mins periods/d, commencing directly following calves finishing each of two milk meals

Conclusion Offering a small amount of cereal straw, directly following milk consumption, reduced cross sucking and increased nutritive and play behaviour, but did not affect the amount of starter consumed by calves.

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The effect of milk replacer fat content on the performance and carcass composition of pre-weaned Holstein Friesian bull calves

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Application Holstein Friesian bull calves fed a high fat compared with a standard milk replacer (MR) had reduced live weight gain and increased systemic concentrations of non-esterified fatty acids, β-hydroxybutyrate, and cholesterol. Fat content of MR had no effect on the composition of the cube roll carcass components measured.

Introduction Pasture based production systems afford a competitive advantage in cost and are also point of difference for Irish beef in many high-value EU markets. However, within such systems of production fat cover is the most variable and onerous of the market carcass specifications to achieve, where entire males are slaughtered at a young age (< 16 months; Murphy *et al*., 2017). It has been hypothesised that increased fat and saturated fat intake, in particular, during calfhood increases adipogenesis and overall body fatness (Tikofsky *et al*., 2001; Bascom *et al*., 2007) and could predispose towards greater carcass adiposity in later life, though there are little or no published data to substantiate this. The objective of this study was to examine the effect of a high fat content milk replacer on calf performance and aspects of carcass composition.

Material and methods Holstein Friesian (n=150) bull calves with a mean (SD) age and bodyweight of 14.7d (2.4) and 47.8kg (4.35), respectively, were purchased from commercial dairy farms. Calves were blocked to dietary treatment within 24 h of arrival on the basis of age, live-weight, dam parity, farm of origin and individual sire PTA for carcase weight, carcase conformation and carcase fat. The study was structured to examine the effect of two levels of supplemental fat inclusion in calf milk replacer (MR) *viz*. a high (HF; 210g/kg CP, 300g/kg fat) and a standard (CON; 210g/kg CP, 180g/kg fat)] fat content. Milk replacer was offered at a daily rate of 125g /L reconstituted to 6 L. All calves were fed both their MR and concentrate (pelleted) allowance using an electronic feeding system (Foster-Technik Vario; Engen, Germany), with concentrate limited to 1kg/day. Calves were weighed weekly and blood samples were collected via jugular venepuncture at day 0, 32 and 63 (timepoints 1-3) of the experimental period to establish a metabolic profile. A subgroup of 15 pre-weaned calves were selected for slaughter from each treatment at Day 63 relative to start of trial (Day 0); CON (n=15; av. live weight 91kg) and HF (n=15; av. live weight 85kg) on the basis of a representative animal, 0.25 SD units either side of the mean ADG of their respective group. Twenty four hours *post mortem*, the carcass was split and the fifth to tenth rib (cube roll) was removed and dissected into fat, lean and bone components. Data were analysed using mixed models ANOVA within the SAS software package. Data reported here are based only on the 30 slaughtered calves.

Results Average daily gain (ADG) (CON 0.67kg v HF 0.60kg; P = 0.03) and bodyweight at slaughter (CON 80.14kg v HF 76.90kg; P = 0.03) were lower for HF. Treatment increased plasma concentrations of β-hydroxybutyrate (BHB) (P < 0.0001), non-esterified fatty acids (NEFA; P = 0.002), cholesterol (C; P <0.0001) and decreased concentrations of albumin (P = 0.02) and IGF-1 (P = 0.04). We observed a treatment x time interaction for concentration of NEFA (P = 0.08), C (P = <0.0001) and leptin (P = 0.02) with calves on HF having increased concentrations at time points 2 and 3 relative to CON. We also observed a treatment x time interaction for albumin (P = 0.008) and adiponectin (P = 0.05) with calves fed CON having increased concentrations at time points 2 and 3. Treatment had no effect on triglyceride (TG) concentration. There was no effect of treatment on the relative composition of the cube roll joint.

Conclusion Increasing the fat content of MR reduced calf ADG and bodyweight up to weaning. However, there was no detectable effect of treatment on the chemical composition of the cuberoll joint. Calves fed high fat milk replacer had increased plasma concentrations of BHB, NEFA and C and leptin all suggestive of increased lipid metabolism/adipogenesis. Further investigation into the digestibility of the fat component of milk replacer and alternative fat sources for inclusion in milk replacers is required.

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Pre-weaning and post-weaning growth performances of lambs may be uncorrelated

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Application Enhanced understanding of liveweight gain patterns across lambs' lifetime can provide insight into how nutrition is best provisioned to ewes and lambs, potentially leading to improved efficiency and profitability of sheep production systems.

Introduction The efficiency of sheep production systems is strongly influenced by daily liveweight gain (DLWG) of lambs, as the longer they take to reach slaughter weight, the more maintenance energy is required over their lifetime (Gascoigne and Lovatt, 2015). While past studies have demonstrated that a lamb's DLWG during lactation is primarily determined by the physical condition of the dam and that DLWG becomes slower after the weaning as the energy source shifts from milk to forage (Kenyon *et al*., 2014), little is known about the mechanism linking these two phenomena and in particular how long the former effect lasts into the lamb's life post-weaning. This study therefore investigated the association between the growth performance of individual animals between these two phases of development.

Material and methods The liveweight of 1391 lambs was recorded at the North Wyke Farm Platform, a BBSRC National Capability grazing trial in Devon, UK (Orr *et al*., 2016), between 2014–2017. Measurements were taken at four weeks, eight weeks and 90 days (immediately before weaning) from birth and every two weeks thereafter until finishing, on meeting the target weight of ~40kg. DLWG was calculated for each animal, for each period between two adjoining weighing events assuming a linear growth within this time window. Statistical analysis using Spearman's rank correlation test was carried out using R 3.5.1.

Results Contrary to expectation, there was no significant correlation between the DLWG of individual animals before and after weaning (r = -0.023, p = 0.40). To further assess the matter, individual DLWG data points for all lambs across their lifetime were plotted, and those for the animals that recorded the top 10% (Figure 1) and bottom 10% (Figure 2) growth pre-weaning were identified. In both cases pre- and post-weaning performance showed no discernible pattern. To account for the potentially confounding effect of litter size, analyses were repeated on three sub-datasets composed of singles, twins and triplets respectively, with all returning comparable results. An auxiliary analysis using matched ewe data showed that lambs' DLWG pre-weaning is positively correlated to ewes' body condition score at lambing (p < 0.001) but DLWG post-weaning is not (p = 0.14), indicating pre-weaning performance is largely driven by ewes' ability to provide milk.

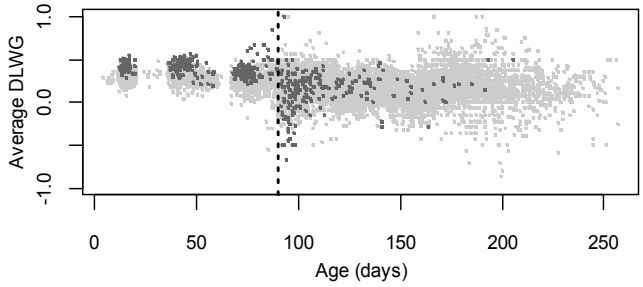

Figure 1. High performers pre and post weaning weight gain

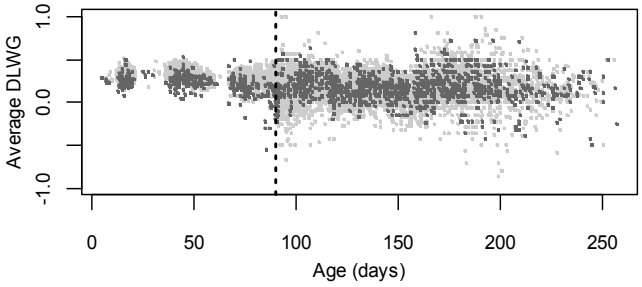

Figure 2. Low performers pre and post weaning weight gain

Conclusion The above results suggest that the overlap between determinants of pre- and post-weaning growth is minimal, with pre-weaning DLWG likely affected more by the ewe's condition than the litter size (Murphy *et al*., 2018). Further research is required to identify factors regulating DLWG post-weaning to help maximise the overall efficiency of sheep systems.

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Effect of breed type and peripartum live weight on live-weight gain and time required to achieve marketing weight by dairy bull calves

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Application Growth performance of Holstein and Kiwi cross bred dairy bull calves was similar and rearing of a dairy crossbred calves for beef and veal was viable, which would reduce on farm culling of bull calves.

Introduction The dairy industry aspires to reduce the number of dairy bull calves euthanised on farm and thus take greater amounts for the production of beef and veal (CHAWG, 2018). The value of Holstein-Friesian bull calves of a higher (≥50 kg) live weight (LW) for beef and veal production is well established (Calf Forum, 2013). However, due to the increasing popularity of pasture based dairying in the UK, there are increasing numbers of Holstein Friesian (HF), Jersey and/or Kiwi cross bred bull calves, which have variable LW and are of uncertain beef and veal potential. The aim of this study was to compare the pre and post weaning performance of spring-born bull calves genetically classified as either HF or Kiwi cross.

Material and methods A total of 60 bull calves were collected from a single spring-calving dairy herd and allocated, at 10 (± 3) d of age, to one three treatments according to breed and LW (n=20 calves/ treatment): Holstein / NZ Friesian (HF: 49.5 ± 0.86 kg LW); HF x Jersey of higher LW (HF x J - H: 51.2 ± 0.86 kg LW) and lower LW (HF x J-L: 44.1 ± 0.86 LW). All calves were offered *ad libitum* access to stored colostrum up until 10 (± 3) d of age, followed by which calves were housed in pairs and individually offered milk replacer (MR) at <10 L/d (150 g MR/L), twice daily, using individual milk feeders fitted with teats. All calves were given *ad libitum* access to water and calf starter (16 % CP and 12.4 MJ ME /kg DM) and weaned at 12 weeks of age, when starter intake was > 1 kg/d for 3 consecutive days. Data were analysed using Minitab (Version 17.2.1, 2016, State College, PA). Live weight, growth rate, feed intake and feed conversion efficiency were normally distributed and analysed using the General Linear Mixed Models procedure (GLM ANOVA), applying breed type/LW group (HF, HF x J-H, HF x J-L) as a fixed effect and animal as a random effect in the model. Significant differences between means were identified using Tukey's test and reported at P<0.05.

Results Holstein Friesian and HF x Jersey calves, of higher and lower LW at 10 (± 3) d of age, had similar pre and post weaning growth rates (Table 1). HF x Jersey crossbred calves that had a starting weight <50 kg were lighter at weaning and required approximately 7 d longer to achieve 120 kg subsequent marketing weight.

Table 1 Mean live weight (± SEM) and live-weight gain, days to weaning and reaching 120 kg live weight of Holstein Friesian (HF) and HF cross Jersey bull calves of higher or lower live weight (LW) at 10 (± 3) d of age

	Holstein Friesian	Kiwi Cross			
		Higher LW	Lower LW	SEM	P value
Observations, No.	20	20	20		-
Starting weight, kg	50.0[a]	51.0[a]	44.0[b]	0.86	<0.001
Weaning weight, kg	139.7[a]	139.1[a]	129.2[b]	2.55	0.008
Weight gain to weaning, kg	84.3[a]	81.1[a,b]	77.0[b]	2.09	0.049
Post-weaning weight, kg[1]	157.6[a]	153.8[a]	141.7[b]	2.35	0.005
Pre-weaning gain, kg/d	1.01	0.97	0.91	0.031	0.069
Post-weaning gain, kg/d[1]	1.57	1.56	1.52	0.105	0.942
Weaning age, d	84.0	84.0	85.0	1.08	0.782
Time to 120 kg LW, d	69.6[b]	71.0[b]	77.7[a]	1.55	0.001

[1] Live weight at and live-weight gain up to 2 weeks post-weaning

	Holstein Friesian	Holstein Friesian x Jersey			
		Higher LW	Lower LW	SEM	P value
Observations, No.	20	20	20		-
Starting weight, kg	50.0[a]	51.0[a]	44.0[b]	0.86	<0.001
Weaning weight, kg	139.7[a]	139.1[a]	129.2[b]	2.55	0.008
Weight gain to weaning, kg	84.3[a]	81.1[a,b]	77.0[b]	2.09	0.049
Post-weaning weight, kg[1]	157.6[a]	153.8[a]	141.7[b]	2.35	0.005
Pre-weaning gain, kg/d	1.01	0.97	0.91	0.031	0.069
Post-weaning gain, kg/d[1]	1.57	1.56	1.52	0.105	0.942
Weaning age, d	84.0	84.0	85.0	1.08	0.782
Time to 120 kg LW, d	69.6[b]	71.0[b]	77.7[a]	1.55	0.001

[1] Live weight at and live-weight gain up to 2 weeks post-weaning

Conclusion The growth rate of Holstein Friesian and HF Jersey cross bred dairy bull calves, of lower and higher LW ay 10 d of age, were similar, and, as such, rearing Spring-born dairy HF Jersey crossbred calves, of both ≥ and ≤ 50 kg LW, were viable for beef and veal production. This could reduce on farm culling of bull calves in the dairy industry. Continued study of the longer term economic viability and potential rearing and finishing systems for optimal product quality is required.

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Effects of ewe parity and litter size on ewe and lamb performance to 5 weeks of age

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Application Multiparous ewes are better able to rear larger litters than primiparous ewes. Triplet-bearing primiparous ewes may need to be managed differently pre and post parturition, in order to increase number of lambs reared.

Introduction Ewe productivity (lambs reared per ewe joined) is a key factor determinant of the efficiency of prime lamb production (Keady and Hanrahan, 2006). As ewe productivity increases, the number of multiple births will increase; for flocks with average litter sizes of 1.8, 2.0, and 2.2 the incidence of triplets is expected to be 8, 15 and 25%, respectively. Triplet lambs are lighter at birth with lower survival rate than those from smaller litters, as are lambs from primiparous ewes (Dwyer, 2003). The objective was to assess effects of ewe parity and litter size on ewe and lamb performance.

Material and methods Belclare ewes (38 primiparous, 36 multiparous) carrying singles (determined by ultrasonic scanning) (12 primiparous, 9 multiparous), twins (14 primiparous, 13 multiparous) or triplets (12 primiparous, 14 multiparous), were selected in the third trimester of gestation. Primiparous ewes were aged 2 years, whereas multiparous ewes were 3 or 4 years. Ewes were shorn and housed, from mid pregnancy, on slats in groups according to ewe parity, litter size and body condition score (BCS) to facilitate nutritional management during late pregnancy. Ewes were offered high feed value grass silage (79% DMD) *ad libitum*. During late gestation ewes received a total of 17, 23 or 29 kg concentrate each depending on whether they were carrying singles, twins or triplets, respectively. Post lambing, ewes rearing singles or twins, and their lambs, were turned out to pasture without concentrate supplementation, and were managed in a rotational-grazing system. Ewes rearing triplets received 0.5 kg concentrate daily for the first 5 weeks post-lambing while their lambs were supplemented with concentrate (up to max of 300 g daily) until weaning (14 weeks of age). Lamb survival was to 5 weeks of age; lambs that required artificial rearing were considered not to have survived (i.e., dam not capable of rearing them). Data were analysed (using SAS 9.4) by fitting a linear model with fixed effects for parity, litter size and their interaction; for lamb weights dam was included as a random term. Lamb survival was analysed as a binomial variable.

Results The effects of parity and litter size on ewe performance are presented in Table 1. Multiparous ewes were heavier, and had a higher BCS at lambing, than primiparae ($P < 0.001$). Single-bearing ewes also had a higher BCS at lambing ($P < 0.001$) than ewes with multiples. Lamb survival declined as litter size increased; in the case of multiple births lamb survival was greater for multiparae than primiparae ($P < 0.05$). The effects of parity and litter size on lamb performance are shown in Table 2; there were no significant interactions between parity and litter size. Lambs from multiparous ewes were heavier ($P < 0.001$) at birth, and at 5 weeks of age. As litter size increased, lamb weight at birth and at 5 weeks declined.

Table 1 Effect of parity and litter size on ewe performance

	Parity (P)							Significance		
	Primiparous			Multiparous						
Litter Size (LS)	1	2	3	1	2	3	s.e.	P	LS	P x LS
Weight at lambing (kg)	67.9	69.6	66.7	82.2	77.6	77.7	1.8	***	NS	NS
Condition score at lambing	3.56	3.32	3.33	3.92	3.65	3.5	0.064	***	**	NS
Lamb survival (%)	100	80.0	63.2	100	98.5	78.0	-	*§	**§	NS§

§From repeated measures binomial analysis of multiple births only

Table 2 Effect of ewe parity and litter size on lamb performance

	Parity (P)		Litter size (LS)				Significance		
	Primiparous	Multiparous	1	2	3	s.e.	P	L S	P X LS
Birthweight (kg)	4.4	5.3	5.6	5.2	3.8	0.167	***	***	NS
Weight at 5 weeks (kg)	15.2	17.7	20.7	15.8	12.8	0.619	***	***	NS

Conclusion Multiparous ewes were better able to rear multiples than primiparous ewes**.** These data, and the effects of parity on ewe BCS, support the hypothesis that pregnancy is more biologically demanding in younger ewes that are lambing for the first time compared to older experienced ewes.

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The effect of milk replacer fat content on adipocyte development in subcutaneous adipose tissue of pre-weaned Holstein Friesian bull calves

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Application Holstein Friesian bull calves fed a high fat milk replacer had a higher number of adipocytes and preadipocytes in subcutaneous adipose tissue than calves fed a low fat milk replacer.

Introduction Fat cover is an important determinant of the market value of beef carcasses in the EU and with minimum specifications more difficult to achieve in bulls slaughtered at a young age (Ferguson *et al*., 2019). In cattle, subcutaneous fat develops through an increase in the number of adipocytes (hyperplasia) and/or the enlargement of existing adipocytes (hypertrophy; Du *et al*., 2010). Indeed, adipocyte formation occurs through two main pathways: (1) the commitment of stem cells into adipocyte precursors and (2) the terminal differentiation of preadipocytes into mature adipocytes. Adipocyte number is a major determinant for fat mass in adults and the number of adipocytes in mammals is thought to be set in early life (Spalding *et al*., 2008). Offering a high fat MR substantially increased carcass fat content when calves were slaughtered at weaning (Tikofsky *et al*., 2001). Such a practice could induce adipocyte hyperplasia and hypertrophy, thus having latent effects on subsequent carcass fatness, though there are little data to substantiate this. Therefore, the objective of this study was to examine the effect of high fat content milk replacer on the dynamics of adipose cell turnover in subcutaneous adipose tissue of pre-weaned Holstein Friesian bull calves.

Material and methods Holstein Friesian (n=150) bull calves with a mean (SD) age and bodyweight of 14.7d (2.4) and 47.8kg (4.35), respectively, were purchased from commercial dairy farms. Calves were blocked to dietary treatment within 24 h of arrival on the basis of age, live-weight, dam parity, farm of origin and individual sire PTA for carcase weight, carcase conformation and carcase fat. The study was structured to examine the effect of two levels of supplemental fat inclusion in calf milk replacer (MR) viz. a high (HF; 210g/kg CP, 300g/kg fat) and a standard (CON; 210g/kg CP, 180g/kg fat)] fat content. Milk replacer was offered at a daily rate of 125g /L reconstituted to 6 L. Calves received both their daily MR and concentrate (pelleted) allowance through an electronic feeding system (Foster-Technik Vario; Engen, Germany), with concentrate limited to 1kg/day. Calves remained on their pre-weaning dietary plans for a 63 day feeding period, following which a representative subgroup were selected for slaughter from each of the two dietary treatments LF (n=15; av. live weight 91kg) and HF (n=15; av live weight 85kg). Post slaughter, a sample of subcutaneous adipose tissue was collected from the rump region on the left side of the carcass for histological and immunohistochemistry analysis. Following sample fixation subcutaneous adipose tissue was sectioned (5µm) using a rotation microtome (Reichert Jung 2030, Munich, Germany) and stained with haematoxylin and eosin (H&E). Sections were digitally scanned using a Leica digital scanner at 200-fold magnification. From each H&E stained section, five randomly selected different fields (0.5 x 0.5µm) were evaluated for adipocyte number and the diameter (µm) of 100 adipocytes per slide was measured. Immunohistochemistry was used to determine preadipocyte number (by assessing DLK-1 staining) and cell proliferation (by assessing Ki67 and CD34+αSMA- double staining). Bovine placenta, kidney and liver sections were used as positive controls for DLK-1, Ki67 and CD34+αSMA- respectively. Data were analysed using mixed models ANOVA procedures in SAS.

Results Animal performance data have been described by Ferguson *et al*. (2019). Calves fed HF had a greater abundance of adipocytes compared to LF (584 *v* 139 cells, respectively; $P = 0.02$). Adipocyte size was not different ($P > 0.10$) between the HF and LF dietary treatments. A strong tendency towards greater staining for the noted preadipocyte marker DLK1 was evident for HF relative to LF (2140 *v* 1425 cells, respectively; $P = 0.08$). Diet did not alter ($P > 0.10$) the expression of Ki67 or CD34+αSMA, indicators of adipocyte cell proliferation.

Conclusion Consumption of a high fat MR by preweaned calves increased adipocyte hyperplasia but not hypertrophy in subcutaneous adipose tissue. Further investigation is required on the biological processes regulating adipocyte development and proliferation in the young calf and whether there are latent effects of increased dietary lipid intake during early life on subsequent carcass composition during adulthood.

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Non-invasive temperature monitoring in domestic species

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Application Body temperature is a key physiological parameter used to monitor animal health and welfare. Traditional methods of monitoring body temperature require restraint, physical contact with the animal and an invasive measurement device, typically a rectal thermometer, therefore less invasive thermometry devices are of growing interest for both biosecurity and research purposes.

Body temperature changes can indicate disease, stress, pain, parturition and exertion. Access to accurate methods of monitoring body temperature is essential for health professionals, veterinary professionals, research scientists, livestock managers and pet owners to name a few. However, the most accurate methods of monitoring body temperature are normally the most invasive, and therefore not appropriate for everyday use. If a method of temperature measurement requires physical restraint or manipulation of the animal, the method may itself influence and alter the animal's temperature (Ozawa *et al*., 2017) and introduce a risk of disease transfer. The ideal temperature monitoring tool is non-invasive, quick, accurate and continuous. This review outlines recent research investigating methods of monitoring body temperature in a range of animal species.

Tympanic membrane temperature (TMT) provides a reasonable alternative to rectal thermometry in dogs, where the ear canal is accessible without causing distress. It is important to use a veterinary specific thermometer shaped appropriately to measure tympanic membrane temperature (Gomart *et al*., 2014). Whilst in human athletes, TMT deviated from rectal temperature following exercise, no deviation between RT and TMT was seen in dogs following exercise (Hall and Carter, 2017a). The use of a correction factor of 0.4^{o}C results in 79.3% of TMT measurements reading within 0.5^{o}C of RT. The normal reference range for TMT in dogs was found to be 36.6-38.8°C (Hall and Carter, 2017b).

TMT has been used to determine the effect of ambient conditions and running speed on post-race temperature of canicross dogs in the UK, and to investigate the potential risk of heatstroke to canicross dogs. Whilst universal thermal comfort index (the 'feels like' temperature) did not correlate to post race temperature, as UTCI increased, the number of dogs with exercise induced hyperthermia increased ($r=0.688$, $P=0.028$). In addition, male dogs and dark coated dogs were more likely to finish a race with a body temperature exceeding 40.6^{o}C, considered to be the critical temperature over which heatstroke is likely. Speed was also found to weakly correlate to post-race temperature, with faster dogs finishing with higher TMT ($r=0.269$, $P < 0.001$) (Carter and Hall, 2018).

Whilst TMT is better tolerated than rectal thermometry in dogs (Gomart *et al*., 2014), TMT still requires restraint and contact and is not suitable for the majority of species. A non-contact infra-red thermometer (NCIT) provides a completely 'hands off' method of temperature monitoring. In 27 anesthetised cats, two animal specific NCIT devices were used to measure eye temperature and compared to RT. Both NCIT devices were also used to compare eye temperature to TMT in resting and exercising dogs. Less than one third of readings fell within the 0.5^{o}C acceptable limits of agreement, with no clear bias to enable a correction factor to be used. In addition, NCIT was poorly tolerated in a number of dogs, due to the close proximity of the device to the eye (Hall *et al*., In Press).

In horses, the larger size of the eye allowed for more targeted measurements of the ocular region. Eye temperature was measured on 22 horses at the medial canthus, lateral canthus and globe regions of both the left and right eye of each horse and compared to rectal ($n=100$). Whilst the Thermofocus device was with 0.5^{o}C of RT <50% of the time, >80% of readings taken at the medial canthus region with the Rycom device were within 0.5^{o}C of RT. This included measurements taken on horses post exercise (Carter *et al*., In Press). Whilst the findings show promise as an alternative to rectal thermometry, further research is needed on clinical patients and those with hypothermia before it is deemed suitable for use in clinical practice.

Conclusion Whilst rectal temperature remains the most appropriate estimate of core temperature in clinical patients, less invasive measures provide viable alternatives for routine monitoring and research in a range of domestic species.

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Effect of probiotic supplemented-diets on serum Malondialdehyde (MDA) concentration of rabbits reared during the hot-dry season in a tropical Savannah

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Application Rabbits fed diets supplemented with varying levels of baker's yeast had lower serum Malondialdehyde (MDA) concentration than those fed the basal diet. Although further studies are required on other biomarkers of oxidative stress, baker's yeast containing *Saccharomyces cerevisiae* (SC) ameliorated the adverse effects associated with heat stress conditions.

Introduction Probiotics such as yeasts and their extracts have been described as excellent sources of natural antioxidants (Gazi *et al*., 2001), and could help promote growth and alleviate oxidative stress in rabbits during thermal stress situations (El-Hanoun *et al*., 2014). Therefore, a feeding trial was conducted to evaluate the effect of SC supplemented-diets on serum MDA (a biomarker of oxidative stress) concentration of rabbits reared during the hot-dry season (temperature-humidity index: 34.11±1.10°C) in the Northern Guinea Savannah zone of Nigeria.

Material and methods The eight-week experiment was conducted during the hot-dry season (temperature-humidity index: 34.11±1.10°C) in a tropical Savannah (Zaria, Nigeria). Sixty healthy weaned heterogeneous breeds of rabbits in equal number of males and females, aged 5 - 6 weeks with live weight of 605.97±14.72 g (mean ± standard deviation) were used for the study. The rabbits were randomly divided into five treatment groups according to average body weight and sex, with twelve rabbits per group; Group SC0 received a control diet without supplementation of SC, and SC2, SC4, SC6 and SC8 received the control diet supplemented with SC at the rate of 2, 4, 6 and 8 x 10^9 colony forming units/kg, respectively. A commercial baker's yeast, Vahine® (Avignon, Monteux, France), containing SC was used for the dietary supplementation. Proximate analysis of the basal mixture (control diet; SC0) which contained maize, soybean, maize offal, brewer's dried grain, groundnut cake, blood meal, rice offal and bone meal as main ingredients showed that it contained 16.0% crude protein, 14.1% crude fibre (CF), 3.9% ether extract, and 10.2% ash/kg feed. The diets were not pelleted and were offered with clean fresh water *ad libitum*. At the end of the feeding period, six rabbits from each treatment were starved overnight of feed for 12 h before blood samples were collected. The blood sample collection and serum evaluation for serum MDA concentrations were carried out according to the procedures described by Shehu *et al*. (2016). Data obtained were analyzed using the General Linear Model of SAS (2006) and Duncan New Multiple Range Test of same package was used to test for significant differences among means.

Results There was a significant ($P < 0.0001$) and linear reduction in serum MDA concentration across the treatment groups. The serum MDA concentration of the rabbits fed the control diet (SC0) was 5.3 mmol/L, as against 3.32, 2.42, 2.07 and 1.58 mmol/L for the rabbits fed the SC supplemented-diets in SC2, SC4, SC 6 and SC8, respectively.

Table 1 Mean (± s.d.)MDA concentration of weaned rabbits fed diets supplemented with varying levels of SC (n=30)

	Dietary treatments					
	SC0	SC2	SC4	SC6	SC8	P-value
MDA (mmol/L)	5.3^{a}±0.14	3.32^{b}±0.35	2.42^{c}±0.07	2.07^{cd}±0.05	1.58^{d}±0.07	<0.0001

^{a,b,c,d}: values with different letters differ significantly

Conclusion Although further studies are required on other biomarkers of oxidative stress, this study has shown that the supplementation of rabbits diets with baker's yeast containing SC could contribute to ameliorate the adverse effects associated with heat stress conditions as shown by the levels of MDA concentrations.

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Influence of age on physical activity in cats (*Felis catus*)

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Application Longevity in domestic cat populations worldwide is increasing in unison with obesity levels. Physical activity is a major determinant of maintenance energy requirements, and information on decline in activity levels with age are important to adjust feeding guidelines and prevent or reduce obesity.

Introduction In domesticated cats (*Felis catus*) an age related decline in physical activity in domestic cats has been reported (Bellows *et al*., 2016). However, reliable scientific evidence on physical activity in cats remains limited as many external factors can influence physical activity. Therefore, the aim of this study was to determine when differences in physical activity occur with age in cats exposed to relatively constant external factors.

Material and methods 139 entire and neutered male and female domestic shorthair cats from the Centre of Feline Nutrition, Massey University, Palmerston North, New Zealand (longitude 175° 38' E, latitude 40° 22' S) were used. All cats were housed in identical colony cages (1.4×2.4×4.4 m), which were located outside and exposed to natural light regimes and temperatures. Data on environmental conditions (temperature, relative humidity and daytime length) were collected from a local weather station (NIWA Tier2, Christchurch, NZ). Cats were fed *ad libitum* with a commercial canned wet feline diet with *ad libitum* access to water. The cats were subdivided into five life stage groups based on the classification of Vogt *et al*. (2010); kitten from birth to six months (n = 11), junior from 7 months to 2 years (n = 37), prime from 3 to 6 years (n = 32), mature from 7 to 10 years (n = 32) and senior from 11 to 14 years (n = 27). Physical activity was measured continuously for seven days (163 hours) using accelerometers (Actical® Respironics Mini Mitter division, Bend, OR, USA) with an epoch length of 15 seconds. The cats were randomly fitted with the accelerometers over the 11-week experimental period, with cats of every life stage group represented in every week. Data were downloaded weekly using Actical® Software (version 3.1). The collected activity data from each cat were combined into intervals of one hour, and differences between age groups were determined using a Kruskal-Wallis test. The study ran from 1 October until 19 November 2018.

Results Results from the first seven weeks of the experimental period are presented. Over this period, the day length increased from 12.5 hours to 14.5 hours per day. The mean temperature and relative humidity over this period were 14°C and 52.6% respectively. Differences in mean physical activity per hour between life stages were found (see Table 1), with a decrease in physical activity between kitten and junior cats ($P < 0.05$) and junior and prime cats ($P < 0.05$), after which the physical activity remained constant (see Figure 1).

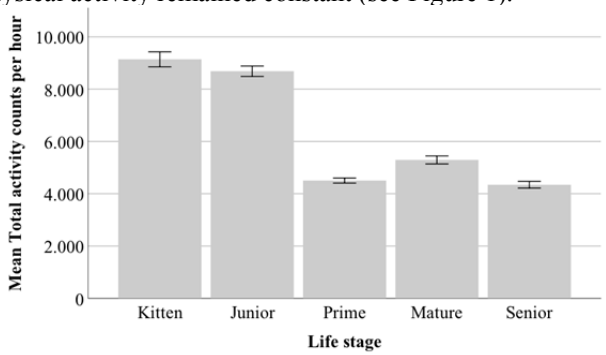

Figure 1 Mean (± SEM) total activity of the different life stages of cats

Table 1 Mean total activity counts per hour of the different life stages of cats

Life stage	Mean (±SEM) total activity counts per hour
Kitten	9383 ± 315.8[a]
Junior	7571 ± 176.4[b]
Prime	4997 ± 128.7[c]
Mature	5238 ± 162.9[c]
Senior	4568 ± 141.3[c]

[a-c] Means with a different superscript are significantly different ($P<0.05$)

Conclusion A significant reduction in physical activity was observed in cats during the first two years of life, after which activity stabilised and remained constant. Senior cats showed a numerical difference in activity counts compared to cats aged 3-10 years. These results have important implications for feeding guidelines, during the first two years of life, which need to reflect this change in physical activity on maintenance energy requirements.

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Can activity be used to distinguish between pregnancy and pseudopregnancy in the domestic cat?

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Application Pseudopregnant female cats could be distinguished by a transient weight gain and similar activity levels to control animals in the five weeks after induction of pseudopregnancy when compared to pregnant queens.

Introduction With a large number of endangered felid species being managed in captivity, there is a need for non-invasive methods of pregnancy detection (Andrews *et al.*, 2019). Distinguishing between pregnancy and pseudopregnancy is important for successful management, as pseudopregnant felids exhibit similar symptoms to pregnant animals, creating complications for determining reproductive state (Dehnhard *et al.*, 2012). Traditional blood sampling is avoided, as it requires anaesthesia. Faecal or urinary hormone analysis, while non-invasive, is expensive and vulnerable to confounding factors. However, advances in accelerometry may provide a new, innovative and non-invasive method of pregnancy detection.

Material and methods This study aimed to determine if bodyweight change and activity could be used to distinguish between pregnancy and pseudopregnancy in the domestic cat. Activity data measured by accelerometers (Actical® Respironics Mini Mitter division, Bend, OR, USA) with an epoch length of 60 seconds were collected from 21 entire female domestic shorthair cats from the Centre of Feline Nutrition, Massey University, Palmerston North, New Zealand. Three experimental groups (control, pregnant and pseudopregnant) each consisted of seven entire females (mean bodyweight (kg): 2.67, 2.77 and 2.68 and age (years) 1.50, 1.89 and 1.76 respectively) were set up in a study which ran from 13 November 2017 until 18 January 2018 (67 days). All cats were housed in identical colony cages (1.4×2.4×4.4 m), which were located outside and exposed to natural light regimes and temperatures. After a two week acclimation period, pregnancy was induced by an entire male, while pseudopregnancy was induced by a vasectomised male that were both introduced to the groups of females for two weeks (from 27 November to 11 December 2017). Pregnancy and pseudopregnancy were confirmed retrospectively using progesterone radioimmunoassay (ImmunoChem™, MP Biomedicals Inc, Costa Mesa, CA USA). Cats were also weighed weekly throughout the experiment. Cats were fed *ad libitum* with a commercially available canned wet feline diet with access to water at all times. Physical activity was measured continually for seven-day (165 hour) blocks. Data was downloaded every week using Actical® Software (version 3.1). The collected activity data from each cat was converted into the average percentage of time spent active, and differences between groups were determined using a PROC mixed model in SAS (version 9.4 SAS Institute Inc., Cary, NC USA).

Results It was found that pregnant females experience a decrease in activity, as do pseudopregnant females. However, this decrease was more pronounced during pregnancy. The activity of pregnant females was significantly lower than control animals after the removal of the males ($P < 0.05$), during the final five weeks of the study. Pseudopregnant females experienced a transient weight gain that plateaued around day 28 of pseudopregnancy and then began to decrease. This was not statistically different from the control group ($P > 0.05$), after the removal of the males. The pregnant females experienced a consistent weight gain that peaked just prior to parturition, and was different to the control animals during the same period ($P < 0.05$). The activity monitoring of pregnant females ceased two weeks prior to parturition, hence the most notable differences in activity levels were potentially not captured.

Conclusion Despite the relatively low numbers of animals used in the current study and high degree of inter-animal variation, differences were still detectable between pseudopregnant and pregnant individuals and should be further investigated in captive felids to explore the use of activity as a method of non-invasive pregnancy detection.

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Assessment of an innovative housing system for fattening rabbits: skin lesions, weight gain and hygienic aspects

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Application Fattening rabbits are usually housed in small wire cages in a poor environment. The aim of the present study was the development of a new marketable housing system for rabbits aimed to enhance animal welfare and to be economically efficient.

Introduction Common rabbit housing is often characterized by restricted space allowance and a barren environment in wire mesh cages. However, animal welfare and health may be affected in such housing systems which prevent the animals from carrying out their natural behaviour. In the present study, an innovative housing system for fattening rabbits was developed which was expected to have positive impact on animal welfare. In this housing system, data on different animal welfare indicators were collected and compared to data from rabbits kept in conventional wire cages.

Material and methods All investigations were conducted on a commercial rabbit farm, where rabbits (HYPLUS PS 19 x PS 59, HYPHARM S.A.S., France) were kept either under innovative housing conditions (IC) or under conventional conditions (CC). In total 24 pens of IC housing equipped with slatted plastic floor (812 cm² per animal), environmental enrichment such as an elevated platform, a plastic tube and different gnawing materials were investigated. IC rabbits were born in this system and weaned at the age of 31 days. At weaning, the does were removed and up to six litters were mixed by opening doors between six adjacent pens. The rabbits remained in the system until slaughter at the age of 78 days. Rabbits from CC housing were born in conventional wire cages. After weaning, they were moved to new wire cages and mixed into groups of eight rabbits originating from two litters each. These groups were kept in 22 cages equipped with wire mesh floor (428 cm² per animal), an elevated platform and one piece of wood as gnawing material. In five replicates a total of 284 fattening rabbits from IC housing and 240 from CC housing were investigated concerning skin lesions, daily weight gain and the occurrence of pododermatitis from weaning to slaughter. To compare the severity of skin lesions, different parts of the body were scored and a cumulative lesion score for each animal was calculated (Min: 0, Max: 28). Furthermore, the cleanliness of feet and floor was investigated using specific scoring systems. Statistical analyses were made with SPSS Statistics. Differences in weight gain between IC and CC were tested with a mixed model with treatment as fixed effect and weaning weight as co-variable. Skin lesions were compared with an analysis of variance for each observation time with treatment, batch and sex as fixed effects and weight as co-variable. Bonferroni corrections were made and the cleanliness was shown and tested with contingency tables and chi squared tests.

Results While IC rabbits showed higher daily weight gains than CC rabbits (46.25g vs. 43.04g, $p < 0.001$), the cumulative skin lesion score was lower in rabbits from IC than from CC in the first half of the fattening period with a significant difference on day 52 of fattening ($p < 0.001$, Figure 1). The cleanliness of feet (Figure 2) and floor differed between the housing systems at any time with CC being cleaner than IC ($p < 0.05$). In both housing systems, pododermatitis was not observed until slaughter. Mortality was higher in IC than in CC housing (18.5 % vs. 12.4 %).

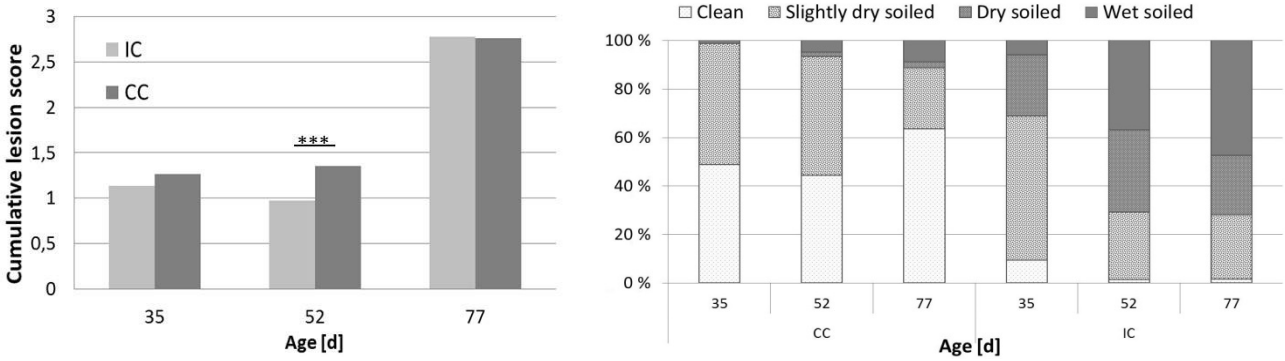

Figure 1and 2 Mean cumulative lesion score and cleanliness of feet at three observation times during the fattening period for rabbits from innovative (IC) or conventional housing conditions (CC), ***$p < 0.001$

Conclusion A lower incidence of injuries in the first half of the fattening period and higher daily weight gain may indicate increased welfare in rabbits from innovative housing conditions. However, the increased mortality and the hygienic challenges posed by this system make further adjustment necessary.

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Smarter systems for livestock production: challenges and opportunities for integrating technology into practice

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Technological innovations in agriculture have opened up a range of capabilities that help to increase production and efficiency in everyday processes through the observation and recording of data. A vast array of developed and developing sensor and response technologies continue to advance our monitoring capabilities, with robotics moving us towards a more automated and semi-automated future for agricultural practice. The advent of greater connectivity and integration technologies through Internet of Things (IoT) opens up the capacity to achieve greater oversight, control and potential efficiency savings through the generation of large-scale databanks for data analytics, machine intelligence, forecasting and intervention. The application of advances from the financial technology sector (such as block chain) offers enormous potential for food safety and traceability.

Forecasted Compound Annual Growth Rates (CAGR) 2014-2020 for precision farming are 15% in Europe, 5% in USA, 20% in South America and 21% in Asia and the rest of the world (Statista.com), and expected global market size is predicted to grow from 13.74 billion US dollars to 26.74 billion US dollars by 2020 (Statista.com). Despite this, integration of technology into practice in livestock production is patchy. This is likely to be linked to a number of specific issues that face the livestock industries that make technology development and integration more challenging. These challenges are both biological and non-biological in nature. For instance, different environmental challenges exist in both indoor and outdoor systems; the focal target for measurement – the animal – is generally not stationary. Socially, the culture for innovation plays a large role and end-user co-development is critical to later phase translation.

In this presentation, the key challenges and future opportunities from up-and-coming technologies currently in development with potential for application to the livestock sector will be explored. The broad range of technologies developed to date and discuss what makes a success story for technology integration, and what the main pitfalls to avoid are for an early phase development project will also be discussed. Finally, how integration of technology could potentially allow a more intimate understanding of the complex systems in which farming takes place will be considered, with deliberation on the broader social and natural landscapes.

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Automatic detection and tracking of individual pigs in a pen

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Application Automatic detection and tracking of individual pigs will allow for unbiased analysis of baseline activity levels, as well as detection of changes in activity level or movement patterns during poor health or welfare.

Introduction The development of affordable precision livestock technologies to automate the detection of potential health or behavioural problems is crucial in the advancement of current pig farming practices. Over the past two decades, a variety of recognition methods have been proposed for on-farm monitoring. These include the use of RFID tags, 3D cameras and image processing using a combination of 2D camera images and uniquely marked pigs (Chung *et al*., 2014; Kim *et al*., 2017; Martinez-Aviles *et al*., 2017). Although the majority of techniques succeed in identifying and monitoring pigs, not all are commercially viable, due to their financial cost or their inability to cope with practical challenges. Common challenges include image occlusion, poor lighting conditions, large numbers of animals and the use of non-routine farming methods, such as having to individually spray mark pigs for identification. Here we present a 2D camera-based system using computer vision and deep learning techniques to track pigs with a custom image analysis algorithm.

Material and methods Video footage of nine finisher pigs (Large White x Landrace) was recorded at Spen Farm (University of Leeds) in June 2017. Footage was recorded with the Longse-400 POE cameras at 30 frames per second, during both lit conditions and night-time (near-infrared) conditions. Manual annotations in the form of bounding boxes and IDs were drawn for each pig in each frame. A total of 18000 frames were used to train the algorithm, and 1500 frames with different scenarios were used for testing. The algorithm was developed with three key components: i) deep learning based Multiple Object Detection (Liu *et al*., 2016); ii) on line learning based Multiple Object Tracking (MOT) with parallel computing; and (iii) Data Association. Multiple Object Detection predicted the locations of objects (pigs) in the image according to the trained model. Object Tracking gave each of the pigs a unique identification and tracked these across consecutive frames. Data Association coupled together the Object Detection and Object Tracking to provide outputs of detections and trajectories.

Results No tracks were lost over the 1500 frames and average tracking success was 95.2%. Tracking was successful even when faced with challenges such as occlusion from flying insects, poor lighting conditions or with pigs obscuring one another. An example result is shown in Fig.1, where pigs are occluded over frames from a-f due to the pigs overlapping and the presence of insects. Even in these conditions, the pigs in the scene are successfully detected and tracked. In particular, our method demonstrates a robust performance of track recovery, in which the tracklets are sequentially built up while maintaining the original IDs in severely occluded conditions.

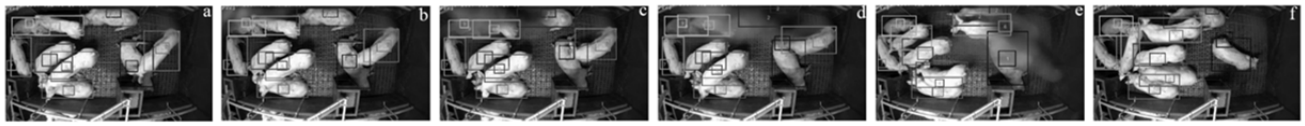

Figure 1 An example result of our method in daylight video with a severe occlusion. The frame sequence order is from a-f.

Conclusion We demonstrate successful tracking of individual pigs in a group without the need for tags or marks. The work is currently being extended for 24/7 recordings with increased numbers of pigs (up to 30 per pen) in a variety of systems. These results form the basis of a warning system able to identify early changes in movement pattern for the detection of health and welfare problems.

Acknowledgements This work was conducted under "PIGSustain: Predicting the Impacts of Intensification and Future Changes on UK Pig Industry Resilience" (BB/N020790/1) funded through the Global Food Security's 'Resilience of the UK Food Systems Programme' with support from BBSRC, ESRC, NERC and Scottish Government.

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Animal-mounted sensor technology to predict 'time to calving' in beef and dairy cows

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Application The availability of early detection and alerts for parturition/dystocia will enable farmers to intervene in a timely manner to prevent the losses associated with dystocia, thus optimising the economic and production efficiency of their business.

Introduction In the UK, the average herd size and animal to stockman ratio is increasing within the beef and dairy sectors, thus the time devoted to monitoring individual animals is reducing. In order to optimise the production efficiency of the UK livestock sector, there is a requirement for the development and use of cost-effective animal monitoring solutions to inform on the health and productive status of individual animals. The non-invasive nature of behavioural observations and the availability of a number of sensors on the market, or near to market, designed to monitor different elements of cattle behaviour provides opportunities for translation of current behavioural and technology validation research into a multi-sensor platform for the prediction of calving onset and calving difficulties. Lying and standing behaviour, eating and rumination patterns, social behaviour and tail raising events are known to change during the 24 hours prior to calving. This study explored the potential of technologies on the market or near-to-market for related and other uses (e.g. detection of oestrus) for their capabilities in the detection of calving and dystocia.

Material and methods Two trials were conducted at separate locations: i) beef cattle (n = 144) at SRUC's Beef and Sheep Research Centre, SRUC, UK and (ii) dairy cattle (n = 110) at a commercial dairy farm in Essex, UK, under the control of staff from Writtle University College. Three sensors were deployed on each cow: 1) Afimilk Silent Herdsman (SHM) collars monitoring time spent ruminating, eating and the relative activity level of the cow, 2) Tail mounted sensors to detect tail-raise events and 3) a real time locating system (Omnisense - OMS) to monitor cow location, orientation and activity level. Cows were monitored from between >30 days to one day prior to calving until 12 hours post calving (beef) or immediately post calving (dairy). CCTV cameras were used to determine the exact time of calving. Machine learning (Random Forest (RF)) algorithms were developed to detect the onset of calving at the earliest opportunity using single sensors variables and by integrating multiple sensor data-streams.

Results The RF models showed that SHM and tail sensors can predict time of calving for both beef and dairy cows for up to four hours pre-calving. When presented with a validation dataset, the tail raise RF for beef cows had a balanced accuracy of 90% one hour prior to calving, dropping to 62% six hours prior to calving (Figure 1a). Results were similar for dairy cows. Time spent ruminating was a better predictor of time prior to calving than time spent eating and combining these two variables (Figure 1b) resulted in only a slight improvement in the beef model performance 0-3 hours prior to calving (particularly at two hours prior where accuracy increased from 59 to 68%), but not the dairy. Combining data-streams from SHM and tail sensors did not substantially improve model performance over tail sensors alone for either beef or dairy. Cumulative deviation from mean acceleration of activity from OMS data indicated a decline in activity up to 10 days prior to calving. CUSUM analyses showed drops in activity greater than two standard deviations from the mean for dairy cows who had difficult calvings – this may prove to be a useful indicator of dystocia.

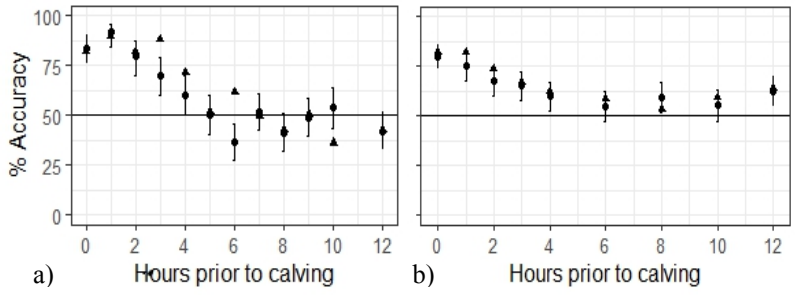

Figure 1 Model performance for predicting 'time to calving' for beef cows using a) number of tail raises per hour for and b) time spent ruminating and eating per hour. Round markers with error bars represent model performance and 95% confidence intervals. Triangle markers represent model performance on the validation data sub-set

Conclusion Tail sensors were effective at predicting calving up to five hours prior to calving. Afimilk collars were less or as good at predicting time to calving. There was no significant improvement to model performance in combining datastreams from these two sensors. Activity level, as measured by Omnisense, may provide a useful early warning indicator of dystocia.

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Markov chain matrices of jaw movement data from grazing animals can be valuable information when examining soil, sward and animal treatment effects

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Application Markov chain summaries of the behaviour of grazing animals reflect soil and sward properties and can be used to compare field managements and animal treatments.

Introduction Jaw movements in grazing animals relate mainly to eating, ruminating and the relative frequency and pattern of these behaviours will be influenced by, for example, herbage type and availability. Herbage biomass will depend upon plant growth, species, plants-soil nutrient matrix interactions and any interventions imposed by the experimenter. Grazing activities tend to be episodic with animals switching between defined activities (Figure 1) in response to physiological, metabolic, endocrinological or environmental cues. Markov chain summary matrices of these behavioural sequences will reflect the animal, soil and plant ecosystems interactions enabling comparison of management strategies and experimental treatments.

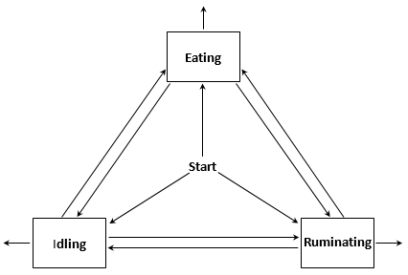

Figure 1 Activity transitions (3-state)

Material and methods IGER Behaviour Recorders (Rutter *et al*., 1997) use a nose band to detect jaw movements and analogue recordings are converted into activity data using Graze software (Rutter *et al*., 2000). As an example, we used data from two groups of lactating dairy cows (A and B) grazing different perennial ryegrass pastures over a 24 h period. Group A cows entered a fresh paddock each day after the afternoon milking, and during the period of recording reduced the mean sward surface height (SSH) from 18.9 to 9.1 cm. Group B cows grazed a paddock maintained at a mean SSH of 7.3 cm by continuous variable stocking management. Each minute of the individual recordings was categorized according to the predominant activity therein, either drinking (D), eating herbage (E), idling (I), ruminating (R) or eating supplement (S). Counts of first order transitions (*i.e.* E-I, E-E, E-R, etc.) were tabulated in a 5 x 5 matrix for each group. The chi square (χ^2) test was used to compare the two r x r matrices (H_0: $A_{i,j} = B_{i,j}$; i, j=1,…,r) with $r(r$-1) degrees of freedom (Anderson and Goodman, 1957). Individual rows were compared between groups similarly but with r-1 degrees of freedom. Degrees of freedom were adjusted for the number of structural zeros in the transition probability matrix or row.

Results Grazing behaviour (Table 1) differed between the groups ($P < 0.001$; $\chi^2 = 105.33$, df = 14). Within row tests suggested that the difference was in terms of eating and idling events ($P < 0.001$). Episodic events are underlined. Cows in group A spent a lower proportion of the 24 h period eating (0.33 vs 0.43) and more time idling (0.32 vs 0.27) reflecting the taller sward height which could have enabled higher ingestion and daily intake rates. Cows in group A were also more likely to switch from eating to idling or from idling to eating *i.e.* bouts of eating were shorter and interspersed with idling and rumination to enable processing of longer ingested material.

Table 1 First-order Markov chain transition matrices for grazing activities by two groups of cows over 24 h

Activity	Group A (n = 12)					Group B (n = 6)					Within row test	
	D	E	I	R	S	D	E	I	R	S	χ^2 (df)	*P*
D	**0**	21	9	1	0	**3**	10	4	0	0	6.28 (3)	0.099
E	23	**5473**	245	8	0	8	**3657**	47	8	0	71.23 (3)	<0.001
I	7	224	**5169**	148	25	6	46	**2168**	65	9	21.87 (4)	<0.001
R	1	31	125	**5620**	0	0	7	65	**2460**	0	4.30 (3)	0.231
S	0	0	25	0	**113**	0	0	8	0	**63**	1.65 (1)	0.198

Conclusion Using Markov chain summary matrices we were able to detect differences between grazing behaviour which could be explained in terms of field management and treatment.

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Hand held technologies for assessment of nutrient digestibility

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Application Combined expertise in animal nutrition and computational image analysis will improve the information and accuracy of predictions of feed utilisation provided by hand held NIRS (near infra-red spectral) analysis of feed and faeces.

Introduction Both under and over feeding of nutrients are inefficient and can lead to environmental, economic and welfare issues. Farm businesses cannot afford to waste expensive resources by feeding nutrients in amounts surplus to requirements. Equally it is not uncommon for farm rations to perform under expectations which can lead to poor productivity and health and welfare problems. However, the farmer's ability to make feed strategy decisions quickly is restricted by the time needed for off-site lab-based chemical analysis of feed. Near infra-red reflectance spectroscopy (NIRS) is a technique used by commercial analytical laboratories to estimate forage and feed quality from prior cross-reference with calibration algorithms derived from standard chemical analyses. This project aims to transfer the analysis from a time consuming, laboratory based approach for measuring digestibility to a real-time, farm based diagnostic tool based on a hand-held instrument with a method applicable to faecal analysis. Furthermore, by combining expertise in animal nutrition and computational image analysis we aim to increase the accuracy of NIRS predictions of feed quality and digestibility.

Material and methods The effect of time and multiple freeze-thaw cycles on NIR spectra generated from faecal samples collected during digestibility trials was evaluated. NIR 4Farm (AUNIR, Towcester) was used to make measurements on samples from a Latin square changeover design experiment (4 periods with 8 cows, 2 on each of 4 diets). Repeated NIRS measurements were made on fresh samples, which were then subdivided and frozen. At weekly intervals between 1 and 10 weeks, samples were thawed, measured and re-frozen such that replicate samples were measured once or after multiple freezing and thawing events. Principle component analysis of NIR spectra was conducted in MATLAB to investigate effects of freezing events, cow, and diet composition. A portable imaging system was developed to include near infrared or visible light sources. Photometric stereo was able to extract data relating to surface normal and depth data from the portable imaging device. A faecal simulation was prepared with a soil/water/straw mixture and used for 3D imaging. Machine learning (transfer learning) was applied to training images to extract data related to presence of fibres and corn kernels in the samples. Further algorithms were developed to describe the “roughness” of the surface of fresh faecal samples.

Results PCA showed effects of cow (Fig 1a) and diet (data not shown) in the clustering of data points within the NIRS data, consistent with the experimental treatments applied. In contrast, there was no effect of amount of time frozen (Fig 1b) nor the number of times thawed and refrozen (data not shown) apparent in the data structure.

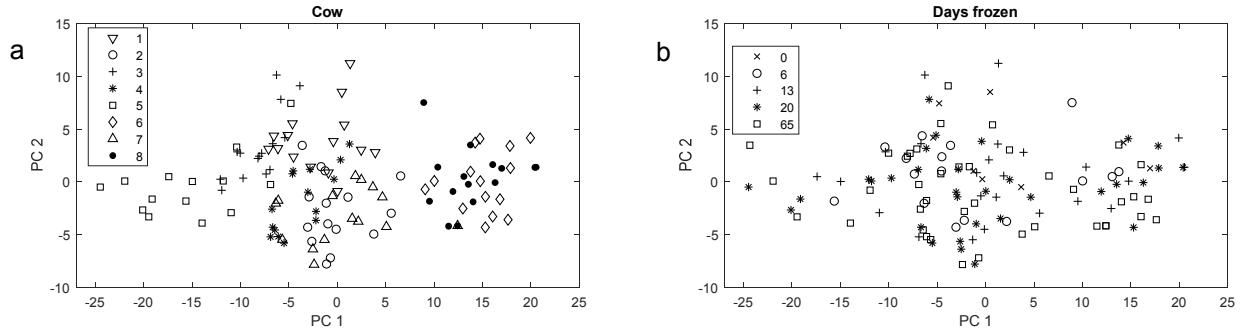

Figure 1 PCA analysis of NIR spectral data from faeces collected from 8 cows on 2 diets with groups identified based on cow number (a) and number of days frozen (b). Machine learning was applied to test data for detection of corn and fibres. Classification rates varied considerably depending on the prominence of the fibres within the images. Rates were as high as 88% in simulated data (soil) although it remains to be seen how this extrapolates to real data. Roughness measures offered comparable metrics to human estimates based on the subjective evaluation of the researcher.

Conclusion Here we have developed a method for making reliable measurements of wet (fresh or after freezing) faecal samples, so increasing industry application potential. Imaging methods have proven feasibility of objective and rapid measurements of corn/fibre content and roughness measures.

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Prediction of methane emissions in sheep using computed tomography (CT) measurements of rumen volume

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Application Rumen volumes, as measured by CT, could help to identify sheep that emit more methane.

Introduction Routine CT scanning of elite sires in UK sheep breeding programmes is used to accurately assess carcass composition and inform selection decisions, accelerating changes in carcass quality. CT could be extended to assess other important traits. Research in New Zealand (Bain *et al*., 2014) and Australia (Goopy *et al*., 2014) showed that sheep divergently selected for methane emissions measured in chambers, have different rumen morphology, when measured by CT. SRUC found previous evidence of differences in methane emissions between lines of sheep, divergent in genetic merit for production traits. These lines were used to further investigate potential rumen differences linked to methane emissions.

Material and methods Scottish Blackface ewes (n=97), ranging from 2-5 years old, with variation in genetic merit (index score) for production traits, were CT scanned, to produce cross-sectional images every 5 mm along the length of the body. Rumen measurements were taken from the CT images and ewes were matched into pairs based on total reticulorumen volume (RRvol), adjusted for live weight at CT scanning (CTWT). Ewes were fed chopped silage, for at least three weeks prior to, and whilst in, respiration chambers for three days in their matched pairs (data successfully collected from 47 pairs in total). Pairs of ewes were recorded to allow sufficient quantity of methane to be measured, since the chambers were originally designed for cattle. Ewe pairs were recorded in one of six chambers across 10 batches, with an attempt to balance ewes of relatively high and low RRvol across batches and chambers. Daily feed intake of ewe pairs was measured and feed samples analysed to calculate dry matter content. Data were combined to produce measurements of dry matter intake (DMI), methane emissions per day (CH_4 g/d) and methane emissions per kg DMI (CH_4 g/kgDMI), for each pair of ewes. Regression analyses were performed using Genstat (16th Edition) to identify factors affecting: (1) RRvol, using data from 98 sheep; and (2) DMI, CH_4 g/d and CH_4 g/kgDMI, using data from 47 pairs of sheep. Generalized Linear Models included: (1) age (in years) and CTLWT; (2) batch, chamber, total live weight of ewe pair entering the chamber (Tot_ChWT), and sum of RRvol of the two ewes at CT scanning (Tot_RRvol). Ewe age was not included (non-significant). Effects of genetic index score of the ewes on RR_vol, DMI, CH_4 g/d and CH_4 g/kgDMI were then tested by adding this covariate to the regression models.

Table1 Significance of model effects on chamber variables

	Significance in final GLM model (P)				R^2	RMSE
Variable	Batch	Chamber	Tot_ChWT	Tot_RRvol		
DMI	<0.001	ns	0.151	0.024	53.2	0.226
CH_4 g/d	0.016	0.150	ns	<0.001	45.2	6.89
CH_4 g/kgDMI	0.062	<0.001	ns	0.002	58.1	2.40

ns = non-significant, dropped from model, as suggested by stepwise regression

Results Only 3% of the variation in RR_vol was explained by CTWT (P=0.05), or 5% by genetic index score (P=0.02). Tot_RRvol of ewe pairs significantly affected DMI and methane emissions per day or per unit DMI (Table 1), whilst Tot_ChWT had no significant effect on methane emissions. After accounting for batch and chamber, Tot_RRvol explained a further 28% and 14% of variation in CH_4 g/d and CH_4 g/kgDMI, respectively. Correlations between rescaled residuals for the methane traits, after adjusting for batch and chamber, and Tot_RRvol were 0.57 for CH_4 g/d and 0.50 for CH_4 g/kgDMI. Index score did not significantly affect DMI or methane emissions, after accounting for batch, chamber and Tot_RRvol.

Conclusion Reticulorumen volume, as measured by CT scanning, significantly affected dry matter intake and methane emissions (per day or per unit of feed) of mature ewes, accounting for substantially more variation in these traits than live weight.

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Combining a process-based model of rumen fermentation with methane production data from respiration chambers

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Application By incorporating the dynamical aspects of the respiration chamber data, the model allows further information on an individual animal's rumen microbiome to be extracted. This represents a potential stepping stone to relating rumen microbial genes to parameters controlling the dynamics of rumen fermentation and hence methane production.

Introduction Time series data of methane production rate (MPR) and feed intake rate from ruminants in respiration chambers give valuable insights into the mean response and variability between animals of methane production from feed (e.g. Troy *et al*., 2015). However, these datasets also contain the dynamical response of methane production to feed intake. This important information has hitherto been largely ignored; here we address this using a process-based model which is driven by feed intake to produce MPR.

Material and methods For this study we used time series data on methane production rate and feed intake rate collected in respiration chambers as described by Troy *et al.* (2015). We used data from two breeds of cow (Charolais Cross and Luing) and two basal diets (in grams per kilogram of dry matter these are forage:concentrate 500:500 (mixed diet) and 80:920 (concentrate diet)). The rumen fermentation model, 'microPopRumen' was built using the R package microPop *(*Kettle *et al*., 2018) for modelling microbial populations. The model has a gas and liquid phase, acid-base reactions for the calculation of pH and a number of microbial functional groups (sugar utilisers, amino acid utilisers and methanogens), similar to the model described by Munoz-Tamayo *et al*., (2016) but adapted for *in vivo* conditions. The model parameters are mostly set from the literature. However, a sensitivity analysis of all model parameters was performed and two microbiome parameters were identified as being the most influential in representing two different aspects of the data (mean values and dynamical response to feed intake). For each individual animal we simulate its MPR time series using microPopRumen combined with the animal's feed intake data. We compare the predicted and actual MPR time series to find the parameter values which best represent the individual animal. This way we gain insight into which aspects of the rumen microbiome are varying between animals.

Results Figure 1 shows the output from microPopRumen fitted to the respiration chamber MPR data for four different animals.

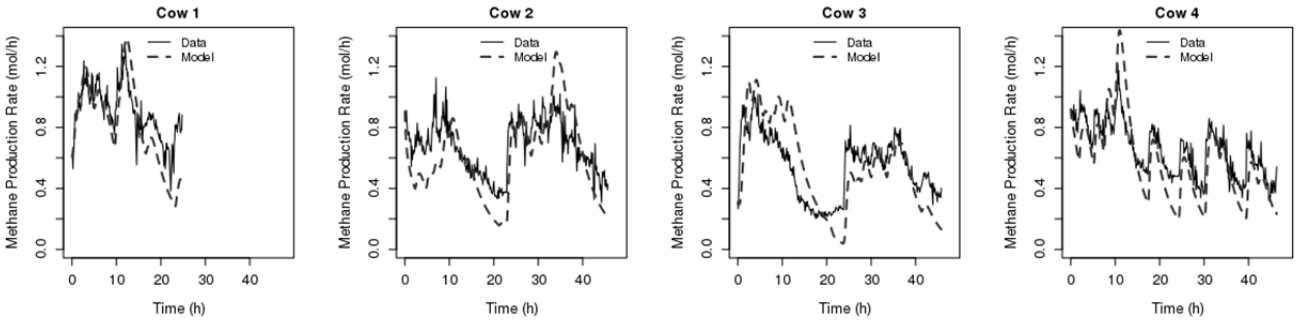

Figure 1 Methane production rate for four example animals. Data is shown as solid lines and predictions from microPopRumen are shown as dashed lines

Conclusion By altering the parameters describing the microbiome, microPopRumen can be used to predict the MPR each animal. The next step is to relate this inter-animal variation in parameters to genomic data.

Acknowledgements We thank the Scottish Goverment's Rural and Environment Science and Analytical Services Division (RESAS) for funding this research.

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The effects of red clover and grass silages on rumen metabolites, detected using nuclear magnetic resonance spectroscopy, associated with methane emissions from growing cattle

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Application A greater understanding of variation in rumen metabolites may provide new, less expensive and higher-throughput proxies for methane emissions.

Introduction Ruminant methane production is a major contributor to greenhouse gas emissions from agriculture. These emissions are produced by rumen archaea, either through utilisation of hydrogen and carbon dioxide (hydrogenotrophic pathway) or methyl compounds (methylotrophic pathway). Diet can have a large effect on these microbes, and thus alter emissions. Current methods to measure methane emissions are expensive and low throughput, so we are exploring alternative proxy methods, such as measurement of rumen metabolites. The aim of the present study was to compare methane emissions from grass silage and red clover silage and assess associated metabolites using nuclear magnetic resonance (NMR). We hypothesized that the metabolites associated with the methylotrophic pathways would be increased by the pectin content in red clover.

Material and methods Twenty-one steers (initial average weight = 241 kg (s.d. = 28.1)) were selected for the study, which adopted a changeover design with a three week diet adaptation period, followed by a one week adaptation to individual pens and a 48 h measurement period in respiration chambers. Steers were randomly allocated and received either red clover silage or grass silage (Table 1) as sole feed in the first period and changed to the other silage for the second period. Each individual animal was allocated a specific chamber to try minimising chamber effects, and feed was given *ad libitum* throughout the study. The respiration chambers were open-circuit and measurements of methane and hydrogen were taken every six minutes using IR absorption spectroscopy. Samples of rumen fluid were taken through a naso-gastric tube immediately after each animal left the chamber. Rumen fluid samples were stored frozen without preservative and then defrosted, centrifuged (10 min, 21,000 rcf) to remove any particles and prepared for analysis. Nuclear magnetic resonance (NMR) was used for detection of metabolites, with a total of 133 signals detected per samples. Analysis of variance was conducted to assess the effect of silage type on methane emissions (Genstat version 16.1). Partial least squares modelling was used to evaluate the relationship between methane emissions and rumen metabolites, initially using only metabolites and then including animal characteristics.

Results Methane emissions, expressed on a DM intake basis, were significantly higher for grass silage compared to red clover silage (Table 2). Metabolites associated with the methylotrophic pathway, in the region described by Ametaj (2010), showed statistically significant differences (P=0.005) between diets; however, levels were elevated for grass silage rather than red clover silage, in contrast with our initial hypothesis.

Table 1 Chemical composition of the two silages (means of four samples, with s.d.)

	Dry matter (g/kg)		ME (MJ/kg DM)		Crude Protein (g/kg DM)		Lactic Acid (g/kg DM)		pH	
Diet	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Red clover silage	188.5	10.01	9.9	0.21	150	14.07	47.3	12.98	4.62	0.12
Grass silage	204.5	22.35	11.0	22.35	133.7	23.93	55	22.20	4.35	0.1

Table 2 Effects of the silage treatments on DM intake and methane emissions

	Grass silage	Red clover	s.e.d	Significance
DM intake (kg/day)	6.52	6.82	0.40	n.s.
Methane (g/day)	133.3	122.0	7.75	n.s.
Methane (g/kg DM intake)	21.2	17.8	1.34	P = 0.016

Conclusion Red clover silage led to significantly lower emissions when compared to grass silage; it is possible that this is associated with higher rumen passage rates for legume silages. Metabolites linked with the methylotrophic pathway were found at higher levels with the grass silage diet.

Acknowledgements The authors gratefully acknowledge SRUC for studentship funding and thank all technicians involved.

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A feeding behaviour-based system to estimate methane emissions in cattle

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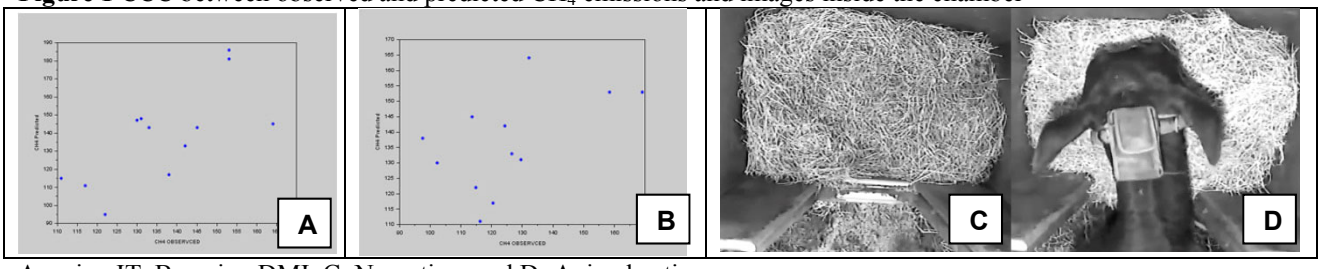
Application Feeding behaviour can be used to estimate enteric methane emissions in ruminants. The equation evaluated in this work can be used as a tool to develop greenhouse gasses inventories.

Introduction Methane (CH_4) is a powerful greenhouse gas emitted by ruminants. There are some techniques to estimate or measure the enteric CH_4 emissions in cattle (e.g. GreenFeed system, Laser, SF6, respiration chamber, among others). However, the use of these tools in large animal groups and for a long time interval is impractical and expensive. Intake behaviour can be used to estimate enteric CH_4 emission in cattle (Munoz-Tamayo *et al*., 2018). Intake behaviour can be routinely recorded by the use of accelerometers (Mattachini *et al*., 2016), implying that CH_4 can be routinely estimated too. The aim of this work was to evaluate the precision and accuracy of CH_4 emission estimations using intake time (IT, min/day) and dry matter intake (DMI, kg/day) as predictors.

Material and methods Five Angus x Brahman crossbreed steers (weight: 198 ± 14 kg) were housed indoors at the Universidad de Antioquia, Hacienda La Montaña bovine research facility (Colombia). A diet was offered to the animals, consisting of hay grass (*Digitaria decumbens* stent) and grains (corn-soya) at a ratio of 70:30, and mineral mix. After 60 days, each animal was placed in a respiration chamber to measure the daily CH_4 emissions, IT and DMI for three consecutive days. The respiration chamber used in this experiment has 21 m^3, with a constant airflow of 500 L/min. The CH_4 concentration in outflow air from the chamber was analyzed using a non-dispersive infrared sensor (MA-10, Sable Systems International, Las Vegas, USA). The CH_4 recovery percentage in the chamber was established, and the CH_4 in inflow air to the chamber was also measured. To measure IT, a video camera was placed over the feeder inside the chamber. A convolutional neural network using the Python language and the Tensorflow library was implemented for image processing. This network uses three convolution layers to detect the animal presence in the image, which was assumed as eating activity. To measure de DMI, the dry matter offered and rejected was measured each day. To estimate CH_4 emission using IT, this equation was used: CH_4 (g) = a + b * IT (min/day), where a is the basal CH_4 emission (g/day), b is the CH_4 emission (g/min) during eating. To use DMI as the predictor, the equation was slightly modified: CH_4 (g) = a + c * DMI (kg), where c is an emission factor (g CH_4/kg DMI). To estimate the best values for a, b and c, a Bayesian Matlab® tool (DRAM, Haario *et al*., 2006) was used. An accelerometer, placed in the animal's head, was used to record IT and to establish the precision of the IT determination using images. The Concordance Correlation Coefficient (CCC) was used to establish the precision and accuracy of CH_4 predictions using IT and DMI.

Results The basal CH_4 emission (i.e. parameter a) was 45 and 36 g/day for IT and DMI, respectively. The mean IT measured using the images and the accelerometer was 251 ± 69 and 226 ± 51 min/day, respectively. The CH_4 emission during eating (i.e. parameter b) was 0.38 g/min. The relationship between CH_4 emission and feed intake (i.e. parameter c) was 13.7 g of CH_4/kg of DMI. The CH_4 estimations using IT or DMI had a low CCC (0.61 and 0.43, respectively) between observed and predicted CH_4, which is comparable with existing CH_4 proxies.

Figure 1 CCC between observed and predicted CH_4 emissions and images inside the chamber



A: using IT, B : using DMI, C: No-eating, and D: Animal eating

Conclusion IT is a similar or even better predictor to estimate enteric CH_4 emissions in cattle than DMI. Consequently, IT can be used to estimate CH_4 emissions under conditions where DMI measure is difficult.

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Near infrared technology applied to faeces as a proxy for indirect prediction of enteric methane emissions from dairy cows.

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Application The results can contribute to improve the estimation of methane emissions from individual lactating dairy cows on a large scale.

Introduction The methane emissions represent about 44% of the total livestock GHG emissions. The development of proxies able to predict the methane emissions from individual cows is a hot research point in order to improve the mitigation strategies to reduce methane emissions. Methane emission is mainly driven by feed intake and diet composition but it is difficult to measure intake in commercial farms. Near infrared spectra (NIRS) has been used as a proxy for enteric methane emission but never applied on faecal samples and in combination with other parameters (Negussie *et al*., 2017). We aimed to verify the possibility of using NIRS of faeces (NIRSf) alone and in combination with other phenotypic parameters available at a farm level to predict methane production (MP, g/d) from individual lactating dairy cows.

Material and methods The study was carried out on 34 Nordic Red dairy cows from calving to 112 days after calving. The animals were fed three diets including a diet based on grass silage and concentrate (55:45 on DM basis), the same diet supplemented with rumen-protected conjugated linoleic acid or with a concentrate high in starch and containing a mixture of sunflower and fish oil (4% on DM basis). Ruminal CH_4 emission was measured using respiratory chambers during four days after one day of acclimatization in each of four measurement periods (3, 7, 11 and 15 weeks of lactation), together with dry matter intake (DMI) and milk yield (MY) and milk composition. Total faecal collection was conducted in the same time with CH_4 measurement. A total of 115 faecal samples were used. Near infra-red reflectance measurements were performed with MPA Multi-Purpose FT-NIR Analyzer (Bruker Italia S.r.l. Unipersonale, Milan, Italy) and the spectra were processed by OPUS© software using a test set validation method. Models for CH_4 prediction were developed by multiple linear regression considering NIRSf, body weight (BW), MY and energy-corrected milk yield (Fat=3.5%, Protein=3.2%) (ECM).

Results NIRSf alone allowed a fairly good estimation of methane yield and the estimations were improved to a similar degree when BW or MY or ECM were considered, whereas combining NIRSf with more than one other parameter improved the estimations to a very little extent only.

Table1 Statistics of comparisons between observed vs. predicted values obtained with different regression equations

Item	ObservedMP[1]	*NIRSf*[2]	*NIR_BW*[3]	*NIR_MY*[4]	*NIR_ECM*[5]	*NIR_MY_BW*[6]	*NIR_ECM_BW*[7]
Average (g/d)	464	464	464	464	464	464	464
SD[8]	102.0	86.1	90.2	90.9	91.4	92.1	92.6
$R^{2,9}$	-	0.71	0.78	0.79	0.80	0.81	0.82
RMSPE[10]	-	85.8	89.9	90.5	91.0	91.8	92.2

[1]CH_4 emission (g/d) measured by chambers | [2]CH_4 emission (g/d) predicted using NIRS | [3]CH_4 emission (g/d) predicted using NIRS and body weight | [4]CH_4 emission (g/d) predicted using NIRS and milk yield | [5]CH_4 emission (g/d) predicted using NIRS and energy-corrected milk yield | [6]CH_4 emission (g/d) predicted using NIRS, milk yield and body weight | [7]CH_4 emission (g/d) predicted using NIRS, energy-corrected milk yield and body weight | [8]Standard deviation | [9]Coefficient of correlation | [10]root mean square prediction error

Conclusion Methane can be predicted using models that consider the DMI, BW or MY but the main boundary is represented by the availability of the data. Near Infrared technique applied to faecal samples, in particular when combined with other phenotypic parameters, can represent a valid alternative for large-scale measurements in commercial dairy farms, when DMI is usually not available, for genetic selection of low emitters dairy cows.

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Novel statistical methods to improve analysis of laser methane detector data

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Application Refining analysis of laser methane detector (LMD) data and establishing techniques to allow approximation to chamber measurements will benefit scientists using LMDs, and improve accuracy when estimating enteric methane (CH_4) emissions from ruminants.

Introduction Methane represents 16% of global greenhouse gas (GHG) emissions with enteric fermentation by ruminant animals such as livestock estimated to generate 28% of all anthropomorphic methane (Beauchemin *et al.*, 2008). Diet digestibility and genetic merit can affect methane produced with estimates for dairy cows reported to range from 278 to 456g CH_4/day (Garnsworthy *et al.*, 2012). The LMD is a nonintrusive method used to measure CH_4 from livestock in the field on the assumption that it is a sufficiently accurate approximation to more arduous methods such as use of closed chambers. Here we investigate the accuracy resulting from various statistical methods of analysis of LMD data by comparison with measurements taken simultaneously in respiration chambers.

Material and methods Eighteen Holstein Friesian heifers were measured over 20 days, with each heifer placed in a chamber for two days during which methane in parts per million (ppm) was measured by the chamber once every four minutes. For 6-8 intervals per heifer, most of 5-6 minutes each (Bruder *et al.*, 2017), methane was also measured (twice per second) using the LMD. This resulted in LMD data from 140 intervals totalling 12.9 hours over 20 days. For each interval, data from the LMD were log transformed (Figure 1) and various statistical methods were used to smooth the LMD data for each interval and remove the impact of zero value data measurements. Some of these methods obtained smoothed estimates of the probability density function (pdf) for each interval whilst others were based on the time series (Figure 2). Each method resulted in a summary statistic for each interval (such as estimated mean or area under curve) adjusted for interval length. The resulting summaries were compared with estimates of g CH_4/day from the chambers for each heifer. These methods were also applied to data from thrice-weekly LMD measurement of 28 cows over 12 weeks in another study, to see whether the LMD could be used to detect differences between two diets.

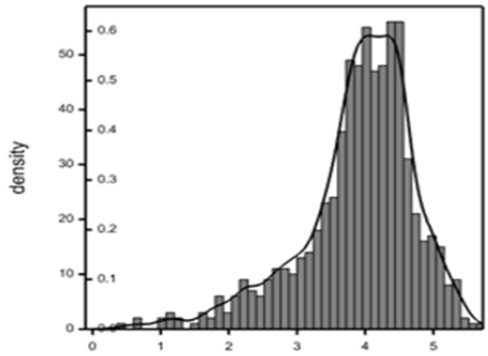

Figure 1 log (methane ppm) from LMD for one interval and pdf estimated using kernel density

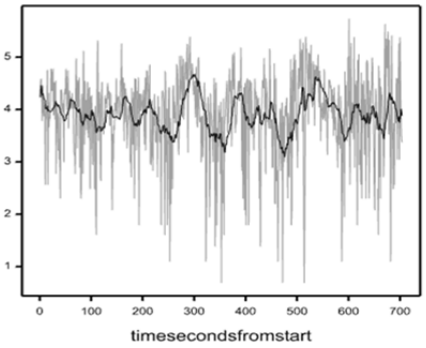

Figure 2 Plot showing time series of log (methane ppm) versus the time (seconds) and a smoother

Results Several of the alternative statistical methods gave very similar results, with Pearson's correlation coefficient between the average over the LMD summaries and the average g/day measured over two days by the respiration chamber of 0.6 ($P < 0.01$). Of the methods investigated there was no evidence to suggest that those that take into account the time series nature of the data outperform those that do not. Whilst these correlations are not particularly high it should be born in mind that they arise from just 6-8 LMD tests mostly between 5-6 minutes long. Furthermore, there was evidence to suggest that the LMD was sufficiently accurate to detect differences in methane emissions resulting from different experimental diets.

Conclusion Whilst further investigation is needed to fully validate these methods on additional studies, results so far suggest they could be used to establish a common approach that will allow the LMD to be used in the field as a proxy for respiration chamber measurement. This would allow more meaningful comparisons to be made within and between animals on farm.

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Robust compositional regression to model methane production from ruminal volatile fatty acids

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Application Investigation of associations between the ruminal volatile fatty acid (VFA) composition and cattle methane production using compositional regression analysis which is robust to outlying and contaminated measurements.

Introduction Ruminants are responsible for about 28% of global methane emissions (Hristov *et al*., 2015). Methane production is mainly associated with fermentation of feed occurring primarily in the rumen. Common quantification by indirect respiration chambers is expensive and slow. The ruminal VFA mixture can however be obtained rapidly and at lower cost. Its association with methane yield in cattle has been investigated using statistical compositional methods addressing the relative scale of VFA measurements as fractions of a total sample volume by Palarea-Albaladejo *et al*. (2017). These are regarded as intrinsically interrelated parts, with their absolute values being less informative than the relative values and, as such, compositional analysis focuses on the ratios between them. Ratios however can be particularly affected by the presence of outlying values derived from e.g. imprecise measurements or varied forms of contamination. Unfortunately, outliers can have a great influence in regression estimates and lead to unreliable results (Maronna *et al.*, 2002). We investigate methods based on statistically robust location and variability measures and introduce a robust regression model of methane production on VFA composition, while also allowing for other diet and animal covariates.

Material and methods Concentrations of VFA (6-part composition in molar proportions) were determined by HPLC from rumen fluid samples (n = 239). These were accompanied by individual CH_4 yield (g/kg DMI), metabolisable energy (ME; MJ/kg DM), dry matter intake (DMI; Kg/day), bodyweight (kg) and diet type (concentrate or mixed). We propose a robust compositional regression procedure combining outlier bivariate filtering (BF) and multiple imputations (MI) with robust MM-estimation to model CH_4 yield in terms of VFA composition and covariates. The VFA parts were represented in the model by log-ratio coordinates which isolated the predominance of each one of them relative to the others. CH_4, ME, DMI and bodyweight were log-transformed to better accommodate model assumptions. The model performance was formally compared with other classic (least squares (LS)) and robust (MM and S) regression methods by simulation under different settings.

Results The simulation study shows that with data contamination our proposal (BF-MI in Figure 1) generally outperforms popular alternatives (LS and ordinary MM), providing results comparable to those assuming an ideal outlier filter (IF-MI).
When applied on the CH_4-VFA data set, the proposed BF-MI method flagged 3.14% of the measurements as outliers. These included both individual parts and entire VFA compositions. The fitted robust regression model reveals a statistically significant positive association between CH_4 and the predominance of acetate ($p = 0.015$) and negative with predominance of propionate ($p < 0.001$). Some diet and animal covariates (DMI, bodyweight and diet type) also display a statistically significant association with CH_4 ($p < 0.001$). However, only a marginally non-significant positive association between animal methane emission and the predominance of acetate ($p = 0.053$) is obtained when ordinary MM-type robust regression is used instead.

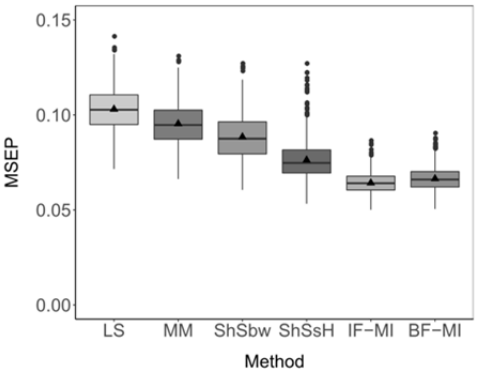

Figure 1 Mean squared errors of prediction (MSEP) across simulations for various regression methods.

Conclusion Our proposal offers a reliable regression method with compositional predictors in case of data contamination. When applied to investigate the association between CH_4 and ruminal VFA measurements, the results are coherent with previous knowledge and stress the role of acetate and propionate as drivers of the relationship.

Acknowledgements The authors gratefully acknowledge John Rooke and Richard Drewhurst from the Scotland's Rural College (SRUC) who originally provided the data used in this study. This work was partly supported by the Scottish Governments Rural and Environment Science and Analytical Services Division (RESAS).

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Equine grass sickness; an update

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Introduction Equine grass sickness (EGS) is a multi-system neuropathy of equids characterised by damage to autonomic, enteric and somatic neurons. An identical disorder occurs in hares, dogs, cats and rabbits, and possibly in sheep and llamas. The reader is directed to a recent detailed comprehensive review of the disease (Pirie *et al*., 2014). This abstract will highlight recent EGS research.

Aetiology While the aetiology of EGS is currently unproven, some evidence is consistent with it being a toxico-infectious form of botulism, whereby a dietary trigger induces intestinal bacterial overgrowth and *in vivo* production of botulinum neurotoxins C and/or D. The clinical features of EGS are however inconsistent with the neuroparalytic effects of botulinum neurotoxins. Furthermore, the occurrence of autonomic and enteric neurodegeneration, and increased expression of soluble N-ethylmaleimide-sensitive factor attachment receptor (SNARE) proteins within neuronal perikarya in EGS but not botulism, again suggests that EGS is not caused by botulinum neurotoxins but does not preclude involvement of other botulinum toxins (McGorum *et al*., 2016). A large (~1000 horses) UK-wide randomised placebo controlled field trial of a killed *C. botulinum* type C toxoid vaccine for the prevention of EGS has just been completed (http://www.aht.org.uk/cms-display/egs_vt.html). It is hoped that the outcome of this study will definitively prove or refute the botulinum hypothesis and provide an effective prophylaxis for this devastating disease.

Leng *et al*. (2018) identified marked intestinal dysbiosis in EGS using next generation sequencing of faecal bacterial DNA. EGS horses had significant increases in Bacteroidetes and decreases in Firmicutes bacteria compared to two control matched groups. Discriminant analysis identified bacterial genera *Desulphovibrio* and *Veillonella* and the bacterial species *Veillonella parvula* as increased in abundance in EGS. There was no detectable increase in *C. botulinum* in the faecal microbiome of EGS horses. The dysbiosis showed a similar shift to that identified previously in equine colitis and human inflammatory bowel disease. It is currently unclear how *Verrucomicrobia* bacteria are linked to EGS.

The author's group is currently performing targeted amplicon sequencing to detect fungi in gastrointestinal contents from EGS and control horses to determine whether EGS is caused by an ingested pasture-derived mycotoxin.

Molecular pathogenesis Proteomic profiling of cranial cervical ganglion extracts from EGS and control horses identified 2,311 proteins, with 320 proteins being increased and 186 being decreased by greater than 20% relative to controls (McGorum *et al*., 2015). This study highlighted a previously unreported dysregulation in proteins commonly associated with protein misfolding/aggregation responses seen in a myriad of human neurodegenerative conditions, including but not limited to amyloid precursor protein, microtubule associated protein (Tau) and multiple components of the ubiquitin proteasome system. This is the first demonstration of correlation and conservation of neurodegenerative molecular cascades spanning from an apparently unrelated large animal neuropathy, small animal models of altered neuronal vulnerability, and a broad range of human neurological conditions.

Prognosis To determine whether the rate and/or magnitude of bodyweight change during hospitalisation of chronic EGS cases provides an objective predictor of survival to discharge from hospital, Jago *et al*. (2016) analysed body weight data from 213 EGS horses, comprising 114 survivors and 99 non-survivors. Percentage survival prediction curves were developed to provide objective data to aid prediction of outcome. Non-survivors had greater bodyweight loss than survivors.

Diagnosis Examination of beta-amyloid precursor protein labelled rectal biopsies can provide sensitive and specific diagnosis of EGS, but has practical and time limitations (Jago *et al*. 2018).

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The practical application of behaviour to veterinary care of equine

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Introduction Working as an equine veterinarian is the most dangerous civilian profession to be employed within. The vast majority of injuries are caused by horses reacting to veterinary care they find aversive. Traditionally management of horses that are non-compliant has relied upon physical restraint and dominance based theories.

Learning Theory describes the process through which horses learn. By understanding these processes, we can alter the way we handle horses that find veterinary care aversive. In doing so, the majority of horses can be trained in a very short time period to accept veterinary care whilst standing calmly. These processes include: -

Classical Conditioning - Making associations between two previously unrelated cues; increases the *Predictability* of the environment for the horse.

Operant Conditioning - Making associations between a stimulus and a response; increases *controllability* for the horse. Operant conditioning allows the horse to learn how its behaviour can alter the environment. It is divided into *Reinforcement* training – Increasing the likelihood a behaviour will be repeated in the future and *Punishment* – decreasing the likelihood a behaviour will be repeated in the future.

Positive Reinforcement
The addition of something pleasant after the desired behaviour. This makes the horse more likely to repeat the behaviour in the future. Common examples would be food or a scratch on the withers.

Negative Reinforcement
The removal of an aversive stimulus after a desired behaviour. Pressure is applied to the horse which motivates it to remove the pressure, provided the pressure is released as soon as the desired response is offered. For example, If you put pressure on the horses halter (pressure) they should walk forwards and the pressure be released

Positive Punishment
The application of an aversive stimulus after an unwanted behaviour has occurred.

Negative Punishment
The removal of a pleasant stimulus after an unwanted behaviour has occurred.

Punishment based methods are not recommended in equine training; as well as the obvious negative welfare implications they may promote fight or flight responses from the horse.

Summary Horses have limited ways in which they can learn and we should not assume an unwanted behaviour is being exhibited because the horse is naughty or has a desire to upset us in some way. By understanding the processes by which horses learn we can not only understand why unwanted behaviours are offered but also understand how to prevent them being repeated in the future. This lecture will look at how this knowledge can be applied to deal with common problems in equine practice.

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Electromyographic and kinematic evaluation of movement and muscle activity in horses with temporary forelimb lameness induction: a preliminary report

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Application Understanding muscular adaptations could inform objective lameness-detection for early diagnosis/treatment, ultimately serving to detect sub-clinical issues in supposed healthy horses and to reduce pain/ incapacity in lame horses.

Introduction The prevalence and impact of lameness on equine welfare has led to extensive research, which has biomechanically analysed lameness-related alterations in movement. Despite this, limited information is available about adaptive muscle activity that facilitates movement during lameness. Surface electromyography (sEMG) is a non-invasive method for quantifying muscle activity. However, no equine studies have employed sEMG to compare inherent and adaptive activity during non-lame and standardised lameness conditions, respectively. The aim of this preliminary study was to compare *Triceps Brachii* (TB) muscle activity in horses before and after induced forelimb (FL) lameness, using sEMG data.

Material and methods Six clinically non-lame horses (5 mares, 1 stallion, age: 7.0±3.7 years, height: 162.3±4.0 cm, body mass: 572.7±45.8 kg) were used. sEMG sensors (Delsys Trigno, Delsys Inc.) were attached bilaterally to locations above TB (long head), that were prepared by removing all hair and cleaning with isopropyl alcohol. Retro-reflective markers were attached to anatomical landmarks for quantitative lameness evaluation (QHorse, Qualisys AB) and gait event detection. sEMG (2000 Hz) and 3D kinematic (200 Hz) data were synchronously collected from horses during in-hand trot trials, conducted on a straight, hard surfaced runway before (baseline) and after FL lameness induction. Baseline data were initially collected, then temporary, mild FL lameness (2-3/5 AAEP Lameness Scale) was induced using mechanical bolt pressure, applied to the tip of the frog and monitored by qualified veterinarians (T.S., F.S.B.) using a modified horseshoe (Merkens and Schamhardt, 1988). Left and right FL lameness induction were randomised. Following data collection, the bolt/ sole pressure was removed and no horses showed adverse reactions to lameness inductions, or residual lameness. For stride segmentation, gait events were detected using kinematic data that were low-pass filtered (Butterworth 4^{th} order, 10 Hz cut-off) and analysed in accordance with the methods described by Holt *et al*. (2017). To quantify lameness, MinDiff was calculated using poll vertical displacement data, where healthy horses exhibit MinDiff between -6 – 6mm and left and right FL lameness are exhibited as more positive and negative values, respectively (Rhodin *et al*., 2016). Raw sEMG signals were DC-offset removed, high-pass filtered (Butterworth 4^{th} order, 40 Hz cut-off) (St. George *et al*., 2018), and full-wave rectified. Integrated EMG (iEMG) and average rectified value (ARV) were calculated using stride duration as temporal domain. To reduce inter-subject variability, iEMG and ARV from each horse were normalised to the maximum value observed for each limb (left/ right FL) across all strides from the baseline condition. Data from the "lame" and "non-lame" limb were grouped, according to the limb where lameness was induced. A 2x2 repeated measures ANOVA was used to compare muscle activity between limb (lame, non-lame) and condition (baseline, induced FL lameness). Post-hoc analyses using Bonferroni correction were performed where significant main effects were found.

Results Mean ± sd MinDiff were baseline:-1.8 ± 8.7 mm, left FL lameness induction:-55.3 ± 34.1 mm, right FL lameness: 56.8 ± 17.9 mm. Significant interactions between limb and condition were found for iEMG ($p < 0.05$, $n^2=0.74$) and ARV ($p < 0.05$, $n^2=0.75$). Post hoc analyses of iEMG and ARV data revealed muscle activity was significantly higher in the lame limb ($p < 0.05$) and significantly lower in the non-lame limb ($p < 0.01$) during the induced FL lameness condition.

Conclusion Preliminary findings reveal neuromuscular adaptations in TB during induced FL lameness. Significant increases in stance duration have been reported during FL lameness (Weishaupt *et al*., 2006). Therefore, significant increases in lame limb muscle activity may be due to prolonged stabilisation of the shoulder and elbow joints, as a compensatory mechanism of gait adaptation to lameness. Further investigations of additional muscles and chronic lameness cases are required to determine whether sEMG can provide a complimentary tool for objective lameness detection.

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Comparison of the faecal bacterial microbiota of healthy horses and horses with equine glandular gastric ulcer disease by high throughput sequencing of the 16S rRNA Gene

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Application Horses with equine glandular gastric ulcer disease (EGGD) were found to have significant differences in abundance of several bacteria compared to a control group.

Introduction The prevalence of horses with gastric ulceration is substantial, with performance horses suffering most frequently. Recently gastric ulceration in horses has been categorised as two separate conditions (Sykes *et al*., 2015). EGGD is a disease which is characterised by ulceration of the glandular mucosa of the stomach, where aetiology is not well understood there appears to be associations with management, stress and breed. The relationship between gastrointestinal disorders, microbial populations and stress via the brain-gut axis have been explored in recent times and are outlined in several human diseases such as irritable bowel syndrome (Mawdsley and Rampton, 2005). The aim of this study was to compare faecal bacterial profiles of horses diagnosed with EGGD to those of horses with healthy gastric tissue.

Material and methods Fresh faecal samples were collected from 20 thoroughbred horses (EGGD, n=10; Control, n=l0). All samples were obtained from horses which were living at the same location (Newmarket, UK) and were under similar management. Horses ranged in age from 2-4yrs. Horses had not received worm treatment in the 4 months prior to sample collection. Horses with EGGD had not received any pharmaceutical treatment for the condition. Stomachs of horses were examined by an experienced vet via endoscope as part of normal veterinary practice at the facility where the horses were housed. During faecal sample collection, approximately 200 mg of stool was placed in a collection tube and 95% ethanol was added and stored until ready for use. DNA extraction, polymerase chain reaction, next generation sequencing on Miseq (Illumina), and analysis using Basespace metagenomic App was performed.

Results An average of 159,393 (SD 19,493) reads per sample were obtained. The mean number of species for the EGGD group was 433 (SD 31.48) while the mean number of species for the control group was 439 (SD 60.3). An independent t test revealed no significant difference in species diversity between groups. Mean Shannon species diversity was 2.34 (SD 0.13). At phylum level, horses with EGGD had significantly less Cyanobacteria than control group (p=0.048). At genus level, horses with EGGD had significantly less *Dysgonomonas* (p= 0.005) and *Pedobacter* (p=0.001), and more *Prevotella*, (p=0.023) and *Ruminococcus* (p=0.002). Statistical results at genus level are described in Table 1; independent t test shown as mean with standard deviation (SD) and the Mann-Whitney U as the median with interquartile range (IQR) as is considered more appropriate presentation of non-parametric data (Olsen, 2003). The first 200 genera were tested, cut off point for inclusion was decided at average of 1000 reads per sample (Table 1.)

Table 1 Significant differences at genus level between EGGD and control groups

Genus	P value	EGGD group: % of total reads per sample		Control group: % of total reads per sample	
Dysgonomonas	0.005	1.6039	1.31 (IQR)	3.1043	2.94 (IQR)
Pedobacter	0.001	1.6734	0.057 (SD)	2.5642	0.43 (SD)
Prevotella	0.023	1.7759	1.83 (IQR)	0.89405	1.11 (IQR)
Ruminococcus	0.002	1.441	1.082 (IQR)	0.87765	0.42 (IQR)

Conclusion Horses with EGGD have differences in abundance of a number of bacteria. It is unclear as to whether bacterial differences are a cause or consequence of EGGD, further investigation is necessary to elucidate this. This study has given further insight into the condition of EGGD and provides information regarding its relationship with the hindgut microbiome which had not been explored previously.

Acknowledgements Dr Matthew Hegarty, Dr Carol Hughes, Dr Debbie Nash.

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Defining faecal core bacterial community of Welsh Mountain ponies maintained in West of Scotland

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Application Limited research is available on equine gut microbiome in health and disease. Pony breeds are often used in equine nutrition research due to lower maintenance costs; thus, it is important to understand whether ponies can be used as a model for horse microbiome studies. The results suggest that ponies have a more stable core microbiome, which may allow them to better tackle nutritional challenges.

Introduction Equids have a complex gastrointestinal microbial community that plays an important role in digestibility of the diet and overall welfare of the horse. The presence of a core bacterial microbiome has been shown in faecal samples and large intestine contents of the horse (Dougal *et al.*, 2013, O' Donnell *et al.*, 2013) with key microbes present in all or the majority of individuals within a chosen population. However, the equid microbiome is highly variable and defining a core microbiome in healthy animals may provide a useful indication of changes occurring due to microbial disturbances.

Material and methods The gut microbiota was characterized in eight healthy Welsh Mountain ponies, with 16 samples from each pony collected over a six week period (May-June). The samples originated from a different study investigating the effect of yeast on faecal microbiome structure and during an abrupt change from hay to grass and vice versa. Genomic DNA was extracted and 16S libraries encompassing the V3-V4 regions were generated prior Illumina NGS of 16S rRNA gene. Biostatistics analysis was conducted using 16S metagenomics pipeline in QIIME v1.9.0. OTU reads for each pony were averaged and core was defined by presence in the microbiota in six or more out of the eight ponies at $\geq 0.1\%$ of the total reads. Total OTUs were grouped by family and the relative abundance of each family is given as a percentage of the total number of sequences. Although the dietary changes and probiotic treatment may impact the microbiota, for the purposes of the current study it was considered beneficial, as the aim was to capture as much variability as possible to define a core microbiome.

Results A total of 128 faecal samples were collected during the experiments and sequenced. Illumina NGS generated 6,664,470 non-chimeric sequences annotated to 6,289 OTUs. The OTU table was rarefied to 5,000 sequences/sample. 200/6,289 (3.2%) of all OTUs were defined as core community; however, they contributed to 63.8% of the total reads per sample on average. The total number of core sequences in OTUs were grouped by family and are given in Table 1. Other families included Porphyromonadaceae (5/200, 1.5%), BS11 (3/200, 1.3%), Prevotellaceae (3/200, 1.2%), unassigned family from order Clostridiales (6/200, 1.1%), Erysipelotrichaceae (3/200, 1.0%), Bacteroidaceae (2/200, 1.0%), Veillonellaceae (4/200, 0.7%) and other.

Table 1 Most abundant OTUs of the Welsh Mountain ponies' core faecal microbiome grouped by family

Core OTUs	% of reads	Phylum	Class	Order	Family
56/200	15.3	Bacteroidetes	Bacteroidia	Bacteroidales	Unassigned
23/200	6.7	Spirochaetes	Spirochaetes	Spirochaetales	Spirochaetaceae
7/200	5.2	Fibrobacteres	Fibrobacteria	Fibrobacterales	Fibrobacteraceae
13/200	3.5	Firmicutes	Clostridia	Clostridiales	Lachnospiraceae
12/200	3.0	Firmicutes	Clostridia	Clostridiales	Ruminococcaceae
11/200	2.3	Bacteroidetes	Bacteroidia	Bacteroidales	[Paraprevotellaceae]
6/200	2.0	Bacteroidetes	Bacteroidia	Bacteroidales	RF16
37/200	1.6	Verrucomicrobia	Verruco-5	WCHB1-41	RFP12

Conclusion The size and structure of the faecal core microbial community of the ponies was similar, while abundance of the core microbiome was higher than the one reported for horses.

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Using the 'pain face' scoring system does not detect pain due to lameness in dairy cows

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Application Comparing still images of cows taken in the home pen whilst lame and then when the condition is resolved is not an effective means of detecting pain

Introduction Pain is a negative sensory experience for animals, and interferes with normal functions such as feeding, drinking and resting. Alleviating pain is clearly important in safeguarding animal welfare. However, as pain is a subjective experience, unique to the individual, determining how much pain is being experienced by an individual is very difficult. Experimentally, physiological and behavioural methods can be used to detect pain. Experienced stockhandlers are able to detect pain by the behavioural and facial expressions in animals. In some species, 'grimace' scales, or descriptions of changes to facial expressions that accompany painful states have been designed. This method divides the face into 'facial action units' (FACS), such as the ears, eyes or cheeks and provides a description of how pain affects muscle definition or expression in this part of the face. Previous work has also shown that these 'pain face' scales can be used to detect pain in a group of dairy cattle suffering ill-health. The aim of the present study was to further this work by determining whether pain face assessments can be used to detect pain in lame dairy cows.

Material and methods Cows in two experimental herds were scored for lameness. The cows were locomotion scored on a 4-point scale ranging from 'perfect gait, no evidence of gait alteration' to the highest score representing cows unable to walk freely. Cows with scores indicating a high degree of lameness were identified. Inspection of the feet showed that they were suffering from claw horn disease or digital dermatitis. Images were taken of the cows in their home pen. A profile image was taken in good light, against a background that allowed the facial expression to be identified. Once the cows had been confirmed as having recovered (return to score zero), a second image was taken, again in the home pen. A total of nine cows had good quality 'lame' and 'not lame' images. Score sheets were then set up with scorers asked to rate the level of tension or tightness around the eyes, lips, jawline and cheeks, the ear position, the quality of the gaze on a scale from zero (not present) to two (highly visible). They were also asked to rate the level of pain on a visual analogue scale from 'no pain' to 'most possible pain'. Six observers completed the scoring. Kendall's concordance was used to assess concordance across observers for each measure. Differences between scores for the GLMM was used to assess the differences in scores in the facial units and ReML to assess differences in responses on the VAS scale between the 'lame' and 'not lame' images.

Results There was variation in the level of agreement amongst observers, with greatest concordance shown for 'gaze' and 'cheek tension' ($P < 0.05$). There was no detectable difference between the 'lame' and 'not lame' images detectable for tension around the eyes, cheek, jawline, ear position or quality of gaze ($P < 0.05$ for all). A difference in scores between 'lame' and 'not lame' images was shown for scores of tension in the lips ($W=4.75$, $ndf=1$, $P < 0.05$) and in the overall pain score ($W=4.95$, $ndf=1$, $P < 0.05$), but scores were higher for 'not lame' than 'lame' cows.

Conclusion Using classical pain face methodology did not allow observers to distinguish between lame and non-lame cows. Using still images may not capture facial or behavioural expression well enough. Capturing the 'not lame' image was somewhat problematic, as cows were somewhat alarmed to be followed in their home pen during capture of the image, which may have been reflected in their facial expression. Additionally, variation in the coat colour and facial conformation between cows may also contribute to the inability of some FACS to discriminate between lame and non-lame cows. However, these issues would also be encountered by farm staff attempting to use this method to detect lameness, so need to be overcome. In a chronic state such as lameness, pain may not be consciously experienced at all times, so may not be expressed at the time of image capture.

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Using social network analysis to measure the impact of social upheaval in captive animals

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Application Investment in non-random social bonds can convey welfare and fitness benefits between individuals that live in social groups. In managed populations, the impact of changes to social structure can be measured using Social Network Analysis (SNA) to reduce potential long-term effects of social disruption.

Introduction SNA illustrates and evaluates the quality and consistency of associations and interactions that occur between individuals in groups. SNA has wide application in the domestic animal world and is being used more frequently in the field of zoo animal management to assess the stability and cohesiveness of *ex situ* groups. Identifying individuals, following their social choices across time and determining the position they hold within a group means SNA can determine how social bonds are altered when the overall network structure changes if new individuals are brought into, or if individuals are lost from, a network. Flamingos are commonly-housed in captive collections and all six species are gregarious birds with a wild ecology that predisposes them to group living. Investigating the lives of zoo-housed flamingos reveals much about the social structure of their flocks (Rose *et al*., 2017), and what types of assortment may take place within their groups as wild flocks can be tricky to follow over time. Flamingos can live for over 80 years in captivity and over 50 years in the wild (Rose *et al*., 2014) and as such, bonds have a long time to form between birds. Disruption to these relationships that affect preferred partnerships may cause individuals to experience an altered social position, which may have welfare consequences.

Material and methods Twenty-one Andean *(Phoenicoparrus andinus)* and 42 lesser *(Phoeniconaias minor)* flamingos were observed at WWT Slimbridge Wetland Centre, Gloucestershire UK from January 2013 to July 2017. Data were collected on preferred partnerships based on a neck-length distance between individuals (Rose *et al*., 2015) for all birds. Five new lesser flamingos joined this flock in September 2014. Observations of birds were collected directly by one observer from 2013 to 2016 and for another observer for April to July 2017. Networks were compared across years to determine bond stability. The aim of this study was to assess the long-term consistency of social bonds and to look at any changes in social network based on the addition of new individuals to the flock of lesser flamingos as well as when deaths occurred (in both flocks). Permutation tests were run in Socprog to calculate the significance of association indices for preferred and avoided partners. Netdraw was used to draw networks of each flock and calculate the number of bonds that each flamingo had with flock-mates.

Results Non-random bonds were present in both flocks (permutation testing indicating a dyadic P value > 0.975). Five flamingos in total (across both groups) experienced social disruption caused by death of a preferred partner; manifested as high impact on an individual level but low impact at a population level. The social connections of a remaining preferred partner of a deceased bird changed markedly but flock-wide associations remained stable. Birds who lost a preferred partner became more gregarious (increased number of connections overall). For new arrivals, a comparison between the association networks for 2015 and 2017 (filtered by individual) showed a noticeable change in the new lesser flamingos' social behaviour since their introduction, with more connections and stronger associations with existing birds occurring only by summer 2017. As an example, for one bird time spent with a pre-existing flock member was 4% in 2015 to 19% in 2016.

Conclusion SNA has an application to measuring the effect of social disruption in gregarious species housed in zoos. Flamingos experienced a change in their "normal" pattern of association after the death of a preferred associate. New individuals added to an established flock, took several years to fully integrate. Such results have important implications for flock management; zoos should ensure that larger flocks are maintained to allow flexibility in social choice should existing conditions become altered. And when moving birds between institutions, closely bonded bird should be moved together where possible.

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Performance of a cow-side, progesterone based, lateral flow test for pregnancy diagnosis under field conditions in smallholder dairy systems

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Application Milk progesterone based, cow-side test for early identification of non-pregnancy in dairy cattle.

Introduction Early diagnosis of either conception success or failure post breeding improves the reproductive efficiency of a dairy enterprise. Cows that fail to conceive are identified early in lactation and re-inseminated and those with reproductive challenges are identified for action (Fricke *et al*., 2016). Cow-side, progesterone based lateral flow tests, such as *P4 Rapid*™, are routinely used for heat detection but not for pregnancy diagnosis (PD). Most progesterone-based pregnancy diagnosis tools in cattle have a high accuracy in identifying non-pregnancy but a lower accuracy in identifying pregnancy. Further, the use of such tools in smallholder dairying in Africa is sparse and the traditional PD method is only conducted from day 60 post-insemination. The objectives of the study were: 1) to evaluate the effectiveness of *P4 Rapid*™ in identifying non-pregnant cows up to 24 days post-insemination under practical field conditions, 2) to investigate the minimum number of tests required and, 3) to identify the ideal day of sampling that would yield the most accurate outcome.

Material and methods The study was undertaken between June 2017 and June 2018, on 66 dairy cows in 30 small-holder farms in Kenya. A sample of milk was collected on the day of oestrus and, if the cow was inseminated, additional samples were collected on alternate days between 18 and 24 days post-insemination (PI). The sample was used to carry out the *P4 Rapid*™ test (Ridgeway Science, UK) and results analysed as per the manufacturer's instructions. To read the test, the colour intensity of the test line was visually compared to the control line. The results were categorised as (1) test line darker than or same intensity as the control line or (2) test line lighter than the control line or no/barely visible test line. The colour intensity of the test line was inversely proportional to the progesterone concentration within the sample. Pregnancy was confirmed by rectal palpation between 60 and 90 days PI and this served as the referenced standard for the test. A total of 922 milk samples were tested and 63.6% of the cows were confirmed pregnant. Test performance was evaluated using sensitivity, specificity, positive and negative predictive values against confirmed pregnancy. Evaluation was based on a minimum of two samples collected between 18 and 24 days PI, where both samples indicated the same outcome.

Results Specificity was highest at 82%, and lowest at 58% when tested on 4 alternate days and randomly on any two days respectively, between 18 and 24 days PI. Testing on days 22 and 24 PI had the highest sensitivity and negative predictive values at 100%. There was a significant difference in the specificities ($P < 0.05$) between testing on all 4 days and on 2 random days and between testing on 2 random days and testing on days 22 and 24. Random testing on any 2 days had the lowest specificity and was the poorest indicator of non-pregnancy. Therefore, based on efficiency and the least number of tests, sampling on day 22 and 24 would give the highest accuracy in detecting non-pregnancy with the least number of samples.

Table 1 Performance of *P4 Rapid*™ in diagnosing pregnancy between 18- and 24-days post-insemination as determined by the sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV)

	Sensitivity	Specificity*	PPV*	NPV
Days 18, 20, 22 and 24 with the same outcome	0.96	0.82[a]	0.84[a]	0.96
Days 18, 20, 22 and 24 with ¾ test showing the same outcome	0.96	0.75[a]	0.79[a]	0.95
Any 3 days between day 18 and 24 with the same outcome	0.97	0.67[ab]	0.76[ab]	0.96
Any 3 days between day 18 and 24 with 2/3 test showing the same outcome	0.97	0.64[ab]	0.74[ab]	0.95
Any 2 Tests between day 18 and 24 with the same outcome	0.97	0.58[b]	0.7[b]	0.96
2 tests days 18 & 20 with the same outcome	0.94	0.70[ab]	0.78[ab]	0.92
2 tests days 20 & 22 with the same outcome	0.97	0.65[ab]	0.74[ab]	0.96
2 tests days 22 & 24 with the same outcome	1	0.74[a]	0.78[a]	1

*rows with the same superscript have no significant differences

Conclusion *P4 Rapid*™, had a minimum specificity of 58% for detecting non-pregnancy irrespective of the sampling regime. The specificity improved when the sampling days were consecutive alternate days rising to 74% with targeted sampling on days 22 and 24 PI. With no significant difference with testing on 4 alternate days vs two consecutive alternate days, this study therefore recommends testing two samples, one each on day 22 and 24 post insemination.

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Discriminant analysis of morphostructural differentiation of White Fulani (Yakana) and Bokolo *Adamawa gudali* cattle in Sub-Saharan Africa

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Application White Fulani is larger in size than the Bokolo cattle of similar age. Neck circumference recorded the highest variation between the breeds. This high variation in neck circumference suggests it could be applied as a suitable genetic indicator of breed difference.

Introduction Sub-Saharan Africa is a rich source of farm animal genetic resources (FAGrR), most especially alleles responsible for the resistance to stress and diseases; however these valuable resources are threatened by non-sustainable use and indiscriminate breeding. Cattle are the single most important livestock species in Nigeria in terms of animal protein, value and biomass. The genetic admixture among breeds in Nigeria is exacerbated with indiscriminate breeding and movement by Fulani pastoralists, making identification with the use of traditional qualitative traits a difficult task. The aim of the present study was to identify the morphometric traits that best characterize White Fulani and Bokolo.

Material and methods The survey cut across the Guinea Savannah region in three Local Government areas (Saki West, Saki East and Atisbo) of Oyo State, Southwest Nigeria in the first stage. Animals were reared semi-intensively with grazing supplement with "cut and carry" grass. A multistage sampling procedure was employed in this study. Strategic selections of Local Governments were based on the abundance of cattle. Villages were randomly selected in each local government in the second stage. Quadrants were drawn in each village to make the sampling as random as possible, the size of which depended on cattle population in the villages. A total number of 1758 cattle comprising 1024 White Fulani, 729 *Adamawa gudali* (Bokola) were sampled from the traditionally managed flocks of Fulani pastoralists in these locations. Body measurements were taken when the animals were in standing position with head raised and weight on all four feet without body movement. Measurements were taken with a measuring tape. Eleven morphometric traits were measured on each animal using the identification marks already documented. Traits measured were Body Length (BL), Hearth Girth (HG), Paunch Girth (PG), Wither Height (WH), Ear Length (EL), Muzzle Circumference (MC), Tail Length (TL), Neck Circumference (NC), Head Length (HL), Head Width (HW), and Shoulder Width (SW). Descriptive statistical for the data were performed. Data were adjusted for variation in sex and age. Two-tailed T-test analysis was performed to identify the effects of breed difference on the morphometric characteristics. All statistical analyses were performed using IBM SPSS (version 19.0).

Results Breed differences on morphometric characteristics of White Fulani and Bokolo cattle are shown in Table 1. There was significant difference between White Fulani and Bokolo ($p < 0.05$) for BL, HG, WH, HL, and HW. White Fulani recorded higher mean values for all statically significant traits. The BL of 189.44±0.63 and 156.32±0.64 cm were obtained for White Fulani and Bokolo, respectively.

Table 1 Morphometric traits comparisons of White Fulani and Bokolo cattle (Mean ± SEM)

Morphometric Traits (cm)	White Fulani	SD	CV (%)	Bokolo	SD	CV (%)
Body Length	189.44±0.63 [a]	20.21	10.67	156.32±0.64 [b]	17.22	7.82
Heart Girth	121.11±0.46 [a]	14.67	12.11	114.23±0.60 [b]	16.11	14.10
Paunch Girth	99.25±1.01 [a]	32.42	32.68	104.22±1.58 [b]	42.53	40.81
Wither Height	116.11±0.42 [a]	13.52	11.64	102.32±0.60 [b]	16.11	15.74
Ear Length	8.68±0.03 [a]	1.11	12.79	8.62±0.04 [b]	1.21	14.04
Muzzle Circumference	14.82±0.07 [a]	2.18	14.71	13.61±0.10 [b]	2.72	19.99
Tail Length	38.65±0.26 [a]	8.44	21.84	35.69±0.32 [b]	8.62	24.15
Neck Circumference	26.71±0.48 [a]	15.35	57.47	24.56±0.45 [b]	12.21	49.71
Head Length	16.61±0.04 [a]	1.39	8.37	14.74±0.06 [b]	1.65	11.19
Head Width	6.81±0.04 [a]	1.39	20.41	6.21±0.05 [b]	1.42	22.87
Shoulder Width	38.94±0.25 [a]	7.84	20.13	36.79±0.26 [b]	7.04	19.14

[ab] Means in the same row with different superscripts are significantly different ($p < 0.05$). SEM: Standard Error of Means

Conclusion Both animals belong to different populations and could be regarded as separate breeds. Muzzle circumference is the most discriminating trait between the two breeds and should be considered whenever there is tendency for misidentification.

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Residual effect of fertilizer types and ensiling durations on fermentative characteristics of *Panicum maximum* (Ntchisi) silage

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Application Availability of both quantity and quality of forage feed for ruminant all through the year in the tropics is a major constraint to profitable animal production and enterprise.

Introduction Forages such as grass and legume are preserved as silage, most especially during the dry season. Silage can be provided as feed for ruminant production throughout the year or in periods of restricted or scare seasonal availability of pasture, by supplementing the diet with valuable energy and protein sources (Heinritz *et al*., 2012). In principle, forage silage was made by controlled anaerobic fermentation. Silage is produced successfully when bacteria producing lactic acid dominate fermentation and restrict the activity of Clostridia (Bureenok *et al*., 2006).

Material and methods The study was a 4 x 3 factorial arrangement laid out in a randomized complete block design comprising of three fertilizer types i.e. NPK, Aleshinloye (organo mineral fertilizer), Poultry manure (layer litter) and control previously applied via broadcasting and three ensiling duration (30, 60, and 90 days) replicated three times. All data obtained were subjected to the analysis of variance (ANOVA). Means were separated using Duncan's Multiple Range Test SAS (1999) package.
Evaluation of Silage fermentative characteristics of ensiled *Pannicum maximum* (Ntchisi): The harvested forage was wilted and chopped to smaller pieces of about 3-5 cm before ensiling into a bottled silo to make it easy to compact, after which the forage in silo compressed gently to expel air as much as possible, compact and tightly tied to avoid air entrance and then stored for a duration of 30, 60 and 90 days at room temperature in the laboratory. Fermentative characteristics of silage were evaluated according to McDonald *et al*., (1991).

Results Significance difference in DM content ($p < 0.05$) in the silage fertilized with Aleshinloye 27.28 having the highest DM, Lactic, Acetic, Propanoic and Butyric acid content of silage fertilized with NPK 8.91, 0.99, 0.66, 0.1 recorded the highest value respectively. Silage with 90 days ensiling duration recorded the lowest pH 4.27 which signified the best silage as reported by McDonald *et al*., (1991) who noted that the characteristics of good silage should have pH values of 4.20 or less.

Table 1 Effect of Residual effect of fertilizer types and ensiling duration on silage fermentative characteristics (%)

Fertilizer	DM	Lactic	Acetic	Propanoic	Butyric	Temp.^{0}c	pH
Aleshinloye	27.28^a	6.12^b	0.68^b	0.45^b	0.07^b	27.85	5.11
Control	25.97^{ab}	7.47^b	0.83^b	0.55^b	0.08^b	27.68	5.02
NPK	25.17^b	8.91^a	0.99^a	0.66^a	0.10a	27.73	5.07
Poultry	26.21^{ab}	7.33^b	0.81^b	0.54^b	0.08^b	27.78	5.07
SEM	0.50	0.72	0.08	0.05	0.01	0.81	0.21
Ensiling Duration	DM	Lactic	Acetic	Propanoic	Butric	Temp.^{0}c	pH
30	26.73^a	6.64^b	0.74^b	0.49^b	0.07^b	29.76^a	5.56^a
60	26.32^{ab}	6.08^b	0.68^b	0.45^b	0.07^b	28.96^b	5.37^b
90	25.43^b	9.65^a	1.07^a	0.72^a	0.11^a	24.56^c	4.27^c
SEM	0.43	0.50	0.06	0.04	0.01	0.06	0.04

Conclusion *Panicum maximum* silage ensiled for 90 days have the lowest pH and lowest temperature since the fertizer treatment dose not significantly affect the temperature and pH, however there was a significant effect of NPK fertilizer on DM, Lactic, Acetic, Propanoic and Butyric acid content of silage.

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Effect of feeding microalgae on the endocrine status and fertility of high yielding dairy cows

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Application Feeding cows microalgae did not affect performance and had only minor effects on reproductive hormones in high yielding dairy cows, although a greater number of cows per treatment may be required to detect differences.

Introduction High reproductive efficiency in dairy cows requires a reduction in disease during the transition period, high submission rate to artificial insemination (AI) and high pregnancy rates per service (Roche *et al*., 2000). Dietary PUFA can modulate prostaglandin synthesis and metabolism, with n-6 PUFA favouring the synthesis of $PGF_{2\alpha}$ which is secreted during the oestrus cycle and mediates the regression of the corpus luteum. The n-3 PUFA favour the synthesis of the 3-series prostaglandins which are involved in improving the environment for embryo implantation and survival by decreasing the secretion of $PGF_{2\alpha}$. Feeding n-3 PUFA has therefore been reported to reduce uterine secretions of $PGF_{2\alpha}$ and improve embryo survival and the maintenance of pregnancy in some studies (Otto *et al*., 2014). Microalgae are particularly high in long chain n-3 PUFA such as docosahexaemoic acid, but its effect on indicators of fertility is unclear. The objectives of the study were to determine the effect of feeding microalgae on indicators of fertility in high yielding dairy cows.

Material and methods Sixty Holstein dairy cows were fed a basal diet containing (g/kg DM) 413 maize silage, 130 grass silage, and 457 concentrates, and were randomly allocated to one of two dietary treatments; unsupplemented (Control) or supplemented with 100 g microalgae/cow/d (*Schizochytrium imancinum sp.,* Alltech, Kentucky, USA; Treatment) based on parity, calving date and milk yield. The diets were fed from 25±0.53 days post-calving for 14 weeks, with feed intake and milk yield recorded daily. Milk samples were collected on days 5 and 20 post AI, and progesterone (P_4) concentrations determined. At 33±0.89 days postpartum, 12 pairs of cows were synchronised using a progesterone releasing intra-vaginal devices (PRID). The PRID was removed after 10 d, and 7 d later a catheter was inserted into the jugular vein and blood samples collected every 15 min for 1 h prior to the infusion of 100 IU of oxytocin, and then every 15 min for a further 3 h. The plasma concentration of 13, 14, dihydryo-15 keto $PGF_{2\alpha}$ (PGFM) was assayed. All data were checked for normal distribution and were analysed using Genstat 17th edition, using repeated measures ANOVA.

Results There was no effect of dietary treatment on DM intake or milk yield ($P > 0.05$) with mean values of 22.1 DM per day and 39.8 kg per day respectively (Table 1). There was also no effect of treatment on conception rate to the first or second AI ($P > 0.05$). There was no effect of treatment on milk progesterone levels in pregnant cows at day 5 post-AI, but by day 20 post AI concentrations were higher in Treatment compared to Control cows ($P < 0.05$). Mean values, area under the curve and peak concentrations of PGFM (Figure 1) were similar between dietary treatments ($P > 0.05$).

Table 1 Fertility parameters in cows fed no (Control) or 100 g microalgae per cow per day (Treatment)

	Control	Treatment	s.e.d.	*P*-value
DM intake (kg per day)	22.1	22.0	0.861	0.905
Milk yield (kg per day)	39.6	39.9	1.02	0.980
Conception to 1st AI (%)	47.4	42.1	-	0.744
Conception to 2nd AI (%)	30.0	54.5	-	0.256
Milk P_4 5 d post AI (ng/ml)	6.29	7.19	1.54	0.563
Milk P_4 20 d post AI (ng/ml)	21.0	35.1	5.77	0.024
Mean PGFM (pg/ml)	50.3	39.1	12.04	0.307
Peak PGFM (pg/ml)	73.9	67.5	17.61	0.731
PGFM area under curve (pg)	4046	2236	987	0.126

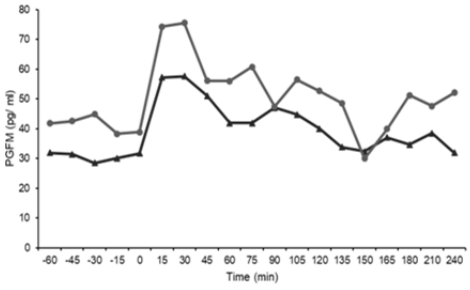

Figure 1 Plasma PGFM concentration after an oxytocin challenge (Time=0) in cows fed the Control (●) or Treatment (▲) diet.

Conclusions Supplementing dairy cows with microalgae did not significantly affect performance or plasma PGFM concentrations, although milk progesterone concentrations were higher 20 d post-AI in cows that received microalgae. Further research is required to measure corpus luteum size, and a greater number of cows per treatment is needed to detect significant differences.

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RNA-Seq analysis of whole blood from early lactation dairy cows reveals changes in leukocyte gene expression associated with circulating IGF1

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Application This study identifies underlying mechanisms for the link between negative energy balance status and a reduced ability to mount a robust immune response in early lactation dairy cows.

Introduction Circulating IGF1 concentrations start to fall around the time of calving, reaching a minimum in the first 1-2 weeks postpartum. This is related to the concurrent rapid increase in milk production and is associated with a loss of GH receptors in the liver. The IGF1 levels at this time are strongly related to the energy balance status of the cow and are predictive of her future fertility in that lactation. Immune responses of cows are also known to be impaired during the peripartum period. The aim of this study was to investigate mechanisms underlying the relationship between IGF1 and transcriptomic profiles of leukocytes from high yielding dairy cows.

Material and methods Holstein cows were recruited from six experimental farms in the UK, Denmark, Ireland, Germany, Belgium and Italy. Whole blood samples were taken into Tempus tubes at 14 days in milk (DIM) from 116 multiparous (MP) cows (lactation numbers 2-7) and these were processed for total RNA-Seq using Illumina NextSeq 500 platform. Libraries were sequenced at 75 nt length single end reads to reach an average 30 million reads/sample. Fastq raw files were quality controlled and mapped on *Bos taurus* ARS-UCD1.2. Its corresponding gene set was used as a reference to map reads by HISAT2. Reads per gene were counted with StringTie and IGF1 was measured by RIA in blood samples taken at the same time. Data were analysed using Partek Genomics Suite (PGS) Software V7. Both Fragments per Kilobase Million (FPKM) and IGF1 values were log2 transformed. Principal components analysis showed that there was difference of gene expression/distribution between herds. The herd effect was, therefore, removed using a normalisation method built in PGS and the expression values were correlated with the IGF1 concentrations using Pearson correlation. Genes which met the selection criteria $P < 0.01$ and $r > 0.3$ were taken forward for further analysis using Panther, DAVID and KEGG pathways.

Results Expression of 278 genes in white blood cells (WBC) from MP cows was associated with circulating IGF1, of which 42.4% showed a positive and 57.6% a negative correlation. For both positive and negative associations, the main molecular functions of genes affected were classified as catalytic activity GO:0003824, binding GO:0005488, transporter activity GO:0005215 and receptor activity GO:0004872. Functional clustering revealed enrichment of genes encoding proteins with sterile alpha motif domains, sushi domains, pleckstrin homology-like domains and disulphide bonds with identified roles in TLR4 signalling, control of the complement system, cellular adhesion and intracellular vesicular trafficking. Genes identified which form part of the IGF signalling pathway included *IGF2BP3, RRAS2* (positive correlation) and *GRB10, MAPK6, PIK3C2A, RAB7B, RAB8A, RAB27B, RASSF6* (negative correlation). Previous studies have shown that knockout of IGF2BP3 in cell lines is associated with decreased biological response to IGF1, due to decreased signalling though the IGF1R, causing reduced migration and cell growth. In this study, leukocyte expression of *IGF2BP3* was also negatively correlated with expression of *IGF1R* and *IGF2R* ($r = -0.31$ and -0.32 respectively, both $P < 0.00002$). Three genes associated with anti-oxidative pathways were identified. *SELENON* and *SELENOP* were both negatively associated with IGF1 ($r = -0.37$ and -0.35 respectively) whereas *PRDX2* showed a positive association ($r = 0.31$). Anti-oxidants have important roles in immune function and may affect health in transition dairy cows. Selenoprotein N is protective against oxidative stress whereas Selenoprotein P is the main transport protein for selenium in plasma. Peroxiredoxin-2 is an antioxidant enzyme, which reduces hydrogen peroxide and alkyl hydroperoxides. Expression of many other genes known to play important roles in immune function were also affected. Some showed a positive relationship with IGF1 (e.g. *COQ2, CUL3, MAP3K7, ST6GALNAC2, TBXA2R*). More showed a negative relationship (e.g. *ABCA6, ABO, ADM, AQP9, C1R, CARD10, CD14, CFB, FTL, HFE, HP, IFRD1, IL17RC, IL2RA, ITGAX, LAMP1, LGALS3BP, LTBR, SLC11A1, TNFSF10).* Proteins encoded by negatively related genes play key roles in antimicrobial activity, macrophage lipid homeostasis; complement system, response to LPS, iron absorption, response to IFNG, response to interleukins, TNF cytokine signalling and neutrophil binding to endothelium.

Conclusion This analysis shows associations between circulating IGF1, which is indicative of metabolic health, and many aspects of immune function in early lactation dairy cows. Changes in gene expression within the IGF signalling pathway suggest a direct link between circulating IGF1 and leukocyte functionality. The results provide new evidence for the mechanisms by which the negative energy balance experienced by many dairy cows at this time can reduce their ability to mount a robust immune defence against microorganisms encountered during the peripartum period.

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Raised α1-acid glycoprotein (AGP) levels in cervico-vaginal mucus (CVM) 7 days *post partum* may identify cows at risk of developing endometritis early *post partum*

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Application Current techniques for detecting uterine diseases are accurate 21 days *post partum* (DPP) or later. The technique developed in this study will diagnose the disease at an earlier stage and identify cattle at risk of developing endometritis, 7 DPP.

Introduction Cervico-vaginal mucus (CVM) contains oviductal, uterine, cervical and vaginal secretions, the production of which is influenced by health status, microbiome or pregnancy. Levels of biomolecules such as cytokines, chemokines and acute phase proteins in CVM reflect the health of the uterus. Among these biomarkers, interleukin 6 (IL-6) and IL-8 are highly secreted in case of uterine inflammation. We proposed that CVM could substitute for more invasive analyses for identifying animals at risk of disease. Due to the physical properties of mucus, processing of CVM with reducing agents is routinely recommended before the analysis of soluble-phase biomarkers (Cronin *et al*., 2015). N-acetyl-L-cysteine (NAC) and Dithiothreitol (DTT) are commonly used to homogenize mucus by reducing the disulfide bonds of mucins (Saraswathy Veena *et al*., 2015). However, many immune biomarkers also have disulfide bonds (Carr *et al*., 2015) and their detection is likely to be compromised by use of reducing agents. The overall objective of the current study is to improve processing of CVM *post partum* for measuring candidate biomarkers that may predict uterine disease. Here we focused on α1-acid glycoprotein (AGP) since its secretions are increased early in the case of inflammation and its level is reported to be highly affected by uterine disease.

Material and methods CVM samples were obtained from the vagina by gloved hand 7 DPP from 36 mixed-parity Holstein-Friesian dairy cows from three farms, two weeks postpartum. A cohort of 16 animals were used to measure IL-6 and IL-8. 20 other cows were diagnosed for clinical endometritis by scoring mucus aspect and odour at day 21. CVM was processed using reducing agent DTT or NAC or without reducing agent. Protein levels measured by bicinchoninic acid assay (BCA assay). AGP levels were measured 7 DPP, using a bovine specific ELISA kit. Statistical analysis was performed using GraphPad® Prism 5 software. Assuming normality with D'Agostino-Pearson omnibus test, a Students *t* test was used to compare results between two groups. Results were presented as mean ± SEM and considered statistically significant at $P < 0.05$.

Results Ten cows (50%) had clinical endometritis at 21 DPP. The use of reducing agents to homogenise CVM affected protein yield and the accuracy of cytokine (IL-6), chemokine (IL-8) and acute phase protein (AGP) detection and measurement. Our protocol, without reducing agents, resulted in lower protein yields (5.1 vs 12.5 mg/ml, $P < 0.001$) but higher detection of cytokine and chemokine levels. Using our modified method to measure AGP in CVM, we detected high levels of AGP at seven DPP from cows that went on to develop endometritis (38.52 vs 4.17 µg/mg of TP, $P < 0.05$).

Conclusion We conclude that processing CVM without reducing agents improves detection of biomarkers that reflect uterine health in cattle. We propose that measurement of AGP in CVM one week *post partum* may aid in the identification of cows at risk of developing clinical endometritis before the onset of clinical symptoms, two weeks earlier than the current diagnostic standards.

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The relationship between milk oestradiol concentrations and activity during oestrus in lactating Holstein Friesian cows

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Application Poor oestrus detection is one of the major problems in the dairy industry. Developing a better understanding of the relationship between oestradiol concentration (E2) in milk and activity during oestrus may help improve the accuracy of oestrus detection.

Introduction A high percentage of lactating dairy cattle do not exhibit behavioural signs of oestrus (called silent oestrus) and the expression of the primary signs of oestrus has declined over the past 30 years (Sathiyabarathi *et al*., 2016). Poor oestrus expression and detection results in considerable economic losses to the dairy industry as a consequence of reduced reproductive performance (Yániz *et al*., 2008) especially in herds where AI is used. Frequent measurements of blood E2 in relation to the behavioural signs of oestrus (Roelofs *et al*., 2004) have shown a positive dose dependent relationship between the oestrus intensity and maximum plasma E2. There is a paucity of published information on the relationship between milk E2 and oestrus activity on the day of oestrus in dairy cows. The aim of the present study was to investigate the relationship between milk E2 profile and activity during oestrus in lactating Holstein Friesian cows undergoing spontaneous oestrous cycle.

Materials and methods Lactating Holstein Friesian cows (n=32) were used for the study from January to March 2018 (BCS 2.8±0.3 (mean±SEM), mobility score 2.1±0.4 and milk yield 34.2±6.2 kg per day) at the Harper Adams University (HAU) dairy unit. Cows were milked twice a day starting approximately 04:30 h and 15:30 h through a 40-point internal rotary milking parlour. Cows were housed in a free stall building (cubicles 2.7 x 1.2 m) with sawdust covered, rubber mattresses and grooved concrete passageways. Cows were fed a total mixed ration *ad libitum* providing DM 42.5 %, ME 12.2 MJ/kg DM, CP 16.5% DM, NDF 36.4% DM, Oil 4.8% DM and Starch 17.7% DM. Milk samples (80 ml) were collected from each cow daily during the afternoon milking from 7 days before the expected day of oestrus until 4 days after the identified day of oestrus and stored at 4ºC until analysis for E2 concentration by (ELISA; Oestradiol Ultrasensitive; ALPCO, Salem, US; assay sensitivity <1.4 pg/ml) and progesterone (P4) concentration by ELISA (Ridgeway Science Ltd., UK). A cow was considered in oestrus when P4 concentration in milk was <3 ng/ml, followed by an increase to >15 ng/ml. Activity was monitored continuously using IceQubes (IceRobotics Ltd., Edinburgh, UK) attached to the back left leg of each cow. A cow was defined to be in *behavioural* oestrus when the IceQube accelerometer generated an oestrus alert. A cow was considered to be in *silent* oestrus when the IceQube accelerometer did not generate an alert and there were no changes in cows behaviour while P4 <3 ng/ml. The datasets were analysed by repeated measures ANOVA to compare between groups (*behavioural* and *silent* oestrus) on the days before and after oestrus and the group x day interaction (GenStat 18th edition). Regression analysis was used to determine the relationship between the number of steps taken per day and E2 concentration on the day of oestrus. HAU Research Ethics Committee approved the protocol.

Results Thirty nine oestruses were detected from milk P4, 28 (71.8%) oestruses were *behavioural* and 11 (28.2%) oestruses were *silent*. Oestradiol concentration increased ($P < 0.001$) from 1.9±0.5 pg/ml 4 days before (4DB) oestrus to 8.2±1.1 pg/ml (mean ± SEM) on the day of *behavioural* oestrus (day 0), subsequently fell to 4.9±0.9 pg/ml on day +1 ($P = 0.028$) and 1.9±0.5 pg/ml on day +2 ($P = 0.008$). Regarding *silent* oestrus, E2 (2.4±0.3 pg/ml) on the day of predicted silent oestrus were also increased ($P < 0.001$) compared to 4DB (1.4±0.2 pg/ml) and 3 day after (3DA; 1.6±0.2 pg/ml). The average duration of *behavioural* oestrus based on the number of steps recorded by the IceQube accelerometer was 12.3±0.6h. On the day of behavioural oestrus the number of steps (2831±224.2 steps) were higher ($P < 0.001$) compared to 4DB and 3DA, while on the day of silent oestrus the number of steps was not significantly higher (1140±157.1 steps). There was a positive correlation between E2 (pg/ml) and the number of steps taken ($r^2 = 0.83$; $P < 0.001$) during the day of oestrus. Furthermore, concentrations of E2 were significantly positively correlated with the duration of *behavioural* oestrus recorded by IceQube accelerometer ($r^2 = 0.55$; $P < 0.001$).

Conclusion On the day of behavioural oestrus the number of steps were increased with increased milk E2 concentrations. However, on the day of silent oestrus only milk E2 concentration was increased, with no changes in activity.

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The effects of temperature-humidity index on conception rates of housed, Holstein Friesian dairy cows in the UK.

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Application Temperature-humidity index (THI) is one of the factors that has a negative effect on dairy cow fertility globally. The present study demonstrates that the THI that housed dairy cows are exposed to in the UK influence conception rates.

Introduction THI gives an indication of environmental conditions taking account of both temperature and humidity. The activity of dairy cows has been shown to be altered where THI exceeds 68 (Cook *et al*., 2007). Many studies have shown the effects of heat stress on aspects of dairy cow fertility including follicle development, oestrus expression, oocyte quality and pregnancy loss (Polsky and von Keyserlingk, 2017). The aim of the present study was to investigate the effects of THI on conception rates of high yielding dairy cows housed all year round, on a commercial UK dairy farm.

Material and methods High yielding Holstein dairy cows (n=78; mean parity 3.3) were recruited to the study from April to October 2017. The cows were managed as part of a commercial dairy herd in South West UK. They were housed throughout the study in a free-stall yard, with 1.07 sand-bedded cubicles per cow. They were fed a mixed ration providing 22.5kg DM / head (ME 12.3 MJ/kg DM, CP 163g/kg DM, NDF 336 g/kg DM) with additional concentrates fed in the parlour (4 kg/hd per day). The cows were milked twice a day at 05:00 h and 16:00 h through a herringbone parlour. Their mean daily milk yield on the day of artificial insemination (AI) was 42.4±1.08 kg. Oestrus was detected using tail paint along with observations for signs of behavioural oestrus. After a voluntary waiting period of 50 days, the cows were AI'd at the next observed oestrus by the same technician using semen from one of 11 bulls (no significant difference in fertility of the bulls was detected). Cows that returned to oestrus were assumed non-pregnant. If cows did not return to oestrus, they were submitted for pregnancy diagnosis by the farm veterinarian from 30 days after insemination. Throughout the study period the temperature (T) and relative humidity (RH) was recorded in the cow housing using two data loggers (HOBO U23 loggers (TEquipment US) positioned at cow height in two areas of the building. The average daily THI was calculated from the mean of T and RH from the two loggers, using the following equation: THI = (1.8xT+32) – ((0.55-0.0055 x RH) x (1.8 x T-26)). For each individual cow, THI data were collated for 40, 30, 20 and 10 days before AI, the day of AI (day 0) and 10, 20, 30 and 40 days after AI. Relationship between conception rate (response variable; pregnant =1, non-pregnant = 0) and THI at each time point was analysed using logistic regression analysis (Genstat version 18.10.17005). The influence of parity and days to AI were also assessed for significance using forward, step-wise logistic regression.

Results The mean ambient temperature during the study period was 15.6°C (range 8 to 23°C). Mean THIs during the study were 62 (range 49-71). Mean interval from calving to first service was 70.4±2.15 days (mean±sem) and the conception rate to first AI was 35.9%. Logistic regression analysis indicated that pregnancy outcome to first AI was positively associated with THI on day -40 and negatively associated with THI on day +10 and +30 (Table 1). Other variables that tended ($p < 0.1$) to be associated with pregnancy were THI -10 days, parity and days to first service. Only parity significantly reduced the residual deviance further when added to models including THI -40d or THI +30d. Logit(p) = 11.6 + 0.19(THI -40d) - 0.30(parity); p=0.001; Logit(p) = 5.8 – 0.10(THI +30d) -0.21(parity); p = 0.01.

Table 1 Means, regression coefficients (b) standard error (s.e.) and constants for the explanatory variables: temperature-humidity index (THI) 40 and 10 days before, 10 and 30 days after insemination, parity and days to first service, assessed by logistic regression analysis. Response variable; pregnant =1, non-pregnant = 0

Variable	mean	*b*	s.e	constant	P value
THI -40d	61.4	0.183	0.066	-11.78	0.003
THI -10d	62.2	0.109	0.060	6.11	0.076
THI +10d	62.3	-0.119	0.050	6.78	0.019
THI +30d	60.4	-0.106	0.042	5.73	0.009
parity	3.46	-0.258	0.149	0.21	0.052
days to first AI	118.8	-0.024	0.015	1.06	0.087

Conclusion The results suggest that there is a positive relationship between THI experienced 40 days before AI and pregnancy rates. However, lower THI 10 and 30 days after insemination, were associated with higher pregnancy rates.

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Effects of uterine infection on milk production and reproduction outcomes in dairy cows in Ireland

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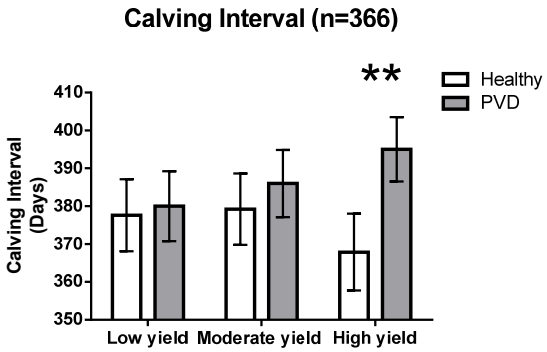
Application The assessment of the effect of clinical endometritis on subsequent milk production and reproduction in the Irish dairy herd will help farmers to identify its risks to herd health and farm profitability.

Introduction Uterine inflammation is ubiquitous in the dairy cow in the first week after calving. Cows that fail initiate a robust immune response to resolve uterine inflammation present with purulent vaginal discharge (PVD) 21 days post-partum (DPP) with approximately 20% of all cows displaying these symptoms (Sheldon *et al.*, 2006). PVD is known to have an important production impact internationally but its relevance under the Irish dairy production system is unclear. This study's objective was to record the incidence of PVD in Irish dairy cows and to investigate the impact of PVD on the milk yield and reproductive efficiency on Irish dairy cows.

Material and methods In total, 440 mixed-parity Holstein-Friesian cows from six breeding herds were assessed for PVD based on vaginal mucus score (Williams *et al.*, 2005) at 21 DPP. Cows were categorised as "healthy" (VMS 0) or "PVD" (VMS1-3). Milk, protein, fat kg and somatic cell count (SCC) yield per day in milk (DIM) (n=429) and the calving interval (duration between successive births) (n=366) were recorded for analysis. Statistical analysis was carried out using SAS 9.4. Residuals of each variable were generated using PROC MIXED and were assessed for normality of distribution. A logarithm transformation was carried out to achieve normality if necessary. Six calving interval outliers were identified and appropriately removed from further analysis. PROC MIXED with a post hoc Tukey correction was used to compute the least means squares of fixed effects. Significance was set at 0.05.



Results The frequency of each VMS was as follows: VMS 0 (40%, n=175), VMS 1 (27%, n=117), VMS 2 (15%, n=67) and VMS 3 (18%, n=81). Overall, the incidence of PVD in this study was 60% (n=265) while 40% (n=175) were healthy at 21 DPP. There was no difference between the VMS groups ($P > 0.05$) or between the healthy and PVD groups for milk, fat and protein yield kg/DIM and SCC ($P > 0.05$). The VMS groups had similar calving interval lengths ($P > 0.05$). The PVD group had a longer calving interval than the healthy group ($P < 0.01$). Cows were categorised into three equally sized groups based on their milk kg/DIM yield (n=143 per group). The groups were described as "low", "moderate" and "high" yielding groups. The calving intervals of healthy and PVD cows in the low yielding and moderate yielding cows were similar in length ($P > 0.05$). The high yielding PVD (395 ±8.5 days) cows had a 27.1 day longer calving interval than healthy cows (367.9 ±10.1 days) ($P < 0.01$).

Conclusion This study reveals that Irish cows with PVD and a high milk yield are more prone to having impaired fertility when compared to healthy high yielding cows. These findings support the theory that the metabolic demands of high milking production can lead to negative energy balance, a suppressed immune response and a consequent diminished reproductive performance (Jackson *et al.*, 2011). Further work will look to identify biomarkers in cows at 7 DPP that are at risk of presenting with PVD at 21 DPP, thereby providing a predictive tool to assist in improving herd health and farm profitability.

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A meta-analysis of the effect of alternative management strategies on the duration of the interval from calving to first ovulation in suckler beef cows

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Application A meta-analysis of 16 published studies was used to derive comprehensive quantitative estimates of the impact of various factors implicated in duration of the interval from calving to first ovulation in beef cows in temperate regions. These data will inform the development of a dynamic beef cow reproductive model.

Introduction The calving to first ovulation interval (COI) is a major component of the variation in the duration of the inter-calving interval and, thus, attainment of a 365 day calving interval in suckled beef cows. Several factors which affect the duration of COI have been identified and include: nutrition, metabolic status, cow-calf bonding, parity, genotype and pre-breeding exposure to an entire male, (Stagg *et al*., 1998). Given the multitude of factors which affect COI, reported outputs are highly variable. The objective of this study was, firstly, to obtain data pertaining to the factors associated with the variation in COI of beef cows and, secondly, by means of meta-analysis, to calculate robust model estimates for these factors and any possible interactions between them.

Materials and methods Using published literature on suckler beef cows, a data set comprising of 78 treatments employed within 15 individual studies was collated. Criteria for inclusion in this analysis were calving to ovulation/oestrus interval, parity, genotype, body condition score at calving (BCSc), postpartum plane of nutrition (PPN) and suckling management of the calf (calf access; CA). Consistent with the design of constituent studies and primary influential factors highlighted in the published literature, both BCSc and CA were further divided into distinct categories. BCSc was evaluated on the 1-5 scale (Lowman *et al*., 1976) as being Low (BCS 0-2.25) or medium to high (Med/high; BCS 2.25-5); CA was categorised as being *ad libitum* (ADLIB), restricted ≥ 23.5 hrs per day and penned adjacent to the dam (RADJ) or restricted ≥ 23.5 hrs per day and penned in isolation from the dam (RISOL). A linear mixed models methodology was conducted using the SAS statistical software package with BCSc, PPN, CA and parity considered fixed effects and study as a random effect. The interactive effect of BCSc and CA was also tested but was subsequently removed from all final models as statistical significance was not reached (P > 0.05).

Table 1 Influence of various management related factors on the COI[1] of suckled beef cows

Parameters		Estimate	P-Value
	Intercept	51.8	<0.0001
BCSc[2]	Med/high	Reference[3]	-
	Low	13.5	0.0002
CA[3]	ADLIB	Reference	-
	RADJ	-7.9	0.15
	RISOL	-21.8	<0.0001
PPN[4]	(+) 1 MJ/ME	-0.18	0.01
Parity	Multiparous	Reference	-
	Primiparous	13.3	0.006

[1]COI, the interval from calving to 1st ovulation
[2]BCSc = body condition score of cows at calving; Low = <2.25, Med/high = 2.25-5.0, (1-5 scale; Lowman *et al*., 1976)
[3]Control group
[4]CA = treatment of the suckling calf; ADLIB = *ad libitum* suckling; RADJ = calf restricted ≥ 23.5 hrs/day, penned adjacent to dam and RISOL = restricted ≥23.5 hrs/day, penned in isolation from dam
[5]PPN = postpartum nutrition

Results Of the factors examined, RISOL had the largest effect on COI, with cows on this treatment having a 22 day shorter COI compared with ADLIB. Cows on RADJ tended to have an 8 day shorter COI compared with unrestricted contemporaries (P = 0.15). There was a 13.5 day increase in COI for cows in low BCSc. There was a relatively small but statistically significant effect of postpartum plane of nutrition on the COI, with a reduction of 0.18 days (P = 0.01) observed for every additional MJ ME consumed daily. Primiparous cows experienced an additional 13 day delay in COI compared to multiparous.

Conclusion This is the first published meta-analysis of the main management factors affecting the duration of the COI in beef cows. The emanating data provides robust quantitative estimates and co-efficients which could be harnessed within the context of a bio-economic model of reproductive management for beef cow herds.

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Potential role of Kisspeptin and Cytochrome P mRNA genes in pubertal development and spermatogenesis in buffalo bulls (*Bubalus bubalis)*

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Application Puberty and spermatogenic activity are associated with higher expression of hypothalamic Kisspeptin gene and steroidogenic enzyme gene and may be useful in understanding the biological regulation of puberty in buffalo bulls.

Introduction Kisspeptin, a neuropeptide produced by the KiSS1 gene, stimulates gonadotropin releasing hormone (GnRH) which is required for puberty. Increased KiSS1r mRNA expression has been observed at the time of puberty in rat, cattle, goat, mouse, monkey (d'Anglemont de Tassigny X and Colledge, 2010). Despite a few reports on the distribution of KiSS1 gene in various regions of hypothalamus in dairy buffaloes, the expression of KiSS1 gene in the hypothalamus of buffalo bulls is lacking. Therefore, we aimed at examining the expression of KiSS1 mRNA in different areas of hypothalamus and cytochrome P450 side-chain cleavage, P450scc (CYP11A1), a rate limiting enzyme of steroidogenesis, in the testicular tissues and their correlations with various determinants of gonadal histomorphometry in buffalo bulls.

Material and methods The study was conducted on Nili-Ravi buffalo bulls brought to a slaughter house located in the city Lahore-Pakistan. The animals were distributed into two groups i.e. prepubertal (n=20) and postpubertal (n=20) based on tooth eruption pattern (Frison *et al*., 1970). Hypothalamic tissues and testicles were collected within one hour of slaughtering. The mRNA expression of KiSS1 gene in the Arcuate area (ARC) and Pre-optic area (POA) of the hypothalamus and the CYP11A1 gene in the testicular tissues were quantified against a housekeeping gene (GAPDH) through the real time PCR. The brain areas were identified as described earlier (Chaikhun *et al*., 2016). The testicular tissues were stained using the haematoxylin and eosin technique and histomorphometry analysis was carried out with software (Pixel Pro 2.1.1, Labo America Inc., USA). Data (Mean ± SEM) were analysed using the independent sample t-test with the SPSS software (Version 24.0, IBM Corporation, Chicago, IL). Gene expression analysis was carried out by $2^{-\Delta\Delta C}$T method as described by Livak and Schmittgen (2001). The correlations between gene expression and various parameters of testicular development were analysed using the Pearson's correlation.

Results The KiSS1 mRNA expression was higher in postpubertal group in the ARC (6.38 fold) and POA (12.03 fold) when compared with the prepubertal group. The expression of hypothalamic KiSS1 mRNA also showed variation in its distribution, being more ($P = 0.057$) expressed in the POA than in the ARC in the postpubertal group. However, this pattern could not be observed in the prepubertal animals. Similarly, the CYP11A1 expression in the testicular tissue was 4.52 fold higher in postpubertal group than in the prepubertal group. Histomorphometry of testicular tissue revealed that the postpubertal group had thicker ($P < 0.05$) tunica albuginea, larger ($P < 0.01$) diameter of seminiferous tubules, taller ($P < 0.01$) epithelial of seminiferous tubules than the pre-pubertal group. Numbers of spermatogonia ($P < 0.05$), primary spermatocyte ($P < 0.01$), round spermatids ($P < 0.01$) and mature elongated spermatozoa ($P < 0.01$) were also higher in the postpubertal group compared with the prepubertal group. However, population of Sertoli cells tended to be higher ($P = 0.067$) in the postpubertal group compared with the prepubertal animals. The KiSS1 expression in the POA was positively correlated with height of seminiferous tubules ($r = 0.699$; $P < 0.05$) and mature spermatozoa ($r = 0.708$; $P < 0.05$). However, only diameter of seminiferous tubules had strong correlation with KiSS1 expression ($r = 0.765$, $P < 0.05$) in the ARC. Gene expression of CYP11A1 in the testicular tissue was strongly associated with the diameter ($r = 0.909$; $P < 0.01$) and height of the seminiferous tubules ($r = 0.958$; $P < 0.01$) as well as number of matured elongated spermatozoa ($r = 0.818$; $P < 0.05$).

Conclusion The KiSS1 mRNA and CYP11A1genes were highly expressed in the postpubertal buffalo bulls. The strong relationships of both genes with stages of spermatogenesis demonstrate their potential role in better understanding the biological mechanism of testicular development in buffalo bulls.

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Development of local and systemic immunophenotyping assays in cattle

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Application Detection methods for standardised measurement of immunophenotypes will aid the selection of cattle with superior immunity.

Introduction The immune response is a critical component underpinning successful capture of all traits of economic interest in agriculture, and yet it remains poorly understood. We contend that inter-animal variation in innate immunity offers important insights into disease susceptibility and response to vaccination. Capturing this phenotype would yield significant dividends in terms of targeted management and treatment practices to reduce the burden of disease at source. Both innate and adaptive immune traits have been shown to be heritable and correlated with disease. Here, we report the development of accessible, low cost, *ex vivo* assays to measure the innate immune response in a high-throughput manner which will provide useful immunophenotypes in cattle.

Material and methods In total, 46 Holstein-Friesian calves aged from 1-18 months of age were used to develop systemic and local immune assays (SIA and LIA respectively) to measure responses using a standardised whole blood stimulation system and either primary nasal respiratory cells or dermal fibroblasts isolated from ear punch tissue (Duffy *et al*., 2014, Stokes *et al*., 2014, Kandasamy *et al*., 2011). For the SIA, 1ml of whole blood volumes were added to an S-Monovette® blood collection tubes pre-filled with RPMI media and either a bacterial or a viral PAMP. For the LIA, cells were recovered from live calves or post-mortem, cultured in a CO_2 incubator at 37°C and all cells stimulated with either lipopolysaccharide (LPS, O55:B5 & O111:B4, 100 ng to 2 µg) or Poly:IC (Lyovec complex, 100 ng to 1 µg). ELISA and qPCR were then used to measure a range of relevant immune read-outs following 6 and 24 h stimulations (Interleukin 1, Interleukin 8 and Type-I interferon genes). Statistical analysis used Kruskall-Wallis and Friedman's tests with significance set at $P < 0.05$ in Graphpad Prism. All samples collected under HPRA licence and with ethical approval from Teagasc.

Results Results for the SIA showed high basal IL-8 expression levels in stimulated and control samples. IL-1β showed a significant increase in response to both bacterial and viral ligands (LPS and Poly: IC respectively, $P < 0.001$). Stimulation with Poly:IC (500 ng and 1 µg) for 24 hrs did not induce IFN-α, or TLR-3 compared to untreated samples, but did increase expression of IFNB1 – $P = 0.0258$. For the LIA, nasal epithelial cells did not display a measurable difference in IL-8 or IL-1β expression on response to stimulation. In contrast, dermal fibroblasts showed significant upregulation of both ($P = 0.0030$ [IL-1β] and $P = 0.0013$ [IL-8]) in response to LPS (1 µg).

Conclusions We have developed and optimised novel immunophenotyping assays which we used to detect clear reproducible differences in the innate immune response of individual calves in response to bacterial and viral ligands. Systemic and local immunophenotypes can now be measured in a larger cohort of calves and data used to correlate to disease incidence and the response to vaccination. Ultimately these immunophenotypes will facilitate the identification of cattle with superior immunity.

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Cysteine and taurine increase HSP70 protein expression and reduce oxidative stress in cryopreserved ram semen

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Application Cysteine and taurine may aid the development of improved semen cryopreservation protocols in sheep.

Introduction Reducing the damage caused by oxidative stress is one of the main challenges for maintaining the integrity of frozen-thawed ram spermatozoa. Cryopreservation stimulates the uncontrolled production of reactive oxygen species (ROS) which exceed the antioxidant capacity of seminal plasma, and damage spermatozoa (Desai *et al*., 2010). Heat shock proteins (HSP) protect cells from stress including oxidative damage and HSP70 protects sperm during cryopreservation (Zhang *et al.*, 2015). Antioxidants such as cysteine and taurine reduce the effect of ROS and protect sperm from lipid peroxidation (LPO) (Bucak *et al*., 2008). This study investigated the effects of cysteine and taurine on HSP70 expression and the integrity of cryopreserved ram sperm.

Material and methods Fifteen ejaculates were collected from three Texel rams (5 x 3) by artificial vagina and cryopreserved in tris-citrate-glucose cryo-diluent with one of three treatments: 1) Cysteine (1.0 mg/ml) added pre-freeze (PF) and post-thaw (PT), 2) Taurine (1.0 mg/ml) added PF and PT, 3) No antioxidant (control). Sperm were assessed at 60 min post-thaw. HSP70 protein expression was determined using immunofluorescence. HSP70 expression at the sperm head, mid-piece and tail was determined using the percentage of HSP70 positive sperm (as a proportion of 200 cells in each sub-sample) and the intensity of expression. Intensity was scored on a scale of 0-3, with 0 displaying no expression, 1 being very low, 2 intermediate and 3 very high. HSP70 was calculated using the equation: score = (% HSP70 expression X intensity score)/100. The proportion of sperm with < 50% ROS present in the sperm head was measured using (0.1%) nitro blue tetrazolium (NBT). Lipid peroxidation (LPO) of seminal plasma (SP) and sperm was determined using the malondialdehyde (MDA) assay. Data were analysed by repeated measures ANOVA with LSD post-hoc tests where appropriate. To accommodate the experimental design, the random effects were treatment nested with ejaculate nested within ram.

Results Spermatozoa supplemented with cysteine and taurine had greater motility ($P < 0.001$), reduced lipid peroxidation in SP and sperm membranes ($P < 0.001$), and a greater proportion of sperm with less than 50% ROS at the sperm head ($P < 0.001$). There was also greater HSP70 expression at the sperm head, mid-piece and tail with cysteine supplementation. Addition of taurine showed an intermediate expression of HSP70 expression, whilst the lowest expression was observed in the control group (Table 1).

Table 1 Means (± SEM) motility, proportion of sperm with < 50% ROS (ROS < 50%), lipid peroxidation (LPO) of sperm and seminal plasma (SP), and HSP70 expression at the head, mid-piece and tail of frozen-thawed (FT) ram spermatozoa supplemented with 1mg/ml (PF+PT) of taurine or cysteine and no supplementation (control) at 60 minutes PT at 37°C

Sperm parameters	Control	Taurine	Cysteine
Motility (%)	17.40 ± 0.99^{c}	28.53 ± 1.700^{b}	29.87 ± 1.350^{a}
ROS <50 %	28.2 ± 1.043^{c}	37.07 ± 1.548^{b}	42.80 ± 1.010^{a}
LPO of sperm(sperm/nmol)	3.23 ± 0.071^{c}	2.79 ± 0.073^{b}	2.27 ± 0.059^{a}
LPO of SP (ml/nmol)	6.65 ± 0.246^{c}	5.13 ± 0.128^{b}	4.61 ± 0.103^{a}
HSP70 (Head)	0.26 ± 0.035^{c}	0.40 ± 0.039^{b}	0.53 ± 0.040^{a}
HSP70 (Mid piece)	0.55 ± 0.060^{c}	0.67 ± 0.074^{b}	1.08 ± 0.093^{a}
HSP70 (Tail)	0.77 ± 0.053^{c}	0.85 ± 0.710^{b}	1.06 ± 0.090^{a}

[a, b, c,] and [d] Values with different superscripts in the same row for treatment are significantly different ($P < 0.001$)

Conclusion HSP70 promotes sperm survival and low concentrations of ROS and lipid peroxidation are associated with improved sperm function. Cysteine or taurine supplementation both pre-freeze and post-thaw may improve sperm function and integrity through increased HSP70 expression and reduced oxidative stress. Using this protocol for antioxidant supplementation can aid the development of cryopreservation protocols and assisted reproductive technologies in sheep.

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Impact of rumen microbiome-host interaction on feed efficiency of beef cattle explained by microbial adhesion and mucosa interaction genes

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Application Identification of biomarkers from the rumen microbiome associated with intestinal mucosal interaction will help to predict feed efficiency in cattle fed high-concentrate diets and to implement nutrition strategies against pathogens.

Introduction Concentrate diets are known to improve feed efficiency. However, Auffret *et al.* (2017) showed that high-concentrate diets can generate a stress on the rumen microbiome (dysbiosis) increasing the abundance of pathogens as well as antimicrobial resistance and adhesion genes in beef cattle. Microorganisms attached to the intestinal mucosa using different mechanisms may play an important role in the host-microbiome interaction, therefore impacting on feed efficiency. The aim of this study was the identification of microbial mechanisms which enhance or reduce feed efficiency.

Material and methods The data in this study were obtained from samples collected in two independent experiments balanced for breed type (Charolais and Luing) and selected for whole metagenome sequencing. The study used 72 animals offered a high-concentrate diet (92% on a DM basis). Feed conversion ratio (FCR) and residual feed intake (RFI) were calculated (Rooke *et al*., 2014; Duthie *et al*., 2016, 2017). Post-mortem rumen digesta samples collected at the abattoir were used and total DNA was extracted prior to metagenomics analysis. We used the same protocols applied in Stewart *et al.* (2018) for the generation of metagenome-assembled genomes (MAG) phylogenetically identified using a combination of databases and the annotation of microbial genes was achieved using KEGG database. A combination of network analysis using Miru (Kajeka, UK) and Partial least squares analysis (PLS, Version 9.1, SAS Institute Inc., USA) was used to identify the most correlated MAGs (genus level) or microbial genes associated with FCR or RFI using Variable Importance in Projection (VIP).

Results Based on Auffret *et al.* (2017), 27 microbial-host interaction genes were selected. Eight genes were found highly correlated (VIP > 0.8) with FCR or RFI explaining about 40% of the variability of each ratio. The fibre degrader and highly abundant *Eubacterium* (Firmicutes, F) proved to be important and highly correlated with better feed efficiency also highly correlated with genes associated with motility, hooking, secretion system and haemolysin to stimulate the immune system against pathogen colonization. Other MAG like *Polymorphum* were involved in biofilm formation (K01840) and fucose sensing (K02429) whilst detrimental effects on feed efficiency were associated with the presence of pathogens, mostly within Proteobacteria (P) and Spirochaetes (S), which carry genes permitting avoidance of the immune system (sialic acid) or releasing toxins through distinct secretion systems. Genes were shared between beneficial and detrimental bacteria (e.g. K02652). Finally, some MAG were potentially involved in the release of metabolites such as formate that will enhance methane emissions known to compete with feed efficiency (Table 1).

Table 1 Example of genes correlated (VIP) with FCR or RFI and associated with a most probable MAG.

KEGG ID	Description	Trait	VIP/trait	Coef.	Most probable MAG
K02652	type IV pilus assembly protein PilB	RFI	1.03	-0.14	*Eubacterium* (F)
K06442	putative haemolysin	RFI	0.84	-0.04	*Eubacterium* (F)
K02283	pilus assembly protein CpaF	RFI	0.83	-0.02	*Eubacterium* (F)
K02396	flagellar hook-associated protein 1 FlgK	RFI	0.74	-0.07	*Eubacterium* (F)
K01654	N-acetylneuraminate synthase	RFI	0.80	0.09	*Lawsonia* (P)
K02429	MFS transporter, FHS family, L-fucose permease	FCR	0.92	-0.14	*Sarcina* (F)
K01840	Phosphomannomutase	FCR	0.89	-0.02	*Polymorphum* (P)
K02652	type IV pilus assembly protein PilB	FCR	0.88	0.02	*Treponema* (S)
K02454	general secretion pathway protein E	FCR	0.87	0.04	*Sphaerochaeta* (S)

Conclusion This study provided further insight into the host-microbiome interaction targeting microbial genes and to discriminate between beneficial and detrimental microbial mechanisms and species associated with feed efficiency. Microbiome mechanisms were distinct between beneficial and detrimental populations affecting feed efficiency. The results suggest that high-concentrate diets enhanced the presence of specific pathogens increasing the risk of animal disease.

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Investigating the impact of rumen microbial genes on feed conversion efficiency, growth rate and feed intake in beef cattle

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Application These results highlight the usefulness of relative abundances of rumen microbial genes for prediction of feed conversion ratio (FCR), average daily gain (ADG) and daily feed intake (DFI), for use in breeding and dietary interventions.

Introduction In a small study, relative abundances of rumen microbial genes have been suggested as suitable predictors of FCR (Roehe *et al*., 2016). The main objectives of the present research were to identify the microbial genes associated with FCR and to validate their use as biomarkers, using a larger dataset. Furthermore, we aimed at extending the analysis to other traits such as DFI and ADG. A further objective was to understand the functional impact of the identified microbial genes on the performance traits.

Material and methods Two factorial design experiments were previously performed to study the impact of adding nitrate, lipid, or a combination of both to beef cattle basal diets on methane emissions and FCR (Duthie *et al*., 2015, 2017). The first experiment comprised of 84 steers (Charolais crosses and Luing) offered two basal diets consisting of forage:concentrate ratios of 520:480 or 84:916 g/kg dry matter and the second trial consisted of 80 steers (crossbred Limousin and crossbred Aberdeen Angus) fed one basal diet (550:450 forage:concentrate g/kg dry matter. A total of 42 animals were selected for whole metagenomic sequencing based on extreme FCR values (selection of animals with highest and lowest FCR within blocks of trial, breed and diet). Partial Least Squares analyses (PLS, SAS v.9.3) were used in a stepwise manner to select the sets of microbial genes that best explained the variation in each trait. In each PLS model (which included besides the microbial genes the fixed factors breed, diet and trial) the number of latent variables was determined by 'leave-one-out' cross validation. For FCR and ADG, microbial genes with Variable Importance in Projection (VIP) values lower than one were progressively removed from the model until VIPs of all microbial genes were greater than one. For DFI, microbial genes were removed until this caused the explained variation of the trait to decrease. The final PLS were performed using three latent variables. Pathway analyses were performed with KEGG mapper. The correlations between microbial genes were investigated in a network analysis using Miru software (Freeman *et al*., 2007). The microbial genes selected in PLS were then located in the clusters. Enrichment analyses of clusters were based on a significance level of $P < 0.05$.

Results The PLS analyses resulted in 20, 14 and 18 microbial genes whose relative abundances explained 63.4%, 65.4% and 72.9% of the variation in FCR, ADG and DFI respectively. Most microbial genes predicting FCR were related to carbohydrate metabolism, being more abundant in efficient animals, such as *ptb*, in the butanoate metabolism pathway (Table 1). There was some overlap between genes predicting FCR and ADG (mostly housekeeping) but not with DFI.

Table 1 Microbial genes identified for prediction of FCR, their mean abundances, PLS estimates and general functions. [a]ADG-predicting genes

Gene name	Mean abundance	PLS estimate	General Function
K01188	0.040	-0.021	Cellulose degradation
aguA	0.010	-0.063	Xylan catabolism
ptb	0.008	-0.008	Butyrate metabolism
idnO	0.085	0.017	Carbohydrate metabolism
uxuB	0.085	0.050	Mannitol metabolism
galK	0.063	0.067	Galactose catabolism
gcvH[a]	0.007	-0.017	Glycine decarboxylation
uidA	0.013	-0.117	Glucuronoside catabolism
xylE	0.040	0.114	D-xylose transport
lctP	0.020	-0.027	Lactate transport
lpxA	0.040	-0.019	Lipid A biosynthesis
murD[a]	0.062	-0.086	Peptidoglycan biosynthesis
punA	0.011	-0.275	Purine nucleoside salvage
fes	0.047	-0.151	Iron ion homeostasis
glo1	0.002	0.155	Methylglyoxal degradation

Conclusion The results of our research suggest that rumen microbial genes abundances are informative predictors of feed conversion efficiency, feed intake and growth rate. Additionally, the results allow for a deeper understanding of the influence of the rumen microbiome on the feed conversion efficiency of the host, highlighting specific enzymes involved in metabolic pathways that reflect the complex biochemical networks impacting the conversion of feed into animal products such as meat.

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Protein nutrition and ETEC exposure impacts on growth performance and ileal but not faecal microbiome richness and diversity in weaned pigs

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Application Dietary protein and ETEC exposure impacts on ileal but not faecal microbiome strongly suggest that studying the nutritional sensitivity of sub-clinical enteric disease and its relation to host microbiome requires sampling at ileal level.

Introduction The emergence of next-generation sequencing technologies allows greater resolution study of complex microbial communities, in comparison to the early molecular and culturing methods used previously. The latter approach showed sensitivity of gut microbiota to protein nutrition and sub-clinical challenge with ETEC in weaned pigs (Wellock *et al*., 2008). Therefore, our objective here was test the hypothesis that increased dietary protein level and ETEC exposure impact on both ileal and faecal microbiota dynamics in weaned pigs as identified through 16S rRNA gene metabarcoding.

Material and methods A total of 144 pigs (Large White × Landrace), weaned at 25.0±0.8 d (d0) and weighing 9.1±1.3 kg, were housed in four pens in each of two rooms for each of four rounds (2 male and 2 female pigs per pen). Pigs were fed *ad libitum* iso-energetic feeds formulated to supply 188 (LP) and 244 (HP) g crude protein per kg, and were dosed with either 3 ml of PBS with 10^8 cfu ETEC per ml (ETEC) or PBS only (SHAM) on d2 (Pollock *et al*., 2015). The resulting four treatment combinations were randomly allocated to one pen in each room. Feed intake was measured daily until d13, and pigs were weighed on d2, 5, 9 and 13. Ileal digesta and faeces were collected at *post mortem* from one pig per pen on d5 and 9 and from the last two pigs on d13, and analysed for microbiome composition (Pollock *et al*., 2018). Sequencing was carried out using Illumina MiSeq generating 2 × 150 bp paired end reads. Primers were removed from the sequences using cutadapt and further sequence curation and analysis was carried out using the mothur software. Resulting microbiome composition were analysed for richness (Chao index) and diversity (Inverse Simpson's index, ISI). Performance, Chao and ISI data were analysed via 2 × 2 analysis of variance, with round as a block and pen as the experimental unit. Microbiome structure and stability were assessed via molecular variance (AMOVA) and homogeneity of molecular variance (HOMOVA), respectively. SRUC's Animal Welfare and Ethical Review Body (ED AE 25-2015) approved the experiment.

Results LP pigs had greater feed intake than HP pigs from d5 onwards, whilst both ETEC exposure and dietary CP level did not impact weight gain (Table 1), nor faecal microbiome richness and diversity (data not shown; $P > 0.10$). At ileal level, however, ETEC exposure reduced richness at d5, whilst increased CP levels increased richness on d9 for ETEC pigs only, and on d13. ETEC exposure also tended to reduce diversity at d5 but increased diversity at d9, especially for the HP pigs. Treatment effects on microbiome structure and stability were present at ileal but not at faecal level (data not shown).

Table 1 Averaged daily feed intake, weight gain, and ileal microbiome richness and diversity of pigs fed low protein (LP) or high protein (HP) diets and exposed to ETEC or PBS (SHAM) until 13 days post weaning

	Days post	Treatments					Probabilities		
	weaning	LP SHAM	LP ETEC	HP SHAM	HP ETEC	s.e.d.	Diet	ETEC	D x E
Feed intake	0 to 5	189	194	199	205	16	0.786	0.416	0.357
(g/d)	5 to 9	428	442	404	391	25	0.047	0.960	0.463
	9 to 13	586	674	574	569	46	0.080	0.209	0.159
Weight gain	0 to 5	161	155	149	177	26	0.793	0.573	0.365
(g/d)	5 to 9	337	385	365	350	36	0.888	0.528	0.225
	9 to 13	383	490	449	431	45	0.926	0.170	0.058
Richness	5	78	52	83	50	20	0.918	0.052	0.798
(Chao)	9	43	36	44	76	11	0.014	0.104	0.017
	13	34	38	48	53	9	0.029	0.489	0.891
Diversity	5	3.6	1.9	4.9	2.9	1.5	0.303	0.097	0.890
(ISI)	9	1.8	2.4	2.4	5.6	0.7	0.002	0.002	0.025
	13	3.2	3.0	3.7	4.0	0.7	0.138	0.930	0.607

Conclusion Whilst this data confirms that pigs may avoid protein scarcity through increasing feed intake on LP rations, it was demonstrated that both variation in protein intake and exposure to ETEC impact on ileal microbiome richness, diversity, structure and stability. Such effects were not observed at faecal level, which support the view that faecal microbiome observations may not be able to inform on ileal microbial communities.

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The relationship between variation in the caecal microbiome and productivity of broiler chickens

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Application The profile of the caecal microbiome of broilers was sensitive to the effects of management strategies, but these differences were not reflected in growth efficiency.

Introduction The gut microbiome of broiler chickens exhibits a plethora of relationships with the host including digestive efficiency (Yan *et al*., 2017). The caecum harbours a complex microbiome, and ongoing research suggests that said microbiome is sensitive to the effects of management strategies. It is unclear whether differences in the microbial profile are indicative of performance, particularly since high levels of variation between individual birds and flocks appear to exist. The aim of the present study was to compile data from a range of experiments, where the effects of management strategies (antibiotic/probiotic treatment, bedding, and diet cereal base) on performance and the caecal microbiome were explored, and to elucidate relationships between variation in the profile of the caecal microbiome and the feed conversion ratio (FCR) of growing broilers.

Material and methods Data from three separate studies were combined; all birds were Ross-308, obtained from the same hatchery and housed in the same experimental facility. Data were recorded at a range of time points spanning 15 to 35 days of age, with a total of 82 pens representing 10 treatment groups. The effects of treatment on average pen FCR were explored through ANOVA and the caecal microbiome of one bird per pen was explored through population profiling on the Illumina platform. Data were processed in QIIME and differences in the relative abundances of bacterial taxa were highlighted by Linear Discriminant Analysis Effect Size (LEfSe). The size of the difference between microbial profiles was characterised by accumulative linear discriminant analysis (LDA) scores, where a higher score highlighted a larger difference. Relationships between numerical differences in average pen FCR and accumulative LDA scores per treatment group were finally explored through regression analysis.

Results FCR did not differ between treatment groups within a study ($P > 0.05$), though there were consistently differences in the composition of the caecal microbiome. No relationship between numerical differences in FCR and accumulative LDA score was observed (Figure 1; $R^2 = 0.386$; $P = 0.270$).

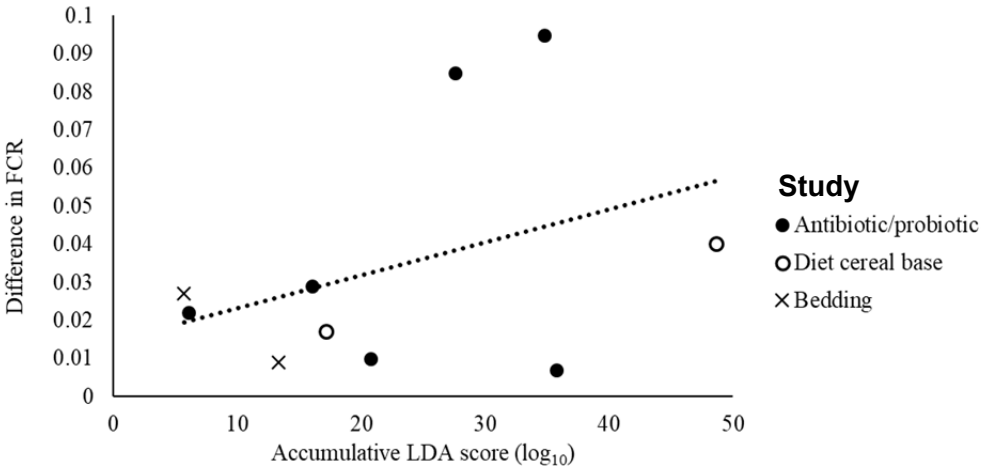

Figure 1 The relationship between differences in performance (FCR) and microbial populations (accumulative LDA score).

Conclusion Observed differences in the profile of the caecal microbiome were not reflected in differences in FCR between groups of birds in the present studies. Whilst the microbiome of an individual bird can appear different from another, variation may not necessarily alter their productive success. It is hypothesised that a 'model' microbiome does not strictly exist, and that the most important factor is the ability of said microbiome to perform key metabolic activities.

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Bacterial composition changes in response to zinc oxide within the gastrointestinal tract of newly weaned pigs until 28 days post-weaning

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Application Determining changes within the bacterial composition of healthy pigs in response to zinc oxide is the first step to uncovering the mode of action of zinc oxide in newly weaned pigs.

Introduction In pig production, weaning is associated with nutritional and environmental changes for the pig. These sudden changes result in microbial alterations within the gastrointestinal tract (GIT) and can provide an opportunity for pathogenic colonisation, often from enterotoxigenic *Escherichia coli* (ETEC), leading to post-weaning diarrhoea (Fairbrother *et al*., 2005). The supplementation of zinc oxide at pharmacological levels (2.5 g/kg) immediately post-weaning reduces diarrhoea (Feng *et al*., 2006) and improves performance of pigs during this critical stage (Miller *et al*., 2009). However, antibiotic resistance and environmental concerns have led to the ban of pharmacological levels of ZnO in weaner pig diets from 2022 (Rajput *et al*., 2018; Vahjen *et al*., 2015). Pressure is now increasing to find sustainable alternatives to ZnO, but to do this, the mode of action of ZnO could prove essential to identify changes that are leading to the improved health and performance currently seen. The aim of this study was to identify key changes in the bacterial composition of the ileum, caecum and colon of pigs receiving 2.5 g/kg ZnO vs a control diet at weaning and at 14 and 28 days post weaning.

Material and methods Experimental protocols were approved by the ethical review group of the University of Leeds. At weaning (D0) 16 litters were selected based on a litter size of 11+ and weaned at 26.03±0.14 days old and 8.02±0.17 kg liveweight (±SEM). From four of the litters, one pig was randomly selected and removed for euthanasia and dissection at weaning. Of the remaining pigs within the litter, two adjacent pens of five pigs were weaned into fully slatted indoor accommodation. One pen per litter was provided a control diet, whilst the other pen was given a matched diet containing 2.5 g/kg ZnO until 14 days post-weaning (d14). At d14 and d28, one pig per pen was randomly selected for euthanasia and dissected to remove the entire GIT. A total of 12 pigs were used for subsequent analysis (four per time point). Samples were collected from the lumen and mucosa of the terminal ileum, caecum and proximal colon and stored at -20 ºC. DNA was extracted (QIAamp stool mini kit; Qiagen Inc, USA) and amplified using primers for the V4 hypervariable region of the 16S rRNA gene prior to purification and library preparation. Libraries were sequenced on the Illumina MiSeq platform (V2; 250bp pair-end reads). Sequencing reads were processed, quality filtered and aligned using Mothur v.1.40.3. Unique sequences were identified and aligned against the SILVA database (v.132). After removal of chimeras, sequences were clustered into operational taxonomic units (OTUs) with 97% similarity and R v3.4.3 was used to determine differences in alpha (Chao1, Shannon) and beta diversity (PERMANOVA). Piphillin was then used to predict gene functions based on representative sequences of each OTU.

Results At d14, beta diversity of pigs receiving pharmacological levels of ZnO was significantly different to that of the control pigs for luminal samples from the ileum, caecum and colon ($P < 0.001$). No differences were seen for the mucosal samples. At d28, beta diversity again differed between the lumen of the ileum, caecum and colon ($P < 0.001$), with ZnO significantly decreasing the abundance of bacterial genera such as *Streptococcus* in all measured locations of the GIT ($P < 0.05$). Alpha diversity did not differ between GIT location or mucosal and luminal samples at d14 or d28. Predicted gene function did not differ between treatments in all locations of the GIT at d14 or between mucosal and luminal samples. However, at d28, predicted gene function differed between treatments with a reduction in pathways such as those associated with bacterial invasion of epithelial cells observed in samples from pigs fed ZnO compared to the control group ($P < 0.05$). The majority of the differences seen in predicted gene function in response to treatment were observed in the colon.

Conclusion Providing pigs with pharmacological levels of dietary ZnO resulted in shifts in the bacterial community composition throughout the gastrointestinal tract which may result in the improved health of piglets. Differences in predicted gene function beyond the time period when pharmacological ZnO was included in the diet could imply longer lasting effects of feeding ZnO on the overall health of the weaned pig.

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Seeking to improve feed efficiency in pigs: microbial modulation via faecal microbiota transplantation in sows and dietary supplementation of offspring with inulin

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Application Faecal microbiota transplantation (FMT) in gestating sows, in combination with post-weaning dietary inulin supplementation in offspring achieved improvements in feed efficiency (FE) as indicated by lower residual feed intake (RFI). However, offspring body weight at 140 days of age was reduced, thereby limiting commercial application.

Introduction Our group showed that FMT in sows and/or offspring, using inoculum from highly feed efficient finisher pigs, negatively impacted offspring body weight at slaughter (McCormack *et al*., 2018). Although some potentially beneficial FMT-associated microbiota were more abundant in FMT-treated compared to control sows, they were not transferred or did not colonise in the offspring. Here we tested the hypothesis that prebiotic supplementation of the offspring might provide a substrate for transplanted microbiota, thereby encouraging their proliferation and potentially improving FE.

Material and methods Approval was granted by the Teagasc and Waterford Institute of Technology ethics committees, and performed according to the 2010/63/EU Directive. On day 61 of gestation, 22 sows were assigned to one of two treatments: Control (CON; n=11), or FMT using faecal extracts from highly feed efficient finisher pigs on days 70 and 100 of gestation (FMT; n=11). At weaning, offspring were allocated, within sow treatment, to either control (CON: no dietary supplement; n=67) or dietary inulin supplementation for 6 weeks (INU: n=65), resulting in four treatments: CON/CON, CON/INU, FMT/CON and FMT/INU. Pigs housed in groups of 8–12, were offered *ad libitum* access to feed using automated electronic feeders. From ~78 days of age, all pigs received the same finisher diet until slaughter (~140 days). Weekly body weight and feed disappearance were recorded to calculate average daily feed intake, average daily gain and RFI. Faeces was collected from 32 pigs throughout the trial (16 per sow and 16 per offspring treatment), and digesta (ileum, caecum, colon) was collected at slaughter from the same 32 pigs for volatile fatty acid analysis and 16S rRNA microbiota profiling using the Illumina MiSeq platform, Flash and the CD-HIT-OTU database. Additional samples (blood, tissue for intestinal histology) were collected. All data were analysed using SAS 9.4 and $P < 0.05$ was considered statistically significant.

Results Although FE was improved in offspring from FMT-treated sows, as indicated by a lower RFI value ($P < 0.05$), live weight and consequently carcass weight were reduced ($P < 0.001$) at slaughter age (Table 1). Increased bacterial diversity and higher abundances of bacterial taxa associated with weight gain and host health (e.g. *Bifidobacterium, Butyricimonas, Prevotella*) were observed in the faeces/digesta of offspring from sows treated with FMT alone or in combination with post-weaning dietary inulin supplementation. Due to FMT and/or inulin supplementation, relative abundance of the potential pathogens *Chlamydia* and *Treponema* was reduced in the ileum. Predicted bacterial pathways related to carbohydrate and lipid metabolism were more abundant due to FMT and/or Inulin. Offspring from FMT-treated sows also had shorter ileal villi and lower caecal concentrations of butyric acid at slaughter age ($P < 0.001$; Table 1).

Table 1 Effects in offspring of maternal faecal microbiota transplantation (FMT) and/or offspring inulin supplementation

Sow treatment	Control		FMT		SEM	P-value		
Offspring treatment	Control	Inulin	Control	Inulin		FMT	Inulin	FMT x Inulin
Day 140 body weight (kg)	104.9^{a}	103.9^{a}	94.3^{b}	96.8^{b}	1.29	<0.001	0.59	<0.001
Carcass weight (kg)	81.0^{a}	80.1^{a}	72.1^{b}	75.0^{b}	1.62	<0.001	0.54	0.01
Residual feed intake (g/day)	13.7^{a}	25.2^{a}	-13.9^{b}	-20.9^{b}	15.96	0.02	0.88	0.01
Ileal villus height (µm)	457	469	418	432	14.3	<0.001	0.36	0.06
Caecal butyric acid (µmol/g)	9.5^{a}	9.8^{a}	6.9^{b}	2.0^{c}	1.50	<0.001	0.01	<0.001

^{a,b,c} Within rows, values that do not share a common superscript are significantly different ($P \leq 0.05$)

Conclusion Overall, FMT in pregnant sows, with/without post-weaning dietary inulin supplementation of offspring beneficially modulated offspring intestinal microbiota (albeit mostly low relative abundance taxa) and improved FE. However, this strategy reduced slaughter weight at 140 days of age. Therefore, the approach used may not benefit pig production, although additional research based on these results may identify specific prebiotic or other dietary supplements for promotion/maintenance of the microbiota transferred via maternal FMT thereby optimising pig growth and FE.

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The effect of xylanase and xylo-oligosaccharides on growth performance and faecal bacterial community composition of growing pigs

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Application Understanding the effect of xylanase and prebiotic oligosaccharides on faecal bacterial community composition will identify if their supplementation improves gut health.

Introduction Alongside increased pressure to reduce antimicrobial usage, the UK pig industry is also facing a future ban on therapeutic levels of zinc oxide and a reduction in copper inclusions; seeking suitable alternatives that promote good gut health and prevent disease is therefore of utmost importance for the industry. It is well established that exogenous xylanases (XYL) can improve the nutritive value of cereal based diets by degrading the plant cell wall, increasing nutrient digestibility and reducing digesta viscosity (Lan, *et al*., 2017). However, XYLs may also have a gut microbial mechanism via the generation of prebiotic short-chain xylo-oligosaccharides (XOS) from the cleaving of the Xylan backbone. Prebiotic XOS can either be fed indirectly via the supplementation of XYL and subsequent production of XOS *in situ* or directly fed via commercially available XOS which is manufactured by the enzymatic hydrolysis of corncobs. The aim of this study was to investigate the effect of XYL and XOS on grower pig performance and faecal bacterial community composition.

Material and methods This study was conducted at the University of Leeds Pig Research Centre and ethical approval was granted by the animal welfare and ethical review body. A 35 day trial involving 464 grower pigs with an average initial body weight of 14.5kg (±1.56kg) were used in this randomised complete block design with 24 replicates and 4-5 pigs per pen. Treatments were arranged in a 2 x 2 factorial with two levels of supplementary XYL (0 and 150 g/tonne) and XOS (0 and 200 g/tonne). On a weekly basis, pen feed intake and individual pigs were weighed. Faecal samples were taken from 32 male pigs (8 replicates per treatment) at timepoints 1, 2 & 3 (0d, 14d and 35d). Within replicates, each pig originated from the same litter and all sampled pigs were free from antibiotic treatment. DNA was extracted from the faecal samples (QIAamp DNA Stool Mini Kit, Qiagen) and the bacterial community was profiled through 16S rRNA sequencing of the V4 region on the MiSeq platform (Illumina). Performance data were analysed as a 2 x 2 factorial (GLM, SPSS v.24) and differences were deemed significant if $P < 0.05$ and as trends if $P < 0.10$. Sequencing reads were processed in the software Mothur (v.1.41.1; Kozich, *et al*., 2013). Chao1 and Shannon alpha diversities were measured in R (v.1.1.463) using the Phyloseq package (v.1.22.3), whilst Vegan and DESeq2 were used to determine beta diversity (v.2.5.3 & 1.18.1 resp.).

Results There was no XYL by XOS interaction for any of the measured performance variables, therefore only main effects are presented. XYL had no effect on performance throughout the trial ($P > 0.05$). During days 0-7, supplementation of XOS significantly increased average daily feed intake (ADFI) compared to those without XOS (0.783 kg/d vs 0.743 kg/d; $P < 0.05$) and food conversion ratio was significantly poorer for those supplemented with XOS (2.161 vs 1.953; $P < 0.01$). During days 8-14, supplementation of XOS significantly increased ADFI (1.132 kg/d vs 1.016 kg/d; $P < 0.05$) and average daily gain (0.546 kg/d vs 0.487 kg/d; $P < 0.01$) compared to those without XOS. There was a trend ($P = 0.085$) for pigs without XOS supplementation to have a lower body weight at day 14 (20.73 kg) compared to those supplemented with XOS (21.03 kg). Alpha diversity measure Chao1 was significantly higher at timepoint 3 compared to timepoint 1 and 2 ($P < 0.001$), whereas for Shannon indices, timepoint 3 was significantly higher than timepoint 2, but not timepoint 1 ($P < 0.01$). There was no effect of treatment on Chao1 ($P = 0.115$), but there was a trend for Shannon Indices ($P = 0.089$). There was a trend for a time by treatment interaction on Chao1 diversity ($P = 0.064$), but not for Shannon indices ($P = 0.975$). There was a significant effect of time on beta diversity ($P < 0.05$) with operational taxonomic units (OTUs) associated with *Enterobacteriaceae* decreasing ($P < 0.05$) and *Bifidobacterium* increasing ($P < 0.001$) over time. No overall treatment effect was seen for beta diversity, however XYL significantly reduced OTUs associated with *Campylobacter* ($P < 0.05$) and XYL, XOS and XYL+XOS significantly increased OTUs associated with *Muribaculaceae* (aka S24-7) by 14.9, 15.1 and 21.4 log compared to control ($P < 0.05$, $P < 0.01$, $P < 0.001$ resp.). *Muribaculaceae* ferment a wide range of carbohydrates including Arabinans and Xylans.

Conclusion XYL had no beneficial effect on pig performance, whilst XOS significantly increased pig growth during days 8-14 of the trial, but not overall. 16S rRNA results indicate that faecal bacterial community composition changed significantly over time but treatment did not have an overall effect.

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Altered abundance of rumen microbial species and reduction in microbial metabolic pathway diversity in sheep that are divergent in feed conversion efficiency

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Application The identification of microbial communities in the rumen of highly feed efficient livestock can inform improved management practices, including a reduction of feed cost and improved livestock breeding programs.

Introduction The rumen microbiome is a complex ecosystem responsible for providing energy sources for sheep nutrition through enteric fermentation. The rumen microbiome fermentation process provides volatile fatty acids (VFAs) to the animal. Hence, the rumen microbial communities producing VFAs play a key role in the feed efficiency of livestock (Hernandez-Sanabria *et al*., 2012). However, the key rumen microbes that functionally affect feed conversion efficiency in important livestock ruminants (such as sheep) is poorly understood. Our aim was to investigate the microbial communities in two cohorts of sheep that have divergent feed conversion ratios using a rumen amplicon sequencing approach.

Material and methods Twenty-six lambs of the Texel breed were separated into two cohorts of 13 animals each (High and Low Feed Efficiency animals i.e. HFE & LFE) according to their extreme feed conversion ratio (FCR) values from a group of 200 individuals. HFE= 3.83±0.40, LFE= 6.05±0.92 ($P < 0.05$). The animals were fed with the same diet consisting of 100 g/d DM of silage and ab libitum access to concentrate feeding (60% cereal-based, 15% crude protein over a 36 day indoor finishing period). The animals were slaughtered over five time periods when 196 to 385 days old. Liquid and solid fractions of the rumen contents were collected at slaughter and separated by filtering through four layers of cheesecloth and stored at -80ºC. DNA extraction was performed using the methodology of Yu and Morrison (2004). The V4 hypervariable region of the 16S rDNA (primers 515F/806R, Caporaso *et al*., 2011) was amplified using a template of 20 ng of rumen DNA. Nextera overhang adapters were added and the libraries sequenced using an Illumina MiSeq platform. Bioinformatic analysis was conducted using the DADA2 pipeline to obtain amplicon sequences variants (OTU defined by 100% sequence similarity) using five databases (SILVA, RDP, Greengenes, NCBI, and Hungate) for taxonomical identification. To determine the differential abundances of the microbial communities a false discovery rate (FDR) control was applied. Shannon and Simpson diversity indices were calculated to analyze diversity at the sample level (alpha diversity). PERMANOVA (Permutational multivariate analysis of variance) with 10 000 replicates and an ordination plot was conducted to examine differences between cohorts (Beta diversity). The CowPI pipeline was used to predict the metabolic pathway differences between the two feed efficiency cohorts and analyzed using NIPALS (Nonlinear Iterative Partial Least Squares) and PERMANOVA.

Results A predominance of *Firmicutes* for the HFE cohort was found. However, there were differences in abundances for the liquid fractions between the two cohorts (FDR =0.02). No overall differences between the microbial relative abundances, and alpha diversity (FDR > 0.05) were found. Differences between cohorts were clear (Pseudo $F = 3.327$, $R^2 = 0.06$, pseudo-p-value < 0.05), suggesting a high bacteria diversity and a different composition for the feed efficiency cohorts and closeness for HFE (in comparison with LFE). 11 microbial species for HFE were differentially abundant (FDR < 0.05) (including: *Bifidobacterium thermophilum_RU326, Prevotella copri, Sharpea p-3329-23G2, Dialister succinatiphilus*) and 7 for LFE (unidentified at species level). Likewise, 37 species were unique for HFE and 50 for LFE, suggesting a presence of specific bacteria in each cohort. Finally, CowPI indicated different use in metabolic pathways for the cohorts (Pseudo $F = 2.77$, $R^2 = 0.05$, pseudo-p-value = 0.02) with 35 pathways with differential activity in the microbial communities of cohorts. Amongst the metabolic pathways enriched in HFE were limonene and pinene degradation and aminobenzoate degradation. In contrast, amino acid metabolism and Bisphenol degradation were more common for LFE. Thus, the results show a closeness for HFE suggesting less diversity of metabolic pathways for that cohort.

Conclusion The results indicate specific microbial species actively involved in the feed efficiency in each cohort. HFE shows a limited diversity for microbial organisms and metabolic pathways, similar to the results of McGovern *et al*., (2018) and Patil *et al*. (2018) in cattle and sheep respectively. The findings can help devise nutritional strategies to enhance feed efficiency in sheep through the identification of potential feed efficiency indicator species.

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Bacterial profiling the gastrointestinal tract of commercial pigs up to 28 days post-weaning

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Application Changes in bacterial composition through time and location within healthy pigs should be considered and included in future research on the effects of disease or alternative feeds on the GIT bacterial populations.

Introduction The gastrointestinal tract is inhabited by large numbers of microorganisms that play various roles in nutrient digestion, immune modulation and resistance to pathogens (Zhang *et al*., 2018). In pigs, bacterial populations are critically important during production and are associated with a number of diseases, such as enterotoxigenic *Escherichia coli* (ETEC). Understanding the bacterial community within the GIT of healthy pigs can be a baseline for further investigation into the effects of disease, feed ingredients and supplements on bacterial composition. Previous studies have focused on profiling the bacterial composition of faeces, with few focusing on locations within the GIT (Looft *et al*., 2012). The aim of this study was to identify differences in the bacterial community diversity and function between the mucosal and luminal digesta within the ileum, caecum and colon at weaning and at 14 and 28 days post-weaning.

Material and methods Experimental protocols were approved by the ethical review group of the University of Leeds. At weaning (D0) one pig was randomly selected from each of four litters for euthanasia and dissection. A further five pigs per litter were randomly selected and weaned at 26.0±0.19 day's old, 7.94±0.23 kg liveweight (± SEM). Pigs were weaned into fully slatted indoor accommodation and littermates remained together within a pen (five pigs per pen). All pigs were fed the same standard commercial diet, *ad libitum,* for the duration of the trial. At day 14 and day 28 post-weaning, one pig per pen was randomly selected and humanely killed. All pigs euthanized within the trial had their digestive tract removed and samples were collected from the mucosal (except at D0) and luminal digesta within the terminal ileum, caecum and proximal colon. Samples were stored at -20°C. DNA was extracted (QIAamp stool mini kit; Qiagen Inc, USA) and amplified using primers for the V4 hypervariable region of the 16S rRNA gene prior to purification and library preparation. Libraries were sequenced on the Illumina MiSeq platform (V2; 250bp pair-end reads). Sequencing reads were processed, quality filtered and aligned using Mothur v.1.40.3. Unique sequences were identified and aligned against the SILVA database (v.132). After removal of chimeras, sequences were clustered into operational taxonomic units (OTUs) with 97% similarity and R v3.4.3 was used to determine differences in alpha (Chao1, Shannon) and beta diversity (PERMANOVA). Piphillin was then used to predict gene functions based on representative sequences of each OTU.

Results Alpha diversity did not differ between luminal and mucosal digesta, time points or location in the GIT. However, location in the GIT had a significant effect on beta diversity ($P < 0.001$), with the ileum clustering separately from the caecum and colon (Figure 1). Time had a significant effect on beta diversity ($P < 0.002$) for all GIT locaqtions. No difference in beta diversity was observed between lumen and mucosal samples. Piphillin showed significant differences ($P < 0.01$) in predicted gene function between the ileum and both the caecum and colon, and the lumen and mucosa at D14 and D28. Pathways associated with quorum sensing were more present in the ileum compared to the caecum and colon *(*$P < 0.01$).

Conclusion Surprisingly, pathways associated with quorum sensing were higher within the ileum, where a lower bacterial density was seen, compared to the caecum and colon, thus providing an area of future research.

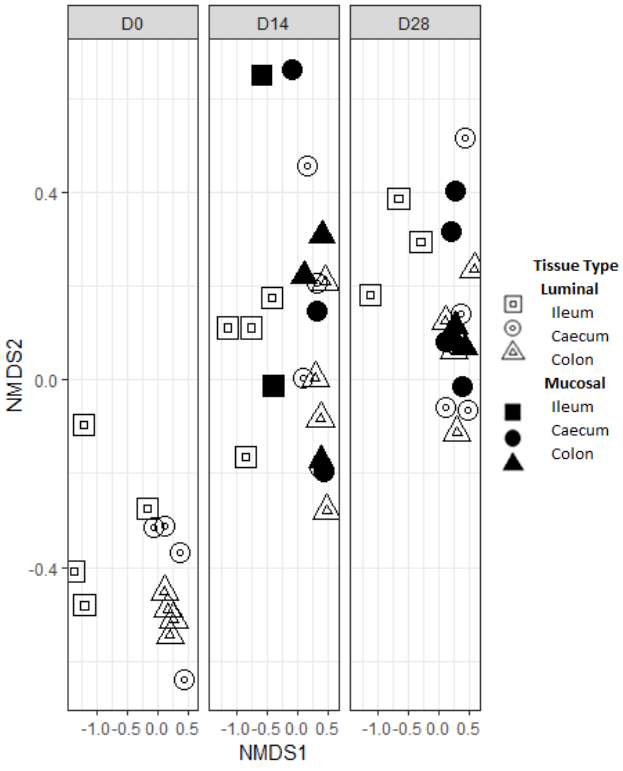

Figure 1 NMDS plot showing bacterial diversity in the The ileum, caecum and colon at D0, D14 and D28.

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The trials and challenges of marketing feed and supplements, a manufacturer's viewpoint

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Application To provide understanding between key stakeholders within the equine industry in the UK and EU, on the challenges of research into complementary feeds for equines, its representation and legal restrictions.

Introduction Within the equine industry views on complementary feeds, or 'supplements', vary widely, from 'miracle cure' to 'waste of money.' Marketing of commercial products often fails to include scientific evidence into their efficacy, which can understandably lead to scepticism of their credentials. There is a need for key stakeholders, including academia, vets, journalists and trainers, within the equine industry to understand the legal restrictions that manufacturers are working under so they can better understand the labelling and marketing presented. The aim of the presentation is to facilitate that understanding, such that horse owners will receive appropriate advice from all sectors, allowing them to make suitably informed choices for their horses.

Presentation The presentation will briefly review the legal definition of complementary feeds and supplements under European law, and the Feed Law under which they work. Claims substantiation for any marketing, including labels, will be covered, and a review of marketing restrictions as they apply to the UK and EU. The presentation will investigate how the industry can better use research, and will discuss options for study design, which may open up rather than restrict marketing opportunities. An overview of a recent case history will be presented to show how research can be represented within legal boundaries. An improved understanding of those legal restrictions should help academia enhance their collaborations with industry, such that they are offering appropriate trial design and protocols for commercial products and so growing research and industry collaboration.

The presentation will also offer guidelines to key stakeholders for recognising reputable manufacturers from the information on their labels, including quality audits and suitability for competition, of both feed and supplements. In such a competitive market, where information is not always clearly disseminated, through no fault of the manufacturer, then any tools which help all professionals offer appropriate advice on supplementary feeding to horse owners should be welcome.

Acknowledgements The author gratefully acknowledges the cooperation of NAF.

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How repeatable is the top-line evaluation system (TES)™ as a palpable muscle scoring system for horses?

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Application Horses are routinely scored for body condition as a measure of fat, however there are currently no validated systems for evaluating muscle via palpation. Muscle scoring would be a useful way to monitor muscle during growth, development and training.

Introduction The top-line evaluation system (TES)™ was developed by Progressive Nutrition™ in the USA as a practical four point scale for scoring top-line muscle via palpation. The theory behind the scoring system is similar to the body condition system described by Carroll and Huntingdon (1988), but focusses on scoring the musculature covering the thoracic to the last sacral vertebrae. Measuring muscle mass in horses has proved more difficult than in humans as bioelectrical impedance studies have not been successful. A practical, hands on tool to measure muscle development alongside fat could be a useful industry tool. A previous study using this technique identified that two assessors could repeat the same score for 63 horses of varying breeds (Wray and Daniels, 2014).
The aim of this study was to test the repeatability of the TES™ when carried out by a range of horse handlers on a range of horses.

Material and methods Thirty horses from four different premises were evaluated by 30 different assessors, each horse was evaluated by each assessor at that premises (P1 n=5, P2 n=7, P3 n=8 and P4 n=10). At each premises there were an equal number of assessors to horses. The horse population as a whole consisted of 18 horses and 12 ponies. Comprising 13 mares and 17 geldings, ages ranged from 4-23 (mean 10 ±4/5 years). Breeds comprised Cleveland Bay (n=1), Connemara (n=3), Highland pony (n=1), Hanoverian (n=2), Irish Sports Horse (n=3), Sports Pony (n=2), Thoroughbred (n=6), Warmblood (n=6), and Welsh ponies (n=6). Participants were briefed on the procedure and given a set of instructions and a scoring sheet. Assessments were carried out and recorded individually from other assessors in the presence of an impartial individual to hold the horse being assessed.
Data were analysed for repeatability and agreement between assessors for each premises using the Fleiss Kappa Coefficient in IBM SPSS version 25.

Results The results identified that at each premises there was a high level of agreement and repeatability between assessors when using the TES™ system (Table 1).

Table 1 Results of the repeatability and agreement of assessors using the TES™ system at four different premises

	Premises 1	Premises 2	Premises 3	Premises 4
Kappa statistic	0.951	0.856	0.822	0.989
Significance (P)	0.000	0.001	0.001	0.000

No effect of breed of type was observed in this study.

Conclusion These finding suggest that the TES™ is a repeatable scoring system that could be implemented by horse managers to monitor muscle condition alongside body condition scoring systems to monitor fat. The findings here also support the findings of Wray and Daniels (2015) for the repeatability of this system. Further work should focus on the TES™ as a tool alongside body condition scoring when used longitudinally by horse managers ranging in assessment experience.

Acknowledgements Progressive Nutrition ™ for the use of their TES™

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Influence of particle size and residual moisture on Near Infrared Reflectance Spectrometer (NIRS) analysis of minerals in hay

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Application Improvement of calibration and prediction capability and accuracy of minerals by near infrared reflectance spectrometer for easy and rapid analysis of forage samples.

Introduction The use of NIRS for mineral analyses in feeds and forages has produced mixed results because minerals do not absorb in the near-infrared region and mineral concentration is low. Attempts to develop calibration equations have resulted in low prediction accuracy. However, little is known about the impact of sample preparation on mineral calibration and prediction accuracy. The objective of this study was to evaluate the influence of particle size and residual moisture on calibration and prediction accuracy of NIRS for mineral analysis.

Material and methods A population of hay samples (n=37) from different locations in Ireland, were used to examine the impact of sample preparation and presentation procedures (presence of residual moisture (RM) i.e. dried/re-dried and particle size variation (PS) i.e. 0.5/1.0 mm on resultant NIRS calibration and prediction statistics. Spectra data were collected by scanning dried ground stored samples in reflectance mode (1100–2500 nm) using a FOSS DS2500 NIRS in a small circular cup (50 mm diameter) after which they were re-dried and rescanned both at 0.5 and 1.0 mm. The samples were analysed for Ca, P, Mg, S, and Na in duplicate using inductively coupled plasma mass spectroscopy (ICP-MS) for collection of reference data. Calibration models were developed using modified partial least squares regression (MPLS) based on cross-validation and tested using a validation set. To optimise calibration accuracy, mathematical treatments (first and second derivative) of the spectra and scatter corrections (SNV and Detrend) were applied. Optimum calibrations were selected based on highest 1-Variance ratio (VR) and lowest standard error of cross validation (SECV) (Huang *et al*., 2009). The predictive ability of calibrations was assessed from the standard error of prediction (SEP) and Residual predictive deviation (RPD). RPD is the ratio of standard deviation to the standard error of prediction (SD/SEP), (Chang *et al*., 2002 and Cozollino *et al*., 2011).

Results The best calibration statistics were obtained at a particle size of 0.5mm dried for all the minerals analysed except for Ca, which was better at 1.0 mm dried. The prediction capacity of the developed models using external validation samples confirms the potential of NIRS to quantify minerals in forages for horses. Overall, these results showed that the NIRS prediction accuracy for different minerals vary with the sample preparation and presentation procedure.

Table 1 Mineral analysis for hay samples (% DM) with the sample treatment preparation and regression technique providing the best calibration and cross validation statistics

Mineral	Calibration				Validation				
	PS+RM	R^2	SECV	1-VR	PS+RM	R^2	SEP	Bias	RPD
Ca	1.0 dried	0.952	0.063	0.639	0.5 re-dried	0.393	0.09	-0.035	1.244
P	0.5 dried	0.901	0.028	0.637	1.0 dried	0.813	0.018	0.011	1.722
Mg	0.5 dried	0.958	0.019	0.677	0.5 re-dried	0.348	0.020	0.0	1.25
S	0.5 dried	0.865	0.012	0.855	0.5 dried	0.169	0.025	-0.001	1.12
Na	0.5 dried	0.833	0.080	0.466	0.5 re-dried	0.222	0.055	0.009	1.127

Conclusion Increased particle comminution as well as sample presentation without re-drying improved the calibration statistics of NIRS for macro-mineral analysis. However, removal of sample residual moisture prior to spectral analysis resulted in better prediction statistics for some minerals but cannot be justified in terms of the extra resources required relative to the improvements in the prediction statistics.

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The effect of hock angle on the stride characteristics and speed of flat raced thoroughbreds

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Application Exploring the potential link between hock angle, stride length and stride count can be beneficial to owners and trainers as it would help to refine their selection process for purchase.

Introduction The arrangement of bones, muscles and tissues determines the physical appearance of the horse (Mcllwraith *et al*., 2003). When evaluating the conformation of the horse and likely success in different disciplines, the physical appearance, including length and straightness of bones, angles of joints, proportions and balance are considered (Cable, 2000). Previously, horses with smaller hock angles have been found to be more suited to dressage, whereas those with larger hock angles were more suited to racing (Holstrom *et al*., 1990). It is therefore pertinent to consider whether the hock angle could have any direct relationship with racing performance, which could be beneficial in informing selection processes for racing. The aim of this study was to establish whether hock angle has any significant relationships with stride characteristics and speed of thoroughbreds raced on the flat.

Material and methods Twelve flat raced thoroughbreds of mixed age (2-4 years old), height (15 hh - 16.3 hh) and gender (g=4, s=8) were selected from a racing yard in the UK. Conformation was analysed using a method adapted from Holstrom *et al*. (1990). Horses were stood against a blank wall on flat ground and four markers were applied to the left hind limb at the point of buttock, stifle, centre of hock, and centre of fetlock. Photographs were taken and hock angle was measured using both a goniometer and an online application (Guenter Guckelsberger). Stride length and stride count were obtained using a FineEquinity device. The device was placed within a pocket on a girth sleeve and horses were exercised at a speed of 25-30 mph over 5 furlongs, on a purposely built fibersand gallop. Relationships between hock angles and stride characteristics were assessed using spearman's correlation. Regression analysis was conducted on any significant relationships to determine the predictive nature of the data.

Results Hock angles ranged from 135°- 148° (mean±S.E. = 144.63°± 1.3°). Stride length ranged from 3.29 m - 6.29 m (mean±S.E. = 5.01 m ± 0.1) A significant positive correlation between hock angle and stride length ($R = 0.853$; $P < 0.01$) was found. Figure 1 represents the regression analysis, showing that stride length could be predicted with 68.2 % accuracy. Stride length and speed were significantly positively correlated ($R = 0.818$; $P < 0.0001$). Stride count negatively correlated to speed ($R = -0.824$; $P < 0.01$). Regression analysis between stride length and speed showed that stride length could be predicted with 67.6% accuracy (Stride length (m)= 1.066 + 0.1647 Speed (Average)).

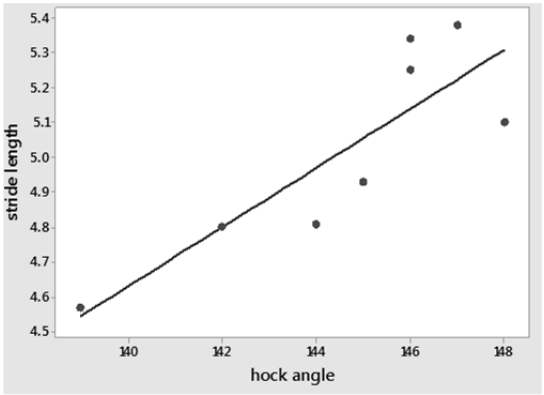

Figure 2 Regression Analysis fixed line plot. Stride length= 7.266 + 0.08497 hock angle

Conclusion A larger hock angle was related to a longer stride length which was shown to significantly affect the speed at which the horses travelled. Identifying these trends will allow trainers and owners to select horses with a larger hock angle.

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The factors that influence the decision – making process of equine euthanasia

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Application Understanding the way in which horse owners reach decisions regarding euthanasia, as well as the wider moral values of public relevance, could help the industry to better support owners at the end of equine life.

Introduction Equine euthanasia is an important aspect of horse care, yet has limited research. McGowan and Ireland (2016) revealed that euthanasia is a tough decision to make by horse owners. No horse should suffer unnecessary pain or distress, so it is essential that horse owners make a rational informed decision concerning their horse's welfare and future quality of life. The study's aim was to discover how horse owners make decisions relating to euthanasia and to compare the public's perspectives on the ethics for equine euthanasia.

Material and methods Two online surveys collecting quantitative and qualitative responses were conducted using convenience sampling. The horse owner survey (n= 1956) explored experiences with euthanasia whereas the public survey (n= 219) asked about ethical considerations. Quantitative results were converted into percentages to allow comparison between factors. Word data were coded using computer assisted technology (SimStat-WordStat v.6 (SS/WS), Provalis Research) following procedures described by Duz *et al*. (2017). Raw data codes were compared and developed into 1st and 2nd order categories using thematic framework analysis.

Results Of the horse owners, 72.7% stated that they would euthanise a horse with an ongoing health condition or in an emergency situation. 16.5% of owners would consider euthanasia of a fit and healthy horse that is no longer needed, compared with 83.4% who would try to rehome the horse first; however, 80.6% of participants think that people keep horses alive for their own benefit. Many horse owners stated that it was their responsibility and duty of care to be present during euthanasia, whilst others outlined reasons for not doing so. The thematic framework analysis explored three main considerations of euthanasia (Table 1). From a public perspective, participants stated that euthanasia was ethically acceptable in certain situations. 32.9% of horse owners think that it's ethically acceptable to euthanise a horse if they are unable to be rehomed.

Table 1 Thematic framework analysis of euthanasia considerations

Consideration relating to euthanasia	No. of raw order themes	No. of second order themes	Second order categories
Reasons for considering euthanasia	28	4	End of life point Quality of life judgement
Reasons why euthanasia would be chosen	49	6	Severity of condition Welfare implications
Support received relating to decision	19	4	Guidance with making decision

Conclusion The decision of euthanasia has been demonstrated to be complex and challenging, influenced by multiple individual factors. Horse owners seem to prefer the hypothetical option of rehoming a horse rather than euthanising it. Emergency or long term health conditions and related poor quality of life are the strongest determinants for the decision, but owners need support from professionals in reaching this decision.

Limitations and future work Use of the online questionnaire tool limited the depth of exploration of owners' experiences; future research should allow depth analysis from owner interviews. Outcomes for the unwanted horse are currently being researched by the author.

Acknowledgements I would like to acknowledge all the respondents who completed the surveys.

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Whole-farm feed efficiency on British dairy farms

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Application Feed efficiency on British dairy farms varies with production system, and varies between farms within systems. Whole-farm feed efficiency is related to stocking rate, milk yield per ha, milk from forage and gross margin per ha.

Introduction Whole-farm feed efficiency (WFFE) is defined as total milk output divided by total feed produced or purchased for all animals on the dairy farm. Feed efficiency is usually considered only for the milking cows in a herd, but efficiency gains in milking cows might be offset by inefficiencies in other areas. These areas could include feed used for youngstock and dry cows, and feed wasted. Therefore, factors such as herd fertility, health, replacement rate, heifer rearing system, dry cow management and feed wastage may affect WFFE. Moreover, WFFE and its components might differ for production systems following different calving, grazing and feeding regimes. The aim of this study was to assess WFFE on a sample of farms representing typical GB dairy systems and to determine which factors influence WFFE.

Material and methods A stakeholder group agreed that GB dairy production systems could best be classified according to calving pattern, number of days that cows graze, and feeding approach (Table 1). Twenty-one farms, representing the five systems, were visited quarterly between February 2017 and March 2018. Data on animal numbers, milk production and composition, feed purchases, stocking rate, grass and forage use, and youngstock rearing were collected. Energy-corrected milk (ECM) yield was calculated, and feed use was estimated on a dry matter (DM) basis. Associations between WFFE and it components were assessed using simple linear regression.

Table 1 Classification of GB dairy systems

	Dairy production system				
Descriptor	1	2	3	4	5
Calving pattern	Spring	Block / All year	Block / All year	All year	All year
Grazing, days	> 274	183 to 274	91 to 182	0 to 90	0
Feeding	Limited supplements	More use of supplements	Mixed ration supplements	Mostly mixed ration	All mixed ration

Results There was wide variation in WFFE and its components, both overall and within systems, which indicates that there is scope for improvement in WFFE in all five systems classifications. Systems 1 and 2 farms featured crossbred cows with lower milk yield and concentrate use than Systems 3 to 5 farms, which featured mostly Holstein cows (Table 2). Mean stocking rate was lowest for System 3 farms, but was similar for other systems. Across systems, WFFE increased as grazing days decreased, and milk yield and concentrate use increased. Overall, however, WFFE was positively associated with stocking rate ($r = 0.585$; $P = 0.014$), milk yield per hectare ($r = 0.759$; $P < 0.001$), and milk from forage ($r = 0.530$; $P = 0.029$). These factors reflected forage quality. Fertility, health, replacement rate and heifer rearing system influenced WFFE on individual farms, but did not have consistent effects across systems. WFFE was positively related to gross margin per forage hectare ($r = 0.557$; $P = 0.025$).

Table 2 Mean performance indicators for all farms and for dairy production systems (1 to 5)

`	All farms		Dairy production system				
	Mean	SD	1	2	3	4	5
Grazing days per year	142	112	286	222	132	57	0
Herd Size (No. cows)	276	142	257	260	161	274	362
Annual milk yield (kg ECM/cow)	8190	1743	6306	7721	9322	9406	8945
Annual concentrate use (t DM/cow)	2.85	1.04	0.91	2.29	3.06	3.65	3.59
Stocking rate (LSU/forage ha)	2.37	1.05	2.45	2.50	1.95	2.57	2.19
WFFE (kg ECM/kg Feed DM)	1.07	0.28	0.99	1.04	1.07	1.08	1.13

Conclusion Comparisons of performance and WFFE on farms in different systems categories revealed variability and associations that can be used to develop strategies for improving WFFE on individual farms. The best overall strategy is to aim for better quality forage that allows higher stocking rates and greater WFFE.

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Nitrogen isotopic fractionation to predict nitrogen-use efficiency of lactating Holstein Friesian dairy cows

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Application Whilst N isotopic fractionation shows considerable potential as a phenotyping tool, it will be necessary to consider parity and other sources of variation in body protein change when using it to predict NUE of dairy cows.

Introduction Several previous studies with sheep, beef cattle and dairy cattle have demonstrated a negative relationship between Feed Conversion Efficiency or Nitrogen-use efficiency (NUE) and the extent of isotopic fractionation of Nitrogen isotopes (^{15}N and ^{14}N; see meta-analysis by Cantalapiedra-Hijar *et al*., 2018). Nitrogen isotopic fractionation is usually expressed as the difference in $\delta^{15}N$ between the diet and product protein (usually measured in plasma, milk or muscle samples; in this case $\Delta^{15}N$ is milk $\delta^{15}N$ – feed $\delta^{15}N$). There is considerable unexplained variation around this relationship with dairy cows and the current study used samples taken from the Langhill Experiment, where cows undergo continuous measurements of NUE, to try to explain more of the variation.

Material and methods The Langhill Experiment involves a 2 × 2 factorial arrangement of genetic lines ((S)elect vs. (C)ontrol) selected on the basis of fat plus protein yield (maximized vs following the national average) for over 40 years and two total mixed rations (High Energy (HE) and Standard Energy (SE) based on 40/60 and 60/40 (DM basis) forage/concentrate ratios and designed to supply 12.2 and 11.3 MJ Metabolisable Energy /kg DM respectively). These cows calve all year round and are housed continually. Cows were milked three times daily and milk samples were obtained from 138 cows (28, 32, 37 and 41 from C-HE, C-SE, S-HE and S-SE) at the mid-day milking on 27 March 2018. At the time of sampling, cows were on average 159 days in milk (DIM; s.d. = 88.1) and there were 43, 31, 31, 27, 4 and 2 cows in parities 1 to 6 respectively. Feed samples were composited over the week prior to sampling and weighed (4 mg) into tin capsules, whilst milk (20 µl) was pipetted into tin capsules and then dried at 40°C. Nitrogen-15 content ($\delta^{15}N$; ‰) of milk and feed was measured by isotope-ratio mass spectrometry (Iso-Analytical Ltd., Crewe, UK). Individual intakes were recorded with Hoko feeders (Insentec BV, Marknesse, The Netherlands), with milk yields recorded in parlour and milk analysis by infra-red milk analyser (National Milk Laboratories, Glasgow, UK). Genetic Line, Diet and their Interaction were Fixed effects in the REML model (Genstat release 16.1), with DIM and lactation number as Random effects. The relationship between $\Delta^{15}N$ and NUE was further explored using linear regression including parity (primiparous vs multiparous) as a grouping factor.

Results Diet CP (g/kg DM) and $\delta^{15}N$ (‰) were 162 and 174 and 3.56 and 4.96 respectively for HE and SE diets. The anticipated effects on production were confirmed and higher producing groups had higher NUE and lower $\Delta^{15}N$ (Table 1).

Table 1 Effects of genetic line and dietary treatment on production, NUE and $\Delta^{15}N$ (milk – feed)

	Treatment					Significance		
	C-HE	C-SE	S-HE	S-SE	s.e.d.	Genetic Line	Diet	Interaction
DM intake (kg/day)	20.9	19.4	23.8	20.7	0.82	<0.001	<0.001	n.s.
Milk yield (kg/day)	32.2	30.0	38.9	29.7	1.83	<0.05	<0.001	<0.01
Milk fat, %	3.79	4.03	4.36	4.46	0.177	<0.001	n.s.	n.s
Milk protein, %	3.26	3.24	3.44	3.51	0.065	<0.001	n.s	n.s.
N-use efficiency (g/g)	0.301	0.288	0.337	0.285	0.0163	NS	<0.01	<0.1
$\Delta^{15}N$ (milk – feed)	1.76	2.03	1.54	1.89	0.102	<0.05	<0.001	NS

There was a highly significant relationship between $\Delta^{15}N$ (milk – feed) and NUE, which was significantly different between primiparous and multiparous animals (equation 1):

$\Delta^{15}N$ (‰) = 1.98 (s.e.=0.157)*** - 2.54 (s.e.=0.499) NUE (g/g)*** + 0.71 (s.e.=0.082) parity (coded as 1 or 2)***
N=138; r^2=39.9; residual s.d. = 0.444; P<0.001 (Cantalapiedra-Hijar *et al*., 2018)

$\Delta^{15}N$ values averaged 1.72‰, which is at the lower end of the range reported by Cantalapiedra-Hijar *et al*. (2018), but consistent with the overall high NUE of these high-producing dairy cows. The slope for the relationship between $\Delta^{15}N$ and NUE is consistent with the analysis presented by Cantalapiedra-Hijar *et al*. (2018), though there was considerable variability around the relationship – which may in part result from the less intensive sampling protocol in comparison with N balance studies. The highly significant effect of parity most likely reflects the fact that heifers are still growing, so that we would need to take protein accretion into account to obtain true NUE values.

Conclusion Whilst $\Delta^{15}N$ explains a significant proportion of variation in NUE of lactating dairy cows, the relationship is diminished by unaccounted variation in accretion (and potentially mobilisation) of body protein.

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Has nitrogen utilisation efficiency of dairy cows been improved since the implementation of the Nitrate Directive Programme

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Application Modern dairy cows appear to utilise dietary nitrogen more efficiently, thus excreting less nitrogen, and consequently less ammonia per kg of milk production.

Introduction Dairy cow diets are formulated to meet nutritional nitrogen (N) requirements for specified levels of milk production, however, much of this N is in excess of what the animal can utilise and is therefore excreted. In 2005, the EU Nitrates Directive (ND) was implemented in Northern Ireland (NI) aiming to reduce N pollution from agricultural sources. This study aims to compare N utilisation data collated from digestibility studies with lactating dairy cattle since implementation of the ND in Northern Ireland with N utilisation data produced pre-ND implementation (Yan *et al*., 2006).

Material and methods Two datasets were compared; (1) 'Post-ND' data collated from 388 lactating dairy cows across 12 diet digestibility studies undertaken at the Agri-Food and Biosciences Institute (AFBI) between 2005 and 2015, and (2) 'Pre-ND' data from 568 lactating dairy cows (majority Holstein-Frisian) across 26 AFBI studies between 1990 and 2004 (Yan *et al*., 2006). All cows were loose housed in cubicles and offered experimental diets for at least 20 days prior to digestibility studies. Animals were then housed in metabolism units for 8 days with feed intakes, faeces outputs and urine outputs recorded during the final 6 days. The two datasets were then compared for feed intake, milk production and N utilisation efficiency via ANOVA. The N utilisation efficiencies between the two datasets were also evaluated via linear regression analysis comparing the two slopes using a common intercept. The effects of experiment, trial year, cow breed/genotype, cow parity, days in milk and forage type on the ANOVA and linear regression were removed.

Results When compared with the Pre-ND data, the Post-ND data showed a lower ($P < 0.001$) average parity (2.5 vs 3.0) and live weight (550 vs 565 kg), whilst higher ($P < 0.001$) days in milk (170 vs 152), total DM intake (18.2 vs 16.4 kg/d) and energy corrected milk yield (24.0 vs 21.8 kg/d). Post-ND data also had a lower dietary forage proportion (0.554 vs 0.581 kg/kg DM, $P = 0.015$) and CP concentration (0.174 vs 0.183 kg/kg DM, $P < 0.001$). Dietary ME concentration did not differ between the two datasets (12.1 MJ/kg DM). Table 1 presents N utilisation comparisons, Figure 1 presents the relationship between N intake and total manure N output. In comparison with the Pre-ND data, the Post-ND data had a higher N intake and consequently higher faeces N output, milk N output and N retention, but had a lower urine N output. As a result, the Post-ND data had a lower ratio of urine N and total manure N, but higher faecal N as a proportion of total N intake. A similar result was obtained when N utilisation efficiencies between the two datasets were evaluated using the linear regression technique. The intercepts were fixed at a common value for each relationship (11.7, 25.7 and 12.0 g/d for urine N, manure N and faecal N outputs respectively). Compared with Pre-ND data, the Post-ND N-utilisation efficiency had a lower slope ($P < 0.001$) for urine output (0.333 vs 0.407) and manure N output (0.614 vs 0.673) as a proportion of N Intake. However, the slope for faecal N was higher (0.285 vs 0.270) in Post ND compared with Pre-ND data.

Table 1 Comparison of N utilisation of dairy cows

	Pre-ND	Post-ND	s.e.d.	P value
N intake (g/d)	486	506	7.9	0.015
Faecal N (g/d)	142	159	2.3	<0.001
Urine N (g/d)	209	179	4.4	<0.001
Milk N (g/d)	109	127	2.3	<0.001
Retained N (g/d)	27	42	2.6	<0.001
Manure N/N intake	0.724	0.669	0.0047	<0.001
Faeces N/N intake	0.296	0.321	0.0033	<0.001
Urine N/N intake	0.428	0.348	0.005	<0.001

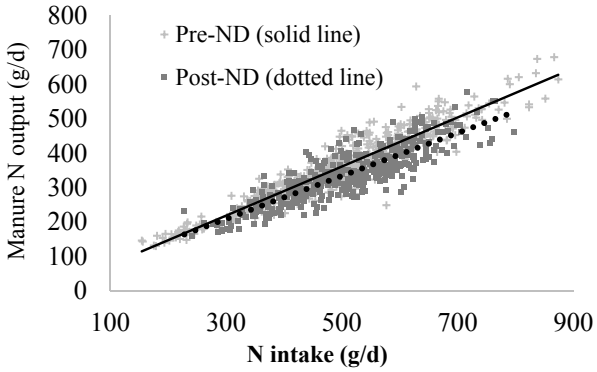

Figure 1 N-utilisation pre/post ND

Conclusion Since the implementation of the Nitrates Directive in 2005, modern dairy cattle appear to utilise a greater proportion of dietary N through increased milk yield, thus leading to reduced N excretion, particularly in relation to urine-N concentrations. Consequently, modern dairy cattle may therefore produce less ammonia per kg of milk production. This is likely derived from the combined effect of improved cow genetic merit and reduced dietary N concentration.

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A rumen drench of prairie meal and rumen protected essential amino acids for 4 days after calving increases milk fat concentration and body weight of lactating dairy cows through 12 weeks *post partum*

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Application Supplemental absorbable essential amino acids given for 4 days immediately *post partum* increased milk fat and protein concentration and body weight throughout early lactation, indicating sustained positive metabolic effects.

Introduction Continuous abomasal infusion of approximately 700 g/d of casein (Larsen *et al*., 2014) or an equivalent supply of free amino acids (Larsen *et al*., 2015) starting 6 hours after calving increased milk yield (9.5 and 5.9 kg/d at 4 and 5 days in milk [DIM], respectively) of Holstein dairy cows. In these studies, infusion rates were incrementally reduced over 4 weeks as feed dry matter intake (DMI) increased. Estimated metabolizable protein (MP) supply was similar for infused and control cows at 28 DIM, but the milk yield response was maintained throughout the infusion periods (on average 7.2 and 7.8 kg/d for casein and amino acid infusions, respectively), suggesting carryover effects. Therefore, our objective was to determine the effects of a daily rumen drench of prairie meal, as a source of rumen undegradable protein (RUP), and rumen protected methionine (rpMet), lysine (rpLys), and histidine (rpHis) for the first 4 days of lactation on DMI and milk production and composition of Holstein cows during their first 12 weeks of lactation.

Material and methods Twenty multi-parous Holstein dairy cows were randomly assigned at calving to a control rumen drench of 30 L warm water or a 30 L suspension of prairie meal and rpMet (MetaSmart, Kemin Industries), rpLys (AjiPro-L, Ajinomoto Co., Inc.), and rpHis (Ajinomoto Co., Inc.) calculated to provide Met, Lys, His, and Leu for absorption equal to their amounts in 600 g casein. All cows received their first drench within 8 hours of parturition and then again 24, 48, and 72 hours later (1 to 4 DIM). From calving cows were fed *ad libitum* a total mixed ration balanced to meet expected nutrient requirements for lactation. At 7 DIM cows were moved from calving boxes to a cubicle yard and measurements of daily dry matter intake (DMI) and milk yield and weekly milk composition, body weight (BW), and body condition score (BCS) were obtained through week 12 postpartum. A blood plasma sample obtained at 7 DIM was analysed for protein and albumin concentration. Weekly average data were statistically analysed as repeated measurements using mixed models procedures for fixed effects of treatment, week of lactation, and treatment by week interaction and random effects of cow, with parity, previous 305-day milk yield, and genetic index as covariates if their effects were significant.

Results There was no effect of rumen dosing on DMI or milk yield, but milk fat concentration was higher and milk protein concentration tended to be higher for supplemented cows during weeks 2 to 12 (Table 1). Whilst BCS was not affected, supplemented cows gained BW over the course of the study (+32 kg), whilst control cows maintained a similar body weight (-3 kg). Plasma protein concentration was higher, and albumin concentration tended to be lower (36.9 vs 34.5, $P < 0.08$), in treated cows on day 7 of lactation.

Table 1 Effects of 4 daily rumen protein doses immediately after calving on subsequent production of dairy cows.

	Control	Treated	SEM	Treatment	Week	Interaction
Dry matter intake, kg/d	26.1	26.8	0.568	0.364	0.001	0.383
Milk yield, kg/d	44.5	46.3	2.45	0.604	0.001	0.634
Milk fat, %	3.44	3.86	0.098	0.002	0.017	0.438
Milk protein, %	3.07	3.23	0.062	0.080	0.001	0.797
Body weight, kg	657	673	18.4	0.482	0.001	0.009
Day 7 plasma total protein, g/L	66.5	71.6	1.58	0.040		

Conclusion Four daily rumen doses of supplemental RUP and rumen protected essential amino acids immediately after calving had sustained positive effects on milk fat and protein concentration and BW of lactating Holstein cows, suggesting homeorhetic effects that warrant further investigation, including development of appropriate diet supplementation strategies.

Acknowledgements The provision of rpLys and rpHis by the Ajinomoto Co. Inc. is gratefully acknowledged.

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Effect of fibre:starch ratio in dairy cow diets differing in maize:grass silage ratio, on milk fatty acid profile and its relationship with rumen hydrogen ion concentration

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Application Concentrations of certain fatty acids in milk fat change due to diet-induced alterations of the rumen environment. These milk fatty acids could be used as markers of compromised rumen function and health.

Introduction Maintaining a stable rumen environment is a challenge when feeding high-yielding dairy cows. A compromised rumen environment can lead to the onset of rumen acidosis, resulting in anorexia, poor body condition and decreased milk production. Given the influence of the rumen environment on milk fatty acids (FA), recent research has focused on using milk FA profile as a tool for identifying rumen problems (Barbano *et al*., 2014). Several milk FA and groups have been identified as possible markers of sub-acute rumen acidosis, such as *de novo* synthesised FA, odd- and branched-chain FA (OBCFA), *trans*-10 18:1 and certain conjugated linoleic acids (CLA). This study assessed the effect of feeding diets designed to alter rumen pH, fibre digestion and passage rate, on milk FA profile.

Material and methods Four multiparous, early lactation Holstein cows were allocated to one of four treatment diets in a Latin Square design experiment with 28 day periods. Diets consisted of a total mixed ration (50:50 forage:concentrate, DM basis), with forage comprising of grass and maize silage at proportions (DM basis) of either 82:18 (G) or 18:82 (M), and concentrates being either higher in neutral detergent fibre (NDF; soya hulls; F) or starch (cracked wheat and maize; S). The predicted NDF:starch ratios were 4.6, 1.4, 1.6 and 0.8 for GF, GS, MF and MS, respectively. Rumen pH was recorded during the last 7 days of each period. Milk samples were taken during the last day of each period, pooled according to yield, and stored at -20°C before FA analysis. Milk FA data were analysed using the Mixed procedure of SAS, with period, forage, concentrate and forage by concentrate interaction as fixed effects, and cow as a random effect. The linear correlation between FA groups and hydrogen ion concentration ($[H^+]$) was assessed using Pearson correlation analysis.

Results Proportion of grass or maize silage in the diets affected milk FA profile, with maize silage resulting in lower ($P < 0.05$) SFA and *de novo* SFA, and higher ($P = 0.022$) OBCFA (Table 1). Maize silage also increased ($P < 0.05$) the concentration of some *cis*- and *trans*-18:1 isomers, total *trans* monounsaturated FA and n-6 polyunsaturated FA compared with grass silage. Concentrate type had relatively minor effects on milk FA profile; higher fibre concentrates resulted in greater ($P = 0.010$) CLA concentrations (Table 1), 18:3 n-3 and branched-chain 15:0 (anteiso). There was an interaction ($P = 0.025$) between forage and concentrate for OBCFA (Table 1). Forage affected mean rumen pH, with M resulting in a lower ($P = 0.018$) pH than G. There was a negative correlation ($P < 0.01$) between mean ($R^2 = 0.664$) and minimum ($R^2 = 0.609$) rumen $[H^+]$ and *de novo* SFA, and a positive correlation ($P < 0.05$) between mean ($R^2 = 0.568$) and minimum ($R^2 = 0.744$) rumen $[H^+]$ and OBCFA, and mean ($R^2 = 0.568$) and minimum ($R^2 = 0.744$) rumen $[H^+]$ and *trans*-10 18:1.

Table 1 Effect of forage and concentrate type on milk fatty acid profile

Fatty acid group[1]	Treatment diet[2]					*P*[3]		
(g/100 g total FA)	GF	GS	MF	MS	s.e.m.	F	C	F x C
Σ SFA	75.3	75.0	71.1	72.8	0.08	0.009	0.059	0.047
Σ *de novo* (4:0-16:0)	62.4	63.9	60.5	60.6	1.07	0.029	0.130	0.186
Σ OBCFA	3.5	3.1	3.5	3.6	0.20	0.022	0.055	0.025
trans-10 18:1	0.29	0.25	0.46	0.50	0.110	0.075	0.991	0.647
Σ CLA	0.48	0.39	0.46	0.45	0.031	0.130	0.010	0.034

[1] SFA, OBCFA, CLA – saturated fatty acids, odd and branched chain fatty acids, conjugated linoleic acids.
[2] GF, GS, MF and MS – forage portion higher in grass (G) or maize (M) silage, concentrate higher in fibre (F) or starch (S).
[3] F, C and F x C - Effect of forage, concentrate and forage by concentrate interaction for n=14 measurements.

Conclusion Diet forage and concentrate type had relatively minor effects on milk FA profile. Although differences in rumen pH were relatively small, correlations between certain FA groups (OBCFA, *de novo* SFA) and rumen $[H^+]$ warrant further investigation.

Acknowledgements The study was supported by the AHDB Dairy Forage, Grassland and Soils Research Partnership and the University of Reading Undergraduate Research Opportunities Programme (UROP). The authors thank staff at the Centre for Dairy Research for their care of the animals.

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Effects of nutritionally improved straw (NIS) in dairy cow diets at two starch concentrations

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Application In lactating dairy cows, feeding nutritionally improved straw (NIS) can potentially result in a higher dry matter intake and milk yield.

Introduction Lactating dairy cattle hold high nutritional demands to meet performance and productivity demands during lactation. High levels of dietary starch are desired to increase dietary energy and improve performance; however, this can cause rumen health issues. The objective of this experiment was to explore effects of different dietary neutral detergent fiber (NDF) sources within diets of lactating dairy cattle with low or high starch concentrations on milk yield and composition, dry matter intake (DMI), digestibility, nitrogen (N) balance and rumen function and health. It was hypothesized that the inclusion of NIS and higher levels of starch in lactating cow diets would result in higher performance compared to untreated straw and lower starch levels, respectively.

Material and methods Holstein cows in early-to mid-lactation (n=12; 666±67 kg of body weight at the start of the experiment) and dry cannulated cows (n=4; 878±67 kg of body weight at the start of the experiment) were used in multiple 4 x 4 Latin square design and fed four different diets. The treatments were 50:50 forage to concentrate diets within a total mixed ration (TMR); consisting on a dry matter (DM) basis of 42% grass silage, as the main forage, 7.8% chopped untreated straw or nutritionally improved straw, and 50% of two different concentrates with low or high starch level (16.0 vs 24.0, respectively). There were four experimental periods, each consisting of a 21 day (d) adaptation period and 7d sampling period. There were two trials, consisting of a lactation trial (trial 1) and a rumen trial (trial 2). During the sampling periods for each experimental period, DMI and rumen fluid pH, ammonia-N (NH_3-N) and volatile fatty acid (VFA) concentrations were recorded for each trial. Sampling for trial 1 also included milk yield and composition, body weight (BW), body condition score (BCS), digestibility of nutrients from the experimental diets and N balance. All statistical analyses were conducted using JMP (version 13; SAS Institute Inc., Cary, NC) and results were analyzed using a mixed effects model. The fixed effects included the starch level (low-LS and high-HS), straw type (NIS and untreated-STR), the interaction between starch level and straw type, the period (1 to 4) and the square (1 to 3 for the lactation data and 1 to 2 for digestibility).

Results DMI and milk yield were affected by the type of straw included in the diet. A 1.45 kg/d higher DMI was seen when NIS was fed compared to untreated straw. The higher DMI was a result of a 4.3% higher NDF digestibility when fed NIS. A higher DMI resulted in a 1.05 kg/d higher milk yield which resulted in a greater milk protein yield. Milk protein concentration was only affected by straw type and was 3.87% higher when NIS was fed due to a 30 g/d greater N intake. The dietary starch level of the diets also affected DMI, which was 1.55 kg/d greater when fed diets with low starch levels, resulting in a 1.05 kg/d higher milk yield.

Table 1 Effect of straw type (STR) and starch level (STA)[1] on dry matter intake, milk yield and milk composition

						P-Value		
	LSTR	LNIS	HSTR	HNIS	SEM	STR	STA	STR*STA
DMI, kg/d	18.1^{b}	20.0^{a}	17.0^{c}	18.0^{b}	0.28	<0.001	0.0001	0.01
MY, kg/d	25.3^{a,b}	26.5^{a}	24.4^{b}	25.3^{a,b}	1.22	0.02	0.02	0.86
Protein, kg/d	0.80^{c}	0.91^{a}	0.81^{c}	0.87^{b}	0.03	<0.001	0.059	0.01
Milk composition								
Protein, %	3.17^{b}	3.33^{a}	3.29^{b}	3.39^{a}	0.06	<0.001	0.01	0.44

$^{a–c}$ Within a row, means without a common superscript differ ($P < 0.05$).
[1] LSTR: low level of starch supplemented with straw; LNIS: low level of starch supplemented with nutritionally improved straw (NIS); HSTR: high level of starch supplemented with straw; HNIS: high level of starch supplemented with NIS

Conclusion This study demonstrated that feeding NIS to lactating dairy cows in low or high starch levels had a positive effect on performance. Inclusion of NIS in diets resulted in a higher DMI and consequently in a greater milk yield compared to untreated straw, while the level of dietary starch in the diet also affected DMI, resulting in a higher intake when fed iso-energetic diets with low starch levels.

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Feed sorting of low and high concentrate diets by Holstein and Jersey dairy cows

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Application Feed sorting by dairy cows should be taken into account in nutrition studies by correcting nutrient intakes for the nutrient content in feed residues.

Introduction Cows often sort their feed and this could pose a problem during nutrition trials, e.g. by interference with digestibility measures. This study aimed to examine the occurrence of feed sorting by Holstein (HOL) and Jersey (JER) dairy cows fed 2 forage to concentrate ratios (F:C). The presented results were obtained in a larger study of Olijhoek *et al*. (2018).

Material and methods Ten HOL and 10 JER were fed a low concentrate (LC; F:C = 68:32; DM content = 513 g/kg) or high concentrate (HC; F:C = 39:61; DM content = 620 g/kg) diet as TMR (grass/clover silage, barley, soybean meal and rapeseed cake) in a cross-over design with back-cross corresponding to 3 periods of 17 days. Cows were fed twice a day *ad libitum* with an expected level of refusals of 1 to 2 kg of feed DM per cow per day. Per period, feed intake was recorded daily by collection of residues; feed samples were collected on day 12 and 13 and samples of residues were collected on day 13 and 14. Feed and residues were analysed for DM, NDF and starch. Data (n = 56, four missing observations) were analysed using SAS (version 9.3, SAS Institute Inc., Cary, NC). The paired samples T-test was used to compare the starch:NDF ratio in residues with the starch:NDF ratio in feed as a measure of feed sorting by the cows. The analysis compared feed sorting among the cows belonging to breed by diet treatment groups (four groups).

Results In Figure 1, the horizontal line at ratio 1.0 reflects a similar starch:NDF ratio in residues relative to the starch:NDF ratio in feed. For the LC diet (black bars) all observations are on or below the 1.0 line, whereas for the HC diet (grey bars) most observations are above the line. Comparison of the starch:NDF ratio in feed with the ratio in residues showed that the starch:NDF ratio in residues among HOL fed the LC diet was 0.097 ± 0.063 (mean difference ± standard deviation) lower than in feed ($P < 0.001$). Similarly, the starch:NDF ratio in residues of JER fed the LC diet was 0.156±0.047 lower than in feed ($P < 0.001$). In contrast, JER fed the HC diet had a higher starch:NDF ratio in residues than in feed (-0.439±0.451; $P < 0.01$), whereas the ratios in feed and residues did not differ for HOL fed the HC diet (-0.185±0.466; $P = 0.18$). The difference between the planned and consumed F:C was larger for cows with the largest amount of residues compared to cows with the smallest amount of residues (data not presented).

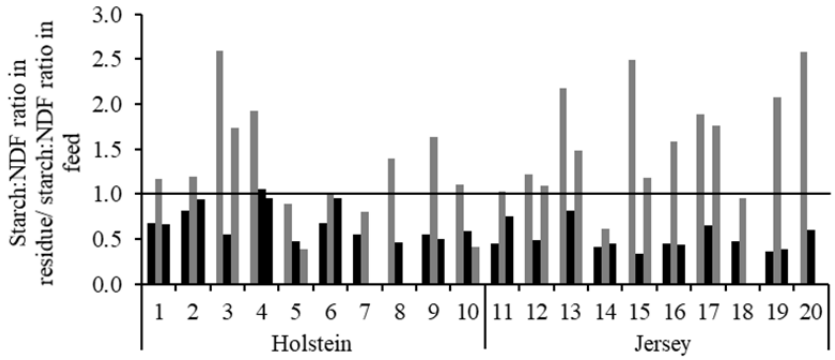

Figure 1 Relationship between the starch:NDF ratio in feed and in residues for Holstein and Jersey dairy cows fed a LC (black bars) or HC (grey bars) diet

Conclusion Jerseys, but not HOL, selected against concentrate in favour of forage when fed the HC diet, which indicated that the concentrate proportion was higher than JER preferred and the high DM content of the HC diet might have enabled sorting despite thorough mixing of TMR. Both HOL and JER were selecting the LC diet by sorting for concentrate. Apparently, cows seem to select towards a certain optimal F:C ratio in between the currently used F:C ratios. In practice, the difference between planned and actual F:C intake can be influenced by regulating the amount of residues (i.e. low amount).

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The grazing efficiency of different varieties of perennial ryegrass for dairy cattle under rotational grazing conditions

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Application Varieties of perennial ryegrass are shown to differ in their level of grazing efficiency. Varieties exhibiting greater grazing efficiency increase on-farm utilisation of grass and allow for easier management of grass swards.

Introduction Increasing the utilisation of grazed grass in the diet of dairy cows has been identified as a major driver of farm profitability (Hanrahan *et al*., 2018). Evaluation of perennial ryegrass (*Lolium perenne* L., PRG) varieties under mechanical harvesting protocols only provides a partial measure of their production potential as varieties are employed within grazing systems on-farm. Grazing efficiency is the proportion of leaf tissue present, which is removed by grazing animals. Grazing efficiency is a trait of interest as it positively influences the ease the management of swards, herbage quality in subsequent rotations and overall utilisation within grazing systems. This study compared the grazing efficiencies between different PRG varieties and examined the varietal characteristics which were responsible.

Material and methods In 2016, 15 diploid (D) and 15 tetraploid PRG varieties of intermediate and late heading types from the Irish Department of Agriculture, Food and the Marine Recommended List were sown in 8 × 4.5 m plots in a randomised block design with three replicates. The plots were rotationally grazed by dairy cows over 2017 and 2018 grazing seasons. On average, 60 cows grazed the 0.6 ha paddock on each occasion. Cows were allocated area based on the demand of the herd and the herbage cover in the paddock. Cows were moved on to the next allocation when the majority of plots were grazed to a height of 4 cm (residency time < 24 h). Prior to grazing, a 1.2 x 5 m section of each plot was harvested with an Etesia mower to a 3.5 cm height. Mown herbage from each plot was weighed and 0.1 kg was dried at 90˚C for 16 h to determine dry matter (DM) content and DM yield. A Jenquip rising plate meter was used to measure grass sward height prior to grazing and the post-grazing sward height (PGSH) of each plot. A separate sub-sample of the mown herbage was freeze-dried at -50 ˚C for 72 h, milled and subjected to Near Infra-red Spectrometry (NIRS) to determine organic matter digestibility (OMD), crude protein (CP) and fibre contents (NDF). Analysis of the morphological structure of the sward was undertaken by selecting 20 tillers from each plot and measuring the leaf, pseudostem, true stem and dead proportions of each plot. The data were analysed in the statistical program SAS using PROC MIXED with variety, block, grazing event and year used as variables in the model. To account for pre-grazing height differences between varieties, the PGSH of each variety was predicted using pre-grazing height as another variable within the mixed model. Residual grazed height (RGH) was developed to evaluate grazing efficiency. It was calculated as the difference between predicted PGSH from the actual PGSH. A negative RGH is indicative of a variety with greater utilisation performance and a high adaptation to grazing use.

Results Varieties were found to significantly differ in PGSH ($P < 0.001$). The average PGSH across the two years was 4.1 cm which ranged from 3.54 cm (Astonenergy (T)) to 4.6 cm (Boyne (D)). Tetraploids were shown to have significantly better grazing efficiency than diploids ($P < 0.001$). Greater pre-grazing height was shown to be significantly associated with a greater PGSH ($r^2 = 0.68$). Boyne had the greatest pre-grazing height at 11.13 cm and Astonenergy had the lowest at 9.06 cm. Astonenergy achieved the lowest RGH of -0.38; Clanrye (D) had the highest with an RGH of +0.34. As DM yield is a trait of major importance for farmers and in variety evaluation, the superior varieties within this trial were those achieving negative RGH values whilst also producing large herbage yields. Twymax (T) and Aspect (T) are examples of such varieties as they had RGH values of -0.2 and -0.18 and produced 13.4 and 12.5 t DM/ha respectively. Traits associated with superior graze-out performances where high levels of OMD and a greater proportion of leaf within the sward. A 10 g/kg DM increase in OMD decreased RGH by 0.2 ($r^2 = 0.63$). Tetraploid OMD (787 g/kg DM) was 115 g/kg DM greater than diploids (776 g/kg DM) which equates to a 0.23 difference in RGH. Increased leaf proportion in the sward was shown to decrease PGSH, with a 50 g/kg DM increase in leaf proportion decreasing RGH by 0.23 ($r^2 = 0.54$).

Conclusion Varieties were found to differ in their level of grazing efficiency, with tetraploids having better grazing potential than diploids. Greater levels of OMD and higher leaf proportions, as exhibited by the tetraploids, were shown to improve the dairy cows' ability and possibly eagerness to graze to lower PGSH. Breeders and evaluators should therefore target genetic progress in these contributing traits and guide farmers to choose such varieties for grazing use. While tetraploids were generally superior, the genetic diversity among diploids showed potential for breeding improvement.

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Field to yield: improving our assessment of livestock value on farm and beyond

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Application Live weight histories of cattle were found to correlate with pre-calculated dry matter intake and emission data. This highlights the possibility of a low-resource metric for the improvement of economic and environmental efficiency.

Introduction Increasing the accuracy of animal performance assessment is essential for the improvement of livestock production. Whilst highly accurate and detailed analysis of livestock systems can be achieved in a research environment (McAuliffe *et al*., 2018, Beauchemin *et al*., 2010), resource limitations make this less practical for real-world farms. There is, therefore, a need to optimise the use of data that is already being collected on farms.

Material and methods Pre-existing data was collated from records of store/finishing cattle at Rothamsted Research, North Wyke. Initial analysis was conducted to investigate the relationship between cattle lifespan, slaughter weight, and sale price. The weight histories of these cattle were then analysed and the growth curve area integrated using the trapezoid rule (GraphPad Prism) to generate an individual score for each animal which summarised the sum of the total weight of an animal at everyday throughout its life. These scores were then compared against greenhouse gas emissions and feed consumption calculations. Cattle sale prices were later integrated into the metric to provide economic context.

Results Weight history results indicate that economic efficiency and emissions of livestock can be estimated from looking at cattle growth curves. Growth curve scores correlated significantly with dry matter intake and greenhouse gas emission data. For example, a positive correlation with enteric methane production ($R = 0.618$, $P < 0.0005$). Results involving post-slaughter data are pending at the time of writing.

Conclusion Growth curve analysis can potentially estimate the gross feed consumption and emissions of individual cattle, enabling a deeper understanding of the economic and environmental efficiency of livestock. The main strength of the methodology is that it utilises pre-existing and routine data, therefore not required additional resources or expertise.
The lack of correlation between basic sale statistics highlights the variability in individual animal productivity and therefore scope for optimisation. The proposed WHD measure allows for typical farms to better understand the economic and environmental performance of their livestock. A primary benefit of this technique is that it does not necessarily require extra inputs/measurements to be taken on farm, but instead aims to better utilise pre-existing data sets. Such a measurement could be integrated into existing farm software and allow farmers to more accurately assess the productivity of individual animals to inform management decision making.

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The environmental cost of increasing pasture productivity in the uplands

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Application Reseeding upland grasslands can increase pasture productivity, but field operations in the form of ploughing, rotavating, reseeding, lime and fertiliser application can lead to increased nitrous oxide (N_2O) emissions from soil.

Introduction Approximately 42% of the United Kingdom's agricultural land is classified as uplands, primarily managed for livestock production (Reed *et al*., 2009). Many existing upland swards have low productivity and low quality of production. Improving grass productivity and management is fundamentally important in order to increase the length of the grazing system, reduce supplementary feed requirements and decrease greenhouse gas emissions intensity for beef. Working on a typical upland system, the aims of this study were to determine: (1) the potential to increase pasture productivity and (2) the environmental trade-offs if the results were applied for cattle production.

Material and methods The experimental site consisted of five treatments (n = 3) in a randomised block design, i.e. fifteen 9 × 4 m plots, separated by a 1 m buffer. Treatments were as follows: (1) control, (2) rotavate, forage crop reseed in the spring followed by autumn grass reseed, lime and fertiliser input, (3) plough, spring grass reseed, lime and fertiliser input, (4) rotavate, spring grass reseed, lime and fertiliser input, (5) control with lime and fertiliser input. Lime and fertiliser application was determined by soil testing results, in accordance with the recommendations reported in the Defra Fertiliser Manual (RB209). Quicklime ('Calcifert') was applied on what was fairly acidic soil (mean pH 5.2±0.8). The grass seed mixture sown was 'Lambhill' variety by Limagrain, a long-term mixture for marginal land (consisting of perennial ryegrass, timothy, fescues and white clover blend), sown at a rate of 45 kg ha^{-1}. The forage crop sown as a break crop at 8 kg ha^{-1} was 'Interval', a rape/kale hybrid by Limagrain. Sward height was measured weekly with the measurements used to indicate the timings of harvesting the plots. Samples were harvested to mimic cattle grazing, and were analysed subject to standard quality analyses. The closed static chamber approach was used to measure N_2O fluxes (Cardenas *et al*., 2016). Sampling frequency was amended according to field operations timings.

Results Daily grass growth was higher in the reseeded treatments that the controls. There were no evident interactions between pasture quality and treatment. Table 1 indicates a significant difference in yield and N_2O fluxes between the treatments ($P < 0.05$).

Table 1 General linear model output for the treatments (NR indicates no results as yet, as work is ongoing. Treatments with different letters are significantly different at $P < 0.05$ ± = SED)

	Production (kg DM ha^{-1} day^{-1})	Flux (μg N_2O-N m^{-2} h^{-1})
Control	8.22^{b} ± 2.23	15.62^{c} ± 6.01
Forage crop - grass	NR	40.52^{b} ± 8.52
Plough - grass	19.99^{a} ± 3.15	44.80^{ab} ± 8.47
Rotavate - grass	18.72^{a} ± 3.15	65.52^{a} ± 8.58
Lime and fertiliser input only	12.09^{ab} ± 3.15	12.79^{c} ± 8.47

Conclusion Increased pasture productivity from reseeded land indicated the potential benefits of increased management in upland livestock systems. However, the environmental burden in the form of N_2O emissions associated with management options was also increased.

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Modelling the impact of climate change on the yield of western European reseeded grasslands

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Application Climate change will affect the yield of grasslands, with consequences for grazing and silage production. It is necessary to anticipate this impact to determine what grassland and system management changes are appropriate.

Introduction Western Europe (here defined as areas with an Atlantic climate, ranging from northern Portugal to southern Norway) will undergo significant changes in the coming decades (Kovats *et al*., 2014). By 2100, mean annual temperatures are expected to increase by 1.5 - 5°C, rainfall could increase or decrease by up to 20% (depending on location) (IPCC, 2013) and there will be a continuing rise in atmospheric CO_2 concentrations. This study aims to quantify the impact of these changes on grasslands using two different modelling approaches. The first is a dynamic model, Century (Parton *et al*., 1987), which is an ecosystem analysis tool which simulates carbon and nitrogen fluxes throughout the plant-soil system. The second is an empirical approach using linear regression. The use of two approaches provides stronger evidence for the results (if they agree) or else highlights issues with the methodologies which can be explored further (if they differ).

Material and methods Data was taken from five experiments covering 39 reseeded grassland sites across Western Europe. Century was applied to one of these sites (Hurley, UK). This site is not grazed and receives multiple different fertiliser treatments. The model was parametrised by adjusting the temperature-response, C:N ratio threshold and N-fixation parameters using data from several different management regimes. Two climate change scenarios were implemented (RCP4.5 and 8.5 (Kovats *et al*., 2014), simulating the expected changes in temperature, precipitation and atmospheric CO_2 concentration. For the empirical approach, stepwise regression was performed using three quarters of the data, with the remaining quarter used for validation. This process was repeated three times, using a different quarter for validation in each permutation. Covariates used were monthly temperature and precipitation, as well as altitude, soil available water capacity, cuts per year, legume percentage of the sward and nitrogen input. The RCP scenarios were applied for temperature and precipitation, after first checking that this was possible without going beyond the bounds of the input data for the models.

Results Both approaches produced models with a very good fit (Table 1), though Century did not capture as much annual variation as appeared in the measured data. Under climate change, yields generally increased (Table 2). The range with the regression equation is larger than with Century, but this is to be expected given that the former covers a large spatial area and the latter represents a single site. The range with Century always falls within that produced by the regression equation.

Table 1 Model fit, yields are in tonnes dry matter per hectare (SE in brackets). Century assumes 150 kg N $ha^{-1}yr^{-1}$ applied.

	Mean observed yield	Mean predicted yield	Correlation	RMSE
Century	4.756 (0.765)	4.637 (0.155)	0.565 (NA)	1.916 (NA)
Regression	9.721 (0.313)	9.711 (0.233)	0.785 (0.014)	2.330 (0.048)

Table 2 Percentage change in annual yield under climate change (relative to 1986 – 2005). Range indicates results from the 25th to 75th percentiles of the predicted climatic change. Both models assume a N application of 150 kg $ha^{-1}yr^{-1}$

	RCP4.5			RCP8.5		
	2016 - 2035	2046 - 2065	2081 - 2100	2016 - 2035	2046 - 2065	2081 - 2100
Century	+1.23 - +6.64	+4.91 - +9.68	+1.87 - +10.91	+1.98 - +5.60	+4.07 - +12.98	-2.36 - +21.04
Regression	-7.37 - +9.10	-10.01 - +17.25	-10.01 - +27.35	-7.37 - +12.22	-4.64 - +27.35	-8.20 - +45.35

Conclusion The regression results corroborate those of Century, with the predicted yield range at one site (Century) lying within that produced for the whole region (regression). While predicted yields under climate change are sometimes reduced with the regression approach, it should be noted that this does not account for the fertilisation effect from elevated atmospheric CO_2 concentrations, so in reality they are likely to be slightly higher. Which approach is better depends on whether a regional or site-specific approach is desired. It should be noted that these models do not account for the increasing frequency of extreme weather events, which are likely to have a negative impact on yields (Kovats *et al*., 2014), though when higher yields are achieved, grazing could be increased, with less use of bought-in feed.

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Whole farm modelling the environmental impact the inclusion of white clover in perennial ryegrass swards has on intensive pasture based dairy systems

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Application Grass based dairy system on perennial ryegrass/white clover (PRG/WC) sward receiving 150 kg N/ha had lower environmental impact across all categories and functional units than dairy systems on PRG only and PRG/WC swards receiving 250 kgN/ha.

Introduction Pasture based dairy systems are heavily dependent on fertilizer N for increasing grass production and thus feed supply. Fertilizer N application has been shown to be one of the main sources of nitrous oxide (N_2O) emissions from grass based systems. This is of great concern as N_2O is a potent greenhouse gas (GHG) with global warming potential (CO_2e) 298 times stronger than CO_2 over a 100 year time. White clover (WC) is a N fixing legume, fixating N from the atmosphere and releases it into the soil through exudates in the root where it is then transformed into plant utilisable N. Thus, the inclusion of WC into a PRG sward has potential to reduce reliance on N fertilizer and associated N_2O emissions. Therefore, the objective of this study was to conduct life cycle assessments (LCA) to investigate the effect of the inclusion of WC into PRG swards receiving different fertilizer N rates on the environmental impact of grass based dairy systems.

Material and methods Cradle to farm gate LCA of grass based dairy systems on three grass treatments were conducted (i) a PRG/WC receiving 150 kg of N/ha per year (CL150) (ii) a PRG/WC receiving 250 kg of N/ha per year (CL250) and (iii) a PRG only sward receiving 250 kg of N/ha per year (GR250). Production data was obtained from clover experiments undertaken at Teagasc, Co. Cork from 2013 to 2016. Stocking rate for all treatments remained constant at 2.74 cows/ha and supplementation was similar across treatments (314 kg DM/cow). Nitrogen was applied as urea (46% N) for all treatments up until the end of April. The remaining fertilizer applied from early May to end of September was calcium ammonium nitrate (CAN) (27% N). A dairy environmental model (O' Brien *et al*., 2011) was amalgamated with the Moorepark Dairy Systems Model (MDSM) (Shalloo *et al*., 2004) to create a hybrid model that allows the interaction of various components from both models to occur and thus the environmental impacts are more representative of the system simulated. Recently developed country specific N excretion equations were added for each animal category. Country specific N_2O and NH_3 emission factors for fertiliser N application and excreta deposited onto pasture were also added to ensure the model is representative of Irish grass based systems. The environmental impact categories assessed were global warming potential (kg CO_2e), non-renewable energy (Energy) (GJ), acidification potential (ACI) ($kgSO_2e$) and eutrophication potential (EUT) ($kgPO_4e$). The impact categories were expressed using four functional units, per tonne of fat and protein corrected milk (FPCM), per tonne of protein, per tonne of milk solids (MS) and per hectare (ha).

Results The GR250 treatment had the highest GWP, Energy and ACI potential per tonne MS, FPCM and protein of all treatments. CL250 had the highest environmental impact across all categories when expressed on area basis (ha) and highest EUT potential per tonne MS and protein. The CL150 treatment was found to have the lowest environmental impact across all categories and functional units. Table 1 shows the LCA impact assessment (LCIA) report of the three treatments.

Table 1 LCIA of three grazing treatment (GR250, CL250, and CL150) on grass based dairy system

	per farm area (ha)			per tonne MS			per tonne FPCM			per tonne protein		
	GR250	CL250	CL150	GR250	CL250	CL150	GR250	CL250	CL150	GR250	CL250	CL150
GWP ($kgCO_2e$)	11007	11431	10813	11721	11171	10687	892	847	812	24612	23582	22536
Energy (GJ)	22.5	23.1	20.1	21.6	20.4	18.0	1.6	1.5	1.4	45.3	43.1	38.0
ACI ($kgSO_2e$)	121.3	125.16	116.7	116.1	110.7	104.4	8.8	8.4	7.9	243.7	233.8	220.1
EUT ($kgPO_4e$)	53.6	58.12	51.4	51.3	51.4	46.0	3.9	3.9	3.5	107.7	108.5	96.9

Conclusion The study shows that grass based dairy systems can reduce their reliance on N fertiliser through the inclusion of WC into PRG swards. The inclusion of WC and subsequent reduction in N fertiliser application rate has been shown to have a positive environmental impact across all impact categories and function units assessed. However a higher level of grassland management through tight grazing and N fertiliser application is required to maintain WC persistence in WC/PRG swards and to overcome low spring herbage availability.

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Environmental impacts of housing and manure management systems in European pig production, through a life cycle perspective

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Application The potential of modifications to housing systems and manure management to reduce the environmental impacts of European pig production systems was evaluated using a life cycle assessment (LCA).

Introduction Pork production is regarded to be among the highest contributors in eutrophication and acidification of fresh water bodies and agricultural land respectively. Non–renewable resources and energy use in pig production are also related to a large amount of emissions and negative environmental impacts. Evidence suggests that the pig housing and manure management systems significantly affect emissions associated with pig production. The aim of this study was the development of an LCA framework able to evaluate pig production systems through a holistic approach and quantify the effect of the pig housing and manure management components, along with their interrelations, on the environmental impacts linked to pig production.

Material and methods An LCA model was constructed in SimaPro 8.4, for the assessment of environmental impacts from Danish pig production systems. The functional unit was 1 kg of pig liveweight at the farm gate. The impact categories assessed were: Abiotic depletion of resources and fuel (NRRU and NREU), Global Warming Potential (GWP), Acidification Potential (AP) and Eutrophication Potential (EP). The study used Danish pig systems as a case in point, with data provided by SEGES. We performed a local sensitivity analysis on pig housing and manure management related parameters to identify environmental hotspots in these components of the system. For that purpose, we created a measure of relative significance based on the effect that each factor had on model outcome compared to the variation explained by all factors assessed. We considered as important those factors that exhibited relative sensitivity > 1%. Following this, the environmental impacts of in-house slurry acidification, screw-press separation and centralised anaerobic-digestion, were compared and benchmarked using parallel Monte Carlo simulations. Further to this, we evaluated each manure management system's impacts against scenarios that described modifications in pig housing, through a 4 (the above plus the base line) x 5 housing scenario analysis. We identified as significant the results for which one alternative scenario had different (lesser or greater) environmental impact than the reference, for more than 95% of the parallel simulations.

Results The environmental impact hotspots and their relative contribution to each impact category significantly affected, were: level of slurry dilution (AP, 15% and EP, 10%), slurry removal regime (AP, 3.8% and EP, 2.4%) and ventilation system efficiency (NREU, 4% and GWP, 4.6%). Our findings showed that the gestating and farrowing production stages contributed approximately 40% in the GWP and NREU. The alternative scenario analysis suggested that in-house, slurry acidification was the only manure management system that systematically, significantly reduced environmental impacts compared to the average manure treatment, for all impact categories. Additionally, it was the least sensitive to modifications in pig housing.

Conclusion We propose, that modifications in pig housing and the consideration of housing related factors in the choice of manure management strategies, have the potential to significantly reduce environmental impacts linked to pig systems.

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Evaluation and prediction of nitrogen use efficiency and nitrogen excretion in beef cattle

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Application The developed equations, using a combination of nitrogen (N) intake (NI), organic matter digestibility (OMd), body weight (BW) and/or N digestibility (Nd), can be used to predict the proportion of manure N excreted in urine of beef cattle.

Introduction Ruminants are inefficient in utilising feed N. This is partly due to the rapid degradation of feed protein in the rumen, which results in increased absorption of ammonia, with subsequent urea formation in the liver and excretion in urine (Bach *et al*., 2005). In addition to the significant financial loss from the lower utilisation of feed protein, low feed N use efficiency (NUE) can also pose an environmental burden through N pollution of the ground water and emissions of nitrous oxide and ammonia (Hristov *et al*., 2011). Our aim was to evaluate the effect of animal characteristics and feed intake, chemical composition, and digestibility on NUE and develop prediction equations for NUE.

Material and methods The database used in this study (n=289 treatment means), was constructed from 69 published studies that included N balance measurements in beef cattle kept in individual crates or penned feedlot operations, conducted in North and South America, Europe, Asia, Africa and Australia between 1980 and 2017. Regression equations were produced using residual maximum likelihood analysis using Genstat statistical package. The potential random effects of the individual study, production stage (growing and finishing), breed, gender and production type were accounted for according to changes in deviance. The response variables were urine N output per NI (UNO/NI), retained N per NI (RN/NI) and urine N output per manure N output (UNO/MNO). The explanatory variables were dry matter intake (DMI), NI, BW, total forage (TF), neutral detergent fibre (NDF), acid detergent fibre (ADF), starch, dry matter digestibility (DMd), OMd and Nd, in single and multiple linear relationships. Explanatory variables were kept in the model only when the Wald statistic was significant ($P < 0.05$). An internal validation was performed to validate prediction equations developed in the current study and those previously published in literature. For this purpose, the whole database (n = 289) was divided into two sub-datasets of n = 197 and n = 92.

Results UNO/NI was positively correlated to DMI, NI, BW, TF, NDF, OMd, Nd and the equation including DMI, Nd and TF as predictors had the lowest mean prediction error (MPE). RN/NI was positively correlated to Nd and negatively correlated to DMI and NDF, but MPE of all equations was high. UNO/MNO was positively correlated to NI, OMd, BW and Nd and the equation including Nd and BW showed the lowest MPE. The best prediction accuracy regarding the proportion of manure N excreted in urine was observed when Nd was included as predictor, potentially because Nd is directly related to the production of ammonia in the rumen and the passage of microbial protein to the small intestine.

Table 1 Single and multiple linear predictions of UNO/NI, RN/NI and UNO/MNO

			Equations[a]	n	R^2	MPE[b]	Eq.
UNO/NI	=	$-230.0_{(51.80)}$	$+ 11.86_{(3.786)}$ DMI + $0.765_{(0.0628)}$ Nd + $0.598_{(0.2809)}$ TF	231	0.87	0.300	(1a)
($x10^3$)		$-479.7_{(142.74)}$	$+ 0.790_{(0.1155)}$ NI + $0.882_{(0.1710)}$ OMd + $0.323_{(0.0943)}$ NDF	133	0.89	0.320	(1b)
		$-192.6_{(47.85)}$	$+ 0.231_{(0.0663)}$ BW + $0.743_{(0.0609)}$ Nd	214	0.88	0.313	(1c)
RN/NI	=	$349.0_{(29.61)}$	$- 10.34_{(3.906)}$ DMI	237	0.83	0.470	(2a)
($x10^3$)		$267.4_{(59.75)}$	$- 11.32_{(3.982)}$ DMI + $0.238_{(0.0659)}$ Nd – $0.195_{(0.0636)}$ NDF	180	0.85	0.459	(2b)
UNO/MNO	=	$-249.0_{(99.26)}$	$+ 1.232_{(0.1232)}$ NI + $0.812_{(0.1385)}$ OMd	142	0.88	0.216	(3a)
($x10^3$)		$-321.9_{(34.93)}$	$+ 0.150_{(0.0465)}$ BW + $1.196_{(0.0467)}$ Nd	214	0.93	0.148	(3b)
		$-281.1_{(32.89)}$	$+ 1.214_{(0.0469)}$ Nd	231	0.92	0.158	(3c)

[a] Units: g/g for UNO/NI, RN/NI, UNO/MNO; kg/d for DMI; g/kg DM for NDF; g/kg for Nd; g/100g DM for TF; g/d for NI; kg for BW [b] MPE derived from an internal validation process

Conclusion This study presents for the first time equations for the prediction of UN/NI and RN/NI for beef cattle, which are indicators of NUE. The prediction accuracy for UN/NI and RN/NI was overall low, but the developed equations revealed a number of feed-related variables that explained much of their variation. Prediction equations for UNO/MNO that included Nd had better accuracy, although acceptable levels of MPE were also seen when OMd and NI were used.

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Does choice of nutrient profiling rule affect relative environmental rankings of food products?

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Application Nutrient profiling has become a common sub-tool to quantify food quality in life cycle assessment (LCA). By accounting for nutritional value, stakeholders can gauge system-wide environmental performance more accurately.

Introduction LCA studies with functional units based on product mass fail to consider differences in product quality. Recent research has addressed this issue by adopting additive nutrient density scores (NDS) (McAuliffe *et al*., 2018); however this approach, in turn, requires decision upon which nutrients to include in and exclude from the analysis. To evaluate the importance of this assumption in farming system evaluation, this study examined the potential impacts of adopting three different NDS schemes on carbon footprints of four food groups (beans, fish, beef and chicken) commonplace in UK diets.

Material and methods NDS 9-3 includes protein, fibre, calcium, iron, magnesium, potassium and vitamins A, C and E, and is currently most frequently used in LCA studies. NDS 15-3 also includes monounsaturated fat, thiamine, riboflavin, folate, zinc and vitamins B12 and D, but excludes magnesium. NDS 6-3 excludes magnesium, potassium and vitamin E from 9-3. All three NDS discourage intake of saturated fat, total sugar and sodium (Fulgoni *et al*., 2009). Nutrient compositions for food items were extracted from McCance and Widdowson (2015) and their NDS were calculated under the three schemes. Mass-based LCA results for corresponding UK farming systems were sourced from Poore and Nemecek's (2018) global database and converted to quality-based values. The resultant carbon footprint has the unit of kg CO_2-eq/% recommended daily intake.

Results The correlation between 15-3 and 9-3 rankings was moderate ($r = 0.50$, $p < 0.001$; Figure 1a), with beef showing a highly nonlinear relationship between the two. The correlation between 6-3 and 9-3 rankings was stronger ($r = 0.84$, $p < 0.001$; Figure 1b). Including extra nutrients (15-3) considerably decreased the carbon footprint gap between beans and salmon, and between beef and chicken, due to generally higher micronutrient contents of salmon and beef **(**Table 1).

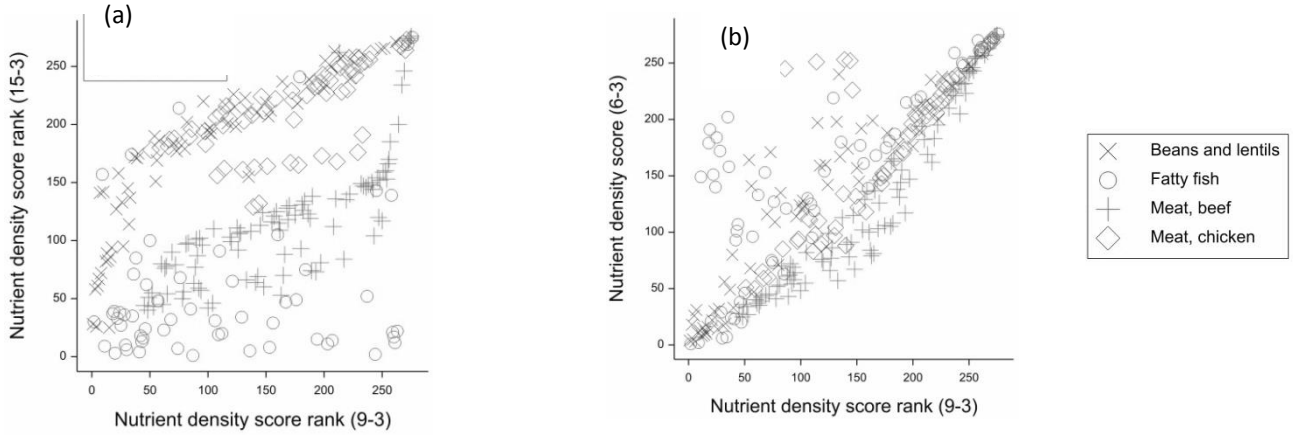

Figure 1 Nutrient density rankings for food items that belong to four food groups. Comparisons are between 9-3 and 15-3 (*left*) and 9-3 and 6-3 (*right*). Scores are ranked in descending order, with the lowest rank representing the highest nutritional value.

Table 1 Breakdown of NDS and carbon footprints for the four food products examined

	NDS 9-3	NDS 15-3	NDS 6-3	kg CO2-eq / kg product	kg CO_2-eq / 1% NDS 9-3	kg CO_2-eq / 1% NDS 15-3	kg CO_2-eq / 1% NDS 6-3
Beans	6.59	6.00	6.23	0.87	0.13	0.15	0.14
Salmon	16.09	35.60	4.08	8.5	0.53	0.24	2.08
Beef	7.25	18.10	8.80	48.35	6.66	2.67	5.49
Chicken	6.84	6.69	7.11	9.74	1.42	1.46	1.40

Conclusion The above results suggest that the choice of micronutrients included in the evaluation framework has strong impacts on relative carbon footprints between food groups. Sensitivity to this choice should be considered in future LCA studies.

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Low-resolution soil sampling may provide no useful information to grazing farms

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Application Accurate understanding of the soil–pasture–animal nexus on grazing farms will enable the use of soil parameters as key performance indicators, offering means to improved efficiency and profitability of pasture-based beef and lamb systems.

Introduction A holistic evaluation of livestock production systems requires understanding of complex physical, chemical and biological interactions between crops, pastures, animals and the intrinsic environment (Firbank *et al*., 2018), yet obtaining such information on commercial farms is a challenging task (de Olde *et al*., 2016). In order to support practical decision-making by commercial producers, it is therefore necessary to develop key performance indicators that are solely composed of parameters observable presently and cost-effectively (McGonigle *et al*., 2014). Data acquired through commercial soil testing satisfy these conditions; however, the literature lacks evidence on whether they are actually associated with animal performance on pasture and, if so, how much samples are needed to capture this relationship (Takahashi *et al*., 2018).

Material and methods Data were collected on the North Wyke Farm Platform, a BBSRC National Capability grazing trial in Devon, UK (Orr *et al*., 2016), between 2011–2017. Soil cores were collected on a 50m x 50m grid created for each of the 21 fields, or 263 locations across the NWFP. The total organic carbon concentration was measured by dry combustion and converted to the soil organic carbon (SOC) content using bulk density. SOC values were subsequently aggregated to the field level to derive the mean and standard deviation, the latter approximating the degree of spatial heterogeneity. Animal performance per ha attributable to each field was quantified as liveweight gains attained by cattle and sheep while grazing on, or eating silage harvested from, the particular field. Based on these data, a multiple regression model was estimated to quantify the effect of SOC and its spatial heterogeneity on animal performance. Following the confirmation that the full information model is statistically significant ($p < 0.001$), a bootstrapping experiment was carried out to investigate how many soil samples were required from each field to reasonably replicate the true results. Here, the values for SOC and its spatial heterogeneity were randomly resampled 10,000 times under each of the 27 "virtual soil sampling" strategies, or from 1–27 sample(s) per field. The successful prediction of the SOC–animal performance relationship defined as iterations that recorded $p < 0.05$.

Results The full information estimation showed that a higher level of SOC significantly improves animal performance ($p = 0.018$) while its spatial heterogeneity is significantly detrimental ($p < 0.001$). This finding is consistent with an earlier report on correlation (but not causality) between similar variables (Takahashi *et al*., 2018). When bootstrapped samples were used, however, these relationships were not always successfully reproduced (Figure 1). An 80% detection was achieved when information from 13 samples per field were utilised, with a 90% detection recorded with 18 samples per field. Importantly, the relationship between the sample size and the detection rate was highly nonlinear and concave, indicating that soil data that do not adequately account for spatial variability of parameters present little value as a key performance indicator for animal growth.

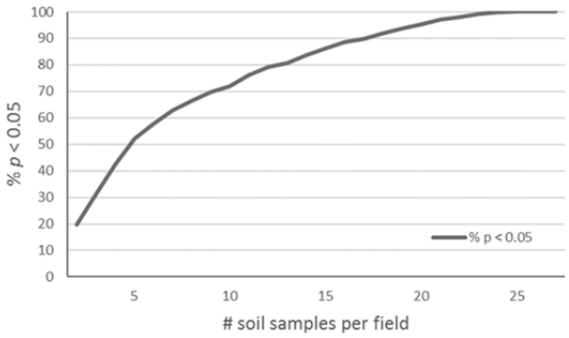

Figure 1 Relationship between spatial resolution of Soil data and accuracy of animal performance prediction.

Conclusion To the best of our knowledge, this is the first study to test the direct causal relationship between "soil health" parameters and the growth performance of grazing animals. The above results suggest that the importance of maintaining SOC on grasslands is quantitatively supported and therefore should be actively communicated to commercial livestock producers. Nonetheless, "half-hearted" soil testing should be discouraged, as it is unlikely to inform optimal management strategies.

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Economic and welfare impacts of providing positive life opportunities to farm animals

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Application Development of an input-based framework to evaluate positive welfare of farm animals will create an opportunity to incorporate quality of life measures into food certification schemes, inducing adoption of high welfare production systems.

Introduction The majority of welfare certification schemes for animal-originated food products are designed to reduce negative behavioural, health and physical outcomes on the farm (Main *et al*., 2012). While this method of certification holds a clear merit of excluding inconsiderate producers from supply chains, it has now been widely accepted that animal welfare should not only be defined by the absence of negative subjective states but also by the presence of positive life experiences (Yeates and Main, 2008). There is little consensus, however, as to how best to quantify positive welfare of animals from observed outcomes and therefore efforts to develop certification framework under this concept would be impractical (Lawrence *et al*., 2018). The present study, therefore, investigated the feasibility, with regards to scientific validity as well as on-farm costs, of utilising input-based measures of positive welfare as part of evaluation criteria for food certification protocols.

Material and methods Assessments of welfare-enhancing resource inputs and welfare outcomes were carried out on 49 free-range laying hen farms in the UK. For input-based measures of positive welfare, the resource tier framework (Edgar *et al*., 2013) was applied to each study farm. The framework consists of 13 resource needs, with each graded on a scale of 0 to 3 (no score, Welfare +, Welfare ++ and Welfare +++) based on physical resources, farm environment and proactive management activities above what is stipulated by UK law and codes of practice. For outcome-based measures of negative welfare, six indicators commonly used by assurance schemes (feather loss, beak trimming, antagonistic behaviour, flightiness, mortality and litter score) were collected on each farm. In addition, the financial cost associated with resource provision on each farm was estimated using ADAS Hennovation farm costing tool (http://hennovation.eu). Correlations amongst variables thus obtained were examined using Pearson's correlation coefficient and associated *t*-tests. Finally, the estimated expense by each farm was compared against the least cost, or the mathematically minimal outlay required to achieve the same resource tier score.

Results The correlation analysis between the resource tier score and outcome-based measures of negative welfare showed that improved on-farm resources are generally associated with reduction of negative outcomes (results not shown). The resource tier score and the estimated total cost also showed a strong correlation (ρ = 0.822, p < 0.001). A closer investigation revealed, however, that this relationship is likely to be nonlinear (Figure 1), as the incremental cost to achieve Welfare ++ and Welfare +++ status tends to be higher than that to achieve Welfare +. Crucially, a large proportion of sample farms were found to have spent considerably more resources than theoretically required to achieve the same score, suggesting that significant room exists to reduce on-farm costs without compromising welfare or, alternatively, to further improve welfare without incurring additional costs. On average across 49 farms, the cost saving potential was 81% of current total expenses.

Conclusion The above results suggest that a degree of market failure exists in the current market of high welfare products, preventing farmers from rationally allocating resources to maximise the "production" of positive animal welfare. While further research is required to understand the exact mechanism behind this misallocation, a policy instrument to reward the supply of welfare-enhancing resources could potentially create a more efficient marketplace that can optimise public goods provision.

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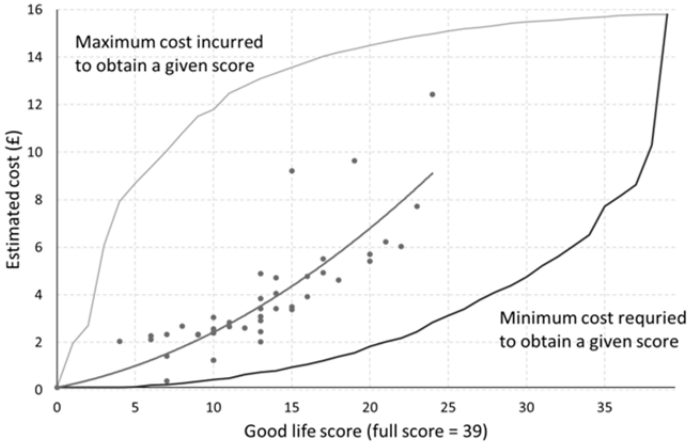

Figure 1 Relationship between resource tier score and estimated cost. Quadratic trend curve suggests an exponential cost structure, whereas the discrepancy between observed data and the minimum cost required to obtain a given score shows the potential to reduce the expenditure without compromising the overall welfare level.

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Prioritisation of farm animal welfare issues in the UK using the Delphi method

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Application Top ranking priority welfare issues for livestock (at individual level) include: behavioural needs not being met, breeding decision consequences, neglect, inappropriate nutrition, lack of pain management, neonatal morbidity, & poor stockpersonship.

Introduction Resources for tackling animal welfare issues are often limited (Buckland *et al*., 2013). Prioritisation of farm animal welfare issues can help identify which areas most require research funding and raise awareness of best practices. To identify the highest priority welfare issues for UK farmed livestock we elicited expert opinion by a modified Delphi method.

Material and methods We recruited 58 UK-based experts with min. 3 years' experience of working with either cattle, pigs, poultry or small ruminants (12-16 experts per group). Experts were a mix of practising veterinarians, academics, charity sector employees, and industry representatives, to canvas a broad range of opinions. Two rounds of surveys were conducted online using the Bristol Online Survey (BOS) tool, and the final round was an in-person workshop with a subsection of experts. In the first survey, experts were provided with a comprehensive list of 65-85 animal welfare issues per species (including general health, management and husbandry, housing, painful procedures, stockpersonship, breeding decisions, euthanasia, and transportation) generated from a range of sources. Participants were asked to score each welfare issue, for i) severity, ii) duration, iii) prevalence on a 6-point Likert scale, where 1 = never/none, and 6 = always/high. The results of the first survey were reviewed and the welfare issues which scored a neutral-to-high response (scores 3-6) were carried forward. In round 2, participants were asked whether they agreed or disagreed with the rankings that were made from the results of round 1. The final stage of the process was a workshop where 2 experts from each species group were invited to attend a 2-day workshop which consisted of a combination of small group and large group exercises and discussions to finalise the priority welfare lists for each species based on the results from round 2.

Results Welfare priority lists were divided into two categories: severity/duration, and prevalence, to identify the priority welfare issues affecting individual animals and the population respectively. The final top three ranked, priority welfare issues from the workshop are presented in table 1. During the workshop discussions, it was decided that dairy goats should be grouped together with dairy cows, and sheep with beef cattle, as the animals faced similar welfare issues.

Table 1 Top three welfare priorities for farm animals as decided at Delphi workshop (issues in same box are equal ranking)

SPECIES	PRIORITY WELFARE ISSUES	
	Severity/Duration	Prevalence
Pigs	Behavioural needs not met	Pain from management procedures
	Tail-biting	Tail biting, including need to dock
	Inadequate stockperson skills	Behavioural needs not met
Poultry	Consequences from breeding decisions	Consequences from breeding decisions
	Poor housing/management	Inappropriate housing conditions/design
	Inappropriate social grouping	Inability to express natural behaviours
Beef cows + Sheep	Neglect	Lack of perception of painful conditions and pain management
	Lameness	Lack of recognition of poor health status
	Sheep scab	Lack of local veterinary care
	Mastitis	Lack of staff to deal quickly with health issues
Dairy Cows / Goats	Inappropriate nutrition	Neonatal morbidity and mortality
	Neonatal morbidity and mortality	Poor pain management
	Poor stockmanship	Inappropriate nutrition

Conclusion The Delphi process resulted in consensus on the most significant welfare challenges faced by UK farmed livestock species and can help to guide future research and education priority decisions.

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Dairy cows prefer a softer laneway surface, especially when lame

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Application Especially lame dairy cows preferred a softer artificial grass walking surface over a standard one. This suggests that such surfaces reduce pain or discomfort when walking and can potentially aid in improving cow flow and hoof health.

Introduction Softer barn floor types are known to have beneficial effects on the comfort and hoof health of dairy cows (Bergsten *et al*. 2015). In contrast, knowledge on the effect of softer laneway surfaces is currently lacking. This cannot be extrapolated from studies on barn floor types, as both the way the cow uses the surface and the available top-surface materials differ. However, as dairy cows often walk long distances between the parlour and the pasture, it can be expected that softer laneway surfaces can have a considerable impact on cow comfort. This may be especially important for lame cows that generally have more tender hoofs (Van De Gucht *et al*. 2017). We therefore hypothesised that, when given the opportunity to choose between a standard laneway surface and a softer laneway surface of artificial grass, dairy cows would use the artificial grass surface more often than the standard surface. Furthermore, we expected this effect to be more pronounced in lame cows.

Material and methods A preference test was conducted using 132 dairy cows that passed through the experimental setup whilst returning to pasture after their afternoon milking. In the days prior to the experiment the cows had passed through the setup several times to allow them to get acquainted with the different surfaces. In addition, they had been exposed to artificial grass on a different laneway for several weeks. Upon leaving the parlour all cows were mobility scored by an experienced assessor to determine if cows were lame (mobility ≥3 on the 1-5 scale of Manson and Leaver (1988)). The preference setup consisted of a dust-over-gravel laneway divided lengthwise into two 2.2 m wide lanes. Each lane consisted of 4 stretches of approximately 23 m. The 1st and 3rd stretch of the left lane and the 2nd and 4th stretch of the right lane were covered in artificial grass, whilst the other stretches were left bare. The two lanes were divided by electrical wire except at the start of each stretch, where cows were forced to the middle of the laneway using sideways exclusion triangles. This was done so the cow would need to make a new choice between the standard surface and the artificial grass at each of the four stretches. Cows were allowed access to the preference setup in pairs, as testing individually was expected to make them less willing to continue on to pasture at their normal walking speed. Therefore, lane choices of paired cows were likely not independent and only the choices of the lead cow of the pair were used (n=66). Wilcoxon signed rank tests were used to determine if cows showed a preference for one of the surface types. Analyses were performed separately for sound and lame cows. In addition, the number of artificial grass stretches used was compared between lame and sound cows using a two-sample Wilcoxon rank sum test. As data exploration suggested an overall preference for the right lane, analyses were repeated separately for the 1st and 3rd stretch (where the artificial grass was on the left) and the 2nd and 4th stretch (where the artificial grass was on the right).

Results 69% of the lead cows were sound (mobility <3) and 31% were lame (mobility ≥3). Both sound and lame cows used the artificial grass more often than expected by chance, thus showing a significant preference for this surface (P=0.004 and P=0.001, respectively). As expected, this preference was stronger in lame than in sound cows (median stretches of artificial grass used ± IQR for lame cows: 3±3-4, for sound cows: 2±2-3, P=0.001). When stretches of artificial grass on the right lane and the left lane were considered separately, both lame and sound cows showed a clear preference for artificial grass when placed on the right side (P<0.001), but showed neither a preference nor an aversion when it was on the left side (P=0.3). This may be because the pasture the cows were ultimately headed for was on the right side of the lane. Thus, staying on the right would slightly reduce the distance walked, which may be another way to avoid discomfort. Alternatively, the left side may have been non-preferred because of partially impaired vision due to the presence of a hedgerow. Importantly, as artificial grass was placed alternatingly on the left and right side of the laneway, the side and surface preferences were not confounded in this study.

Conclusion The preference for the artificial grass surface, which was more pronounced in lame cows, suggests that a softer walking surface is more comfortable for all cows but especially important for lame ones.

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Behavioural response to temperature and wind in dairy calves

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Application Calves show an avoidance response when exposed to wind suggesting that calf housing should be designed to avoid draughts.

Introduction One of the main objectives for housing dairy calves is to protect them from extremes of climatic and thermal conditions, for example wind and low temperatures. No matter which type of housing is chosen the aim should be to provide thermal comfort for the young animal. The thermal comfort zone can be defined as when the body can maintain its core temperature. In essence, there is a balance between heat production and heat loss. It is suggested that the thermal comfort zone for calves is between 15 & 25°C (Stull & Reynolds, 2008). The lower critical temperature (LCT) is the temperature below which, in this case, the calf needs to increase heat production from its metabolism in order to maintain homothermy. In calves less than 3-4 weeks of age, the LCT is approximated as being 10°C (Webster, 1984). This LCT can be altered by wind speed and humidity levels (Webster, 1984). The behaviour an animal expresses can be used to determine how an animal perceives its environment. With respect to response to climatic conditions, Graunke *et al*., (2011) demonstrated that cattle found microclimates that had lower wind speed and higher temperatures rather than being in the open.
The aim of this experiment is to examine the behavioural response of the pre-weaned dairy calf to temperatures around and below its LCT under different wind speeds.

Material and methods A 3x3 factorial design experiment was carried out using eighteen Holstein heifer calves at SRUC Dairy Research & Innovation Centre, Crichton Royal Farm, Dumfries. Each calf was tested between seven and twenty-five days of age. The calves were tested at a combination of each of the three temperatures (5, 10, 15, ±2°C) and three wind speeds (0, 1, 3.3m/s). The temperatures were naturally occurring whereas the wind was created using pedestal fans. Each calf was tested in a random order of temperature/wind combinations. The testing area consisted of a pen with two sections. The calf started in the "test" section where it was exposed to the wind speed dictated by the test schedule. The adjacent section allowed the calf to retreat from the wind. Every calf was given two training sessions in the testing area so that this area was familiar to the calf before it was tested. Each test was twenty minutes in duration and was video recorded. From each video recording, specific behaviours indicative of irritation were noted. Latencies and proportions of time were also calculated from the videos. Other data collected included body live weight and milk intake information (time of last feed, volume consumed in previous 24 hours, milk replacer consumed in previous 24 hours). The data was analysed using R by applying mixed effect models.

Results From the analysis so far, the proportion of time that the calf would spend in the test section was significantly affected by wind speed ($P<0.05$). The higher the wind speed, the less time the calf spent in the test section. A similar result was found for the latency of the first behavioural reaction. The higher the wind speed, the less time it took the calf to display one of the recorded behaviours ($P<0.05$). There was no significance of temperature on the proportion of time the calf spent in the test section or in the latency of first behavioural reaction ($P>0.05$).

Conclusion Early conclusions from this study indicate that calves show a negative response to higher wind speeds. Therefore this provides some evidence to try and minimise draughts at calf level within calf housing.

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The effect of number of lambs attempting to suck on triplet ewe behaviour

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Application Triplet lamb survival is a challenge for New Zealand farmers with an increasing proportion of ewes bearing triplets as lambing percentages increase. A greater understanding of the suckling behaviour of triplet-bearing ewes may provide an opportunity to select ewes based on their suckling behaviour to improve triplet lamb survival.

Introduction The national average lambing percentage in New Zealand has increased from less than 100% in 1987 to 129% in 2017 (Statistics New Zealand, 2018) resulting in an increase in the number of ewes conceiving triplet foetuses. The morality rate of triplet lambs (35–54%) is greater than single (7–19%) or twin lambs (15–33%; Hinch *et al*., 2014). This greater mortality rate is due to greater rates of death due to starvation and exposure due to their low birth weight (Hight and Jury, 1970). Birth weight alone, however, does not explain the increased mortality rates of triplets. In a comparison of lambs with the same birth weight, triplet lambs had a greater chance of death compared with single and twin lambs (Hinch *et al*. 1985). This difference in morality is likely due to increased competition for milk. While the sucking behaviour of triplet lambs has been investigated, there is a lack of information about the suckling behaviour of the ewe. The aim of this study was to investigate the behaviour of the ewe when one, two or all three lambs attempted to suck. The hypothesis was that the suckling behaviour of the ewe would change depending on how many lambs were attempting to suck.

Material and methods Forty-three triplet-bearing mature Romney ewes were observed twice daily to identify ewes that had newly lambed. Ewes that had three lambs alive were enrolled in the study (n=26). Once lambs had been cleaned by their dam and were mobile (minimum of 3 hours of age) they were ear tagged, weighed and had their sex recorded. At 12 pm each day any ewes whose lambs had been tagged after 10 am on the previous day, or prior to 10 am on the same day, were moved with their lambs into yards in preparation for behaviour observations. Each ewe and lamb was identified with its ear tag number sprayed in large numbers on its side with stock marker. Video recordings were made using two video cameras from 1 pm until 4 pm daily on three consecutive days. Only ewes with three lambs alive were observed, therefore, ewes were removed from the study if a lamb died, or was removed due to welfare concerns. Recording were made using two video cameras placed outside the observation paddock at a height of 2m to allow at least half of the paddock to be observed. The ewe suckling behaviour was assessed from the video footage recorded between 2 and 4 pm on each day. The behaviour of the ewe was assessed during each suckling event, which was defined as the period during which one or more lambs were within 0.5 m and actively searching for the teat or sucking. The suckling event terminated when no lambs were within 0.5 m or any lamb within 0.5m was not attempting to suck. The suckling event termination behaviours were either "Ewe kick", "Ewe butt", "Ewe sit", "Ewe walk" or "Lamb terminates". Behaviour observations were coded using the behavioural software BORIS. All statistical analyses were conducted using the Genmod procedure in SAS.

Results Of the 26 ewes enrolled in the study, 11 were observed for one day, three for two days and 12 for three days. On day one of the observation period there were 1150 suckling events, of which 575 had one lamb present, 228 had two lambs present and 174 had three lambs present at the termination of the event. The majority of suckling events, regardless of the number of lambs present, were terminated by the ewe walking away from the lambs (50.9, 50.9 and 53.2%, for one, two or three lambs respectively). For ewes that had three days of observations, the number of suckling events were similar on each day ($P>0.05$). Termination behaviours, however, changed over time and with the number of lambs present. The frequency of the ewe walking away was greater ($P<0.05$) on day 1 than 2 and 3 whereas the reverse was seen in lamb terminations. The frequency of events terminated by the ewe walking away was greater ($P<0.05$; 50 vs. 64% respectively) and lamb terminations fewer ($P<0.05$; 29 vs. 39 and 41%) when three lambs were attempting to suck compared with one or two lambs.

Conclusion Ewe suckling behaviour was influenced both by the number of lambs present during the suckling event and the day of observation. If more than two lambs are present a greater percentage of suckling events are terminated by the ewe walking away.

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Using the effect of resting space allowance on resting behaviour in assessing heifers' welfare

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Application Resting behaviour duration and frequency were significantly influenced by resting space size, making it suitable to be used in assessing heifers' welfare. The best time period within the day to assess heifers' welfare using resting behaviour is probably in the morning.

Introduction Resting behavior is one of the most important behaviors for assessing animal welfare with a significant influence on animal productivity (Tucker *et al*., 2009). Resting is important for regeneration while disturbances are welfare relevant as they may be associated with insufficient recuperation, frustration, discomfort or pain and increased risk for health problems such as lameness or lesions (Plesch *et al*., 2010). Lying down is considered an important behavioral indicator during evaluation of diseases in terms of animal welfare (Niss *et al*., 2009) and is greatly affected by resting space allowance.

Material and methods Twenty 18-month old and clinically healthy Holstein Friesian heifers were observed. They were randomly assigned to two pens with straw bedding, 10 per pen. The pens had different resting space of 5.0 m^2 (Group A) and 4.5 m^2 (Group B) per heifer. All heifers were fed with 1.2 kg of concentrates mixture and 35 kg alfalfa fresh grass. Resting behaviour was video recorded continuously for one day (24 hours). The number and length of lying down periods were assessed within three time periods: 07:00 to 15:00 h (morning), 15:00 to 23:00 h (afternoon) and 23:00 to 07:00 h (night). Averages and standard errors of the means were computed, and significance between experimental groups was tested by non-parametric Mann-Whitney U test (Wilcoxon) using MINITAB® (United States and other countries) software (a=0.05).

Results The size of resting space had a statistically significant effect on the total time spent resting by the heifers. Animals of Group A rested for 872.7 minutes within 24 hours and animals of Group B for 676.7 minutes within 24h ($P \leq 0.05$). Group A heifers rested for 450.5 minutes during the night (23:00-07:00 h) compared to 396.8 minutes for Group B and the difference was significant ($P \leq 0.05$). Group A also rested significantly more during the morning (07:00-15:00 h) (262.8 minutes), compared to 137.2 minutes for Group B ($P \leq 0.05$). The frequency of resting periods within 24 hours had similar values for the two sizes of resting space. The frequency of resting behaviour in 24 hours was not influenced by the size of resting space ($P \geq 0.05$), but during the morning (07:00-15:00 h) Group B heifers rested for 2.6 periods when the size of resting place was 4.5 m^2 per heifer and for only 1.6 periods for Group A heifers ($P \leq 0.05$). In the afternoon (15:00-23:00 h) Group A animals rested significantly more frequently (during 3.4 periods) and only 2.4 periods when the size of resting place was 4.5 m^2 per animal in Group B ($P \leq 0.05$).

Conclusion Heifers rested for significantly longer within 24 hours when the size of resting space was decreased from 5.0 to 4.5 m^2 per heifer. Resting behaviour duration and frequency were significantly influenced by resting space size, making it suitable to be used in assessing heifers' welfare. As the most significant differences for resting behaviour were found during the morning (07:00-15:00 h), (more than 2 hours), it was concluded that morning is probably the best moment in the day to assess heifers' welfare using resting behaviour.

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Can magnesium reduce stress and aggressive behaviours in pigs? – A systematic review

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Application Supplementary dietary magnesium may be an effective way to improve pigs' welfare, health and overall production performance by reducing stress and aggressive behaviours.

Introduction On a commercial farm, pigs experience stressful events throughout their lifecycle, such as weaning, mixing, transport, slaughter and heat stress. Stress and aggressive behaviours are not only detrimental to the pigs and their welfare but also for performance and production as increased stress/aggression can increase susceptibility to disease (McLamb, *et al*., 2013) and stress is also known to impact negatively on meat quality (Hambrecht, *et al*., 2005). Magnesium is used in many commercially available products claiming to act as calming agents for horses and dogs, and similarly, in pig production magnesium is sometimes to be added to pig feed during an outbreak of aggression or stress in an attempt to alleviate this (O'Driscoll, *et al*., 2013). However, the scientific evidence to support this strategy has not been systematically reviewed. Our aim was to perform a systematic review of studies in which magnesium was given to pigs to examine the effects on measures of stress and aggressive behaviour.

Material and methods A search was performed using Web of Science with the search terms "magnesium", "pig, "swine", "livestock", "stress", "aggression" and "behaviour". Inclusion criteria were any whole animal magnesium studies after 1990 with a focus on aggression, behaviour or stress. The study species must be the domestic pig. Studies were excluded or included based on title, abstract and then full paper in that order.

Results Of the initial 2,249 papers identified, 15 studies met the criteria. Stress was assessed using cortisol measurements in 10 studies, however epinephrine / norepinephrine measurements were used in two studies and other physiological parameters by one. The levels of aggression were monitored based on behavioural observations carried out in seven studies and lesion scores were used in a further four studies. A total of nine different magnesium compounds were used across the 15 studies and the dose of the compound varied greatly with 17 different levels used. Of the 15 studies, 10 found at least one statistically significant positive effect of magnesium on reducing stress or aggressive behaviours. For example one study showed that pigs receiving the magnesium rich marine algae supplemented diet had significantly lower salivary cortisol in comparison to control pigs fed a standard diet (O'Driscoll, *et al*., 2013). However, two studies found at least one statistically significant negative effect of supplementary magnesium, such as Caine, *et al*. (2000), which found a short-term high dose of magnesium (40mg/kg for 7 days) increased the frequency of aggressive behaviours. A further three studies found no effect of magnesium on stress or aggression. Seven studies also included pigs that were genetically susceptible to porcine stress syndrome (PSS), however magnesium did not seem to affect these pigs, for example one study found that pigs supplemented with magnesium were calmer for longer in the abattoir's CO2 stunning unit, yet not if the pig was susceptible to PSS (Panella-Riera, *et al*., 2009). This difference in response between genotypes may suggest that magnesium is ineffective at reducing stress caused by any genetic susceptibility.

Conclusion Overall there are a limited number of studies investigating the possible effect of magnesium on reducing stress and aggression in pigs, and although results were varied, many found some positive effects of supplementary magnesium. This area would benefit from further research to more confidently conclude whether magnesium may be a beneficial addition to reducing stress and aggressive behaviours in pigs.

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Meta-analysis of the probiotic effect of yeast (*Saccharomyces cerevisiae*) on egg productions in laying hens

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Application The results on the use of yeast as an alternative to antibiotics to improve production indices in chickens have been variable among several investigators. Our result has established the potential of yeast to improve egg production in commercial chickens.

Introduction Variable probiotic effects of yeast on egg production in laying hens have been reported by many authors. Factors such as study country, the strain of chicken used, bird age, yeast supplementation levels and duration may be responsible for inconsistent outcomes observed. Meta-analysis is an inferential statistical method that enables all published data to be combined and analysed to draw quantitative conclusions, which cannot be obtained from individual studies or narrative reviews (Sauvant *et al*. 2005). The aim of this study was to determine the probiotic effect of yeast on egg production in commercial laying hens using a meta-analysis.

Material and methods Peer-reviewed papers published in English were retrieved from AGORA, Scopus, Science Direct and Google Scholar databases. To guarantee quality and reduce bias, the authors designed the following condition each paper must satisfy to be included in the study. Studies were included if they have randomized and control trial, reported egg production and a measure of dispersion (i.e. standard error, the standard deviation) for each effect. From 26 studies published between 2006 and 2018, only 11 met the inclusion criteria, from which information on the surname of the first author, the year the article was published, duration of feeding, age and chicken strains, inclusion level, measures of variance (SE, SD or p-value) and analysed outcome were extracted. Lack of randomization and data duplications were the basis for the rejection of the other 15 studies. Data generated were analysed using the OpenMEE software. The overall effect estimate is considered significant when the confidence interval (CI) has no contact with a line of no effect (Koricheva *et al*. 2013). DerSimonian and the Laird test (Q - statistic) and Inconsistency index (I^2) were employed to compute heterogeneity.

Results The result of pooled estimate revealed that yeast intervention significant increased egg production [Standardized Mean Difference; SMD = 0.096; 95% CI = 0.011 to 0.181; P = 0.027). I^2 - statistics showed that all the studies used in the analysis were homogenous (I^2 = 20.57, P = 0.174). Restricted subgroup analysis (Table 1) revealed that study country, chicken age, strain, and inclusion level had positive and significant influence egg production.

Table 1 Restricted sub group analysis of the moderators

Parameter	subgroup	Pooled estimate	Confidence interval Lower	upper	SE	p-Value
Age (weeks)	Less than 40	0.099	0.009	0.188	0.046	0.031
	Greater than 40	0.036	-0.247	0.319	0.144	0.804
Country	Turkey	0.112	0.012	0.212	0.051	0.028
	Iran	0.092	-0.086	0.270	0.091	0.313
	Brazil	0.233	-0.012	0.478	0.125	0.062
	Egypt	-0.244	-0.527	0.038	0.144	0.090
Duration of feeding (d)	Less than 70	0.130	-0.023	0.282	0.078	0.097
	Greater than 70	0.083	-0.022	0.188	0.054	0.121
Inclusion (g/kg feed)	Less than 10	0.129	0.034	0.223	0.048	0.008
	Greater than 10	-0.053	-0.222	0.116	0.086	0.538
Strain	Hyline	0.135	0.021	0.248	0.058	0.021
	Lohmann	-0.049	-0.202	0.103	0.078	0.525

Conclusion It was concluded that yeast could be used to improve egg production in hens and may replace antibiotics to counteract the negative effects of their widespread use.

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The effect of selenoprotein on the growth performance, indicators of oxidative stress and meat quality of broilers exposed to cyclical high temperature

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Application Under cyclical high temperatures, Se supplementation may improve the antioxidant capacity and meat quality of birds, which could have an impact on the poultry production in subtropical and tropical region.

Introduction Selenium, as an essential trace element in poultry nutrition, plays a prominent role in growth, immunity and anti-oxidative stress, especially in cyclical high temperature. Organic selenium sources appear to be more efficient than inorganic forms, due to higher bioavailability, lower toxicity and higher GPx levels (Kuricova *et al*., 2003; Briens and Mercier *et al*., 2013). Selenohomolanthionine (SeHLan), a new selenoprotein found in selenized Japanese pungent radish (Ogra *et al*., 2007), is less toxic than selenomethionine. There is limited information on the role of SeHLan in poultry production. The aim of this study was to investigate the effects of incremental levels of SeHLan on growth response, meat quality and markers of oxidative stress in heat stressed broiler chickens.

Material and methods A total of 160 day old Ross 308 (Aviagen) male broiler chickens were used in this study, fed diets based on wheat, soybean meal and canola meal, as shown in Table 1. Starter diets were offered to birds from 1 to 14 days and finisher diets from 15 to 34 days post-hatch. The control diet contained a custom vitamin-trace mineral premix formulated to Aviagen recommendations for Ross 308 birds, except that it did not contain extra Se. The treatment diets contained 0.3mg, 0.6mg or 1.0mg SeHLan (BiOnyc® Tor-Sel). Each of the four dietary treatments (Control, SeHLan 0.3 ppm, SeHLan 0.6 ppm and SeHLan 1 ppm) was offered to 8 replicates of five birds per cage on an *ad libitum* basis from 1 to 34 days post-hatch as starter (0-14 d) and finisher (15-34 d) diets. All broiler chickens were housed at standard temperatures (22 ± 1°C; RH 60%) until the age of 21 days and then temperature in all treatment groups were raised to simulate a cyclical high temperature (8 hrs at 32 ± 1°C; RH 80-90%). Water and feed were provided *ad libitum*. The variables assessed included growth performance (body weight, average daily gain, average daily feed intake, feed conversion ratios and mortality rates); indicators of oxidative stress (GPx and SOD); meat quality (drip loss, shear force, muscle pH, muscle temperature, meat colour and Se content).

Results SeHLan content had no effect on growth performance. SeHLan significantly affected GPx concentration in kidney and Se content in muscle ($P < 0.01$).

Table 1 Se content in muscle and GPx concentration in kidney

Parameter	Control	SeHLan 0.3 ppm	SeHLan 0.6 ppm	SeHLan 1 ppm	s.e.	Overall Model	Linear	Quadratic
Se content (mg/g)	0.77	1.50	2.45	3.23	0.10	<0.001	<0.001	0.850
GPx* in Kidney	40.0	53.5	56.7	71.9	4.93	<0.001	<0.001	0.822

*mg/g protein

Conclusion SeHLan under cyclical heat exposure can significantly improve Se concentration in muscle and GPx concentration in kidney with normal growth performance. In this experiment, 0.6 ppm SeHLan in diets would be the best inclusion rate in accordance with growth performance, Se content in muscle and GPx concentration in kidney.

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Effect of selenium and yeast in the broiler diet on ampicillin resistance, virulence and nutrient utilisation by *E. coli* isolated from the broiler caecum

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Application Identifying factors in broiler management that prevent the development of virulent *E. coli* in the broiler caecum may also limit the development of ampicillin resistance by *E. coli* in broilers. However, there was no evidence that this might be achieved by supplementing the broiler diet with either probiotic yeasts or selenium.

Introduction Antibiotic use in UK broiler production has decreased substantially, but the growing prevalence of antimicrobial resistance (AMR) by bacteria is a threat to both human and animal health. Dietary interventions may alter the gut microbiome and the strains of sentinel species such as *E. coli* that proliferate in the gut, which may alter the AMR status of the bird. Selenium has a role in protecting the bird from oxidative stress but may also affect the microbiome of the host by altering its redox potential. Probiotics such as yeasts may have antibacterial properties, which would again alter the composition of the microbiome and may favour the proliferation of bacteria that are not AMR. The objective of this experiment was to investigate the effect of supplementary selenium and yeast in the broiler diet on the characteristics and AMR status of *E. coli* isolated from the broiler caecum.

Material and methods A total of 168 male Ross 308 broiler day old chicks were weighed, blocked and randomly allocated to one of six brooder rings (37 chicks per ring, two rings per yeast treatment) and a common starter diet (containing no supplementary selenium) was fed until the birds were 14 days of age. Water was provided either untreated (no yeast, NY) or with a suspension of *Candida famata* (CF, 10^5 per ml) or *Saccharomyces cerevisiae boulardii* (SB 10^5 per ml) administered in 2 L drinking water on days 9-11. Water hoppers were replenished with fresh (untreated) water when required. On day 14, birds were weighed and from each brooder ring they were allocated to one of four pens (total of 24 pens). A grower/finisher diet containing either no additional selenium (Se-) or 3.5 mg/kg of a hydroxyl analogue of se-methionine (Se+). There were four replicate pens for each yeast/Se interaction. Birds were kept in these pens from 15-35 d. 16 birds were sacrificed as day old chicks, and one bird per pen was sacrificed when birds were 14, 21 and 35 d of age. A swab of caecal contents was taken immediately *post mortem*, mixed with nutrient broth (4 ml), diluted appropriately and spread on MacConkey agar with (50 µg/ml) and without ampicillin to estimate the total and ampicillin resistant (Amp^R) caecal *E. coli* population. A well isolated colony was then taken from each plate, incubated in nutrient broth and 15% v/v glycerol, placed in a cryovial and stored frozen. Sensitive and Amp^R *E. coli* colonies were then characterised based on their ability to utilize five sources of carbon (sucrose, adonitol, arabitol, dulcitol and sorbose). *E. coli* were also analysed for seven avian pathogenic *E. coli* (APEC) virulence factors (pyelonephritis-associated pili C [papC], iron-uptake systems of *E.coli* D [iucD], temperature-sensitive hemagglutinin [tsh], iron-repressible high-molecular-weight proteins 2 [irp2], increased serum survival [iss], arginine succinyltransferase A [astA], and haemolysin [hlyA] using PCR. The effect of yeast, selenium and their interaction on the total and Amp^R *E.coli* populations was determined by ANOVA. Chi square analysis was used to determine associations between *E. coli* characteristics and their AMR status, age of bird and dietary intervention used.

Results *E. coli* from the caecum was sensitive to ampicillin on day 1, but by d14 all birds had Amp^R *E coli*. Total *E. coli* population (CFU/ml) declined with age. Administration of yeast did not affect *E. coli* populations but selenium supplementation increased total *E. coli* but decreased very slightly the proportion of *E. coli* that were Amp^R (Table 1). None of the *E. coli* isolates could utilise adonitol or arabitol, and none showed evidence of having the papC gene. Utilisation of sucrose (84%), dulcitol (82%) and sorbose (45%) was high. Most associations between Amp^R and treatment, C source utilisation or virulence factor were not significant ($P>0.05$), but carriage of the irp2 gene was more associated with Amp^R *E. coli* rather than ampicillin sensitive *E. coli* (55% and 19% respectively, $P=0.026$). Carriage of irp2 increased with bird age ($P<0.025$) but was not associated with either treatment with yeast or selenium.

Table 1 Effect of treatment on total and AMP^R E. coli populations (CFU/ml)

	Yeast						SEM	P		
	NY		SB		CF			Yeast	Se	YxSe
	Se+	Se-	Se+	Se-	Se+	Se-		(Y)		
Total	6.09	5.75	5.79	5.67	6.05	5.46	0.174	0.482	0.016	0.397
Amp^R	6.00	5.81	5.67	5.66	5.88	5.55	0.166	0.307	0.183	0.621
Amp^R as % of total	98.5	100	98.3	99.9	97.5	101	1.38	0.802	0.009	0.590

Conclusion Supplementary selenium in the broiler diet may reduce total *E. coli*, but a low dose of yeast at a young age had no effect. Ampicillin resistance in *E. coli* appears to be associated with the irp2 virulence gene. Amp^R and irp2 were not affected by supplementation of the broiler diet with either selenium or a probiotic yeast.

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Effects of replacing vitamin-mineral premix with leaf meal composite on the performance of broiler finisher chickens

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Application Leaf meal composite effectively replaced vitamin-mineral premix in the diet of broiler finisher chickens without any adverse reaction.

Introduction Supplemental vitamin-mineral premix (VMP) is an essential feed ingredient in the diet of broiler chickens (DBC) as the gut of broiler chickens cannot synthesise adequate vitamin-minerals (Islam *et al*., 2004). Synthetic vitamin and minerals for producing VMP are manufactured by few companies globally and are thus expensive and subject to sporadic scarcity. Green leafy vegetables (GLV) are known to be innately rich in vitamins and minerals (Achikanu *et al*., 2013) however, information on supplemental VMP from GLV sources in DBC is scarce. Therefore, this study was aimed at assessing the effect of replacing dietary VMP with leaf meal composite from GLV in broiler finisher chickens.

Material and methods Arbor Acre Plus chickens (n=320) at day 21 were randomly allocated to four treatment groups with eight replicates of ten chickens each. Leaves of *Telfaria occidentalis*, *Celosia argentea*, *Vernonia amygdalina* and *Moringa oleifera* were destalked, air-dried, milled and mixed in equal proportion to constitute a leaf meal composite (LMC) because of their high nutrient levels as reported in literature. Four isonitrogenous and isocaloric broiler finisher diets were formulated; the control diet was a standard broiler finisher diet without LMC but with VMP (T_1), other diets contained 1.5 (T_2), 3.0 (T_3) and 4.5 (T_4) % LMC in replacement of VMP. Experiment was duly approved by the Animal Care and Use Research Ethics Committee (ACUREC) of the University of Ibadan, Nigeria. Chickens were given feed and water *ad libitum* from day 22 to day 42. Records of weekly feed intake and weight gain were accurately taken and feed conversion ratio (FCR) calculated between days 21 and 42. Data were analysed using ANOVA at $\alpha_{0.05}$ and means were separated using Duncan's multiple range test.

Results Performance of broiler finisher chickens fed graded levels of LMC in replacement of VMP is shown in Table 1. Weight gain was similar (P>0.05) across the treatment groups but significant differences (P<0.05) were observed in feed intake and feed conversion ratio. The lowest feed intake (g) of 2300.90±49.63 was recorded in chickens on diet T_4. Similar feed intake (P>0.05) was observed in chickens on diets T_2 and T_3 with 2310.38±82.40 and 2346.25±136.6, respectively. However, feed intake in chickens fed diet T_1 (2540.9±105.60) was significantly higher (P<0.05) than the other three treatments. The FCR was significantly higher (P<0.05) in chickens on T_1 (2.8±0.31) compared with those on T_3 (2.34±0.18) and T_4 (2.34±0.23) but was similar to T_2 (2.55±0.23). However, the FCR of broiler chickens on T_2, T_3 and T_4 were all similar (P>0.05).

Table 1 Effects of replacing vitamin-mineral premix with leaf meal composite on the performance of broiler chickens (finisher phase)

	T1	T2	T3	T4	SEM	P value
Feed Intake (g)	2540.9±105.6^{a}	2310.38±82.4^{b}	2346.25±136.6^{b}	2300.9±49.63^{b}	24.13	<0.0001
Weight Gain (g)	926.6±84.9	914.41±93.9	1008.81±99.8	991.03±100.7	17.54	<0.07
FCR	2.8±0.31^{a}	2.55±0.23^{ab}	2.34±0.18^{b}	2.34±0.23^{b}	0.05	<0.0001

Conclusion The lower feed conversion ratio in broiler chickens fed leaf meal composites in replacement of VMP strongly suggests better performance with dietary LMC. It was therefore concluded that leaf meal composite from *Telfaria occidentalis*, *Celosia argentea*, *Vernonia amygdalina* and *Moringa oleifera* could replace vitamin-mineral premix in broiler finisher diet.

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Evaluation of the combination of Vitamin D_3 and Papaya Leaf on muscle antioxidant activity of spent layers

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Application This paper reports the effect of feeding vitamin D3 and papaya leaf meal on muscle antioxidant activity of spent chicken.

Introduction The poultry industry is faced with a large number of spent layer hens which are normally sold as old chickens and carry lower prices than the broiler chickens. Several approaches such as salt additives, calcium chloride marinating, infusion or injection have been applied to improve meat quality of carcass meat (Koohmaraie *et al*., 1988). Attempts to improve meat quality through improving tenderness through post-slaughter manipulations are either costly, labor intensive, need large storage areas or require longer storage time. This paper reports the effect of feeding vitamin D3 and papaya leaf meal on meat quality of spent chicken.

Material and methods The experiment was undertaken with 320 spent, ISA-brown layers, which were taken from a layer farm of University Putra Malaysia after a period of lying of 80 weeks. Chickens were kept in individual cages. A 10 day adaptation was conducted and thereafter, the experiment lasted 21 days. The diets were fed individually in the feeders with a specified weight every day. Eight diets which were served in this research were basal diet, with or without vitamin D_3 which was supplemented with 0, 0.5, 1 and 2% Papaya Leaf Meal (PLM). Papaya leaves were collected from local plants and separated from the stems, dried in a 65°C oven until constant weight. The dry leaves were ground, passed through a sieve of 1 mm and properly mixed into the appropriate diet. PLM was analyzed for crude protein, crude fiber, fat, dry matter, ash and calcium content using atomic absorption spectrophotometer. At days 1, 7, 14 and 21, 80 birds (20 per treatment) were slaughtered and left and right breast muscles of each bird were taken to determine antioxidant activity. Samples were kept in -80°C for later analysis. This experiment was a 2 (with and without vitamin D3) × 4 (four levels of PLM) factorial arrangements with a basis of Completely Randomized Design with 10 replicates per treatment combination.

Results The interaction effects of vitamin D_3 and papaya leaf meal on antioxidant activity (±SEM) is shown in Table 1. For antioxidant activity, treatments contained 0.5, 1 and 2% PLM with vitamin D_3 had significant improvement ($p<0.01$) in antioxidant activity of meat compared to the group fed no vitamin D_3 at days 1, 7, 14 and 21. For groups contained no vitamin D_3 as the level of PLM increased, the antioxidant activity decreased ($p<0.01$). Interaction between vitamin D_3 and PLM was significant ($p<0.01$) at days 1, 7, 14 and 21.

Table 1 The effect of papaya leaf meal (PLM) and vitamin D_3 on antioxidant activity (μM) in spent layer hens

Vit D_3	+				-				Vit D_3	PLM	$VitD_3$ *PLM
PLM	0%	0.5%	1%	2%	0%	0.5%	1%	2%			
d1	0.16^{d} ±0.005	0.26^{a} ±0.003	0.24^{c} ±0.008	0.27^{a} ±0.004	0.29^{a} ±0.010	0.21^{ab} ±0.001	0.21^{ab} ±0.001	0.13^{c} ±0.005	***	***	***
d7	0.17^{b} ±0.003	0.27^{a} ±0.003	0.27^{a} ±0.004	0.28^{a} ±0.001	0.30^{a} ±0.002	0.22^{b} ±0.001	0.21^{c} ±0.004	0.14^{d} ±0.003	***	***	***
d14	0.17^{b} ±0.002	0.28^{a} ±0.003	0.28^{a} ±0.003	0.28^{a} ±0.001	0.31^{a} ±0.003	0.23^{b} ±0.002	0.22^{c} ±0.005	0.15^{d} ±0.002	***	***	***
d21	0.18^{b} ±0.002	0.29^{a} ±0.003	0.29^{a} ±0.003	0.29^{a} ±0.003	0.33^{ab} ±0.004	0.35^{a} ±0.103	0.23^{ab} ±0.003	0.16^{b} ±0.002	***	***	***

Conclusion It could be concluded that dietary supplementation papaya leaf up to 2% of dry matter in the diets supplemented with vitamin D_3 might improve muscle antioxidant activity of spent chicken, especially if this intervention starts a few weeks before slaughtering. Other research conducted to study Vitamin D_3 antioxidant activity and its mechanism that showed Vitamin D_3 has a membrane antioxidant activity which inhibits iron-dependent lipid peroxidation in liposomes compared to cholesterol, ergosterol and tamoxifen. On the other hand, total phenolic content of papaya seed extracts was positively correlated with antioxidant activity and chloroform-methanol extract of papaya seeds had and antioxidant activity due to a high phenolic content (Kothari *et al*., 2010).

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Assessment of the nutritional quality of crop contents of scavenging local chickens in Akwa Ibom State of Nigeria

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Application Scavenging local birds reared in villages in Akwa Ibom state were under-nourished except for energy and would not perform to its full genetic potentials without daily supplementary rations.

Introduction Scavenging Local Chickens (SLC) reared for food, income and socio-cultural benefits in Nigeria are abundant. They grow and produce below their genetic potentials due to the extensive system of managing them and its associated shortcomings. The nutritional quality of feed resources available to local scavenging chickens reared in four villages in Akwa Ibom State, Nigeria was assessed by evaluating the nutritional composition of their crop contents compared to their nutrient requirements.

Material and methods The study was carried out on 56 SLC reared in four agrarian villages (Mbiabam-Ibiono-MI, Ekpene-Ukim-EU, Ibiaku-Issiet-II and Utu-Abak-UA) in Akwa Ibom state, in rain forest zone of southern Nigeria. The SLC (cocks and hens) reared on free range were purchased from the four villages, carefully stunned, slaughtered, dipped in hot water (70°C) for few seconds and de-feathered before they were eviscerated. Full crop contents were obtained from the birds, emptied into aluminium foil separately and left in the oven to dry at 70°C to a constant weight. The samples were subjected to proximate, mineral and vitamin analyses (AOAC, 2010). An indirect method (Wiseman, 1987) was used to calculate True Metabolic Energy (TME) as TME (kcal/kg DM) = 3951 + 54.4 EE% - 88.7 CF% - 40.8 ash%; and AME = 92% TME. Nutrient components of the crop content of SLC between the villages were subjected to Analysis of Variance and their means were separated by Duncan's Multiple Range Test (P = 0.05) using GENSTAT (2005).

Results The weight and DM of fresh and dried crop contents of scavenging local chickens and their proximate components, TME, minerals and vitamin composition except Ca and AME varied significantly($P < 0.05$) between the villages. The TME and AME were higher than their requirement levels of 2934 and 2700kcal/kg DM respectively. The birds might have scavenged or selected different ingredients to meet their energy requirements. The CP and minerals (Ca, Fe, & P) levels were lower than their requirements for optimal performance, while vitamins levels met layer bird's requirements (NRC, 1994).

Table 1 Nutritional composition of crop content of scavenging local chickens in four villages in Akwa Ibom state

Parameters/Village Name	MI	EU	Ibiaku-Issiet	Utu-Abak	SEM	P
Wt. of fresh crop co tent (g)	20.6^{bc}	16.5^{c}	36.67^{a}	26.83^{b}	0.33	0.001
DM of fresh crop content (%)	41.76^{b}	43.64^{b}	32.27^{c}	52.17^{a}	0.62	0.001
DM of dried crop content (%)	90.62^{a}	90.50^{a}	90.48^{a}	90.15^{b}	0.10	0.021
Ash (%)	3.97^{a}	3.57^{a}	3.87^{b}	3.98^{a}	0.04	0.001
Protein (%)	14.10^{ab}	13.27^{c}	13.85^{b}	14.18^{a}	0.10	0.001
Crude Fibre (%)	3.45^{a}	3.10^{b}	3.20^{b}	3.40^{a}	0.06	0.003
Ether Extract (%)	5.95^{a}	5.50^{b}	5.77^{a}	5.93^{a}	0.06	0.001
Nitrogen Free Extract (%)	63.15^{bc}	65.07^{a}	63.80^{b}	62.82^{c}	0.24	0.001
AME (Kcal/kg)	3502	3523	3503	3516	7.54	0.320
TME (Kcal/kg)	3807^{b}	3830^{a}	3808^{b}	3822^{ab}	4.81	0.007
Calcium (mg/100g)	235.8	234.2	233.3	235.8	1.43	0.528
Iron (mg/100g)	12.13^{a}	11.70^{b}	11.83^{ab}	12.13^{a}	0.13	0.062
Phosphorus (mg/100g)	180.0^{a}	170.8^{b}	179.2^{a}	176.7^{ab}	2.19	0.032
β-carotene (mg/100g)	42.50^{a}	36.87^{b}	40.00^{ab}	43.33^{a}	1.46	0.018
Niacine-Vit. B3 (mg/100g)	2.36^{a}	2.20^{b}	2.33^{a}	2.36^{a}	0.02	0.001
Riboflavin-Vit. B2 (mg/100g)	0.16^{a}	0.128^{c}	0.14^{b}	0.16^{ab}	0.005	0.001
Thiamin -Vit. B1 (mg/100g)	0.12^{a}	0.08^{b}	0.10^{b}	0.12^{a}	0.006	0.001

Conclusion The nutrient levels except for energy of crop content of SLC in the four villages studied varied significantly and were below their requirements and inadequate for optimal performance. Awareness creation on the importance of supplementary feeding to alleviate poverty and malnutrition among the subsistent rural poultry farmers is vital.

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Differential effects of fibrolytic enzymes on the *in vitro* release of xylobiose from different cereal types

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Application Generation of **x**ylobiose is thought to impact the gut microbiome and thereby affect digestibility and feed efficiency. If the results observed here *in vitro* are also observed *in vivo* it may be possible to target specific fibrolytic enzymes for use with specific cereals to manipulate the microbiome and improve animal feed efficiency.

Introduction The use of β-1,4-xylanases and other fibrolytic enzymes are now well established in poultry diets. Bird performance in high non-starch polysaccharide (NSP) cereals is improved through the depolymerisation of NSP. Xylanase enzymes reduce digesta viscosity for wheat and barley, promoting feed intake and increasing nutrient digestibility by enhanced enzyme efficacy (Bedford and Morgan, 1996). How xylanase improves bird performance in lower viscosity diets is a contentious issue. The most recent theories suggest that xylo-oligosaccharides (XOS) such as xylobiose, generated by xylanase enzyme activity, could be acting as prebiotics (Apajalahti and Bedford, 1999). Recent observations suggest XOS modulate the gut microbiome in a favourable way to strengthen the immune system and improve feed intake and digestion (Ribeiro *et al*, 2018). The aim of this study was to compare the *in vitro* release of xylobiose from four individual cereals (barley, wheat, oats and maize) following 72 hour incubation with a range of commercially available fibrolytic enzymes.

Material and methods Barley, wheat, oats and maize samples were ground to a 300 micron powder and subjected to *in vitro* incubations with four treatments: control (no exogenous enzymes added), and one of three commercially available enzyme cocktails at the manufacturer's suggested dosage (40-100g/tonne). Enzyme A contained predominantly xylanase activity (160,000 units/g); enzyme B contained predominantly β-glucanase activity (700,000 units/g), with endo cellulose (165,000 units/g) and endo- xylanase (190,000 units/g) activities; enzyme C contained predominantly mannase (1,000,000 units/g) with β-glucanase (300,000 units/g) and endo- xylanase (200,000 units/g) activities. All the cereals were mixed at 5mg/ml in 50mM sodium citrate buffer (pH 5.2), then treatments added and incubated at 40.7°C in a shaking incubator for 72 hours to replicate temperature and maximum transient time in the crop of poultry. The concentration of xylobiose was determined using High-Performance Anion-Exchange Chromatography coupled with Pulsed Electrochemical Detection fitted with a CarboPac PA200 Column (Dionex, Thermo Scientific) using a xylobiose standard (Megazyme, LTD). Data was collected in triplicate and analysed using two way ANOVA (cereal x enzyme) with $P<0.05$ taken as being statistically significant.

Results There was a significant Cereal x Enzyme interaction ($P<0.001$), indicating that the different enzymes had different substrate specificities (Table 1). Interestingly, no measurable xylobiose was released from Maize, with no effect of any of the enzymes. Barley and wheat released the most xylobiose (0.006 ± 0.001/100g) in the absence of any enzyme, with Oats releasing less (0.002 ± 0.0008/100g). Enzyme A, containing β-1,4-xylanase, released the most xylobiose from barley, oats and wheat, with the highest release seen with a combination of barley and enzyme A. Enzyme B released similar amounts of xylobiose from barley and wheat, but nothing from maize or oats, while enzyme C only released any xylobiose from wheat.

Table 1 The release of xylobiose (g/100g) after 72h *in vitro* incubation with different enzymes

	Control	Enzyme A	Enzyme B	Enzyme C	Cereal x Enzyme interaction
Barley	0.006	0.035	0.016	0	
Maize	0	0	0	0	SED = 1.9
Oats	0.002	0.013	0	0	P <0.001
Wheat	0.006	0.028	0.014	0.009	

Conclusion There were clear differences in the release of xylobiose from the 4 cereals, with enzyme A releasing the most from barley, wheat and oats. However, the amounts of xylobiose being released are low and, since xylobiose may account for around 80% of all XOS generated by xylanase, then it wouldn't be expected to contribute much in terms of energy available for growth. Interestingly a recent *in vivo* study (Ribeiro *et al*, 2018) suggests that XOS at 0.1g/kg in the diet have prebiotic effects in broiler chickens fed wheat or corn-based diets, resulting in increased growth and feed efficiency. Hence the small amounts of xylobiose released *in vitro* may have prebiotic effects that enhance growth and feed efficiency *in vivo*.

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Population genomic structure and linkage disequilibrium analysis of Ashanti Dwarf pigs of Ghana using genome-wide SNP data

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Application This study provides the first overview of the population genomic structure of the Ashanti Dwarf pig (ADP) and other local pig populations in four regions in Ghana.

Introduction The Ashanti Dwarf pig (ADP) is an indigenous pig breed found in all ten regions of Ghana. It is adapted to the harsh environmental conditions in the tropics and is easily reared by local pig farmers in Ghana with relatively low financial input. However, little is known about the genomic structure, genetic diversity and the genetics that influence the adaptation of this local pig breed. In this study, population genomic structure of local pig populations in Ghana were investigated and linkage disequilibrium analysis were performed using genome-wide SNP data.

Material and methods Using purposive sampling based on phenotype, a total of 96 porcine ear tissue samples were collected from local pig breeds of perceived ADP (n=59), Exotics (n=6), Crossbreds (n=31) in the Upper East, Brong-Ahafo, Volta, and Western Regions of Ghana and assessed using the Illumina porcine 60K SNP Bead chip assay. Genotyped input data was converted into PLINK format (Purcell *et al.,* 2007) using a plug-in compatible with the Genome Studio. The population genomic parameters, MAF, F_{IS}, observed and expected heterozygosity were all estimated in PLINK. Principal component analysis (PCA) was used to evaluate the population cluster in R version 3.5 (R core team, 2013) and ADMIXTURE version 1.3.0 (Alexander *et al.,* 2009) was run from K=1 to K=6 to determine the most likely number of ancestral populations. Linkage Disequilibrium analysis was performed in PLINK (Purcell *et al.,* 2007) as described by Mdladla *et al.,* (2016).

Results The admixture results are dependent on breed history and separate into three different populations (population 1, population 2 and population 3) with the lowest cross-validation error (K=3). However, the three populations are admixed. Based on the relative proportions of the three (3) populations identified, the breeds were reclassified as ≥75% of population 1 = 'Other' breeds, ≥ 75% of population 2 = Ashanti Dwarf pig breeds, ≥75% of population 3= Exotic breeds and 40%-60% of both population 2 and population 3 but not ≥ 10% of population1 = Crossbreed. High proportions of polymorphic SNPs (0.84) were recorded in the Ashanti Dwarf pig populations although this is lower than (0.925-0.995) recorded in Chinese pig breeds (Wang *et al.,* 2015). The observed heterozygosity (Ho) values (0.22-0.29) and the expected heterozygosity (H_E) values (0.22-0.31) recorded across all the populations (Table 1) were lower than observed in Western commercial breeds. This could be attributed to the fact that the porcine 60K SNP chip's discovery and its development (Ramos *et al.,* 2009) were designed using European and Asian breeds. Principal component analysis results indicate that sampled pigs cluster according to regions. This may be due to the fact that the pig samples were obtained from regions in different ecological zones with different production systems. The low inbreeding levels (0.003-0.07), minor allele frequency range of (0.16-0.24) and low LD (r^2) values recorded in the ADP populations may be due to less rigorous selection in these populations and a greater genetic variability of their ancestors.

Table 1 Within-population genetic diversity indicators calculated for each breed and whole population

Populations	*N*	%SNPs >0.05	MAF±SD	HO ± SD	HE± SD	F_{IS}
ADPs	28	0.84	0.23±0.15	0.28±0.17	0.31±0.17	0.07±0.08
Crosses	17	0.81	0.24±0.16	0.29±0.19	0.31±0.17	0.06±0.13
Exotics	15	0.83	0.23±0.16	0.29±0.19	0.31±0.18	0.05±0.12
Other	9	0.65	0.16±0.16	0.22±0.22	0.22±0.19	0.003±0.16

n, number of individuals; *MAF*, minor allele frequency, *HO*, observed heterozygosity; *HE*, expected heterozygosity; *FIS,* inbreeding coefficient.

Conclusion The study suggests that most of the pigs classified phenotypically as ADPs are admixed. This will be further investigated using additional samples from the remaining regions of Ghana as part of an ongoing project.

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Correlation of somatic cell counts and California mastitis test for the diagnosis of subclinical mastitis in dairy sheep

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Application Results from this study can contribute towards defining a routine protocol for controlling ovine mastitis at flock level.

Introduction Ovine mastitis is an issue of major economical, legal and hygienic concerns (Bergonier *et al.*, 2003). The most important cases are associated with contagious bacteria causing subclinical mastitis and there are several methods for its diagnosis (Contreras *et al.*, 2007). Milk somatic cell counts (SCC) have been widely used as an indicator of subclinical mastitis and can be measured either directly using technology of fluorescence image cytometry or indirectly by California Mastitis Test (CMT). The objective of the study was to estimate the correlation of CMT and SCC for the diagnosis of subclinical mastitis in intensively reared ewes of the Chios dairy breed in Greece.

Material and methods The study was carried out in four commercial farms of purebred Chios dairy ewes. A total of 609 dairy ewes (1st or 2nd lactation) were used. Individual milk samples were collected monthly for the first four months of the milking period. Each sample was subjected to cytological examination using CMT. Tests were, also, performed in the laboratory to assess SCC using Fossomatic 360 (Foss Electric, Hillerød, Denmark). Samples with CMT score≥2 (on the five-point scale) and SCC≥500,000 cells/mL were further subjected to bacteriological examination. Total number of repeated records amounted to 2,436. Statistical analysis regarding distribution of CMT scale among SCC, both overall and in each lactation period, was performed using descriptive statistics and analysis of variance. Pearson's correlation coefficient (r) was used to display the relationship between the two indirect traits. The validity of the results was investigated by calculating sensitivity (SE) and specificity (SP) of the two methods.

Results Incidence of subclinical mastitis was 26.1% (638/2436 samples). *Coagulase negative staphylococci* (66.2%) were the prevalent bacteria isolated. Figure 1 shows the distribution of CMT scale among SCC clusters. Overall, the variance analysis indicated statistically significant differences between CMT scale (P≤0.05). The highest value of SCC (3,610.57 cells/ml) was recorded in CMT scale 4. Similar results were observed in both lactation periods. There was a statistically significant difference in average SCC values between CMT scale, both in 1st and 2nd lactation period (P≤0.05). The correlation between the two methods was high (r=0.855, P<0.05), while SE and SP were 96.7% and 86.4%, respectively.

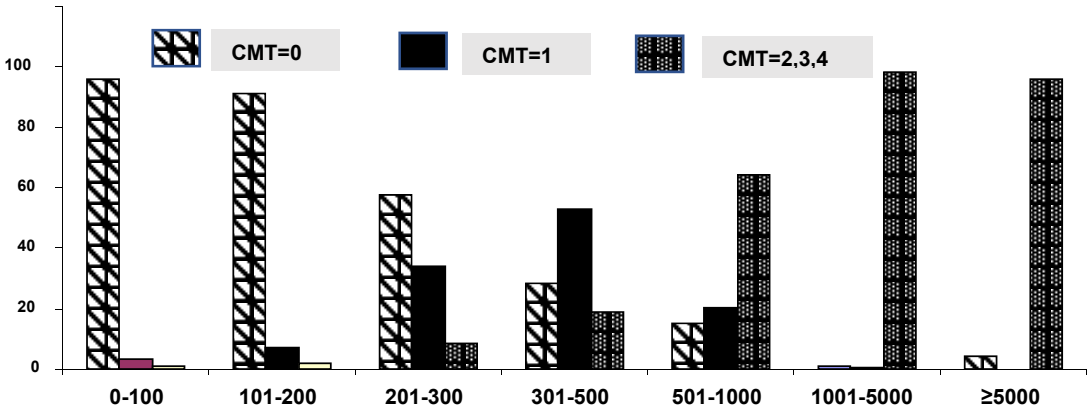

Figure 1 Distribution of CMT scale among SCC; X-axis is percentage (%); Y-axis is SCC (*10^3 cells/mL) clusters.

Conclusion The results revealed a high incidence of subclinical mastitis for Chios ewes. The high correlation between SCC and CMT measurements suggests that the routine implementation of CMT in the flock, in combination with microbiological tests and assessment of SCC, can offer a significant diagnostic solution for the detection and treatment of mastitis in ewes.

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Sedation of Australian Merino lambs with acepromazine to reduce stress-related behaviours at weaning

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Application Sedation of weaner Merino lambs could decrease stress-related behaviours at weaning, with the possibility of reducing production losses related to weaning stress.

Introduction In Australia, it is common practice to wean lambs from their dams at six to eight weeks of age, around two months younger than the natural weaning age. This can induce a severe stress response in the lambs. Various methods of 'gradual' weaning such as nose rings and udder covers have been trialled in cattle and sheep with varying success (Enríquez *et al*. 2010; Loberg *et al*. 2008; Norouzian 2015). These methods may not be suitable for use in Australia due to the large scale of production. Sedation of weaner lambs to reduce stress has not been reported in literature, and poses a potential alternative to traditional weaning. Acepromazine (ACP) is a sedative registered for use in livestock species, commonly used with veterinary examinations or minor procedures. It is suitable for this application, as it delivers a 'standing sedation' where the animal is conscious, and locomotion, feeding and drinking is not inhibited.

Material and methods 46 ram lambs were randomly allocated to treatment groups within liveweight strata. Six groups of seven lambs were formed (n = 42) with the lightest four lambs kept as spares. Three groups were randomly assigned to the sedative treatment, and three to the control. As the weight range was fairly large, three weight brackets were used to calculate dosage rates- 20-25 kg, 25.1-30 kg and 30.1-35 kg, with the dosage rate calculated at the midpoint of each weight bracket- 22.5 kg, 27.5 kg and 32.5 kg respectively. Oralject Sedazine-A.C.P. ™ (Virbac, Australia Pty Ltd) was used for sedation, calculated at 0.05 mg ACP per kg of liveweight as recommended by Hall and Clarke (1991). The sedative was mixed with 0.8% agar for ease of application. The control groups received an equivalent volume of agar only. At weaning (day 1), lambs were drafted into their assigned groups, caught, given the treatment orally, marked with an identifying symbol and moved into their pens. On day 2, lambs were dosed again in the morning and in the afternoon. A feed ration was given each day, and water was available *ad libitum*. Lamb behaviour was recorded by two day/night video cameras per pen. On days 1 and 2, collation of behaviours started five minutes after the pen gate was locked post-treatment administration. A scan sampling method was employed at 5-min intervals for the first 2 h and thereafter at 15-min intervals for 8 h. On days 3-5, sampling started 5 mins after feed was given, and scans were performed every 15 mins for 10 h. At each sample, the lamb was observed for 1 min, and one behaviour was recorded for each scan according to the behavioural catalogue. Behaviours were pooled into groups and three interest groups were analysed with a Chi-Square test- total lying, total agitated and total feeding.

Results Day 1 hour 1, sedated lambs were more agitated than control lambs ($P < 0.001$). Hour 2, placebo lambs were more frequently observed feeding ($P < 0.001$) and lying ($P < 0.001$). For the remainder of day 1, sedated lambs were more agitated ($P < 0.001$), more frequently recorded lying ($P < 0.005$) and tended to be feeding less (P= 0.052). Day 2 hour 1showed no significance. Hour 2, sedated lambs were more frequently recorded lying ($P < 0.001$). Hours 3-6 showed no significance. Hour 1 after the second dose, sedated lambs were less agitated than control lambs ($P < 0.001$). Hour 2 after the second dose showed no significance. For the remainder of the observation period, sedated lambs were less agitated ($P < 0.001$) and were lying more ($P < 0.001$). There were no significand differences between groups on days 3-5.

Conclusion Sedation with ACP appears to be ineffective in relieving stress immediately post-weaning, as sedated lambs were more agitated than control lambs. On day 2 however, the sedative was more effective, as sedated lambs were less agitated than control lambs, and were more frequently lying. Sedation should be further investigated, possibly with other sedatives or other doses, as it has a potential to improve lamb welfare at weaning.

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Dietary sodium diformate supplementation in sows during late gestation and lactation can improve performance of suckling piglets

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Application Dietary sodium diformate can be used in sow feed at 0.8% and acts as a performance enhancer for suckling piglets under commercial conditions.

Introduction The application of organic acids and their salts to diets for pigs has been studied extensively for more than 50 years (Lückstädt & Mellor, 2011). Despite its well-documented effects, data on its impact in sows during late gestation and lactation, and their subsequent effects on suckling piglets under commercial conditions is scarce. This study aimed to explore the impact of sodium diformate fed to sows at a commercial supplementation level on selected performance parameters in their piglets.

Material and methods This study tested the effects of sodium diformate (Formi® NDF, ADDCON, hereafter referred to as NaDF) fed to sows on their suckling piglets. 20 sows (Landrace × Big Yorkshire) on a commercial farm in Northern Serbia were equally divided into two groups, containing 10 sows each. The study was conducted under veterinary supervision. The sows were fed from one week before farrowing till the end of weaning (day 27) on a typical lactation diet (corn-wheat-soy based), containing either 0.8% of NaDF, or a negative control which did not contain the additive. The lactation diet was fed *ad libitum* and daily feed intake measured. From the first day after farrowing, only the 12 heaviest piglets from the litter of each sow were kept within the trial. The following parameters were monitored: number of piglets born alive, individual weight of new-born piglets and litter weight of new-born piglets. At weaning the number of weaned piglets, the individual body weight of weaned piglets as well as litter weight during weaning was recorded. Data were analysed using the t-test and a significance level of 0.05 was used in all tests.

Results Feed during the trial was well accepted by both groups. Sows fed the NaDF-diet had a noticeably higher feed intake compared to sows from the negative control group (+460 g/day, Table 1). During farrowing the weight and number of piglets born alive increased ($P<0.1$) due to the addition of the additive: piglet weight by 90 g; live births increased by more than 2 piglets per sow. Consequently, litter weight of piglets at birth differed significantly ($P<0.01$) by more than 5.5 kg, for the NaDF-fed sows. Furthermore, uniformity of piglet and litter weight was improved. During weaning at day 27, the number of weaned piglets differed significantly (10.5 and 11.5 for Control- and NaDF-group, respectively; $P=0.03$), due to a higher mortality during nursing in the control-group ($P<0.1$). The weaning weight of the piglets was only numerically influenced (60 g heavier piglets in the NaDF-group). However, due to the increased number of weaned piglets, the litter weight during weaning of NaDF-fed sows was also higher ($P<0.1$) by more than 8.6 kg. Again, uniformity of piglet and litter weight was improved, leading to a better manageable pig production.

Table 1 Performance parameter of piglet from sows fed with or without NaDF

Parameter	Control (n=10)	0.8% NaDF (n=10)	P-value
Mean daily feed intake sows [kg]	3.69	4.16	n.d.*
Piglets born alive, per sow [n]	10.6±3.6	12.8±3.2	0.092
Weight of new-born piglets [kg]	1.50±0.24	1.59±0.16	0.16
Litter weight at birth [kg]	15.90±5.21	21.44±3.69	0.009
Nursing mortality piglets [n]	1.2±1.33	0.5±0.81	0.096
Piglets weaned, per sow [n]	10.5±1.2	11.5±0.8	0.027
Weight of weaned piglets [kg]	8.31±0.94	8.37±0.66	0.45
Litter weight at weaning [kg]	87.70±16.08	96.35±11.29	0.102

*P-value not determined (pooled data)

Conclusion Previous studies (Øverland *et al*., 2009, Lückstädt, 2011) with potassium diformate have shown a benefit on piglet performance when the additive was fed to sows. This is the first study to show that supplementing sow feed with 0.8% sodium diformate may also support piglet production indirectly during the suckling period.

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Diet effects on methane emissions from grazing cattle measured using the sulphur hexafluoride (SF_6) technique

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Application This analysis suggests an approach to reducing methane emissions from grazing cattle by maximising feed intake; this would also reduce emissions intensity by increasing rates of liveweight gain and reducing finishing times.

Introduction Forage-based diets lead to higher methane emissions and it is well recognised that grazing ruminants contribute substantially to global greenhouse gas emissions. Difficulties in measuring feed intake and methane emissions from grazing animals means that there are relatively few data about the effects of herbage characteristics on methane emissions. The sulphur hexafluoride (SF_6) technique (Johnson *et al*., 1994) has been adopted for methane studies with grazing ruminants, but is laborious and prone to large experimental errors. The aim of this study was to assemble and analyse a set of treatment mean data from literature studies with grazing cattle consuming herbage as sole feed and methane emissions estimated using the SF_6 technique.

Material and methods A literature search of studies conducted around the world and published in refereed journals identified 17 studies (15 papers) published since 2002 in which growing (52 treatment means), mature (4 treatment means) or lactating cattle (8 treatment mean) grazed herbage as the sole feed. Herbage intakes were measured using n-alkanes (n = 8), other digestibility markers (n=35), back calculation based on energy output (n = 14) or field measurements pre- and post-grazing (n = 5). Methane emissions were estimated using the SF_6 technique. All studies reported animal weights and at least herbage crude protein (CP) and neutral detergent fibre (NDF) contents; a further chemical fraction (REST) was calculated as 1000-CP-NDF. Simple correlations and linear regressions were conducted using Genstat 16 (VSN International, 2013).

Results The ranges of values for herbage composition, herbage intake and methane emissions are shown in Table 1.

Table 1 Herbage composition, herbage intake and methane emissions (n = 64)

	Minimum	Maximum	Mean	s.d.
Herbage CP (g/kg DM)	44	314	154	64.0
Herbage NDF (g/kg DM)	270	754	585	85.3
Herbage DM intake (kg/day)	3.8	17.9	9.4	3.30
Herbage DM intake (% of body weight)	1.00	5.15	2.23	0.725
Methane emissions (g/day)	98	373	186	48.3
Methane emissions (g/kg DM intake)	9.6	37.4	21.1	4.95

There were highly significant negative correlations between NDF and CP contents of herbage (r = -0.59) and between NDF and REST (r = -0.68) indicating that in some situations fibre is replaced by protein, whilst in others it is replaced by sugar. There were no statistically significant relationships between methane emissions (g/kg DM intake) and herbage composition. However, despite the technical difficulties of the SF_6 technique and the challenges of estimating herbage intake, there were highly significant relationships with DM intake, whether expressed as kg/day [1] or as a percentage of body weight [2]:

Methane (g/kg DM intake) = 31.7(s.e. = 1.25)*** – 1.13 (s.e. = 0.126) DM intake (kg/day)*** [1]
R^2 = 55.2; residual s.d. = 3.37; P < 0.001; n = 65

Methane (g/kg DM intake) = 31.4 (s.e. – 1.54)*** – 4.59 (s.e. = 1.54) DM intake (% of body weight)*** [2]
R^2 = 42.5; residual s.d. = 3.82; P < 0.001; n = 65

Conclusion Methane emissions (g/kg DM intake) from grazing cattle were reduced when there were higher DM intakes. The reduction in methane emission with increasing intakes of herbage may be the consequence of higher rumen passage rates resulting in a reduced proportion of digestion occurring in the rumen and/or less favourable conditions for rumen methanogens, changes in molar proportions of short-chain fatty acids in the rumen (which are in turn associated with reduced hydrogenotrophic methanogenesis), or some other mechanism.

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Effect of weaning age on body length, heart girth and withers height of dairy heifer calves

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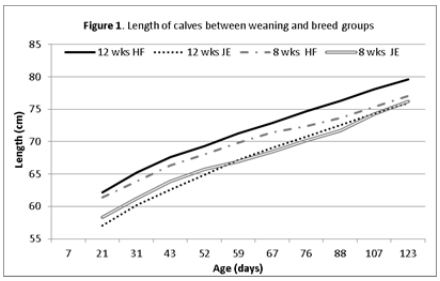
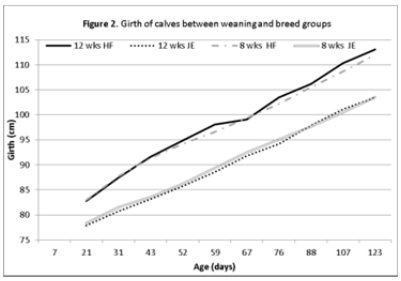
Application This study will help the dairy industry to find the ideal weaning age so that linear body measurements of the calf is optimised as the results showed that weaning at 12 weeks of age compared to 8 weeks resulted in heifers with larger body length and withers height measurements in the post-weaning period.

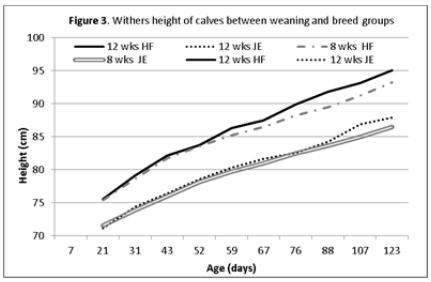
Introduction Delayed weaning has been found to positively influence the production potential of the calf (Bjorklund *et al*., 2013). Heifer growth is commonly measured by weighing, however, body measurements are also an effective way to measure growth (Wilson *et al*., 1997). The hypothesis of the present study was that Holstein Friesian (HF) and Jersey (JE) dairy heifer calves weaned at 12 weeks would have increased body measurements compared to those weaned at 8 weeks.

Material and methods This experiment was undertaken at the Teagasc, Dairygold Research Farm, Fermoy, Co. Cork, Ireland. At birth, 98 heifer calves were balanced for breed (61 HF and 37 JE), birth weight (30.2 ± 6.9 kg) and birth date (10th February ± 13.2 days), Once balanced, calves were randomly assigned to one of two pre-weaning treatments where they were weaned at either 8 (early; E) or 12 (late; L) weeks. Within an hour of birth, calves were fed 3 litres of high quality colostrum (refractometer reading > 22%; Bielmann *et al*., 2010). Heifers were fed 6 litres/calf/day of transition milk for 3 days before milk replacer (MR; 26% crude protein) was offered at a rate of 6 litres/calf/day (reconstitution rate 15%). Heifers were grouped by age from 5 days old and offered fresh water, *ad-libitum* concentrate and straw in their group pens, until they were gradually weaned at either 8 or 12 weeks. Body measurements (body length (BL), withers height (WH), and heart girth (HG)) were recorded twice a month to monitor calf growth. A measuring tape was used to measure the distance between the withers and pin bone to determine BL. A measuring tape was also used to measure the body circumference behind the animal's front legs to determine HG. A specialised measuring stick (Nasco, Fort Atkinson, WI); which provided an accurate measurement of height at the shoulder by lowering a sliding crossbar, was used to determine WH. Measurements were taken by the same person to minimise variation. Data were analysed using the mixed models procedure in SAS (v.9.4). Independent variables were age, treatment, breed and the interaction between treatment and breed. For body measurements the respective BL, HG and WH of the animal at 7 days was used as a covariate in the statistical model.

Results Throughout the duration of the experiment, the E and L calves consumed different amounts of milk replacer; E calves consumed 50.4 kg/calf and L calves consumed 75.6 kg/calf. There was an interaction between treatment and breed in terms of BL and WH from week 10 and 11, respectively. The interactions were due to E HF calves having lower growth rates then L HF calves during this time which may be due to L calves being offered MR for an extra 4-weeks. The hypothesis is therefore accepted. There was no effect of treatment on HG during the 16 week experimental period. Breed, however, significantly impacted all measurements (P <0.01) during both the pre-weaning and post-weaning periods. When the experiment concluded, HF calves had an average BL, HG, WH of 78.3, 112.5 and 94.1 cm, respectively. In comparison JE calves had an average BL, HG, WH of 76.1, 103.5 and 87.2 cm, respectively.







Conclusion Maintaining HF calves on MR for extra 4-weeks increased BL and WH compared to HF calves weaned at 8-weeks. Throughout the experimental period JE calves were smaller in size than HF; this is reflective of the smaller body size of the mature JE cow.

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Assessing efficiency of meat sheep farms in the UK by performance evaluation and benchmarking

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Application Efficiency analysis serves as a useful tool for revealing best management and production practices. Efficient sheep farms have large flocks, utilize economies of scale, depend on home-grown feed and use infrastructure at full capacity

Introduction Sustainable economic performance of sheep farms is associated with improved production techniques and effective management practices. Productivity and competitiveness of the sheep sector can be enhanced and strengthened through the adoption of "best farm practices" and innovations. Technical efficiency (TE) (Fried *et al*., 2008) is related to producers' management capacity and it is a useful tool for identifying best-practicing producers and benchmarking the performance of the rest against the top performing. The objective of this study was to estimate TE of sheep farms in the UK, to describe the structure and the profile of "best practicing farms" and to identify the characteristics of a production system that achieves highest economic performance.

Material and methods Technical and economic data collected from 119 meat sheep farms in the UK were used. The TE level of these farms was estimated by Data Envelopment Analysis (DEA) to identify the relatively efficient ones. The inputs used in the DEA model were: (i) flock size (number of ewes), (ii) human labour (hours), (iii) variable cost (€) and (iv) fixed capital cost (€). The output variable was gross revenue (€). Studied farms were categorized according to their TE level; their main technical and economic characteristics were calculated and compared.

Results The results showed that 22/119 farms are relatively fully efficient and that the mean TE level of studied farms was 77.3%. Hence, there is a considerable margin of approximately 23% to increase value of production of these sheep farms in the UK, providing that they adopt best observed practices. The composition of gross revenue showed that their output was dominated by sales of lambs for breeding and meat production that contributed 43.74% and 38.74%, respectively. Involuntary culling of animals accounted for 14.67% of gross revenue, while contribution of wool was marginal; only 2.85%. A key characteristic of the efficient farms is that they have comparatively larger flocks and manage human labour effectively, utilizing economies of scale (Table 1). Moreover, infrastructure was used at full capacity in efficient farms leading to considerable decrease of fixed costs per animal. However, it was revealed that less efficient farms had higher meat production per ewe. Although there were not significant differences in gross revenue between the two groups, efficient farms achieved higher gross margin (82 *vs.* 73 €/ewe).

Table 1 Economic characteristics of relatively efficient and inefficient farms

Economic data	Farm group		Average farm (TE = 0.773)
	Efficient (TE = 1.000)	Inefficient (TE = 0.722)	
Labour cost (€/ewe)	24	35	32
Feed cost (€/ewe)	15	20	19
Variable Capital cost (€/ewe)	45	47	46
Fixed Capital cost (€/ewe)	48	68	64
Production cost (€/ewe)	131	170	161
Gross revenue (€/ewe)	142	140	140
Gross margin (€/ewe)	82	73	75

Conclusion The measurement of efficiency and the description of the structural and economic characteristics of efficient meat sheep farms in the UK could be a practical tool for identifying best practices and management strategies to improve economic performance. Efficient farms utilize poorer land, rely mainly on grazing, have "easier care" ewe breeds which are lambing outdoors and often sell meat directly to consumers.

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Assessing the precision and repeatability of thermal image measurements in dairy calves

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Application Infrared thermography offers the opportunity for the non-invasive collection of repeatable and reliable temperature measurements of the eye in pre-wean calves. In addition, capturing 3 image replicates allows the detection of infrared temperature differences of less than 1°C.

Introduction Changes in core body temperature are commonly used as an indicator of inflammation or infection in veterinary medicine, however, the use of devices such as rectal thermometers can be invasive for the animal and time consuming for the producer. Recently, infrared thermography (IRT) has been highlighted as a remote sensing method capable of detecting changes in heat production and loss in farm animals as a result of blood flow changes due to ill-health or stress. More specifically, infrared (IR) temperature of the eye has been indicated as a means of detecting ill-health at an earlier stage in cattle when compared with more traditional methods. However, difference in IR orbital temperature between disease positive and negative animals can be <1°C, as such, there is a need to assess the precision and repeatability of IR measurements in pre-wean dairy calves. It was hypothesised that IRT would provide a reliable and repeatable means of temperature measurement in pre-wean dairy calves.

Material and methods Following the methodology of Byrne *et al*. (2017), an experiment was conducted to assess the level of precision obtainable through capturing a predetermined number of image replicates, and to determine the level of within- and between- calf variances. Within this experiment, precision was defined as the 95% confidence interval (CI) range within which the average of the measured temperature was expected to lie relative to the average of 30 temperature measurements. All images were captured using a calibrated, handheld FLIR E8 thermal camera (FLIR Systems UK, Kent, U.K) at a consistent distance of no less than 0.5m and at an angle just off perpendicular to the eye whilst the calf was standing. Thirty replicate images of both the right and left eye from each of 16 calves (8 male and 8 female) of an average age of 17.5 (±3.1d) days of age were captured by a single operator over 2 consecutive days. Following image capture, images were processed using FLIR Tools® software (FLIR Systems UK, Kent, U.K) from which maximum, minimum and average temperature measurements for each image were manually extracted. All data were analysed using GenStat® (version 18.1, VSN International Ltd). Between-calf and error variances were calculated for maximum, average and minimum temperature measurements of the right and left eye using a residual maximum likelihood estimation (REML) mixed model with calf included as a random effect. Proportion of total calf variation (H_{Calf}) was calculated by dividing the between-calf variance by the sum of the between-calf variance and error variance. The coefficient of variation (CV) for each eye and descriptive temperature parameter was calculated by dividing the between-calf standard deviation by the average of the temperature parameters of each eye. The following equation, wherein n represented the number of image replicates between 1 and 30 and σ_e^2represented the error variance, was used to calculate the number of images required to achieve a certain precision (Pn) within a 95% CI: $Pn = 1.96*\sqrt{\sigma_e^2/n_{\epsilon(1,30)}}$. In order to determine stability of temperature measurements over time, temperature measurements from each eye and descriptive temperature parameter were averaged across image replicates for each calf. Pearson's Product Moment correlation function was used to determine correlation coefficients between temperature measurements from the first image and all subsequent replicate images.

Results Error variances for maximum temperature were similar for both eyes, with values of 0.08 and 0.10°C^2 for the right and left eye, respectively. A greater proportion of the total variation was attributed to the calf for maximum temperature of the right eye (80.48%) when compared with maximum temperature of the left eye (67.02%). Maximum temperature yielded the most precise results when only one image was captured, with standard error values of ±0.56 and ±0.63°C for the right and left eye, respectively. Precision of maximum temperature was increased when 5 images were captured, with standard error values of ±0.25 and 0.28°C obtained for the right eye and left eye, respectively. Lowest level of precision was found within minimum temperature measurements. Within maximum temperature measurements, correlation between the first image replicate and all other image replicates ranged from 0.71 to 0.92 and 0.37 to 0.80 for the right and left eye, respectively. Within average temperature measurements, correlation between the first image replicate and all other image replicates ranged from 0.24 to 0.91 and 0.18 to 0.82 for the right and left eye, respectively.

Conclusion Results of the present study indicate a low level of variability and high level of repeatability within IR temperature measurements of the eye in young dairy calves, particularly within the maximum temperature parameter. Precision of image capture improved with increasing replication, whereby standard error of a single measurement was reduced by half when the average of 5 replicates was taken. In practical terms, results of the present study suggest that capturing 3 replicate images would offer sufficient precision to detect temperature differences of less than 1°C.

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Consumer preferences for sheep and goat products in Greece: Qualitative insights

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Application There is little knowledge about the consumption preferences of Greeks regarding sheep and goat products although the sector is important for the country. Their preferences vary in terms of types of products and retailers, while important innovations are needed to boost the sector.

Introduction Sheep and goat production is the most important sector of livestock industry in Greece. However, there is a remarkable decline in the market share of this sector over the last decades. Although there is a plethora of research data regarding technical issues and farm management, little is known about the linkages of primary production with industry and, even more, with retail sales and consumption habits of Greeks. The objective here was address the latter issues and to present the findings of a qualitative study regarding preferences of Greek consumers for sheep and goat products.

Material and methods Four focus group (FG) meetings were held in December 2016 in Thessaloniki, Greece. The city constitutes a good study area for consumption patterns, as sheep and goat production is one of the main activities around the city and is combined with a very well developed retail sector. Consumers varied in terms of age, gender, employment and frequency of purchase. Two FG meetings concerned dairy (12 and 9 participants respectively) and two meat consumption (11 and 8 participants respectively). Discussions were semi-structured but consumers were encouraged to express their own opinions and questions. The main discussion topics included (a) types of products purchased; (b) shopping habits; (c) preferred and un-preferred characteristics; (d) interventions and preferred innovations to increase purchases.

Results About dairy products, discussion highlighted 'feta' cheese as the most preferred type, followed by goat cheese, while sheep and goat products were generally considered healthier and more suitable for children. Yoghurt was in general a controversial product in terms of frequency of consumption. Serious reservations were expressed about the consumption of pasteurized goat milk, especially regarding the smell. Many types of retailers were mentioned by participants: supermarkets, small groceries, farmers' markets, producers/farms, food exhibitions and festivals etc, but small neighbourhood groceries - with which they have built personal relationships - and supermarkets were the most preferred. Most of them prefer to buy specific brands and cheeses from local dairies, while many of them declared that they buy cheese from producers that they know personally; trust (healthy products), stable quality, particular cheese-making technique and specific taste were the main reasons. Consumption varied during the year - especially in quantity and not by type - and depended on the consumption of other foods and dishes. The main attributes of cheeses (sheep and goat) in general were taste, texture and healthiness as well as the place of origin (also in relation to production systems), while some participants cared more for price and less for specific brands. Common proposals and preferred innovations for increasing consumption included lower cholesterol and lower prices, followed by novel packaging, pasture-based primary production and less use of antibiotics.
When it comes to sheep and goat meat, the qualitative analysis confirmed that Greek consumers are traditionally inclined to consume light carcasses (lamb and kid meat, usually not older than 40-50 days). Whole carcasses are the most popular, followed by ribs and leg, hence butchers prefer to sell whole or half carcasses (but only transverse cuts). Consumption depends on the time of year and is linked to specific occasions, family and friend reunions, social events etc. Some respondents tended to trust small neighbourhood butcheries more than supermarkets to buy meat, because of personal relationships. On the contrary, others mentioned that the staff of supermarkets is better trained, while big super markets are audited more often under strict protocols; because of high consumption, super markets which sell sheep and goat meat offer more fresh products, which do not remain many days in store. Concerning prices, consumers agreed that sheep and goat meat is more expensive than other types of meat (veal, pork, chicken), which does not permit to be consumed very regularly and also that kid meat is more expensive than lamb. Taste and smell were the most preferred attributes of lamb and kid meat, followed by healthiness and nutritiousness. Origin and tradition were important factors in consumption decisions, along with advertisement, more availability (also of specific cuts) throughout the year and PDO certification. These could be achieved through better labelling (providing information about origin and production methods), stress-free slaughter for improved meat quality and better feeding strategies for animals.

Conclusion The qualitative results of this survey yielded important issues for future qualitative research. Combined with innovative approaches across the supply chain, such research could shed more light on potential ways to increase consumptions of sheep and goat products, thus boosting an important sector for the Greek economy in general.

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Effect of different rapidly fermentable carbohydrates sources addition on *in vitro* neutral detergent fibre (NDF) digestibility

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Application With fibre being the major feed component of ruminant diets it is important to maximise its digestion in then rumen. By adding specific carbohydrates to a diet, it may be possible to improve fibre digestion and subsequent livestock performance.

Introduction Since the rumen itself is well designed to ferment fibre to obtain energy and drive microbial protein production, factors that are able to increase or depress this process will have an impact on how the diet performs. It is known that other dietary energy sources are also able to impact fibre digestibility. The aim of the current study was to evaluate different rapidly fermentable carbohydrates sources for their effects on *in vitro* ruminal NDF digestibility.

Material and methods The study was conducted at the University of Bologna, and all procedures including animals were approved by the University of Bologna Institutional Animal Care and Use Committee. For this study, several carbohydrates sources were selected: cane and beet molasses, pure starch, glycerol, milk whey, pure sucrose, and ED&F Man Liquid Feed, a cane molasses based liquid feed combined with isolmaltose and organic acids, with 32% moisture, 12% ash, 11.2% crude protein and 63.2% water soluble carbohydrates, on D.M. basis. For the fermentation set up, each one of these feeds was added to represent a 60g/kg of carbohydrate addition, on dry matter basis. As forage fibre source, a slowly digestible corn silage was used. Corn silage itself was fermented as the control reference for digestibility values. *In vitro* fermentations for NDF digestibility were performed at 8, 24, 48 h using the Tilley and Terry (1963) modified technique. Carbohydrates sources were analysed in duplicate, in each of the 2 different *in vitro* incubations, for a total of 4 observations each, as described by Palmonari *et al.* (2017). Briefly, 0.5 g of sample (forage substrate plus the amount of specific feed) was weighed into each flask before the addition of 40 mL of Goering and Van Soest (1970) buffer and 10 mL of rumen fluid. Fermentation flasks were placed in a heated (39.3°C) water bath under CO_2 positive pressure to ensure anaerobiosis. When the given time point was reached, samples were processes for NDF determination. Data obtained were used to calculate fibre digestibility. In order to evaluate any difference of carbohydrates addition on fibre digestibility, data were analysed using one-way ANOVA test, with digestibility as the dependent variable, while carbohydrate sources and control were considered fixed effects, thus having treatments and control one against each other.

Results Each carbohydrates source acted differently. In particular, it was possible to observe a common way to act of single sugars, for which we observed an increased digestion in early time points, but almost no differences at 48h. Pure starch resulted in an improved digestion, which was, however, less than those obtained by molasses. Pure sucrose also improved digestibility, but at a lower degree compared to pure starch. Glycerol gave its impact at 8h, with lower effect during time. Similar dynamics was observed in milk whey. Major impact was observed with the Liquid Feed which resulted in the highest improvement. The Liquid Feed used is a blend of different ingredients, in which molasses represent a high percentage of its dry composition.

Table 1 Impact of different sugar sources on *in vitro* NDF digestibility.

Time point	Control	Cane Molasses	Pure starch	Pure sucrose	Glycerol	Milk whey	Liquid Feed	S.E.M.	P
8h	28.50^{b}	31.88^{a}	31.54^{a}	30.19^{ab}	31.71^{a}	30.12^{ab}	29.75^{ab}	1.18	0.044
24h	32.70^{b}	40.86^{a}	35.21^{ab}	33.36^{b}	34.45^{ab}	32.63^{b}	40.39^{a}	1.73	0.021
48h	49.04^{b}	57.69^{ab}	53.21^{b}	51.56^{b}	51.73^{b}	49.22^{b}	61.04^{a}	1.34	0.013

Conclusion The results obtained in the current study suggest that fibre digestibility could be improved by the addition of other feeds, which are able to impact microbial fermentations. The degree of these effects changed among them and across time points. Considering the different feeds tested, those more complex, such cane molasses and ED&F Man Liquid Feed, appeared to be more effective in increasing fibre digestibility.

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Comparative evaluation of nutritional values of chicken, quail, turkey and duck eggs

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Application There is a need for this research due to emphasis placed on the nutritive value of food by consumers. The results may serve as a guide to providing useful information on food composition.

Introduction Global egg production, consumption and their effects on human health, and use of eggs as a functional food are expanding owing to their capacity to decrease the risks of some diseases apart from easy availability and affordability. In both developing and developed countries an increased egg production and consumption could significantly improve nutritional needs of a common man and children with developing minds. Eggs are an economical source of nutrients for a healthy diet and life, especially important for the mental development of growing children. (FAO, 2012).

Material and methods One hundred eggs, laid within 48 hours, of chicken (*Gallus domesticus*), quail (*Coturnix japonica*), turkey *(Meleagris gallopavo*) and Duck *(Anas platyhyncha*) were collected. The sample of various egg species were weighed, carefully cracked and the contents also weighed and then emptied into a beaker. Moisture, ash, protein and ether extract were determined by AOAC (1990). Hanus (1966) method was used to determine the iodine value and other mineral element were analyzed using the atomic absorption spectrometry. Data collected were statistically analyzed at $P<0.05$ (SAS, 2002) and means were separated using Duncan's multiple Range Test.

Results The results revealed no significant difference ($P \geq 0.05$) in the crude protein between turkey and duck, however, it shows significant difference ($P \leq 0.05$) in the protein content when compared across all other egg species. Significant difference ($P \leq 0.05$) was observed in the Iodine value of all egg types with quail eggs having the highest value. Sodium, potassium, calcium, magnesium, zinc, iron and copper in the whole egg samples ranged between 0.049 - 0.065 ppm, 0.715 - 0.975 ppm, 0.940 - 1.420, 0.08-0.100ppm, 0.305 - 0.0.475ppm, 2.800 -4.560ppm and 1.00 - 2.810ppm respectively. No significant difference ($P\geq 0.05$) was seen in the magnesium, calcium, copper and Zinc content of the egg species but across the egg types, results revealed significant differences ($P \leq 0.05$) between iron and other mineral elements in chicken, quail, turkey and duck eggs.

Table 1 The Proximate and Mineral Composition of chicken, quail, turkey and duck eggs

Parameter	Chicken±SEM	Quail±SEM	Turkey±SEM	Duck±SEM
% Crude protein	29.97^{ab}±5.91	21.22^{b}±3.72	33.23^{a}±1.09	35.00^{a}±1.09
% Ether extract	33.80^{d}±0.97	37.44^{c}±1.75	41.60^{b}±0.84	48.01^{a}±0.01
% Ash	4.70^{c}±0.06	7.65^{b}±0.60	7.32^{b}±0.67	10.79^{a}±0.81
% Moisture	74.3^{a}±0.01	71.01^{b}±0.04	71.66^{c}±1.16	66.45^{d}±0.56
Iodine value	246.07^{b}±28.04	267.32^{a}±5.87	234.64^{c}±10.45	247.65^{b}±16.13
Potassium (K) (ppm)	0.75^{c}±0.002	0.975^{a}±0.023	0.760^{c}±0.003	0.885^{b}±0.005
Calcium (Ca) (ppm)	0.94^{d}±0.056	1.420^{a}±0.043	1.00^{c}±0.055	1.110^{b}±0.064
Sodium (Na) (ppm)	0.050^{c}±0.011	0.065^{a}±0.012	0.053^{b}±0.043	0.049±0.071
Magnesium (Mg) (ppm)	0.093^{c}±0.061	0.121^{a}±0.067	0.089^{c}± 0.076	0.100^{b}±0.051
Iron (Fe) (ppm)	4.56^{b}±0.055	4.620^{a}±0.051	2.820^{c}± 0.093	2.800^{c}±0.087
Zinc (Zn) (ppm)	0.405^{b}±0.009	0.305^{d}±0.042	0.380^{c}± 0.001	0.475^{a}±0.045
Copper (Cu) (ppm)	2.180^{a}±0.006	1.00^{c} ±0.008	1.270^{b}±0.065	1.260^{b}±0.033

Means with different superscripts are significantly different ($P < 0.05$) , ± SEM (Standard Error of Mean)

Conclusion It was found that quail and turkey eggs had the highest level of mineral composition with quail being richer in Calcium and Iron than chicken, duck and turkey eggs. This makes it good for inclusion in the diets of infants, young adults and pregnant women. Whole eggs of all the eggs contain high level of unsaturated fatty acids as indicated by the Iodine number but quail eggs contain higher level of unsaturated fatty acids than the other eggs which make it a good choice for people with heart diseases (Jeke *et al*., 2018).

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In vitro organic matter degradability and gas production measurements on whole canola (*Brassica napus*) seeds or canola seed meal, as potential constituents of ruminant diets

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Application *In vitro* organic matter degradability and gas production measurements on whole canola seeds or canola seed meal, as potential constituents of ruminant diets

Introduction The main purpose of most animal production systems is to produce food in quantity and quality, and as cheaply as possible. On the other hand, the search for more sustainable renewable energy sources increased the world´s biodiesel production and also their by-products, which have potential to be used in animal nutrition. The aim of this study was examine the suitability of whole canola (*Brassica napus*) seeds and canola meal in ruminant diets by evaluating *in vitro* organic matter degradability and gas production parameters.

Material and methods Whole canola (*Brassica napus*) seeds and canola meal were homogenized in a Wiley mill (1 mm) then analysed to determine the content of dry matter (DM), ash, organic matter (OM) ether extract (EE) and crude protein (CP) according to Bueno *et al*. (2005) at Laboratory of Bromatology and Animal Nutrition, UFFS, Erechim campus, Brazil. In the Laboratory of Animal Nutrition (CENA-USP, Piracicaba, Brazil) *in vitro* gas production and OM degradability assays were performed, using as inoculum, rumen fluid from castrated adult male Santa Inês sheep, fitted with permanent ruminal cannulae and, fed on pasture plus a commercial concentrate supplementation (500g/d). Twenty-five samples (0.5g) each of canola seeds and canola meal were weighed and incubated at 39°C in 160 mL bottles, with 50 mL of Menke´s buffered medium and 25 mL of inoculum. Gas production (GP) was measured at 48h of incubation. The fermentation process was then stopped by putting the bottles in cold water (4°C) and the non-degraded substrate was collected to determine the organic matter degradability (OMD) according to Blummel *et al*. (2005). Net GP (NGP) was calculated excluding the accumulated GP of blanks. The experiment was a completely randomized design, the analysis of variance was performed (PROC GLM) and means were compared by Tukey test at 5% probability level using the software SAS.
Results The canola meal treatment had a higher ($P<0.05$) gas production than whole canola when expressed as mL per gram of DM and per gram of degraded organic matter (OMD). The OM degradability was also higher for canola meal ($P<0.05$). Total gas production (ml), and $N\text{-}NH_3$ concentration did not differ between canola meal and whole canola seed diets.

Table 1 *In vitro* net gas production (NGP), organic matter degradability (OMD) of whole canola seeds (WC) and canola meal (CM) after 48 hs incubation

Variables	NGP (mL/gDM)	OMD (g/Kg)	NGP (mL/gOMD)
WC	149.83	645.34	96.60
CM	186.00	791.20	147.04
P	<0.05	<0.05	<0. 05
SD (%)	22.88	82.47	28.56
CV, (%)	7.56	3.18	6.64

Conclusion Interpreting the results obtained in this study we concluded that CM presented better results concerning organic matter degradability when compared to WC seeds, probably due to its lower fat content than in the seeds. In addition, it is important to mention that, as by-products from biodiesel production, canola meal is much more abundant than whole canola seed. The observation that CM produced 1.52 times more gas (ml/gOMD) than WC seeds suggests that CM is of potential use in animal production systems.

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The effect of organic management strategies on milk production and milk processability characteristics within an Irish pasture-based system

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Application Matching calving date and turnout to grass with growth of organic clover-based pasture in spring and an extended grazing season into the following winter is a prospective grazing system for organic dairy farms.

Introduction Milk can be produced at low cost from white clover-based grassland over a long growing season in temperate regions of the world (Humphreys *et al*., 2017). A weakness is poor spring growth and delayed turnout to pasture in spring compared with N-fertilized grassland. Conversely, lower stocking densities on organic compared with conventional dairy farms and high productivity of grass-clover swards during late summer and autumn provide the potential to compensate for a later calving date in spring by extending lactation into the following winter. Clover based pasture accumulated during late summer and autumn can be rationed to grazing dairy cows in a controlled way during early winter. The main objectives of this study were to investigate the productivity of three grazing-based systems of dairy production and examine the effects of alternative calving dates on milk production and composition, herbage production, clover content of swards and biological nitrogen fixation (BNF) during two years when a large proportion of the dairy cow diet was grazed grass-clover pasture.

Material and methods An experiment was conducted on clover-based grassland at Solohead Research Farm (52° 51' N, 08° 21' W) during 2008 and 2009. Fifty four primi- and multiparous spring-calving Holstein-Friesian dairy cows were used in a complete randomized block design consisting of three grazing-based systems. Systems compared had: (i) mean calving date of 17 February, annual fertilizer input of 100 kg N ha^{-1} (ES100N) and a stocking density of 2.15 cows ha^{-1}, (ii) mean calving date of 17 February, no fertilizer-N input (ES0N) and a stocking density of 1.6 cows ha^{-1}, and (iii) a mean calving date of 16 April, no fertilizer-N input (LS0N) with stocking density of 1.6 cows ha^{-1} between calving and 1 September and 1.2 cows ha^{-1} between 1 September and 18 February. Cows were indoors while not lactating were turned out to pasture three days after calving. Sward measurements included pre-grazing herbage mass, nutritive value, white clover content in herbage and BNF. Animal production measurements included milk production and composition. Analyses were undertaken on all variables using mixed model (PROC MIXED) in SAS.

Table 1 The mean production and composition of milk for 280 d lactation over two years, the mean number of days that dairy cows were at pasture and concentrates fed

	ES100N	ES0N	LS0N	s.e.m.	P value
Milk (kg cow^{-1})	6371	6511	6605	182	NS
Fat (%)	4.31	4.34	4.18	0.096	NS
Protein (%)	3.62	3.63	3.48	0.075	NS
Lactose (%)	4.73	4.72	5.04	0.144	NS
Days at pasture (days cow^{-1})	220	234	231	1.7	***
Concentrate fed (kg cow^{-1})	590	590	847	21.3	***

Table 2 The effect of grazing system (sys) on herbage dry matter (DM) production (t ha^{-1}) and BNF (kg ha^{-1}).

Grazing system		ES100N	ES0N	LS0N
		Mean herbage production (t DM ha^{-1})		
2008	Grass	8.22	6.41	7.11
	Clover	2.13	2.47	2.07
	Total	10.35	8.88	9.18
2009	Grass	8.18	5.83	6.73
	Clover	1.69	2.80	3.58
	Total	9.88	8.63	10.31
		Mean BNF (kg N ha^{-1})		
2008		113	131	110
2009		90	149	191
		S.E of means		
	Grass	Clover	Total herbage	BNF
System	0.29***	0.26*	0.39*	16.6*
Year	0.24	0.14	0.32	10.8*
Sys x Yr	0.41	0.38*	0.55	18.8**

* P < 0.05, ** P < 0.01, *** P < 0.001

Results There were no differences in milk production and composition between the three systems (Table 1). The lower stocked ES0N and LS0N had a longer grazing season than ES100N. Cows on LS0N system consumed an extra 260 kg of concentrates compared with ES100N and ES0N systems (P < 0.001, Table 1). Herbage production was lower in ES0N than the other two systems in both years (P < 0.05, Table 2). Annual clover herbage production was affected by a significant interaction between grazing system and year, being similar across all three systems in 2008 (P > 0.05) and with lower (P < 0.001) clover yields in ES100N in 2009. The BNF estimates were also lower in ES100N in 2009 (Table 2).

Conclusion Grazing during late autumn and winter on LS0N had no adverse effect on milk output per cow or milk composition. A long grazing season was possible with LS0N herd. Grazing over the winter had a positive effect on clover content in the following year compared to the early turnout systems. The LS0N system has potential to be a profitable system on organic dairy farms across temperate regions.

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Quantitative label-free proteomic analysis of hepatic tissue from cattle during dietary restriction and subsequent compensatory growth

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Application This study provides an insight into the key liver proteins involved in compensatory growth (CG) in cattle. Data will contribute to more accurate identification of DNA based biomarkers for the selection of cattle with a greater ability to undergo compensatory growth and thus improved lifetime feed efficiency.

Introduction Compensatory growth (CG) is defined as a physiological process by which an animal has the ability to accelerate its growth following a period of under nutrition (Hornick *et al*., 2000). The naturally occurring CG phenomenon is exploited worldwide in beef cattle production systems as a method to lower feed costs. While the liver only represents between 1 and 3% of body-weight it accounts for ~24 % of whole body energy use (McBride *et.al.,* 1990). Transcriptome based data (Connor *et.al*. 2010, Keogh *et al.* 2016) have provided a useful insight into the molecular regulation of the CG trait in cattle. However as mRNA abundance does not always translate to protein syntheses, which ultimately govern biological function, it is necessary to focus on the influence of the CG process on the proteome. The objective of this study was to examine the hepatic proteome of Holstein Friesian (HF) bulls following a period of restricted feeding and subsequent compensatory growth, using shotgun global proteomic analysis.

Material and methods This study used tissue collected as part of the study of Keogh *et al.* (2016). Briefly, 40 purebred HF bulls were assigned to one of two groups: (i) restricted feed allowance for 125 days (Period 1) (R1; n=10) followed by *ad libitum* access to feed for a further 55 days (Period 2) (R2; n=10) or (ii) *ad libitum* access to feed throughout (ADLIB; n =20). At the end of Period 1, all animals from R1 group and 10 ADLIB animals were slaughtered. Tissue collection procedures were described by Keogh *et al.* (2016). Proteins were extracted from samples firstly using a Percellys homogenizer, solubilised using ultrasound techniques and then using an iST Kit (PreOmics, Germany). Samples were subjected to tryptic digestion followed by high performance liquid chromatography and subsequent mass spectrometry (MS). The acquired MS data was processed by MaxQuant followed by protein identification using the integrated Andromeda search engine. Spectra were searched against an in-house built database which was assembled to identify transcript variants from RNA-Seq libraries, and putative peptide sequences were assembled *in silico* from these transcripts. Protein fold changes were computed based on intensity values and were considered differentially abundant if the Bonferroni corrected p-value was <0.05 and log2 fold change >1.

Results During Period 1, R1 and ADLIB were managed to achieve a target mean daily growth rate of 0.6 and 1.9 kg/d, respectively. During Period 2 the R2 group underwent significant CG, exhibiting an ADG 1.8 times that of the ADLIB group (2.5 v 1.4kg/d, respectively; $P < 0.001$). 23 proteins were identified as differentially abundant in R2 compared to R1 and the proportional classification of these proteins is displayed in Figure 1. Proteins that were found to be differentially expressed in this study are involved in cellular growth, metabolism and ATP production. Similarly in the study of Keogh *et.al*. (2016) expression of genes associated with cell proliferation and growth was greater in animals undergoing CG. In comparing these differentially regulated proteins with the corresponding differentially expressed gene dataset of Keogh *et.al.* (2016) one gene, *METTL27,* which is involved in methyl transfer, was found to be differentially expressed in both datasets.

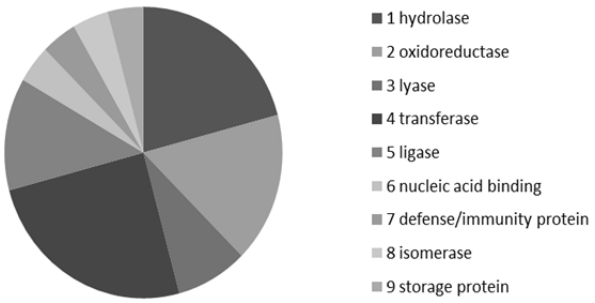

Figure 1 Pie chart of protein classes identified as differentially abundant between ADLIB and CG cattle groups

Conclusion These results show consistency between the expression of genes and their functionality at a protein level. This data aids in the identification of potential biomarkers which can add to genomically assisted breeding programmes to select for animals with a greater ability to undergo CG and ultimately reduce feed costs.

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Milk consumption monitoring as a farmer friendly indicator for advanced treatment in calves with neonatal diarrhea syndrome

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Application Diarrhea syndrome is the most common cause of illness and mortality in neonatal calves and early detection of the disease increase the success rate of treatment. It could be suggested to seek for veterinary assistance when the consumption of milk is reduced for about ≥25% and to closer monitoring calves when milk intake is reduced ≥16%.

Introduction Diarrhea syndrome is the most common cause of illness and mortality in neonatal calves. Early detection of the disease and prompt intervention increase the success rate of treatment. Nowadays, it is a common practice the initial diagnosis and treatment of neonatal calf diarrhea to be predominantly carried out by primary producers (farmer or manager), who utilize oral rehydration and buffering solutions as a first inexpensive attempt to address diarrhea (Sayers *et al*., 2016). However, in the course of the disease some calves will need IV fluid therapy to correct severe dehydration, acidosis and septicemia (Naylor *et al*., 2006; Berchtold, 2009; Meganck *et al*., 2014). So, it would be of great value for the success of treatment if the producers had an indicator available for early detection of the symptoms associated with these complications and asking for veterinary assistance in time. Although until now there is no relevant reference in the available literature, milk consumption could be used as such an indicator given that calves with severe dehydration and acidosis have decreased appetite. The purpose of the present study was to investigate under field conditions whether milk consumption could be used as a farmer friendly indicator for advanced treatment in diarrheic neonatal calves

Material and methods Milk consumption and health records of 103 diarrheic calves aged less than 15 days were used in the study. MC reduction rate (MCRR) was calculated after each feeding during the diarrhea course, based on the MC prior to the diarrhea onset for each calf. Calves with fecal scores (FS) ≥2 (1=normal, 2=intermediate and 3=watery) were considered diarrheic. They were all clinically examined daily after the morning feeding from the onset of diarrhea until recovery (FS=1) by the same veterinarian who was blind to milk consumption. The degree of dehydration, determined as described by Naylor (1987) and Constable *et al*. (1998), the ability of the calf to suckle and stand as well as rectal temperature and severity of depression were the clinical signs which were taken into account for selecting the appropriate treatment regime as suggested by Berchtold (2009). Standard treatment was applied to 58 calves that were not considerably dehydrated (<8%) and had no signs of acidosis-septicemia; it consisted of offering one or two extra meals of 2 L per day, based on dehydration status, of an oral electrolyte solution between milk feedings. Advanced treatment was consisting of IV fluid therapy with or without antibiotic administration and was offered to 45 calves with significant dehydration (>8%) and/or signs of acidosis-septicemia. The optimal cut-off value of MCRR on the last meal and that 12h earlier, yielding the highest diagnostic sensitivity (DSn) and specificity (DSp) for the detection of animals that need advanced treatment was determined by receiver operating characteristic (ROC) analysis (IBM SPSS statistics).

Results The diarrhea onset at the study population was observed between days 4 to 10 of age. The analysis of the data revealed that using the cut-off point of ≥24.5% for MCRR, the milk consumption on the last meal (time point 0) is a very reliable indicator for the necessity of advanced treatment in diarrheic calves. The corresponding value of DSn and DSp for this cut-off point was very high, 95.6% and 98.7%, respectively (AUC: 0.987, 95% CI: 0.971 – 1.000), suggesting that only a small proportion of calves will be left untreated. Taking into account the MCRR 12h prior to advanced treatment administration, the analysis showed that using the cut-off point of ≥16.5%, milk consumption at this time point is a good but less reliable indicator than that of time point 0. Despite the low DSn and DSp (DSn: 86.7%, DSp: 90.7%; AUC: 0.958, 95% CI: 0.940 – 0.976), this cut-off could be used as an alarm point for closer monitoring of the diarrheic calf.

Conclusion Milk consumption monitoring is a reliable indicator for the identification by the farmer of the diarrheic calves that need advanced treatment. So, it could be suggested to the farmers to seek for veterinary assistance when the consumption of milk is reduced for about 25% or higher and to closer monitoring their calves when milk intake is reduced for more than 16%.

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Does the presence of maternal antibodies affect immune responses to vaccination in Merino lambs?

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Application Maternal antibodies may have influenced immune responses to vaccination in lambs. A larger study should confirm results and investigate the effects of observed differences in immune responses on the efficacy of vaccination.

Introduction Vaccines are regularly used to protect farm animals from a range of bacterial and viral diseases and are routinely used by sheep producers to manage the health and welfare of their animals. The important role of maternal antibodies in protecting lambs against disease until their own immune system develops is well known (Barrington & Parish, 2001); however results from some studies have shown that the presence of maternal antibody levels in young animal at the time of vaccination can influence responses to vaccination (Patil *et al*., 2014; Bucafusco *et al*., 2014). The aim of this experiment was to investigate the impact of maternal antibodies on immune responses to vaccination in Merino lambs.

Material and methods The study was conducted using a randomized block design with two treatment groups. Different levels of maternal antibody in lambs were generated by vaccinating only 50% of the lambs' dams four weeks prior to lambing. Lambs from those ewes then formed two treatment groups (Table 1). To assess the effect of maternal antibody on vaccine responses, lambs received a primary vaccination at 2-8 weeks of age, in accordance with standard farming practice in Australia, and a booster vaccination 4 weeks later. Ewes and lambs were vaccinated with a clostridial vaccine (Ultravac 5in1, Zoetis), containing tetanus toxoid. Following vaccination, antibody and cellular immune responses to vaccine components were assessed in individual lambs. Blood samples were collected from lambs on days -7, +21 and +37 (relative to the primary vaccination) and serum prepared. Maternal antibody levels (d-7) and antibody responses to vaccination (d+21, d+37) were assessed using an ELISA to quantify production of anti-tetanus toxoid specific serum IgG1. Cellular responses to vaccination were assessed by measuring the magnitude of delayed type hypersensitivity (DTH) skin reactions to vaccine components on day +39. Responses to vaccination were analysed using a general linear (DTH data) or a repeated measures linear, with animal as random effect (ELISA data) model in R with age, gender and dam vaccination status fitted as fixed effects. Least squares means (LSM) were estimated to evaluate the effect of dam vaccination status on antibody and cell-mediated responses in lambs. To improve normality, antibody and DTH data were transformed using cube root and log transformations respectively for analysis.

Results Lambs from vaccinated dams had significantly higher antibody titres pre-vaccination (maternal antibody d-7) compared to lambs from non-vaccinated dams ($P<0.0001$) indicating the presence of maternal antibodies. After vaccination, lambs from vaccinated dams had lower overall antibody titres ($P=0.033$) and greater DTH responses to vaccine antigens ($P=0.003$). Age and gender had no significant effect on responses. All results are reported on transformed data in Table 1.

Table 1 Number of lambs (n), influence of dam vaccination status on antibody (OD) & DTH (mm) responses to vaccine components, reported as LSM & standard error. Differing superscript letters indicate significant differences within columns

Treatment	n	Dam Status	Maternal Antibody d-7	Antibody Response*	DTH Response d+39
A	55	Vaccinated	0.418 (0.02)^{a}	0.491 (0.02)^{a}	1.160 (0.03)^{a}
B	53	Not Vaccinated	0.189 (0.03)^{b}	0.538 (0.02)^{b}	1.051 (0.03)^{b}

*Antibody levels in serum at d+21 and d+37 were analysed as repeated measures in the model, reporting the overall antibody response to vaccination as affected by dam vaccination status

Conclusion In this study vaccination status of dams was associated with lower antibody and higher DTH immune responses to vaccination in 2-8 week old lambs suggesting the presence of maternal antibodies may have influenced responses.

Further Work Further investigation is required to assess the impact of observed differences in immune responses on vaccine efficacy. More research is also required to identify the mechanism by which maternal immune factors (antibodies and/or cells) transferred to the neonate influence the generation of responses to vaccination in lambs.

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The effect of rotational grazing speed on sheep and grassland performance

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Application An 8-paddock rotational grazing system produces higher levels of herbage production but results in lower lamb live weights at weaning.

Introduction Grass, our cheapest feed resource, can supply up to 95% of the energy requirements of sheep (Davies & Penning, 1996); thus, the efficient production and utilisation of herbage in lamb production systems is the key to profitability. Currently, there are inefficiencies in the level and quality of herbage utilized ha^{-1} within sheep production systems; as utilisation rate is a major factor affecting the cost per kg of grazed grass consumed, it is imperative that strategies to improve herbage utilisation are investigated (Keady *et al*., 2009, Earle *et al*., 2017). The objective of this study was to examine the effect of 4 versus 8 paddock rotational grazing systems on animal performance and herbage production, quality and utilisation.

Material and methods The experiment was carried out from April 13 to September 12, 2018, using a predominantly *Lolium perenne* sward, at AFBI, Hillsborough. There were two grazing treatments (4 vs. 8 paddock rotational grazing system) which were balanced for ewe live weight, body condition score and lamb sire breed. Each system consisted of 1.6 ha which were rotationally grazed at a stocking rate of 14 ewes ha^{-1} which equated to 22 twin-rearing ewes per treatment. The target pre-grazing cover was 2200 kg DM ha^{-1} for the duration of the experiment and the target post-grazing cover was 1600 kg DM ha^{-1} on both treatments. Herbage mass was recorded before and after each grazing by taking four quadrat (0.5 x 0.5m) cuts with Gardena hand shears. The harvested herbage was weighed and retained for dry matter determination. Herbage compositional quality was analysed at each grazing using near infrared reflectance spectroscopy. Ewes were weighed and body condition scored at turnout, 6 and 10 weeks post-lambing and weaning. Lambs were weighed fortnightly using portable electronic scales (Shearwell, UK) and were drafted for slaughter on reaching 44kg of liveweight. Data was analysed using linear mixed models in GenStat with ewe as a random effect and lamb sire breed, gender and deviation in lamb age at each weighing day included as fixed effects. Differences were considered significant at $P<0.05$.

Results There was no significant effect of grazing treatment on ewe liveweight or body condition score. Lambs grazing the 4-paddock rotational system had higher average daily gains (ADG) from birth to weaning ($P<0.01$) compared to those grazing the 8-paddock system (Table 1) and this was driven by higher ADG from 10 to 14 weeks of age ($P<0.001$). This resulted in higher weaning weights ($P<0.01$) for lambs on the 4-paddock rotational system. A surplus of 1.7t DM ha^{-1} was produced from the 8-paddock system than the 4-paddock system with no significant effect on grass quality (Figure 1).

Table 1 Lamb performance from birth to weaning

Variables	Paddock System		SED	P
	4	8		
Birth weight (kg)	5.0	4.8	0.253	0.474
ADG (g/day);				
Birth to 6 weeks	243	247	0.014	0.777
6 to 10 weeks	314	290	0.015	0.112
10 to 14 weeks	267	202	0.014	<0.001
Birth to weaning	257	232	0.009	0.007
Weaning weight (kg)	30.2	27.5	0.973	0.008

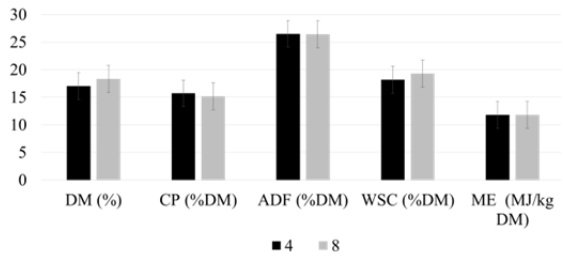

Figure 1 Grass quality parameters in spring

Conclusion Preliminary data indicates that lamb performance was higher on the 4-paddock system compared to the 8-paddock rotational grazing system.

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Malaysian and UK veterinarians' knowledge and attitudes towards cat pain

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Application Correct management and understanding of animal pain is essential for maintaining good animal welfare in a veterinary practice.

Introduction The assessment and treatment of animal pain is a complex issue, which can be greatly affected by the country in which assessment and treatment are taking place in. There are differences due to historical curricula, cultures and attitudes (Lascelles B.D.X. *et al.,* 1999) (Kongara K. *et al.,* 2016). Individual animal treatment may therefore differ across countries not necessarily because of clinical reasons, but because of a lack of education, and an animal's welfare may suffer as a result. This study explores the differences between Malaysian and UK veterinarians in treating cat pain.

Material and methods This paper discusses the current attitude towards, and knowledge of cat pain assessment and management by UK and Malaysian veterinarians. The study was approved by ethical review boards in both UK and Malaysia and was piloted in both countries. SurveyMonkey® was used to develop a 27-question survey, and collect responses from the UK and Malaysia. The survey was available for 12-weeks both in the UK and Malaysia during 2017.

Results Of 204 UK respondents, 171(83.4%) successfully completed the survey, whereas out of a total of 342 Malaysian respondents, 263 completed the survey (77.7%). Both countries showed strong agreement for 'Cats experience pain like humans do'. However, there were some geographical differences between respondents. For example, UK veterinarians agreed that they had adequate knowledge ($W = 13187$, $p < 0.001$, $r = .37$) and training ($W = 13067$, $p < 0.001$, $r = .37$) in pain management. Whereas most Malaysian respondents only partially agreed with this. There was also a significant difference in the way they assess cat pain ($W = 19408$, $p = 0.02$, $r = .11$). Most of UK veterinarians chose 'Mostly behavioural, some physiological parameters' and for Malaysia, they preferred 'Equally physiological and behavioural parameters' to assess cat pain. The way in which UK respondents rated the intensity of pain of the two approaches of ovariohysterectomy (OHE) differed a) midline approach rated as severe pain (score 8-10) (50%) and b) flank approach as moderate pain (score 4-7) (51%). In contrast, Malaysian respondents judged both approaches of OHE as moderate pain (a) 59% and b) 56%). Another difference was shown in the decisions made about pain management. For example, the majority of UK veterinarians' decision to provide analgesia for cat patients had a strong contribution/influence from veterinary and veterinary nurse colleagues (70%). In contrast, Malaysian veterinarians were mostly the sole decision maker about providing analgesia for cat patients (71%) and fewer required veterinary colleagues or veterinary assistants to contribute to their decision (28%).

Conclusion Veterinarians in both countries have a strong concern for the welfare of cats in pain. However, we can see that veterinarians in Malaysia have a lower level of confidence in recognising and managing pain in cats. As such this suggests that educational materials targeted towards Malaysian veterinary professionals would help to upskill veterinarians in the area of cat pain.

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Relationships between the application of readily available nitrogen, and ammonia and ammonium concentrations measured by a National Ammonium Measurement Network sampler on the AFBI farm

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Application Relationships between organic nitrogen (N) applications and ammonia (but not ammonium) concentrations measured on the AFBI farm were significant but R^2s were too low for ammonia concentration to be predicted.

Introduction Ammonia emissions from the livestock sector are a cause of concern within Northern Ireland (NI), with a significant proportion of these emissions derived from the application of organic manures to agricultural land. This study was conducted to examine if a relationship could be identified between ammonia and ammonium concentrations recorded at a sampler located on the research farm of the Agri-Food and Biosciences Institute (AFBI) at Hillsborough in NI, and applications of readily available nitrogen (RAN) in organic manures within the farm boundary.

Material and methods The National Ammonia Measurement Network (NAMN) has three sites in NI, one of which is located near the north-west boundary of the AFBI farm. At this site gaseous ammonia deposition is sampled via a diffusion denuder tube in the sampler, while particulate ammonium is sampled on a filter within the tube. The tube and filter are replaced monthly, approximately, and the amount of accumulated particulate ammonium and captured gaseous ammonia, expressed as µg/m^3, is determined by the Centre for Ecology and Hydrology at Lancaster. Data relating to monthly ammonia deposition (1997 – 2016) and ammonium concentrations (1999-2016) were available for the sampler on the AFBI farm. The AFBI farm comprises approx. 178 ha of predominantly grassland and 181 ha of forest. The farm currently has a dairy herd (approx. 340 cows, plus young stock), a beef herd (approx. 460 animals, including 110 suckler cows and their calves), a sheep flock (approx. 240 breeding ewes plus lambs), and a 150 sow pig herd, with all progeny reared to slaughter. Organic manures produced from these livestock enterprises are stored in a number of underground and above ground slurry tanks and stores, before being applied to grassland (both owned and rented) using both splash plate and trailing-shoe type systems. Records of applications of organic manures (date, type, application rate and method) within the AFBI farm boundary were available from 1997 onwards. Quantities of RAN in the organic manures applied were calculated from published values (2.5, 1.2, 0.9 and 0.3 kg/t fresh weight, for pig slurry, cattle slurry, farmyard manure and dirty water, respectively), and used to calculate monthly loadings of RAN to the four fields (total, 31 ha) closest to the sampler (within 500 m) and to all fields on the farm (including fields up to 1.3 km away). Relationships between total monthly applications of RAN (to the four fields closest to the sampler, and to all fields on the farm), and ammonia and ammonium concentrations recorded by the sampler for the corresponding month, were examined using trend lines in Microsoft Excel 2013.

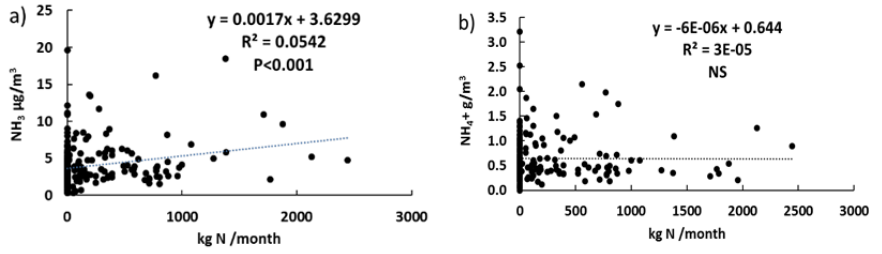

Figure 1 Relationships between concentration of a) gaseous ammonia and b) particulate ammonium, and loading of readily available organic N to the four fields closest to the NAMN sampler

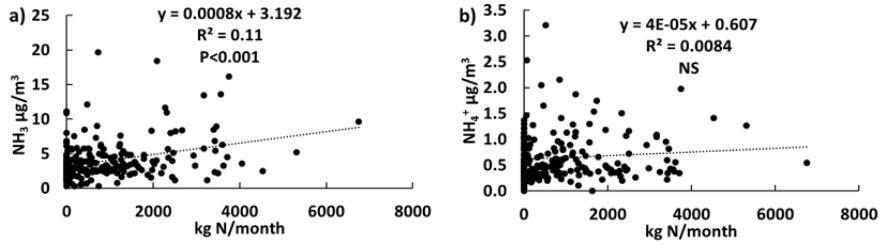

Figure 2 Relationships between concentration of a) gaseous ammonia and b) particulate ammonium, and total loading of readily available organic N to all of the fields within the farm boundary

Results The relationships between mean monthly ammonia concentrations and RAN applied in organic manures to fields close to the sampler were significant, but had low R^2s (Figure 1a: $R^2 = 0.054$, $P<0.001$); Figure 2a: $R^2 = 0.11$, $P<0.001$). The poor predictive relationships (low R^2s) are likely to be due to the prevailing wind direction being from the sampler towards the farm, and the low resolution of sampling (accumulated concentration over each month). Relationships between measured ammonium concentrations and applications of RAN were not significant ($P>0.05$).

Conclusion Significant but poor predictive relationships were identified between applications of readily available N in organic manures, and ammonia concentrations recorded on the AFBI farm.

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Effect of weaning age on growth performance of dairy heifer calves

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Application This study will help the dairy industry to find the ideal weaning age so that growth of the calf is optimised as results showed that weaning at 12 weeks of age compared to 8 weeks resulted in heavier heifers in the post-weaning period.

Introduction Early transition from milk to solid feed is considered an important economic objective for dairy farmers, however increased milk consumption as a result of delayed weaning can also benefit the production potential of the calf (Bjorklund *et al*., 2013). The hypothesis of the present study was that Holstein Friesian (HF) and Jersey (JE) dairy heifer calves weaned at 12 weeks would be heavier than those weaned at 8 weeks.

Material and methods This experiment was undertaken at the Teagasc Dairygold Research Farm, Fermoy, Co. Cork. At birth, 98 heifer calves were balanced for breed (61 HF and 37 JE), birth weight (30.2 ± 6.9 kg) and birth date (10th February; ± 13.2 days). Once balanced, calves were randomly assigned to one of two pre-weaning treatments where they were weaned at either 8 (early; E) or 12 (late; L) weeks. Within an hour of birth, calves were fed 3 litres of high quality colostrum (refractometer reading >22%; Bielmann *et al*., 2010). Heifers were fed 6 litres/calf/day of transition milk for 3 days before milk replacer (MR; 26% crude protein) was offered at a rate of 6 litres/calf/day (reconstitution rate 15%). Heifers were grouped by age from 5 days old and offered water, *ad-libitum* concentrate and straw in group pens until gradual weaning at 8 or 12 weeks old. Heifers were weighed twice a month for the duration of the study (Tru-Test, Palmerston North, NZ). Weight gain was calculated as the increase in live-weight between weigh dates. Data were analysed using the mixed models procedure in SAS (v.9.4). Independent variables were age, treatment, breed and the interaction between treatment and breed. There was no evidence of an interaction between treatment and breed so the interaction was removed from the model.

Results In the pre-weaning period, E calves consumed 50.4 kg/calf of MR and L consumed 75.6 kg/calf. There was no effect of treatment up to week 8; calves were fed identical diets. The E calves were then gradually weaned off MR over 7 days; L remained on MR for 4 weeks. All calves had access to concentrates and roughage. In the MR feeding period L calves gained 0.58 kg/calf/day and E gained 0.36 kg/calf/day. When all calves had been weaned off MR in week 12, weights were significantly (P<0.05) different between L (80.6 ± 17.8 kg) and E (71.6 ± 15.8 kg). Therefore, the hypothesis is accepted. In week 13-16, both treatments gained 0.48 kg/calf/day. Breed significantly impacted weight (P <0.01). The JE calves were consistently lighter than HF; this is as a result of lower birth weights (JE 27.7 kg; HF 34.4 kg) and is reflected in the mature bodyweight of the JE cow.

Table 1 Pre-weaning and post-weaning liveweight gains across weaning groups and breed groups

	Weight (kg)					ADG (kg/calf/day)							
	12wks		8wks			12wks		8wks				Pr > F	
Day	HF	JE	HF	JE	SEM	HF	JE	HF	JE	SEM	Treat	Breed	Age
7	36.6	25.5	36.3	26.4	0.563	0.33	0.34	0.30	0.52	0.106	0.593	<0.001	0.001
21	41.7	30.2	41.2	30.9	0.669	0.36	0.35	0.36	0.37	0.043	0.928	<0.001	0.001
31	46.7	34.2	45.8	33.7	0.756	0.51	0.39	0.48	0.32	0.053	0.385	<0.001	<0.001
43	53.0	39.0	52.1	38.4	0.993	0.51	0.41	0.46	0.39	0.065	0.451	<0.001	<0.001
52	60.1	45.8	58.3	43.1	1.220	0.82	0.79	0.76	0.58	0.097	0.069	<0.001	<0.001
59	66.8	49.6	64.9	48.7	1.333	0.12	0.08	0.11	0.09	0.013	0.300	<0.001	<0.001
67	70.3	56.1	69.6	53.2	1.459	0.77	0.84	0.58	0.47	0.108	0.230	<0.001	<0.001
76	80.2	61.3	76.4	58.3	1.657	0.87	0.53	0.97	0.63	0.156	0.045	<0.001	<0.001
88	90.2	71.1	81.9	61.4	1.879	1.23	1.19	0.78	0.55	0.144	0.001	<0.001	0.001
107	103.5	79.7	95.2	70.2	2.292	0.62	0.42	0.59	0.28	0.059	0.003	<0.001	0.001
123	113.6	86.9	107.4	80.0	2.102	0.55	0.31	0.66	0.48	0.070	0.026	<0.001	<0.001

Conclusion There was no effect of treatment on liveweight up to week 8. The additional milk replacer consumed by L calves from week 8-12 resulted in a significant weight advantage, however differences existed between breeds. In the post-weaning period from 12-16 weeks ADG was similar between treatments.

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Effect of supplemental inorganic or chelated blends of copper, zinc and manganese on broiler chickens' performance

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Application Trace minerals are characterised as essential nutrients that play vital roles in growth performance of broiler chickens.

Introduction Trace minerals, such as Zn, Cu, and Mn, are required to ensure good health and optimum performance of the birds. They function as enzyme cofactors and are also constituents of metalloenzymes. Zinc plays a prominent role in the synthesis of keratin and collagen, copper helps in cross-linking collagen and elastin, while manganese is essential for the maintenance of bone mineralization (Manangi *et al*., 2012). Chelated trace minerals as amino acids ligand protects the essential trace minerals from other dietary minerals that are chemically reactive in gastrointestinal tract. This ensures absolute absorption without any interference by other minerals (Abdallah *et al*., 2009; Ao *et al*., 2009). The present study aimed at evaluating the effect of chelated trace minerals on growth performance of the broiler chickens.

Material and methods A 42-day feeding trial was conducted with 300 Arbor Acre (AA) broiler chickens. The experimental birds were reared in a battery cage system. The birds were allocated to 5 dietary groups. Individual dietary group was replicated 6 times with 10 birds each. The dietary groups were control (basal diet), 100% inorganic trace minerals (ITMs) supplemental level (15, 100, 100 mg/kg for Cu, Zn, Mn respectively), 50% ITMs supplemental level (7.5, 50, 50 mg/kg for Cu, Zn, Mn respectively), 50% Chelated trace minerals (CTMs) supplemental level (7.5, 50, 50 mg/kg for Cu, Zn, Mn respectively) and 25% CTMs supplemental level (3.75, 25, 25 mg/kg for Cu, Zn, Mn respectively). The birds were weighed at the beginning and the end of the experiment. The records of feed intake, body weight and feed conversion ratio were taken on a weekly basis. The experiment was arranged in a Completely Randomised Design. Data collected were subjected to one – way Analysis of Variance using SAS (2007) and significant (P<0.05) means were compared using Tukey test of the same software.

Results The groups fed diets supplemented with 100% ITM and 50% CTM had higher (P<0.05) final body weight and daily weight gain than the control, 50% ITM and 25% CTM which had similar (P>0.05) values but the daily feed intake was significantly higher for the group fed 100% ITM supplemental level. Birds that received diet supplemented with 50% CTM had better (P<0.05) feed conversion ratio between 0 and 42 days of the experiment.

Table 1 Effect of inorganic and chelated trace minerals on growth performance of experimental broiler chickens (42 days)

Parameters	Control	ITM		CTM		SEM	*P*-value
		100%	50%	50%	25%		
Initial Body Weight (g/bird)	40.18	40.20	40.22	40.24	40.01	0.04	0.31
Final Body Weight (g/bird)	1875.17^{b}	2151.83^{a}	1963.33^{b}	2127.67^{a}	1993.00^{b}	23.47	0.00
Daily Feed Intake (g/bird/day)	95.65^{b}	103.32^{a}	93.61^{b}	95.99^{b}	92.99^{b}	0.92	0.00
Daily Weight Gain (g/bird/day)	43.69^{b}	50.28^{a}	45.79^{b}	49.70^{a}	46.50^{b}	0.56	0.00
Feed Conversion Ratio	2.19^{a}	2.06^{ab}	2.05^{ab}	1.93^{b}	2.00^{b}	0.02	0.00

Conclusion The study showed that supplementation of both chelated and inorganic Cu, Zn and Mn improved growth performance of broiler chickens. The use of chelated trace minerals at lower supplemental level (50%) in diets of broiler chickens had no detrimental effect on the growth performance of the birds.

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A retrospective study: behavioural changes pre- Equine Grass Sickness diagnosis

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Application Equine Grass Sickness (EGS) is often misdiagnosed in the early stages. Knowledge of any common pre-onset behavioural changes may be beneficial to veterinary surgeons to hasten accurate diagnosis and inform appropriate welfare friendly decisions for treatment or euthanasia.

Introduction With the cause of equine grass (EGS) still unknown, the lack of understanding of what owners should be looking for when horses present certain symptoms or changes which could be related to EGS is an area which even veterinary surgeons struggle with. Much of the evidence supports the theory that the horse ingests a neuro toxin which is in the soil with Clostridium Botulinum being the main focus of current theories. The aim of this study was to identify any changes and commonality in horse behaviour prior to EGS diagnosis. If indicative behaviours could be identified these could provide a clearer picture for owners and veterinary surgeons, allowing the possibility of more rapid diagnosis and better treatment. Milne and McGorum (2006) highlighted that areas such as the West Coast of Scotland have a higher prevalence with more cases occurring between April and July with a peak in May, so any early behavioural changes would be of particular use in these areas. The clinical signs of EGS include colic, patchy sweating, salivation, rhinitis sicca, tachycardia ptosis, weight loss, and loss of interest in food (Wylie & Proudman., 2009), all of which can lead to initial difficulties in obtaining an accurate diagnosis. Taking into consideration other factors surrounding the horse, such as subtle behaviour changes, could aid a swifter diagnosis and intervention. With current research focusing on determining a cause, finding a possible cure and preventative measures through vaccinations (Ireland *et al*., 2016), further knowledge of any behavioural changes in the weeks prior to diagnosis may prove invaluable. This study aimed to understand the behavioural changes within horses from four weeks leading up to diagnosis of EGS with surrounding factors of the horse taken into account.

Material and methods An online survey was publicised via Social Media and The Equine Grass Sickness Fund within the United Kingdom. The questionnaire asked for information from four weeks prior and up to diagnosis and consisted of 32 questions, both open and closed. Participants were required to have first-hand experience of the management of a horse with a confirmed EGS diagnosis. The participants were asked to supply details including; horse gender, breed, age, changes in behaviour, environment, management, changes in ridden behaviour, eating habits, work load, when diagnosis took place, whether other horses had suffered from EGS previously within the same establishment and whether there were any other cases at the same time. Participants were encouraged to include any other information which they felt may be relevant, to allow for the collection of data that may not have occurred to the primary researcher. Due to the personal nature of this study the results had to be carefully assessed for any bias or individual opinions which may not be relevant, 12 questionnaires were discarded in total.

Results From the 68 respondents, 46% (n=31) were from England, 28% (n=20) in Scotland and 2% (n=1) from Guernsey. When location was further assessed to county level, most counties had one case within each area; however, 6% (n=4) cases were in Ross-shire, 4% (n=3) in Aberdeenshire and 3% (n=2) in Merseyside. From these respondents 34% (n=23) of cases were assigned to the acute category and 12% (n=8) sub-acute cases and all were euthanized or died, only one reported case within the acute and sub-acute recovered. Within reported Chronic cases 10% (n=7) were euthanized with the survival rate being 25% (n=17). When assessing behavioural and temperament responses Chi Squared tests showed a significant reporting of changes prior to diagnosis ($\chi 2$ (2) = 30.5588, $P < 0.001$); 69% (n=40) of cases reported behavioural changes in the week leading up to diagnosis with 27% (n=25) also reporting that temperament changes occurred in the same time frame and 44% (n=23) observing both behaviour and temperament changes. There were, however, no common behaviours reported over the sample as a whole. Of the respondents, 4% (n=3) reported that their horse had been traumatized before a diagnosis, for example changes in their routine or changes within their environment (new horses). However, 4% (n=3) also reported that there were no behavioural or temperament changes or signs before diagnosis took place.

Conclusion Although this study did not show clear, indicative behaviours prior to EGS diagnosis, general changes to the behaviour or temperament of many horses were reported and possible areas for further investigation were identified. As behaviour changes and differences in temperament were observed in many cases further investigation of horse behaviour prior to diagnosis is warranted. A more wide-ranging study may, in future, quantify specific and identifiable behavioural and temperament changes which could enable owners in susceptible areas to maintain a better level of vigilance, leading to timely intervention and ultimately providing the best care and welfare for the affected horse.

Acknowledgements Thanks to all respondents who completed the questionnaire recalling a difficult experience and to the Equine Grass Sickness Fund for publicising the survey.

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Equine parasite management practices

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Application Diagnostic testing for parasites is recommended to determine the requirement for anthelmintic treatment in horses to help reduce the development of drug resistance. Despite such recommendations, owners continue to routinely administer such treatments. Veterinary advice is a key avenue for disseminating such advice although it is essential that it is up to date and correct.

Introduction Parasite control methods most commonly used for horses are based on concepts that are now over 40 years old. It is still common for veterinarians to recommend routine anthelmintic treatment, despite concerns over anthelmintic resistance and published parasite control guidelines by the American Association of Equine Practitioners (2013) recommending diagnostic testing before treatment. Diagnostic testing reduces the amount of anthelmintic treatment used, yet still achieves reduced parasite eggs shedding (Kaplan and Nielsen, 2010). This study determined how horse owners manage parasite burdens and the sources of information used to guide their decisions.

Material and methods Twenty-two closed questions were formulated on SurveyMonkey© to gather information from horse owners on parasite management practices for their horses. A pilot survey was undertaken to ensure there were no issues. The survey was launched on social media platforms in December 2017. There were 116 respondents. Descriptive statistics were performed.

Results Any respondent that was not personally responsible for the management of parasite burdens in horses was disregarded from the study, leaving the total number of respondents at 85. Ninety-four percent of respondents were female. Sixty-two percent were from the Republic of Ireland, 33% from Northern Ireland, 2% from England and 2% from Scotland. Fifty percent fell in to the 20-29 age category.
A positive result was that 79% of respondents knew what the term anthelmintic resistance meant for their horses. In contrast, 71% of respondents said they had never performed a faecal egg count test (n=60), and when asked why, the most common reason was lack of information on the subject, despite 67% (n=57) of respondents obtaining their information from veterinarians.
The most common method of parasite management was interval dosing, every three months, closely followed by dosing every six months. The greatest motivation for change was veterinary advice, and concerns over anthelmintic resistance (Table 1)

Table 1 Motivation for change of parasite management practices

Motivation for change	No. of respondents
Reduced cost	27
Concern over resistance	49
New yard practices	13
Veterinary advice	53

Conclusion Despite published guidelines by AAEP (2013) recommending diagnostic testing, this survey shows the most common practice used for management of parasite burdens amongst horse owners was still routine treatment. An encouraging results was that if horse owners knew the management practices they were using were leading to the development of anthelmintic resistance, they would change their management practices.
Out of the respondents that obtained their information from vets, 21 respondents said they wormed every 6 months and the same number of respondents said they wormed every 3 months. This form of management, more commonly known as routine treatment, has been associated with the development of anthelmintic resistance (Kaplan and Nielsen, 2010). These results indicate that veterinarians may not be giving horse owner's up to date information on recommended parasite control practices. This may be due to the fact that horse owners are not using specialised vets. Educating owners and vets on appropriate parasite control methods could be the missing link to ensuring correct information reaches horse owners.

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Equine end of life (EEoL): from a veterinary professional's perspective

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Application As the equine industry grows, innovations in veterinary medicine make it more achievable for horses to live well into old age. Euthanasia is a subject that is not often talked about, yet it is an inevitable situation that many will have to face.

Introduction Aim of study: from a professional and third-party view is there enough support and information given to horse owners before, during and after euthanasia, as well as if there is delay in equine euthanasia.
Equine euthanasia is an important subject, yet it is an aspect of horse care that is often not given a sufficient amount of consideration prior to the event. The primary purpose of euthanasia is to relieve suffering to that animal; the decision to action this option will be upon assessment of multiple factors (Stull, 2013). When owners are confronted with the decision of euthanasia they often feel guilty about making the decision to end the life of their horse, in some cases the decision to euthanize is clear cut but many cases it may be difficult, particularly with an older retired horse. Evidence shows that there are more and more owner's delaying euthanasia to allow time for human acceptance which in turn is compromising the horse's welfare. The loss of a horse can have a colossal effect on someone's life so it is no wonder that so many people delay euthanising their horse. Stull (2013) concluded that the guilt and grieving process for a horse owner after euthanasia is comparable to the loss of a long-term companion animal. Recognising and understanding the psychological response of an individual during euthanasia could potentially contribute to an effective support network (Stull 2013). Rohlf and Bennett (2005) investigated a form of post-traumatic stress disorder (PTSD) in professionals that took part in euthanasia. It concluded that PTSD was minimal, less than 15%, however the fact that it may occur questions the need for the employers to risk assess the staff's health as a result of working with euthanasia (Rohlf and Bennett 2005).

Material and methods Depth interviews (n=13) were conducted with equine veterinary professionals, the veterinarians varied in expertise from equine surgeons, interns, mixed practice and equine specialists' practices. The guided interviews took a maximum of 20 minutes each, areas of investigation were; delay in equine euthanasia; specific protocol for the veterinarian; advice given to the owner; appropriateness of information given; accessibility of owner information and finally exploring any support for both owners and veterinary professionals before, during and after equine euthanasia and its appropriateness. The data was transferred to Wordstat in verbatim; thematic and inductive content analysis was used to establish meaningful patterns within the data, which presented in higher and lower order themes. The data was then analysed using a distribution frequency of keywords in a 'Jaccard's Cofficient' dendrogram.

Results A common theme emerging throughout the interviews with veterinary professionals were the type of 'Ownership groups'; delaying equine euthanasia. The results demonstrated 85% (n=11) considered Leisure/Pleasure owners delayed euthanasia, however 15% (n=2) also rated racing owners/trainers potentially delay euthanasia due to the number of people they must legally get consent from prior to euthanasia. During the interview process veterinary professionals conveyed that there is a clear welfare concern due to owners delaying the decision to euthanize. It was highlighted by 30.7% (n=4) of respondent that owners need to recognise the signs of pain and quality of life (QoL) and that prolonging the process can be detrimental to the horse. This then led to investigations of how owners should be provided with more information regarding euthanasia and equine end of life. The opinions varied throughout the interviewing process; 77% (n=10) agreed that horse owners should be provided with more information surrounding euthanasia and equine end of life. However, only 69.2% (n=9) believed that it may make the process of electing for euthanasia easier for the owners. Furthermore, 30.7% (n=4) concurred that more accessible information needs to demonstrate how to recognise the level of pain and assessing QoL in the horse.

Conclusion Veterinary professionals stated in some euthanasia cases horse welfare had been compromised and the equid should have been euthanized much sooner. Acceptance from owners plays a pivotal role in delaying euthanasia and the veterinary professionals believed that owners were putting their own needs before those of the horse. Areas identified in this present study suggest information provided to owners should be based around recognition of pain and QoL, not simply euthanasia, as previous studies have stated (Bushell & Murray, 2015; Stull, 2013). To the authors' surprise evidence in this study showed that 77% (n=10) did not believe that owners having an equine end of life plan in place would make this decision easier and may further upset the owner, this area warrants further study to identify effective protocols to enhance equine welfare at end of life and ease the decision making process for a range of owners.

Acknowledgements This dissertation is one of the parallel projects carried out alongside the large collaborative EEoL project (Equine End of Life) and the results reported here cannot be taken to represent the overall findings. Any views or comments made in this dissertation cannot be taken as the views of the British Equestrian Federation, Advancing Equine Scientific Excellence, The Donkey Sanctuary, World Horse Welfare or anyone else involved in the project.

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Rohlf V and Bennett P 2005. Society & Animals: Social Scientific Studies of the Human Experience of Other Animals 13, 201–219. Equine is used to cover horses, ponies and donkeys.

Lipidaemic changes in pubertal boars fed Aidan (*Tetrapleura tetraptera*) pod pulp meal

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Application Aidan pod pulp meal could find useful application in controlling fat deposition in slaughter pigs but has to be applied with caution in the diet of boars selected for breeding purposes as it possesses the potentials for hypolipidaemia, which may interfere with male fertility.

Introduction Ban on application of pharmaceutical antibiotic growth promoters (AGPs) in food animal production has led researchers into exploring many potential alternatives. Promising candidates are the phytogenic additives. Plant-derived feed additives are known to possess a plethora of bioactive principles (phytochemicals), which gross and specific influences on systems of animals should be explored for scientifically informed decisions and recommendations for safe application. In the light of some long held conceptions about cholesterol and the current understanding of the importance of lipids to fertility and overall function of mammalian cells and their integrity (Tolbert, 2017; Teicholz, 2018), there is need to establish a link between potential lipidaemic changes occasioned by the phytoadditive-*Tetrapleura tetraptera*, and the implications on the fertility of male porcine subjects.

Material and methods Eighteen peri-pubertal boars of Large White x Duroc crossbreeds, aged 18 weeks, of 35.45kg average live weight, randomly assigned to three equal treatment groups, each replicated thrice in a completely randomised design, were used for the study. Dry pod pulp of Aidan was milled and added to a basal boar diet at 0.0%, 2.5% and 5.0%, respectively, corresponding to treatments 1 (control), 2 and 3. The boar basal diet was constituted by maize, groundnut meal, palm kernel meal, wheat offal, bone meal, oyster shell, vitamin/mineral pre-mix, methionine, lysine and table salt; and contained 16.03% crude protein and 11.79 MJ/kg of digestible energy. Routine and ethical management protocol were duly observed while the experiment lasted. At 30 weeks of age, the boars were slaughtered. Blood was collected into sample bottles without an anticoagulant. Sera were separated by centrifugation. Total lipids, triglycerides and high-density lipoprotein cholesterol were determined using the Randox commercial kit (Randox Co. UK.), while low-density and very low-density lipoprotein cholesterol were derived according to Friedwald *et al*. (1972).The dataset was subjected to analysis of variance according to Steel and Torrie (1980), using SPSS version 22.

Results Table 1 shows the serum lipid profile of the pubertal boars. There were changes in the parameters studied though without defined patterns in most of the parameters, that could be attributed to the level of the test ingredient. However, it could be observed that triglycerides were reduced ($P<0.05$) by application of the test ingredient. This seems to confirm the findings of Kuate *et al*. (2015), who observed hypolipidaemia in rats treated with hydro-ethanolic extract of Aidan pod pulp.

Table 1 Lipid profile of pubertal boars fed Aidan pod pulp meal

Parameter	0.0% APM	2.5% APM	5.0% APM	SEM
HDL cholesterol	50.79^{b}	79.74^{a}	52.19^{b}	4.72
LDL cholesterol	7.35^{a}	6.65^{ab}	7.57^{a}	0.30
VLDL cholesterol	28.49^{a}	26.46^{a}	25.47^{b}	0.46
Triglycerides	142.44^{a}	132.30^{b}	127.35^{b}	2.24
Total cholesterol	86.63^{b}	112.85^{a}	85.23^{b}	4.50

^{abc} Means on the same row with different superscripts are significantly different ($P<0.05$)

Conclusion Serum triglycerides of pubertal boars were reduced by addition of 2.5% and 5.0% of Aidan pod pulp meal. Reduced triglycerides could reposition pork as a meat of choice in climes where it is loathed due to much fat. Overweight in breeder boars could be stemmed in small-holder farms where natural mating is commonplace.

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A brief history

of the

BRITISH SOCIETY OF ANIMAL SCIENCE

1944 – 2019

75 years of improving the understanding of animal science

Colin Whittemore

for

bsas

british society of animal science

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This is an abridged version of the full-length document which may be found in the BSAS Archive. It is a fascinating and easily read account not merely of a Scientific Society, but of the personalities who made it. The Society was built upon the mantra that until a research finding is published, transferred to others and ultimately put to use for the benefit of food production and animal well-being, it has no purpose. The life of the British Society of Animal Science from 1944 to 2019 has been one committed to enabling the exchange of science amongst the membership. The Society has served well its members, the farm animals, and society at large, through the whole of the era of the second agricultural revolution.

Colin Whittemore, FRSE, Emeritus Professor of Agriculture at Edinburgh University, is an Honorary Member of the British Society of Animal Science and has been active in the work of the Society for fifty years.

The information contained herein has been sourced by the author, and its interpretation is that of the author.

Colin T Whittemore, FRSE, October 2018
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Dedication

BSAS is what it is because its members have volunteered for 75 years to work on its behalf. They should at least be properly thanked. I hope I may be forgiven for not mentioning them all by name. Maybe it will be enough that as I write of the Society's success, I write also of all of them.

I have been greatly helped in the preparation of the manuscript by those two stalwarts, Gerald Wiener and Mike Steele.

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1. Pioneers:
The backdrop to the Society's beginnings

Nineteen-forty-four, the year of the foundation of The British Society of Animal Production, and the early years that followed, were filled with urgent opportunity – these were the post-war hunger years and the beginnings of the second agricultural revolution. The time was ripe for research and development in Animal Science. Unsurprising then if that same time gave rise to pioneering people and pioneering places. In tracking the British Society of Animal Production (BSAP) first seventy-five years, it is neither possible, nor necessary to mention all and every path-maker involved in the moulding of the Society. The Universities and Research Institutes have been persistent in their support of the society, as have the Knowledge and Information Transfer Services, and perhaps most importantly of all the Trades and Industries that provide to the agricultural industry the wherewithal for its effective functioning.

White, and Ewart's inheritance

The core of the British Society of Animal Production's values had been laid down through the early nineteen hundreds by a Scot, Thomas Middleton. Hailing from the Black Isle, Middleton was successively a Lecturer in Agriculture at Aberystwyth, Professor of Agriculture at both Durham (Newcastle-upon-Tyne) and Cambridge (First Drapers Professor, despite the University considering Agriculture insufficiently academic a subject for undergraduate study), Ministry civil servant, and Chairman of the Agricultural Research Council. Middleton saw that Agriculture could only feed the British Nation if a three-part plan, fully government-funded, was carried through. First, there would need to be basic research to determine facts and bring forward new knowledge. As the seekers-after-truth were not likely to be best employed spreading the word to practical agriculturalists, or to the agricultural trades and industries, a technological arm should be formed. This would be the Advisory and Development function which would both demonstrate innovations in practice and travel the field proselytising. The last of Middleton's elements was Agricultural undergraduate and postgraduate education at University level. This was the same three-legged stool upon which the British Society of Animal Production was founded and upon which the British Society of Animal Science (BSAS) still sits. BSAP from the start was the forum where Researcher, Technologist, Industrialist, Practitioner and Teacher could gather to exchange ideas, aspirations, information, facts, differences, and (occasionally) knowledge.

How was it that The British Society of Animal Production originated out of *Edinburgh*? Why Edinburgh, when *Cambridge* was the obvious choice? Cambridge was the home of William Bateson, FRS. At Cambridge also were T B Wood (Second Drapers Professor of Agriculture), H E Woodman, and R E Evans, the pioneers of the quantification of nutrient requirements of animals, and, not least, John Hammond and Arthur Walton, reproductive biologists in the process of revolutionising animal breeding through artificial insemination, whilst striving for an understanding of reproduction and growth in farm animals. Their work would effectively *enable* the second livestock-farming revolution that took place after the Second World War.

The obvious did not occur because of a persistently persuasive Borders Scot; Cossar Ewart, a Penicuik carpenter's son. Ewart was an animal breeder by trade – an animal geneticist. It was genetics that would be the core of innovations in Animal Science in the mid nineteen-hundreds when BSAP was launched, and Animal Genetics by that time had gone up to Edinburgh. By 1944 the balance had shifted. The axis for bright young talent in Animal Science was no longer at Cambridge – it was at Edinburgh. How had that happened?

Ewart delivered three quite outstandingly original contributions to Animal Science. First, he believed that if student learning was to have practical utility it should be founded not in didactic teaching and artful theorising, but in practical observations and live classes in the science laboratory and in the field. Second, he was convinced that research into matters agricultural needed to be conducted at agricultural scale. He set up an animal research farm, unheard of at the time, capable of containing *populations* of animals (flocks, to be exact). The third of Ewart's priceless inheritances to Animal Science was that, inspirationally, he stole the march on Cambridge by setting up a Lectureship in Genetics in 1911 in Edinburgh's Zoology Department (of which he was by now the head). Cossar Ewart had the foresight to recognise the talent needed in the post and appointed not a zoologist, but a young mathematician with a penchant for statistics.

To seal into place Edinburgh's pre-eminence in matters animal genetical, Ewart then went (in 1913) to The (HM Government) Board of Agriculture in London and got them to set up a Special Committee at Edinburgh, under the joint responsibility of the University and the East of Scotland College of Agriculture. The purpose of this Committee would be to forward the use of animal genetics to increase the rate of British food production from farm animals. It was Ewart's master-stroke.

Progress stalled until after the Great European War. In 1919 the Special Committee supported at Edinburgh an Institute of Animal Breeding and a Chair of Animal Genetics to direct it; the first incumbent of which was Professor F A E Crew. In 1927 a new building went up at The King's Buildings (which because of its grand steps and entrance was affectionately called the 'Town Hall' and now called The Crew Building), and into it went the Institute of Animal Genetics. (The

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Lecturer in Genetics in 1928, it might be noted, was W.C. Miller, later to head up the Royal Veterinary College and become BSAP fourth President).

In parallel, the University set up the University Department of Genetics. No sooner had the Institute got up a head of steam than the Second World War intervened. It was decided (regrettably) that there should be clear division between the government-driven applied research and the University-driven basic research. C H Waddington was appointed to the University post in 1947 (a later Professor of Genetics, William (Bill) G Hill, would be The British Society of Animal Science's fifty-sixth President in 1999). On the 'other' side the Westminster government set up The National Animal Breeding and Genetics Research Organisation. The Agricultural Research Council instructed Professor R G White, then at Bangor University in North Wales to be the first Director of NABGRO (later ABRO) when it was formalised in 1943. White's ambitions were in Agricultural applications. He was clear on the matter of Genotype / Environment Interaction; better animals need better farmers, different production environments need animals of different types. White would become The British Society of Animal Production's second President (1945).

The tensions (usually virtuous, but by no means always) now created between the two parties in the Genetics Town Hall, have reverberated throughout the life of the British Society of Animal Science. The University academics with a dual teaching / research role and a bent toward fundamental research on the one side, and on the other, the Government funded researchers placed into dedicated research institutions charged with more directly putting food on the nation's table. It was White who established the ABRO field laboratories and farms.

The Second World War had depopulated the Institute of Genetics Building, which was now being refilled with floods of ambitious researchers and post-graduates. Amongst others, were Alan Robertson (BSAP twenty-fifth president, 1965, and Bill Hill's PhD supervisor) brought by Waddington from Coastal Command, and Squadron-leader Thomas Carter (to be head of The Poultry Research Centre which was established at The King's Buildings around the same time). Peter Wilson, the thirty-fourth (1977) President of BSAP, was there as a post-grad diploma student before becoming a research manager with the animal feed industry and later the Professor of Agriculture at Edinburgh University and Principal of the East of Scotland College of Agriculture.

Waddington's charismatic leadership attracted brilliant original thinkers intent upon what was to be the discipline of molecular biology, while White, as Director of ABRO, appointed a plethora of mathematical and reproductive biology talent. This was all crammed into the University's Institute of Animal Genetics building (The ABRO building was not built until 1964), and grand houses in the Edinburgh suburbs. The confusion of who did what, whose salary was paid by whom, and who was funding which project, would have been the downfall of anything other than an academic organisation (disorganisation) populated by bright minds with burning ambitions. Throughout the following years, through to the present time, there has been pretty much free movement of staff between Edinburgh University (Biology, Agriculture, Veterinary), The Edinburgh Research Organisations (PRC, HFRO, ABRO, Roslin), and the Agricultural College. This flux amongst so large and diverse a community has been a huge benefit to both scientists and industry, and bears testament to the advantages of a 'Centre of Excellence'.

White retired in 1950. H P Donald was appointed Director of NABRO in 1951. He was the Society's 30th President (1973). Donald brought with him his assistant – Gerald Wiener, in whose careful hands would lie the future of BSAP publications.

Hammond

Perhaps Sir (1960) John Hammond, FRS (1933) is an eccentric enigma that could only have been spawned by, and survived in, the University of Cambridge, England, as that academic institution existed in the years between the two world wars. John Hammond was a farmer's son, from a family of veterinary surgeons, and never forgot it. It was good fortune that one of his father's friends was T.B. Wood of the Cambridge Department of Agriculture, for that is how he got to enter University. He then joined the staff there which had included Thomas Middleton and F.H.A. Marshall (with whom he studied reproduction, and who, in 1943, he would succeed as Reader in Agricultural Physiology). After the Great European War (where he had distinguished himself) he returned to Cambridge. There he would stay until retiring in 1954.

His most memorable utterance was "*Science is not science until it is applied*" – very fitting for BSAP. This was not just about the need to put science to industrial use; for science not to become a self-serving end in its own right. It was also that science in theory – science in the laboratory – may not work out in the field – in practice. And if it did not work in the field, then it was not much use!

At first sight, it is not straightforward to grasp why John Hammond is considered to have been such a force in Animal Science in general and in the British Society of Animal Science in particular (which honours him twice yearly through the *Hammond Award* (for research excellence) and the *Hammond Lecture* (the leading invited lecture at the Winter Meetings). The first Hammond lecture was given by one of his students, C.P. McMeekan, in 1969, *Science and world animal production*. Hammond rarely published in BSAP's Journal, **ANIMAL PRODUCTION**, preferring his own home journal, The *Journal of Agricultural Science (Cambridge)*. His importance must surely be in his all-pervading influence on a very

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broad range of the animal sciences and animal scientists. He was also an ardent mingler – equally as ready to natter with scientists at conferences, with farmers at markets, or students in the laboratories. All his life he remained a hands-on researcher; ready to pick up a dissecting knife when the need arose. Hammond was never a professor, never a head of an academic school, never a research institute director. Hammond did experiments, worked with colleagues, encouraged post-graduate students, and got out into the world of practical animal farming.

Hammond arrived on the experimental scene at Cambridge at the right time. There was interest in growth and reproduction, but quantitatively very little understood. Hammond's incisive mind meant that he would design critical experiments and make the data talk to reveal the fundamental physiological truths of fertility (and its failure) and of growth (and its retardation through nutritional inadequacy). Those who he influenced when they worked with him at Cambridge are scattered throughout the life of BSAS.

M.M. Cooper

Mac Cooper (29th President) made his mark upon Animal Science not only through the application of his own wide-ranging portfolio of research, but through the persons that he appointed and encouraged, and the students that he nurtured at the Universities of Wye and of Newcastle-upon-Tyne.

Malcolm McGregor Cooper was born in New Zealand from a Scottish immigrant family (whilst at Oxford he played rugby for the Scottish National team). Bright at school (unlike his contemporary in BSAP affairs, and fellow agricultural revolutionary, Kenneth Blaxter), he studied at Massey Agricultural College (under C.P. McMeekan) from where he won, in 1934, a Rhodes Scholarship to take an agricultural post-graduate degree at Oxford. It is not apparent that Mac Cooper either enjoyed, or got much academic (or agricultural) benefit from his three years at Oxford. He however passed his graduate exams, failed to submit his doctorate, and played a lot of Rugby. His final report from Oxford seems to say that Mac Cooper was a good bloke of forceful character who would go far (in his own country of New Zealand, that is), but was "not naturally a very clever man".

Cooper went back to New Zealand to a post in the Department of Scientific and Industrial Research (DSIR) in Wellington. Mac Cooper did not much like his job, returning to Massey to teach and research. In 1943 he took leave of Massey to go to Egypt as part of the NZ Expeditionary force. Nineteen-forty-six finds Mac Cooper returned to Massey as Head of Dairy Husbandry. There was no Professorship there for him. Scott-Watson, Professor Rural Economy at Oxford thought that the new post of Professor of Agriculture at Wye (now part of University of London, having transmogrified from the South East Agricultural College) might be appropriate and fitting for both parties.

Professor M.M. Cooper took up his post in 1947. He insisted, as had Ewart, in teaching theory on the back of practice. The farms at Wye were the perfect medium. He was impatient and unsympathetic to Britain's farming ways which he saw as "Going off at half-cock". He wanted to see in practice all the available technologies; he espoused the very same philosophy of 'science applied in the service of agriculture' as did the founders of BSAP.

When Mac Cooper took the job of (permanent) Dean of the Faculty of Agriculture at King's College (in 1954) he would be master of his, and his faculty's, destiny. He would have 1300 acres at Nafferton and Cockle Park under his direct control and by the time he was through, separate Departments for *every* branch of agricultural science.

Professor Wheldon (his predecessor) had let things rather lapse at Newcastle. When Mac Cooper arrived, there was little research going on. Not much decent farming either; it had neither inspiration nor utility. Cooper found that the Faculty of Agriculture at King's College was, like its teaching and research programmes, in a dissolute mess. Charles Bosanquet (Vice-Chancellor), made his contribution to animal science, first by appointing Mac Cooper to his post, next by funding the construction of the much needed new research facilities, and third by moving agriculture out of its archaic (but beautiful) quarters in the Old Quad and into a brand-new eight-story glass slab monstrosity with green windows, but which held everybody together. Bosanquet gave his unstinting support of Mac Cooper. Mac Cooper had, by good fortune, fallen on his feet in exactly the right place at exactly the right time - which was typical of that age. In the 1950s agriculture was in receipt of substantial State supports, at both academic and industrial levels. It was a good time to be of pioneering spirit – a good time for a British Society of Animal Science to be launched.

David Armstrong (first BSAP Hammond award winner) was a natural appointment for Mac Cooper to make to lead the Faculty's Animal Biochemistry and Nutrition research. In no case did Mac Cooper appoint 'teachers' to lecture to his students. He insisted that University students should get their learning from those who knew about their subjects by their own first-hand experience of research and production. David Armstrong was the perfect example. Never a natural teacher, he excited his classes with tales of his exotic research. He led a post-graduate school which came to populate academic and industrial establishments with the next generation of quantitative nutritionists (such as John McCrea (Rowett, 62nd President), David Beever (Professor of Animal Science at Reading and first Director of the Centre for Dairy Research (CEDAR), Colin Whittemore (Professor of Agriculture at University of Edinburgh and 55th BSAS President). Armstrong had come from The Hannah when Blaxter moved to head up the Rowett Research Institute. Armstrong and Blaxter it was who had begun to break open the complex biochemistry of rumen nutrient utilisation. Their work would underpin cattle

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and sheep nutrition (still does). The experimental sheep in the basement of Mac Cooper's new building were a legend in their own time at Newcastle. That fact – that there was live acute experimentation going on in the same building as the lecture halls and offices – said everything about Mac Cooper's approach to his vocation.

Cooper dedicated Cockle Park Farm to research. He appointed a statistician to design and analyse Cockle Park's experiments, and then also Maurice Bichard (46th President), a quantitative geneticist with a love for mathematics of the Edinburgh (Douglas Falconer) variety. Maurice was allowed to combine University work with that of acting as a Consultant for The Pig Improvement Company, who he subsequently joined full time. Through Bichard, PIC became the largest pig breeding company the world has known, and through PIC the globe became populated with British-bred hybrid pigs.

Bill Smith, from the West of Scotland, had gone to Massey for a Post-grad year and was summoned by Mac to come back, do a part-time PhD, and join the staff as the lecturer in pig husbandry and manager of the pig research facility. Bill Smith was responsible for a large and influential national pig improvement programme. Bill managed his pig unit 'hands-on'. His willingness to 'pitch in' endeared him to the staff – even though his experimental programmes were most inconvenient. Bill Smith was a perfectionist, writing the most exact papers in the most economical of prose. His presentations to BSAP Winter Meetings were a master-class in the art. Simple, straightforward, rehearsed, intelligible, timed to be minute-perfect, and delivered in a slow loud clear Scots Ayrshire brogue projected to the last row of the audience.

Murray Black (BSAP's most faithful of servants) came as 'Assistant Farm Manager' to Cockle Park, but was actually employed to deliver into reality Mac Cooper and R.J. Thomas's programmes on clean-grazing, parasite control, and pasture management.

John Prescott (45th President) was appointed from Nottingham to cover the Dairy and Beef sides. Whilst at Newcastle, Prescott was involved with innovating cereal beef production, eighteen-month finishing, bull (and bred-heifer) beef. After a spell seconded to Argentina, Prescott went to Edinburgh where he headed up the East of Scotland College of Agriculture Animal Production Group before following Frank Elsley as Professor of Animal Production in the University of Edinburgh. Subsequently he was appointed Director of the Grassland Research Institute (GRI, Hurley), and finally ended up as Principal at Wye.

Mac Cooper made Newcastle pre-eminent. The place to go; transformed from laggard into leader. The beneficiaries were his staff, his students (including, John Craven (42nd President), David Leaver (53rd), Jeff Wood (57th), and very many others, and indeed the undergraduates who benefitted not just from the privilege of learning from a research-active and enthusiastic staff, but also from Mac's (note-less) lectures themselves. It was a given that Mac, his staff, and his postgraduate students would be BSAP members attending, and giving papers at, the BSAP Winter Meeting.

What must have been obvious (and frustrating) to Mac Cooper was that all the research being presented at the BSAP Winter Meetings and in the journal **ANIMAL PRODUCTION** was not being well enough applied in the UK livestock industry to the benefit of food production (viz Hammond!). The transfer of relevant research and development work into industry use was, to his mind, woefully ineffective.

Mac Cooper was elected President of BSAP for the 1972/73 year. He left Newcastle late in 1971 to work for the World Bank in Spain. He was an absentee President, much to the huge disappointment of all his very many disciples and admirers who had hoped that he would prepare the British Society of Animal Production for the last quarter of the century much as he had so admirably done for the University of Newcastle and UK Livestock Industry. He got back from his Spanish misadventure rather earlier than expected in 1975. Yesterday's man, he disappeared from the UK Animal scene.

Stephen Watson's legacy – The Edinburgh School of Agriculture

Edinburgh University established its Professorship in Agriculture (Britain's first) in 1790 (A chair subsequently held by BSAP's 3rd, 34th and 55th Presidents).

Robert Wallace came to the post in 1885 and was there till 1922. He created The Edinburgh School of Rural Economy where 'University' and 'College' level courses were provided in the same place by a combined staff. Robert Wallace served as both Professor of Agriculture and Rural Economy, and Principal of the East of Scotland College. He had two funding streams and two political networks; University and Government. This made Wallace both powerful and influential in the Edinburgh milieu. Why this mattered to BSAP was because half of the Special Committee which delivered genetics research and development to Edinburgh, and from which sprung the creation of BSAP, comprised Wallace's Organisations. It would be difficult to deny Wallace's influence in Animal Breeding affairs at Edinburgh.

The 1920s saw a division of Wallace's integrated empire with J.A. Scott Watson appointed to the University Professorship, while Ernest Shearer was brought to the post of College Principal. Scott Watson went on to the Sibthorpian Professorship at Oxford (1925-1944). In his Presidential year at BSAP he had been appointed Head of the Ministry's National Agricultural Advisory services. Scott Watson's academic background at Edinburgh and Oxford framed the ethos of the

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Advisory Services in presenting their advice on the back of evidence and the realistic demonstration of research into applied practice at farm level. NAAS was not just to be involved in passing on best farming practice, it was to be itself an initiator and driver of innovative change. As such, the Members of NAAS and its successor the Agricultural Development and Advisory Service (ADAS), together with these organisation's numerous and generously endowed Experimental Husbandry Farms, were natural members of BSAP. The Ministry-backed advisory organisations had substantial input into the society's development in its first fifty years.

With Scott Watson's departure, Shearer added the mantle of the Professorship to his post of Principal, and the organisations were once more combined under one physical and administrative structure, but with (the magical) two funding streams (University and Department of Agriculture for Scotland). This was what Stephen Watson inherited in 1944.

Stephen J. Watson had joined the staff at Imperial Chemical Industries's Jealott's Hill Research Station in 1927, rising to Head of Animal Nutrition and Research. At Edinburgh, his contribution to Animal Science was through the changes and expansions he achieved in infrastructure which allowed a vibrant animal research environment, and through his unstinting encouragement of his young staff. Stephen Watson's crowning glory was to have built for his new and greatly expanded School of Agriculture a single dedicated building on the University Science Campus at The King's buildings – close by The Institute of Genetics, The Animal Breeding Research Organisation, The Poultry Research Centre, and the Department of Forestry and Natural Resources. Stephen Watson guided the hands of the architects at every office, laboratory, engineering space, veterinary post-mortem room, canteen, lecture hall, seminar room, library, greenhouse, stair, door and architrave. It was to be *his* building. It was opened in 1960. It is not evident why Watson's triumph should now function under the name of 'The Peter Wilson' building. I am sure it would not have been Peter's choice.

Stephen Watson cemented the University Department of Agriculture and the East of Scotland College of Agriculture into *The Edinburgh School of Agriculture.* He began the drive that would place applied research at the core of both student teaching and county advisory work. He was happy to see University or College staff doing either or all of the three functions, distributing tasks according to individual talent rather than structures. Amongst others, Stephen Watson appointed to his team J.M.M. (Ian) Cunningham. Ian established the experimental sheep flocks and the pig research unit at Boghall and Easter Howgate, before being promoted to head up the Hill Farming Research Organisation and then becoming Principal of the West of Scotland Agricultural College. He was BSAP's 35th President. Around the same time, Watson appointed K.V. Runcie (who managed the herd for dairy research on the University's farm at Langhill in 1953), and of course, McDonald, Edwards and Greenhalgh (54th President).

Stephen Watson it was who, with J.A. More, established at the Bush Estates a Centre of European Livestock research of unparalleled excellence. The University Department of Agriculture and the College of Agriculture would share the Bush with all the other agriculturally related organisations at Edinburgh, including (of interest to BSAP), ABRO (Roslin), the Poultry Research Centre (PRC), The Royal (Dick) Veterinary School, The Moredun (Animal Diseases Research Association), and the Hill Farming Research Organisation (HFRO), under the title *The Edinburgh Centre of Rural Economy*. Sadly, Bush House, a magnificent and dignified edifice and grounds at the centre of the Estate, was, on Peter Wilson's and Quintin Brown's watch, sold-off in a moment of utter madness.

By his facilitation of the research and development work of so many animal science organisations at Edinburgh, it is impossible to overestimate Watson's and More's contribution to British Livestock science and to BSAP/BSAS. The number of Presidents, Committee members, Hammond Prize winners, servants of the Society and givers of papers – plenary, ordinary and short – that have emanated from the Edinburgh School of Agriculture and the other institutions of the Edinburgh Centre at Bush and Roslin defies any attempt at their counting. Sir Stephen Watson retired from Edinburgh early in 1969, to be succeeded by Noel Robertson. Noel, the nicest of men, but being a plant pathologist had no particular understanding of animals. He did however see, correctly, that a Professorship in Animal Production would sort that nicely. He appointed Frank Elsley, who had done his post-graduate work at Leeds, and then gone with Vernon Fowler to the Rowett to work under Kenneth Blaxter. Unfortunately for Noel, Ian Cunningham (sheep and pigs) was in line for the Director of The Hill Farming Research Organisation, and Ken Runcie (dairy and beef) was moved to head the new Advisory and Development Department. Noel sought the advice of the best known agriculturalist around, Professor Malcolm McGregor Cooper next door at Newcastle upon Tyne. Charlie Hinks, one of John Prescott's PhD students, was dispatched north to cover for beef, while Colin Whittemore arrived in Edinburgh simultaneously with Frank Elsley. Noel Robertson gave them both their heads. The same year Murray Black (BSAS Secretary / Treasurer 1981-2000, 52nd President), Mac Cooper's assistant at Cockle Park, came back from managing the An Foras Taluntais experimental farms in Ireland to be Farm's Director with overall responsibilities at Bush for both commercial and field research operations.

Noel Robertson retired in 1984 and Peter Wilson, following his spell at Unilever's Colworth House, was invited to the last shared appointment of Professor and Principal, and while in that post he oversaw the dissolution of The Edinburgh School of Agriculture.

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Pioneers have, by definition, a blank canvass upon which to paint. BSAP was a pioneering organisation. The mid 1900s were a time of demand for food and a time of developing technologies to provide it – the need and the means. The second Agricultural revolution was about to happen and the pioneers rode that wave. Above all there was both will and money coming from Government.

That it was relatively easy for Hammond and the Edinburgh and Cambridge communities to launch BSAP in 1944 does not detract from the credit due to them for seeing and seizing the opportunity. Mac Cooper had funds at his disposal to deliver a wake-up call to Britain's livestock farmers and grazers, but he used them wisely and sent out from Newcastle a generation of science excellence; as did White, Hugh Donald, Stephen Watson and Noel Robertson from Edinburgh.

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2. Winter Meetings: Proceedings of the British Society of Animal Production (1944-95) and the British Society of Animal Science (1996-2019)

In the minds of many members of BSAP (and BSAS) the work and worth of the Society lies in its organisation of scientific and technological meetings. By far the most important of these was (is) the Winter Meeting (now, Annual Meeting) at which the animal science of the day is exchanged amongst the Society's members. These meetings are reported in the Society's 'Proceedings'. The **Proceedings** are a bellwether for what the BSAP and BSAS has mostly done over its first 75 years. This is therefore the most substantive chapter in the story of BSAS.

In 1939, a European Association of Animal Breeding (sic) was proposed in Zurich. The timing was not auspicious. Later that year John Hammond was way-laid at a genetics conference in Edinburgh by J.E. Nichols (then at the Institute of Genetics). It was highly likely that what was originally in the minds of Nichols and Hammond was a *British Society of Animal Breeding*; following the planned European model. This indeed was well reflected in the predominance of breeding topics in the early years. Also germane are the implications: Breeding (not genetics), Production (not science) – *The Society was to be about Applications*. Nichols persuaded Hammond of the notion that there should be a British Society comprising about one third University and Research Institute researchers and teachers, one third ministry and trade advisors and consultants, and one third farmers. The idea was kept warm through the war until 1944 by J.E. Nichols, J. Hammond, R.G. White, H.R. Davidson, W.C. Miller and E.C.J. Allday. In 1943 it was Nichols (now looking after the Imperial Bureau of Animal Breeding and Genetics at The King's Buildings, Edinburgh), who put his shoulder to the wheel by setting up the first meeting in London and sending invitations to all those he thought fit to attend.

The Inaugural meeting of the British Society of Animal Production was held on 6th January, 1944 at The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, with Dr John Hammond FRS in the chair. John Hammond, invariably lauded as the Society's first President was not in fact so. He was the Chairman of the first meeting. He only became named as President retrospectively after he had stood down from the Chair and White was elected the second President under the constitution which was implemented that year. There were present at Keppel Street eighty-seven individuals who were duly accorded membership of the British Society of Animal Production. (i.e. they were the founding members). The meeting discussed '*Cattle Breeding Policies*'. The intent is clear. BSAP is about taking the best of current science and placing it into the context of application to improve productivity.

Later that same year the Society met again at The London School of Hygiene and Tropical Medicine on 24th and 25th October in a joint meeting with the Institute for the Study of Animal Behaviour. This second meeting continued the theme of '*Science in the service of production*' with papers from White, Hammond, Wallace and Edwards. There is a strong element of the need to bring together academe with the ways and needs of the farming community, and to understand how 'animal behaviour' relates to farm-level 'animal husbandry'.

By the end of the first year it was evident that the meetings of the society were (a) addressed by the leading luminaries of the day, (b) were popular and well attended, and (c) were generating information of such quality that it was deserving of wider dissemination. Further, now that the Society was extant, it would need to have its scientific activities formally recorded in the form of a publication – A '*Report of Proceedings'*. Thus began '**Proceedings of the British Society of Animal Production**'.

The **Proceedings** from 1944 through 1958 are held in five volumes, each of 100-150 pages packed with learned and lengthy expositions; worthy even yet of a reader's consideration.

The third meeting was on 21st February 1945 addressing the general topic of '*Meat'*. The Society now has a named 'Vice-President' who will succeed to the Chair. Thus is born the annuality of the Presidency. The fourth meeting was in the summer of 1945, with the 'General Topic' of '*British Pig Production*'. Unlike the first three meetings, this was at the University of Reading. In the afternoon, members are treated to a *Visit to the National Institute for Research in Dairying*, where they will doubtless have been entertained by Phil (Raphael) Braude, whose *forte* was investigating best practices for feeding pigs.

The Society is beginning to gain confidence in itself and spread its wings. The fifth meeting (February 1946), has an extended format. On the first day, '*Breeding methods in livestock improvement*', and on the second '*Artificial Insemination*'. The extensive papers presented are published in full in the **Proceedings** and are from six to twenty-six pages in length. The published proceedings are effectively the transactions of a learned society and comprise research reports in their own right. The **Proceedings of The British Society of Animal Production** had now become a *bona fide* medium for the publication of science.

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The Summer Meeting of August 1946 deals with '*The collection, interpretation and use of milk and butterfat records*'. The Winter Meeting of 1947 quite specifically deals with the '*Genetics of inbreeding'*, while there is also arranged a Summer Meeting which this time is held jointly with the British Grassland Society at Aberystwyth and focusses on *'Improvement of hill grasslands'*. The theme of '*Animals and grass'* (with a paper from S.J. Watson) continues in the 1948 Winter Meeting.

By 1950, the BSAP has settled into something of a routine. The Winter Meetings tend to be 'indoors events' for the exchanging of new science amongst research workers & teachers, and exploring the means whereby animal science can be usefully applied to the benefit of livestock farmers. The audiences are mixed research workers and leading farmers. The Summer Meetings reverse this exchange as the members go 'outdoors' to visit and learn directly of farming's leading practices.

It has come to be realised that the published proceedings of the Society have a value in their own right to exchange knowledge widely amongst both the scientific and the farming communities. The **Proceedings of the British Society of Animal Production** (1950) has an Editor (I.L. Mason, Institute of Animal Genetics Edinburgh) and will be published formally annually.

Up to now, it has to be said, the subject of Animal Production at the scientific level ('*finding new knowledge by unbiased analysis of objective observation*') has been frequently interpreted as either animal improvement by the application of genetics, or as reproductive biology. At the technological level ('*using scientific evidence in the real world'*) the subject of animal production has largely been dealt with by descriptions of how recent advances in animal science research will, or already have, resulted in successful innovative farming systems. Surprisingly, so far there has been little on animal nutrition, despite the presences of Woodman and Evans, and the HMSO publication for MAFF in 1948 of the ground-breaking and hugely influential "Rations for Livestock". At this point in BSAP history 'Industry' is Primary Agriculture. The Allied Trades – i.e. the animal feed and health industries – have not yet been given a voice.

It is evident that in the early years *all* the 'scientific papers' are 'invited plenary contributions' from the top experts in the field – the University Professors, the heads of research teams, leading farmers. Equally significant is that these papers are formally opened for substantive discussion *amongst* the members in the audience. The discussion was as important as the paper, and elements of the papers were specifically intended to generate audience participation. There is no doubt that those taking the platform are those that are at the top of their respective game. The line-up for the 1953 meetings, for example, included; Alan Robertson, Geoffrey Sykes, J.W.B. King, I.A.M. Lucas, K.L. Blaxter, D.S. Soutar, H.P. Donald, W.P. Blount, J.P. Maule, H.R. Davidson, I.L. Mason. These, in modern parlance, were the giants of their day.

The practice of *all* papers being invited was relaxed after 1953 when the first day of Conference tended to be invited papers on a specific topic (as before), but the second day allowed for shorter volunteered papers. This was a *seminal* change in the Society's affairs. The pattern continued through to 1965.

By 1954 Gerald Wiener had joined Ian Mason as editor of the **Proceedings**. There were sixteen papers dealing with animal production systems, feeding pigs, and, of course, animal breed improvement. The content is something of a mixed bag, which has clearly defeated the editors who were unable to find any suitable general title for the meeting. The **Proceedings** would be entitled merely '*Papers on Animal Production*'. The 1955 **Proceedings** likewise included a catholic mix of papers across the range of animal science disciplines.

The *raison d'être* for the Winter Meeting was evolving. *Previously* the Executive Committee would identify a subject area (usually an animal production problem with an emerging animal science solution) that it would be timeous to have dealt with, and would then invite the notables of the day to deliver invited review papers. *Now* the Executive would come forward with topics not which so much fitted into a particular subject area, but rather which were scientifically *à la mode* – and invite the research leader to tell the members all about it. But importantly, at the same time, it was apparent that exciting research might perhaps be best presented by members of research teams (the 'lower orders') who were actually doing it. Two elements however remained firmly in place; (i) however exciting the research was, it had to be that which addressed industry production problems and (ii) the speakers were to be established experts in the field who could speak with authority. So it was that those with something to say would volunteer their services and come forward to the Winter Meeting to explain what they had done, share their ideas, open up their work for criticism by their peers and discuss with members the best directions for future work. And maybe also forward their findings for transfer into productive use within the industry.

By 1956 the (new) pattern of an eclectic mix of offered (rather than invited) papers at the Winter Meeting seems now to be set. One also begins to feel that something of the proselytising pioneering spirit of the original meetings has been replaced by exchange of scientific information amongst peers. The **Proceedings** now begin to have all the appearance of a learned journal, with the papers presented as research reports in the classic (and still used) form that would have a ring familiar to today's conference-goer, and quite different to that of the 1940s.

In 1959, the **Proceedings** of the Society's scientific meetings were no longer published separately as an independent record. In truth, the Winter Meeting had changed so much in its content and approach that the **Proceedings**, formerly containing erudite reviews, now incorporated matter more akin to a scientific research paper's abstract.

The proceedings had completed their evolution into medium for experimental reports.

At this point it had become apparent to Gerald Wiener that the material being published should be properly and more fully recounted through the medium of a proper 'Journal'. He took the idea to J.P. Maule (BSAP Secretary and prime-mover, whose office was next door in the Edinburgh building), who agreed readily, having already also noted that the enthusiasm of the research community for publishing papers exceeded that which could be presented at the Winter Meeting (and thereby published in the **BSAP Proceedings**).

No sooner therefore had the **Proceedings** become a recognised journal than it would be eclipsed! In 1958 BSAP laid its plans to launch the dedicated journal **ANIMAL PRODUCTION**. This journal, like its sister '*The American Journal of Animal Production*' would receive papers from the science community at large, would be independently refereed by peers, and which would be published to an international readership. The exercise would be wholly completed through the written word – no platform delivery or conference intercourse would be involved. The first issue of the journal **ANIMAL PRODUCTION**, containing papers written especially for it, appears in 1959.

Given the existence of the journal, there was now no need for the Winter Meeting to have its proceedings separately published. Thus, at the very moment of their zenith, the **Proceedings of the British Society of Animal Production** ceased. What had been the Society's iconic and sole statement of its existence as a gathering of scientists and technologists to exchange knowledge was (for the time being) suspended.

The presence of the Journal **ANIMAL PRODUCTION** had a dramatic effect upon the purpose and focus of the Winter Meeting. Results (and methodologies) of finished research programmes could be published in full in the Journal, together with a 'discussion' of the results made by the authors themselves. The 'finished article', as it were, was destined for the Journal. The Winter Meeting therefore could be a place for interim results from work in progress presented from the platform in shorter form.

All these things being so, the logical place for the publication of the abstracts of papers presented to the Winter Meeting (and of the Summer Meeting), was in the form of a few more pages added to the back of **ANIMAL PRODUCTION,** under the heading "**Proceedings of the nth meeting of the British Society of Animal Production … *Titles and Abstracts of papers presented.***" BSAP now had all its scientific activities (the journal and the reports of its two meetings every year) in one publication. A publication that the Society wholly owned, edited, published (with Oliver & Boyd), had printed and distributed.

The 1959 Winter Meeting started with a wide-ranging symposium '*Recent developments in Sheep Production*', comprising invited papers and erudite discussions. This was followed with a mixed bag of a score or so of '*Other papers on current research*'; one of which showed 'coloured slides'! These latter papers appear to have all been 'submitted' (rather than invited). The same pattern was used in the following year; a substantial symposium on '*Crossbreeding*', and a dozen papers of '*Current research*'.

The Society enters the sixties with a mixed mind as to what it is about. There are still a good number of 'farmer-relevant' papers being invited, but the balance is clearly shifting to the reporting of more reductionist, discipline-related, experimentation. There is movement toward interim reporting of on-going investigations; rather than of finished work ready for application.

It is not clear if the speakers on the platforms see themselves as talking to each other (as in a workshop), or to an audience expected to put what they are hearing to good use in farming applications, advisory messages, or teaching. This matter was germane as in England the sixties had seen the (misplaced) separation of the presumed purposes of the ARC Research Institutes (ground-breaking research), the Universities (teaching), and the Ministry-backed advisory services (instructional advice). Were the Winter Meetings to exchange ideas about science in progress or to transfer wrapped-up technological information? Even if there were any such discussions in the BSAP Executive, no clear policy was emerging. The membership however *was* changing. It was the membership, by their actions rather than their words, who were driving the agenda.

The BSAP home journal **ANIMAL PRODUCTION** had become, almost instantaneously, *the* premium English language medium for the international publication of peer-reviewed animal production and animal science research and development. Second only to the much larger (and more grandly supported) *American Journal of Animal Science* – the organ of the American Society of Animal Science. No sooner had the **Proceedings** been strapped into the back of the Journal, than their incongruity in that place became apparent. The presence of the reports of titles and abstracts at the Winter and Summer Meetings as an integral part of that prestigious publication, **ANIMAL PRODUCTION,** was an

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anachronism – an embarrassment even. The texts of the abstracts lacked precision and discipline, whilst the investigations described (and the conclusions reached) could be short on experimental rigour. Animal Production papers and Proceedings papers were different in both kind and quality!

Over the next few years a number of measures were put into place to address these issues. First, full and complete abstracts, following a professional pattern of content would need to be submitted before any paper was included in the Annual Conference programme. These would be 'reviewed' (gently) by chosen BSAP committee members. This substantially improved the quality of papers submitted to Winter Meetings, but also favoured the reporting of neat, small-scale experiments – the all-embracing thinking review not fitting comfortably into the format.

Through the sixties the numbers of papers volunteered was so great that the invited papers addressing specific topics were largely dropped. The volunteered papers tended to be short (fifteen plus five minutes for discussion), technical, and with their discussion focused on scientific niceties (which might have had much to do with farmer membership now being in steep decline).

At the Winter Meeting of 1962, in Edinburgh, after a couple of review papers, the delegates get an intense diet of nearly fifty *current research reports* on just about every conceivable aspect of animal production research; each with a 250 word data-packed abstract. As usual however, animal breeding and genetics are the dominant contributors, but there is now a greater number of nutrition papers coming forward, reflecting the growing concern of the community (not least at the Rowett) with the nutritional requirements of farm livestock.

The 1963 Winter Meeting in London continues the pattern of Symposium (*Growth & Development*), and then a plethora of reports of on-going research. The presenters, it can be noted are invariably the project leaders themselves. The audience therefore (mostly of researchers, teachers, and the knowledge transfer agencies) would be getting the benefits of hearing from (and questioning and discussing with) the leaders in the field. Standing on the platform that year were, amongst other notables, Eric Lamming, Malcolm Castle, Reg Preston, Kenneth Blaxter, John King, Bob Orskov, Vernon Fowler, Arthur Jones, Lawrence Mount, Geoff Lodge. It would have been a memorable meeting.

Meanwhile, a new format for the Summer Meetings was emerging. Originally the Summer Meetings were concerned with visits to farms and R&D establishments, with a low level of 'explanatory' papers. As time went by, the visits to farms were reduced, while those to research establishments gained in prevalence. At the same time the number of presented papers to the summer delegates increased; some reviewing the state of science and its rate of application (much as the Winter Meetings of the early years). The Summer Meetings had been the strongest of the Society's links with real life in the agricultural industry. They were attended by men from Whitehall, farmers, the feed industries, the advisory services, research workers, and academics. They were however heavy on organisational resources and upon attendees' time, and it was the Winter Meetings that were the more popular and well-attended.

The two-day Winter Meetings became evermore frenetically crammed with scientific exchange. For two more years the conference continued to be started off with a leading symposium (1964, London, '*Education'*; 1965, Harrogate, '*Research into practice'*). But then this format seems to have been dropped. The reason for this is not clear, as these symposia dealt with current topics of import and delivered a state-of-the-art review from those best placed to be authoritative upon their subjects. They were an opportunity for a holistic approach (largely lost in the '*Reports of current experiments*', which comprised the rest of the programme).

For the meetings of 1966 through to 1971 there were forty to fifty '*Papers on current research*' with comprehensible abstracts. The Winter Meetings became so busy with presented papers that the 20 minute time slot became the norm and from 1962 parallel sessions had become necessary. At the beginning of the sixties, Animal Breeding and Genetics, and Animal Feeding and Nutrition are (about equally) the most frequently occurring subjects. These were, of course, areas where (a) funding was forthcoming and (b) experimentation was relatively well facilitated. Animal management was proving rather intractable to both fund and report in coherent and objective (scientific) ways. This latter was also associated with (caused) a widening of the gap between the experimental scientists and the practical agricultural community. Nonetheless, attendances at the Winter Meeting increased steadily through the sixties; in 1968 the Harrogate meeting attracted 400 delegates.

The 1970s brought a new generation of research workers into the Universities and Research Institutes who are no longer driven by a need to see their work applied to the feeding of a hungry Europe. This generation is driven by a fascination for the science itself – responsibility for the applications can be looked after by someone else. Animal Production scientists and technologists are moving ever further away from market. Papers dealing with animal breeding plans are now being joined by papers seeking a more fundamental understanding of mathematical and cellular genetics. Papers on feeding regimes are joined by papers on nutrients and metabolic processes.

Whilst the Society itself might bear a responsibility to ensure a coming together of the professional scientist with the professional knowledge transfer agent (not least at the Winter Meeting and at workshops), the membership (whilst warm on

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words) seems not to have had the appetite to deliver that part of the Society's remit. Have the Society's members begun to be more inward-looking in their approach? Are the members now talking amongst themselves more than they are talking to their 'customers'? This need not necessarily be a bad thing for Animal Production Science, because progress demands understating. Simple measurement of what is happening is not enough. However, this paradigm shift requires also that Middleton's far sightedness is heeded. Innovations in breeding, feeding and managing livestock at agricultural industry level require linkages between research worker and farmer – the pattern so exemplified by the likes of Hammond, Mac Cooper, R.G. White, Woodman and Evans. With the shift in scientist attitude, there is a greater than ever need for advisers and developers. Those who can first understand the scientists (which the farmers cannot, or do not have time), and then translate the findings of science into usable technologies.

Fortunately for the UK farming industry, which was to lead the world in livestock technology through the sixties, seventies and eighties, the Technology Transfer industry was alive and well and in large number in the BSAP conference audiences; scribbling notes, asking questions, often remonstrating. The Marketing and Development Boards, and the advisory services of both government and industry, all attended the Winter Meetings avidly. In truth, only with their presence could the BSAP fulfill its constitution's promises.

Unfortunately, as will be seen, this happy position was not to continue.

At the beginning of the 1970 Winter Meeting, the Society is formally addressed by its President, K.L. Blaxter, Director of the Rowett Research Institute. He offers thoughts that the (1100 member) Society might do well to ponder upon. Here are some of them. Blaxter notes the extending gap between BSAP members and the farming industry. He fears that BSAP would become "simply another scientific society". He asks if **ANIMAL PRODUCTION** is to become more scientific, should BSAP launch a Development journal? Blaxter warns that the heady environment of ample funding that characterised the post-war hunger years would not last into the second twenty-five years of the Society's life which would be characterised not by food shortage, but by its over-production. He raises (in 1970) the upcoming problem of a population of obese people. Blaxter regrets the increasing 'specialisation' of the Winter Meeting, seeking the use of the forum to consider the 'wider whole'. He regrets the emphasis on "communication of short-term research findings to the exclusion of integrative accounts of where those research findings lead". Blaxter suggests that Society funds could be used for "integrating reports". In the political dimension, Blaxter wishes the Society to place itself in the same position as the British Veterinary and British Medical Associations (BVA and the BMA); professional organisations representing their members and whose opinions are sought by, and provided to, policy-makers and the public.

The Society *does* divide its journal, but not in the way Blaxter suggested. **ANIMAL PRODUCTION** had become a leading international science publication and wanted to stay that way. Peer reviewing for what was or was not publishable at such a level had to be rigorous, with a high level of rejection. Standards of experimental design, analysis and reporting veracity had to be of the highest. Such demands, appropriate to the final publication of research and investigations in the Journal, were not appropriate to the **Proceedings** of the Winter Meeting, which reported current research 'in progress'. Here, a more lax approach was appropriate to the production of the abstract / summary. Yet, in the Journal, both were still to be found under the same cover and editorship (even though the matter had been argued about over the previous decade). This state of affairs was not fitting for **ANIMAL PRODUCTION**'s ambitions. There was a self-evident case for a separate publication for abstracts and symposia. Further, there was the danger of confusion amongst readers with regard to credibility and authority; the **Proceedings** abstracts having a much lower score in these respects than the Journal. What had been seen as an obvious step in 1958 was in 1971 hampering the Journal's progress.

Finally, in 1972 the matter is resolved by the creation of a completely separate publication, **Proceedings of the British Society of Animal Production**. In the first publication, we see a return to earlier years with special symposia entitled '*Artificial rearing of pigs*', '*Processing of roughages*', '*Animal production from grassland*', '*Aspects of carcass evaluation',* Review papers are prepared by the leading exponents and reported *in full*, with references. They were (still are) of immense value. In the same publication are the abstracts of the '*Papers on current research*', now called '*Short papers'*. There are 54 of these, each with 250-word precision abstracts.

The report of the (3-day) 1974 Winter Meeting includes the full text for the 1974 Hammond lecture and 64 abstracts. Nutrition dominates the agenda. Interestingly there was also a forum on '*Sow nutrition'*, a hot and disputed topic at that time with active research at Nottingham, Edinburgh, Rowett, and ADAS EHF. The forum concluded "*No useful purpose would be served by collecting together a consensus view and publishing it as a set of BSAP standards*". This unbelievably disappointing conclusion would have infuriated Ken Blaxter, and is completely at odds with BSAP ethos.

1975 sees a text by H.P. Donald, recently retired from ABRO, given in full. He warns the Society of becoming introspective and of its science becoming self-serving. He urges not just a holistic approach to research (he would have abhorred the presentations that would shortly follow his presentation), but a better understanding by BSAP's members of Animal Science's place in society at large.

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P.D.P. Wood of the MMB edited and introduced a symposium in December 1975 that ended up as a one-off booklet '*Proceedings of a symposium on cattle experimentation'*. Apart from dealing with the eponymous subject-matter, both Wood and Clair Taylor (ABRO) share a moment of navel-gazing. Wood writes a foreword that suggests that an experimenter might have motives other than benefitting the farming industry; adding to the sum of knowledge, bringing greater good to mankind, etc. A PhD student, Wood suggests, might be most interested in just getting the degree. Wood talks of research workers as jockeys riding other people's hobby horses, or as seekers not after truth, but after fame (or even money). Wood implies that not just the experiment chosen, but also the analysis presented, might not reflect the highest of motives. These words are as vital to heed today as they were then.

Equally as remarkable is the paper from St C.S. Taylor…ever the thinker. He starts by pointing out that it is experimen*ters*, not experiments, which have objectives, and then lists them. Paraphrasing, they are as follows; (i) the avoidance of inconvenient routines for technicians, (ii) peer esteem for the scientist, (iii) advancement of the commercial interests of the sponsor, (iv) advancement of personal career, (v) fitting within the confines of analytical and interpretive methods in which the experimenter is competent, (vi) reputation of the research organisation, (vii) keeping within budget, (viii) avoidance of 'outcry' from sectors of the public, (ix) creation of profit for the end-user of the results, (x) reduction in costs of production …

Clair Taylor went on to raise other issues of a more practical nature; (i) national scale experimentation to accommodate millions of animals, (ii) clearer definitions of experimental objectives, (iii) what to do with new information (enjoy intellectual pleasure, confirm the already known, reject that which is inconvenient, use for nefarious purposes, provide data for decision-makers), (iv) the need to decide what the experiment is testing – and thereby the choice of variables measured, (v) restriction of the ambition of information gainable within the defined (cost) limit of the facilities available (researchers asking questions of inadequately sized data sets), (vi) the essential nature of determining whether to do a comparative (difference) experiment, or a relationship (regression) experiment, (vii) the difference between the reliability of a result and its relevance (classically demonstrated in the 'significant correlation').

Between 1960 and 1990 some thirty to fifty percent of the total membership might expect to go to at least one BSAP meeting in the year. About half of these were the researchers – the seekers and deliverers of wisdom – and the other half were there to receive that wisdom. As things developed, year on year, some of the 'receivers' would become increasingly doubtful as to whether the 'wisdoms' being offered to them were relevant to their day-to-day activities, while some of the 'seekers and deliverers' became increasingly prone to use BSAP as a place for scientific exchange.

The demand for twenty-minute papers describing 'C*urrent research in progress*' across a range of subjects in parallel sessions was getting ever greater. The issue was whether the attendees at the Winter Meeting were there for the symposia or for the reports of current research. The latter appeared to be winning the day.

Apart from providing a means to apply some degree of quality control and to organise the Winter programme into sensible sessions of related topics, the short (250-300 word) abstracts came to have little of worth after the Winter Meeting was concluded. They were insufficiently informative to either stand in their own right (the full paper would be out in **ANIMAL PRODUCTION** the following year anyway if it was any good) or help audiences to better understand the spoken presentation (by now all papers were accompanied by visual aids liberally endowed with tables and graphs). In 1975, Conference delegates were given a compendium of abstracts at Registration at the start of the meeting. But it seems that they were considered as ephemera, of no value to posterity, as there are none to be found in the archive. In 1975, after a short four-year life **Proc. Br. Soc. Anim. Prod.** had come to an end.

Through until the turn of the century there were no more properly published Proceedings, just a book of summaries – 'delegates for the use of.'

It has to be observed that over these same years, despite the dramatic increases in the numbers of people involved in Research and Development, and the vastly increased numbers of PhD students and Post-docs who would become members of BSAP/BSAS because of its function as a science forum, the total numbers of the BSAP/BSAS membership did *not* increase, *neither did the number of persons attending the Winter Conference*. The BSAP was becoming science dominated. Many 'industry and technology transfer' members were finding the reasons for their having become members of BSAP in the first place; (a) getting the journals **ANIMAL PRODUCTION** and the **Proceedings** (b) going to the Winter Meeting, were no longer relevant to their particular needs. The Journal was not anymore addressing industry problems in ways that industry could learn from it. It was addressing science. This was not surprising. There was no kudos (or advancement) for either Journal or research worker coming from the promulgation of 'Applications'. As to the Winter Meeting, many delegates found ever more papers addressing matters which were to them either unintelligible, irrelevant or both. The membership was losing its following of farmers, feed industry technologists, advisors, technology transfer specialists, development workers. Many elements of the membership did not find this regrettable, nor did they see the consequences as in any way damaging to the Society's future in what was a changing world. A scan of the Presidents over the years will show that in the early years the Society was in the hands of those with direct interests in the farming industry – having a

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hands-on understanding of the issues. In the later years, the Presidents are invariably at least one step removed from the industry work-face.

In passing, it might be also noted that following the 1975 Summer Meeting in Bangor, no further Summer Meetings are reported. They too have been discontinued.

* * * * *

The one-hundredth meeting of the BSAP was the Winter Meeting of 1990, held in Scarborough. There have been big changes since 1976. There are 65 'Theatre' presentations and over 100 'Posters'.

For the convenience of the delegates there is printed '**Programme and summaries**'. It is A4, 15mm thick. The s*ummaries* are no longer 250-word abstracts, they are 850 words (two sides of A4), they have an introduction, materials and methods, results and conclusion. They are clearly there to do more than inform the Programmes Committee of the likely content and standard of a submitted presentation. Nonetheless, the front cover of the **Programme and summaries** unequivocally states the following disclaimer: "*These summaries have been collected together as a service for conference delegates: They have not been checked or edited and the Society can accept no responsibility for their accuracy."* There are no Editors named (compare the situation through till 1975).

The Poster, as a means of scientific communication, had been introduced a number of years earlier, and the medium was seen to be highly useful (a) to encourage delegates who cannot be given space to present their work in the main theatre sessions to nevertheless gain many of the benefits of attending BSAP, (b) to demonstrate legitimacy of attendance (particularly important for organisations which would only fund those who were on the programme as giving papers, and (c) as a medium through which PhD students could 'cut their teeth'.

In 1995, the British Society of Animal Production passed at its AGM a resolution to change the name of the Society to the British Society of Animal Science. This was not as revolutionary as it appears. It was an inevitable reflection of what had come to be the fact-of-the-matter. For good or ill, the primary focus of much (but by no means all) of the membership was no longer the 'production', but the 'science'. But if a name change does have inner meaning, then in this case it is that the discarding of the heritage of the Pioneers has been recognised. The future of the Society will be in its members' pursuit of scientific excellence. BSAS *is* 'simply another scientific society'.

Winter Meetings through to 1997 followed a similar format. The '*Programme and summaries*' being "a service for conference delegates" (As well, of course, as a medium through which submitted papers could be vetted by the Programmes Committee and the Conference Programme organised in a sensible way.) The appetite for symposia and plenary sessions has somewhat diminished. The summaries themselves are down to one side of A4, but still with the complete 'mini-paper' format. These abstracts are scientifically informative, but nonetheless, BSAS considers them trivia. The blunt health warning carried on the front page since the eighties is unambiguous; "*These summaries have been collected together as a service for Conference delegates; they have not been checked or edited and the Society can accept no responsibility for their accuracy. Please check with the author before using any of the information.*" Since the cessation of the **Proceedings** in 1975 there seems to have been over many years a schizophrenic approach to the summaries: Do they have merit in their own right, or not? If not, then are they not a little over-elaborate to be treated as discards? Two-hundred and fifty A4 pages of detailed scientific results are a most generous 'service' to conference delegates, many of whom would not ever read them.

The 'Winter' Meeting of 1997 has become the 'Annual' Meeting. The 200+ pages of S*ummaries* have become (no less than) the re-incarnated **Proceedings of the British Society of Animal Science;** published by BSAS with an ISBN number. It has evidently been decided that the descriptions of experiments *are* good enough to be printed as a permanent record, but are not *bona fide* reference sources (the disclaimer is still there!). The increasingly scientific nature of the papers reflects what has been a steady trend since the early years of the society. Whereas fifty years earlier papers tended to be integrative, holistic and with a clear eye on agricultural applications, now the research seems more reductionist, smaller in scale, more focussed on matters of scientific interest. The title page of the **Proceedings** no longer states that their purpose is to be a 'service' to conference delegates, nor however does it state what the **Proceedings** *are* for. Presumably, given the ISBN, as a permanent record.

The Winter (Annual) Meeting programme of events is not described in the **Proceedings**. If there have been plenary sessions and/or symposia within the programme, it is not evident. All the reports are in the form of mini papers (introduction, materials and methods, results, conclusions). This formula follows through to 2000. There are in the year 2000 forty-four theatre presentations and one hundred and seven posters.

As to the **Proceedings** themselves, the constant chopping and changing seems to suggest that there is no policy focus. Prior to 1975 it was quite clear to everybody what the purpose of the **Proceedings** was. But for the next 25 years no clear reasoning has been apparent. That all this good material should be published in some form, rather than lost, seems agreed,

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but how, exactly, are either the end-user or the scientific community expected to employ this dense mass of information from which the society has so purposefully distanced itself?

In 2001 the Annual Meeting has symposia back on the programme. There are six invited theatre presentations; *Endocrine Disrupting Compounds; Future Directions for the Livestock Industry; The Science of Meat and Milk Quality; Tropical Animal Production; Ethical Issues in Animal Science; Improving Beef Production Systems*. What is more, these wide-ranging review papers are printed in the **Proceedings**. There is no reason to doubt the benefit of these thoughtful (and sometime thorough) over-views to the audience, nor the equal benefit to subsequent readers. It may be noted that the caveat, "These summaries have been collected together as a service for conference delegates" has been dropped. Thus it may be assumed that these printed reviews of the symposia sessions are there for the benefit also of those who were not delegates at the conference. If these contributions are of value to the broader span of science communities (which they are), it is a pity that they have been so well hidden. There is for example a page (p.262) of pure gold "*Animal rights and wrongs*" by Roger Scruton – a greatly respected philosopher – that should be compulsory reading for every student of all branches of the biological sciences and every member of the rationally thinking population.

The **Proceedings** continue in much the same vein through to 2007, with similar proportions of current research, invited papers and posters. Substantive contributions from the Equine sciences to the BSAS Annual meeting are now becoming established. The purposeful encouragement of papers relating to equines has had a noticeable beneficial effect upon the composition and value of the Annual Meeting. The inclusion of equine research and development as normal elements of the BSAS science agenda (as is the case for EAAP) was further encouraged through the twenty-teens by a series of successful BSAS workshops targeting investigational techniques and statistical analysis. Equines and equine research was seen as not merely important in the horse's standing as a *bona fide* livestock species, but also because equine studies were recognised as an important component of many courses in the tertiary education sector and therefore of increasing interest to the BSAS conference-going membership.

The BSAS Annual Conference and its **Proceedings** have all the appearance of settling into a programme of short papers, invited contributions, and posters that will produce not only a conference of scientific worth, but the output of a volume of **Proceedings** which, much like those prior to the 1980s, are of genuine value *in their own right* as a means of communication through the written word.

What role did the Society see itself as fulfilling in the second millennium? The **Proceedings**, being the record of the Society's Proceedings – its doings – are the test for that. The disinterested browser might be forgiven for concluding that whilst the Society was acknowledging that in Hammond's words "*Science is not science until it is applied*", in actuality, the measure of the success of the individual active members at the Annual Meeting was the *science itself* and *not* its *applications.*

The **Proceedings of the British Society of Animal Science** in their published form (with ISBN) are, through to 2007, firmly in the Society's hands as a Society publication dealt with wholly by the BSAS Office. It is however emerging as something that is quite different to merely a 'service for delegates'. The years 2007 and 2008 show the **Proceedings** as a medium of scientific communication which puts together a great number of original science reports (around 150 Theatre presentations, 120 Posters,) with a dozen or more invited review papers mirroring the changing nature of international animal science.

Unfortunately, the invited speakers, whilst giving presentations of undoubted worth, have not (in the main) considered it worth their while to prepare (as had often and beneficially been the case in the past) full papers for publication in the **Proceedings**. It is as if they too had got the idea that their summary was merely for the convenience of the conference organisers and the attending delegates – not for wider promulgation.

It has become noticeable that a significant number of the theatre presentations of work in progress now covers not interim reports of large on-going projects presented to colleagues by the programme leaders, but reports of shorter, smaller scale, less ambitious programmes, of the sort that often emanate from PhD and Post-doc programmes. These appear to be usually presented by the students themselves. Inevitably, this changes the tenor of the Annual Meeting. It is less obvious that the 'receiving' members – those interfacing directly with the feeding, breeding and livestock farming industries – are able to see the meeting as an essential part of their professional career development and technical updating. The following year the Treasurer (Brian Cooke) regrets that the membership has fallen to 770 (from an earlier high of over 1000), and the Technical and Ethical Committee recommends market research by an outside body to find out why membership is falling!

Given that most papers are multiple author, and that there are a great number of them, it is perhaps surprising that the conference attendance numbers have not gone up. (They have in fact stuck resolutely at around 400 for most of the life of the Society). It may safely be concluded that a large proportion of the members at the Annual Meeting are there because they are giving papers. It is also becoming evident that invited speakers are addressing not the user industries, but emerging scientists. In 2007 it was decided that, due to the large number of submitted papers that were needing to be fitted

into three parallel sessions, the Mini (5 minute) paper should be introduced into some sessions to "accommodate more speakers as delegates".

In 2009 the **Proceedings of the British Society of Animal Science** announce themselves as **'Advances in Animal Biosciences**' and state "*This book is part of a series which is a companion to the journal ANIMAL*". But apart from these few words on the inside cover, nothing has changed.

There however remained the need for those wishing to present their papers (current research reports) to the Annual Conference to prepare summaries so that, (a) the Committee responsible for programming the conference can be satisfied that the required (scientific) standards are met and then prepare a programme of parallel sessions in a coherent way through the conference's duration, (b) as a service to delegates the summary can be read to supplement the heard word (and visual aids) delivered from the platform, and (c) afterwards there is a permanent record of events.

Volume 1 of **ANIMAL** (the successor Journal to **ANIMAL PRODUCTION** and **ANIMAL SCIENCE**) was produced in 2007. Three years later, under the same auspices published by Cambridge University Press, Volume 1 of **Advances in Animal Biosciences** is published.

Within **Advances** are the **Proceedings of the British Society of Animal Science.** Cambridge University Press see **Advances in Animal Biosciences** *"as an associated publication to the journal **ANIMAL***. The stated aims give it much of the appearance of a Development Journal. A journal that can be used by those wishing to translate science into utility. Perfect! Ken Blaxter would have been delighted. Here at last was a means of securing the value of the BSAS **Proceedings**. There were many involved, but Cledwyn Thomas was a prime mover – this amongst many others, for Cled has been a stalwart champion of EAAP/BSAS affairs over very many years. Importantly however, **Advances in Animal Biosciences** under the controlling auspices of the **Animal Consortium** (INRA, EAAP, BSAS) does not just look after BSAS Proceedings, it publishes other such materials from other Societies and other Conferences as well. This should ensure the sustainability of the new journal, but it does not belong to BSAS anymore. BSAS is a contributor. Does this mean that BSAS has become just another Conference Events Organiser?

The 2010 **Advances in Animal Biosciences, Proceedings of the British Society of Animal Science** cover the Annual Meeting held in Belfast (with the Irish Agricultural Research Forum) earlier in the year. There are one page (A4) mini-papers (now called 'Abstracts' for the research reports, and one page (or less) summaries (also now called 'Abstracts') for invited papers.

ANIMAL PRODUCTION, especially in its first quarter-century, was as much a *Development* Journal as it was a science journal. Indeed, it did not see any clear distinction between 'pure' science and 'applied' science; only between 'good' science and 'bad' science. Only with the evolution of **ANIMAL SCIENCE** away from integrated and development works did the need for a separate 'Development' Journal come to be discussed. The discussion over recent decades has not reached any satisfactory resolution to this matter. The stated aspirations of **Advances in Animal Biosciences** to also publish Applied Development papers have, unfortunately, yet to see fruition.

Importantly for the future veracity of the content, there is a named Editor (Cledwyn Thomas, EAAP), an Editorial Board of thirty senior animal scientists and the statement inside the front cover "*The summaries have been edited.*" This document has clearly fulfilled a purpose for those organising the programme for the Annual Meeting, and it is of value to the Conference goers. But is the intention of **Advances** to be a formal scientific publication, or is it to serve only as a record?

Volume 2 (2011) of **Advances in Animal Biosciences** covers the Annual BSAS Annual Meeting at Nottingham. There are some fourteen invited speakers scattered through seven symposia sessions. By this time the annual meeting had three concurrent parallel sessions, and presentation times had been cut from 20 to 15 minutes (with questions), further limiting the amount of information that could be shared, and further curtailing time for useful discussion. Posters were beginning to lose their appeal (down to 60 in number) and were less visited by conference members.

Meanwhile, whilst BSAS symposia plenary paper givers are still restricted to 'summaries' of one page or less, the three presenters to the Plenary session of that year's EAAP meeting had (Volume 2, part 3.) published their (excellent) papers in full over 16 pages. It would appear that BSAS might have missed a trick.

By 2017 **Advances in Animal Biosciences** advertises the fact that it has a management board with representatives of BSAS, EAAP and INRA (as well as the Editor-in-Chief and a Board of Editors). The publication itself is looking to publish proceedings and symposium papers from any appropriate conferences. The 2017 BSAS Proceedings are thin with 131 summaries (of which 20 were posters), but the Animal Biosciences publication itself is handling output from three other conferences. The **Proceedings of the British Society of Animal Science,** in the form of their inclusion into the new journal **Advances in Animal Biosciences,** could now have the possibility of reaching for a wider audience – of particular benefit with regard to symposia reviews. But the scientific purposes (as opposed to conference-organising and record-keeping roles) of the proceedings remain to be exploited. 'Advances' is **not** the companion to **ANIMAL** such as Blaxter

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had envisaged – a medium to extend new science out to innovating users. Its promise to deal with *"the translation of basic and strategic science into the whole animal and farming system"* has yet to be utilised by BSAS. But then maybe the Annual Meeting no longer has any such intention.

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3. The wider whole: Occasional Meetings and Other publications

In 1970 Kenneth Blaxter urged the British Society of Animal Science to avoid over specialisation – to consider the 'wider whole'. He regrets the emphasis on "communication of short-term research findings to the exclusion of integrative accounts of where those research findings lead". He suggests that Society funds could be used for "integrating reports".

One of the ways that this shortfall in the Society's delivery of its objectives (as stated in the constitution; to collect and publish information, to encourage the incorporation of research findings into farming practice), was addressed by the launch around 1978 of the '**Occasional Meeting**' series.

These were anything but occasional, and became a central plank in BSAP activities. They were the natural successors to the format of the Society's early meetings through its first ten years. At the rate of about one or two a year, special meetings, colloquia, workshops or symposia have been held for the benefit of members and others wishing to attend. These were/are popular and considered by the ***science user community*** as highly valuable. They attracted audiences of fifty to two-hundred and fifty, taking the form of invited (expert) speakers asked to present formal state-of-the-art papers in a field usually highly topical to the time. There would follow ample discussions both between speaker and audience, and importantly, amongst the audience members – views being freely exchanged.

The normal procedure was for papers to be prepared for full and proper publication. From 1978 to 2006 these reviews were presented as printed books in a designated series entitled '**BSAP (BSAS) Occasional Publications'**. Substantial both in volume and in quality of content, they were considered as particularly valuable for narrowing the Knowledge Transfer gap between Science and Practice, for affording a means of quick updating in fast-moving subjects, and for providing ready review material for consultants, teachers and students. BSAS has also published (at a rate of around one every year) a number of separate volumes dealing with symposia papers presented to various conferences (such as livestock fertility, meat science, precision livestock farming, etc.) with which BSAS has been involved in the organisation. This represents a substantially important science resource, but one that has become of limited circulation; lacking a formal streaming medium such as is provided by an internationally recognised journal.

The **Occasional Publications** together with the Meetings from which they emanated were clearly a much sought after and strongly supported part of BSAP/BSAS activity – fulfilling a defined need. Why then did they falter and finally cease as a formal series? Post the millennium, professional animal scientists found themselves with ever-pressing shortages of time for (a) up-skilling, (b) organising such events, (c) preparing 'conference review papers' and the subsequent 'book chapters'; none of which counted to Research Assessment Exercises or career development on cv publication lists.

The Society has, on a number of 'occasions', been minded to publish material from workshops, or to specifically commission work, functioning in the role as a forum to come to some agreed views (through objective research) on how industry problems can be addressed, and to produce appropriate integrative reports.

The case history of one of these might yield useful insight. In 2002 there was acceptance in both the feed industry and academia that the Nutrient Requirement Standards for Pigs were either (like the ARC UK 1981 recommendations) hopelessly outdated or (like the NRC US recommendations of 1998) inapplicable to British circumstances. The absence of any useable reference standard was becoming an issue for both research workers and the feed trades themselves. BSAS, as a disinterested party, had commissioned a report a year earlier on the *Nutritional standards for livestock; pigs, dairy, poultry, beef cattle, sheep*. Unfortunately, nothing came of this excellent report apart from the work on pigs. *Nutrient requirement standards for pigs* was completed (including full consultations) within a calendar year by a trio of BSAS members representing academia, the feed trades and independent consultants. The resulting document was published by BSAS in 2003. It has been widely respected, read, referred to and used over subsequent years.

Unfortunately, the notion that BSAS should initiate commissions of this kind in other spheres has been studiously consigned to the long grass; presumably for fear of some difference of opinion arising and causing discomfort to some part of the BSAS membership!

Equivalent needs in both animal breeding and management were identified in 2011. While in relation to animal feeding, there are no standards extant for the other species (and pigs needs updating), nor for appropriate methodologies for nutrient evaluation, nor for reasonable expectations for rates of production from livestock enterprises. These initiatives appear to have entirely lapsed.

The strategy plan of 2011/12 calls unequivocally for Independent reports and recommendations such as standards for animal breeding, feeding, management & well-being, transportation, slaughter, product processing, food quality,

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environmental protection, food security, experimental design. There is every reason to suppose that **Advances in Animal Biosciences** would publish such material, and there might even be scope for Europe-wide integration.

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4. Journals:
Animal Production, Animal Science, Animal

The British Society of Animal Production's professional Journal, **ANIMAL PRODUCTION**, *Journal of the British Society of Animal Production* (Editors I.L. Mason and G. Wiener), was an instant success (thanks to the herculean efforts of its two Editors). It was much sought after as '*The'* journal of choice in which to publish. It was compulsory reading for all researchers, teachers, and advisors in Animal Science and Production, and much respected by industry technologists. It was the journal to go to for state-of-the-art information of importance and value to both the Science and the Industrial communities. It had, from the outset a healthy subscription list, and its free delivery to members was a prime reason why the Society was so swiftly populated with an increasing membership after 1960. Ten years after its launch, **ANIMAL PRODUCTION** had a circulation of well over 2000. Thirty years after, it would stand second only to the American Journal in its publishing across the range of the animal sciences.

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By the end of the 1950s, The **Proceedings of the British Society of Animal Production** had become so important a medium for publishing animal science that it had become a journal in all but name. However, as 'Proceedings' it lacked the gravitas of a proper international publication of the sort that post-war scientists now needed to publish in. UK needed an International Journal in which to publish original peer-reviewed research; papers with full explanation of materials and methods, results, proper analysis and considered discussion, and abstractable summaries. Gerald Wiener (who had taken over as Proceedings Editor from Iain Mason) went with John Maule to visit Oliver and Boyd, the Edinburgh Publishers, and asked them if they might be interested in publishing a journal. They were.

Volume 1 (1959) has a generous 191 pages and 24 papers (thanks mostly to Gerald Wiener's substantial persuasive powers!). From that point on, **ANIMAL PRODUCTION** was publishing a balanced mix of original research papers on breeding, feeding and management, and continued to show a healthy respect for 'industry applications'. Through the sixties the journal is holding true to its name – and to the expectations of BSAP founders and members. There is much on how levels and quality of production can be improved. There are also papers emerging on behaviour and welfare (effectively the objective and scientific analysis of animal husbandry). There is a healthy balance of applied papers and those dealing with the more basic studies of underlying principles – the *what* and the *why*.

The journal is very much an integral part of BSAP. In the beginning, to a great extent, it is the Society's members who are publishing. And although the readership is evidently far wider than just BSAP members, one senses that it is for members that the published papers are being written. This position however soon changes; the journal coming to boast an international authorship and readership. It would be difficult to imagine that any member of the Animal Production community – research worker, university academic, college lecturer, student, advisor, consultant, policy-maker, member of a feed company, breeding company, innovating farmer, agri-business, etc. – could possibly ply their trade without being up to speed on what was being published in the Journal.

The research and development workers themselves (of UK, then internationally) shared this notion and were anxious to use **ANIMAL PRODUCTION** as a preferred medium for publishing their papers. In the early sixties the journal was about 300 pages in length, by the end of that decade it had more than doubled in size. The sheer volume of papers coming in for peer-review and editorial scrutiny was causing overload on its two editors. In 1963 James Greenhalgh (feeding) joined Gerald Wiener as an Editor. K.J. Robertson was added in 1965. By the end of the decade the team has been joined by Geoff Harrington (meat quality) and Lawrence Mount. The journal had started well in 1959; by the end of its first decade it was nothing less than an outstanding success. Papers are now being submitted in increasing number from overseas; including European Continent, North America, Antipodes. There is a stream of work from the ARC and DAFS research Institutes, from the Universities, the Development boards, and the R&D arms of the Irish, English, Welsh and Scots Advisory services, as well as from Industry (the feed industry in particular) .

By 1970 the journal is offering an eclectic mix of genetics, breeding, reproduction, carcass quality, feeding, grazing, nutrition, environmental physiology, in all the livestock species (pigs (dominant), cattle, dairy, sheep, beef), but the tone of the papers has become more scholarly, and experimental discipline stronger.

The decision made in 1971 to create a separate publication for the (relatively more gently refereed and edited) abstracts of the **Proceedings,** freed up **ANIMAL PRODUCTION** to be a rigorous international peer-reviewed scientific journal of excellence. It was entirely rational. However, it had unexpected consequences for the way the Society would see itself and behave from then on.

Up until 1970, what had started as a 'club' for scientific exchange amongst scientists, and for transfer of science into practical utility – a show, run entirely by its members for its members – had begun to change into an 'organisation'. Blaxter had alluded to this in his Presidential presentation. A Technical Committee had been set up in 1964 to help the

Society be more outward looking. Donald in his 1975 'End of an Era' speech talked of the need for the Society to be more outward-looking – to take its place in the world at large and not simply be a chat-shop for animal scientists to talk amongst themselves. These changes in the way the Society should see itself were proving difficult. Previously things 'just happened' and the meetings rolled along. Now there was a developing need for forward thinking and proper organisation – *management* for want of a better word.

ANIMAL PRODUCTION in its early years was not only avidly read by the members, but was also found of immense worth by non-members; especially academic libraries and students, and those others who were animal scientists and technologists, although not necessarily BSAP members. It was when it became obvious that the prime function of the journal was not to be read just by members, but to be read by *others* that the need to split it in 1972 from the **Proceedings** (only five years after they had joined together) had become unavoidable.

As soon as **ANIMAL PRODUCTION** was given a life of its own, it began to see itself as an outward-looking journal publishing science reports for benefit of the readers of the world. It was part of BSAP, but separate from it. It would come to have a Board and an Executive that saw the Journal as somewhat differentiated from the life of BSAP which centred more around the Meetings. The Journal had an independent set of objectives (and separate accounting head) focused around its being an '*International science journal of excellence*'. This was achieved to the considerable benefit of BSAP members and the world at large.

But what had happened with the Journal had unexpected effects upon the way the Society became to be orientated. The British Society of Animal Production had become for its members two separate entities. The journal **ANIMAL PRODUCTION** was where research papers were to be published and read, and the Meetings were where face-to-face exchanges took place. BSAP members both digested enthusiastically **ANIMAL PRODUCTION,** and BSAP members went to BSAP Meetings. But these functions were perceived quite differently. In the eyes of many, the Society was the Meetings – BSAP had a reputation for arranging really good meetings to which members went to 'network', to meet and challenge the scientists, to catch up on evolving trends in animal science, and to be apprised of the state of the game.

ANIMAL PRODUCTION, released from also publishing proceedings in 1972 went full-bore. Through to 1995 the Journal **ANIMAL PRODUCTION** will publish more than 800 pages annually of original research papers. The extent of the Journal's success, financially as well as in the service of Animal Science and BSAP cannot be overstated.

The front cover strap line for **ANIMAL PRODUCTION** always read "*Journal of the British Society of Animal Production*". As from 1987, however, it is not the Journal of the Society; it is "*An international journal of fundamental and applied research*". This is a most telling development. It states that the Journal is no longer the organ of the Society; it is a separate and independent entity. It might be suggested that this apparently innocent emendation has substantially strengthened the Journal, but has weakened the Society. .

The journal is also beginning to reflect a change in research worker's publication behaviour. Through the middle years of nineteen-hundreds scientists did not publish until they had a substantial body of analysed work that was sufficient to justify full discussion and proper conclusions to be drawn. The published paper was often a weighty exposition of a good number of years work by a research team. By the seventies, and increasingly thereafter, published papers were shorter, tending to deal with individual experiments, rather than experimental series. There was advantage in a scientist increasing *numbers* of papers, not their substantiveness. This would lead to an explosion of research journals and a dilution of the value of individual papers therein. Being in at the beginning, **ANIMAL PRODUCTION**, as an enterprise, largely benefitted.

The nature of the Animal Science Community itself had shifted. Prior to the 1980s there were very large state-supported entities in the form of the Agricultural Research Institutes and the Experimental Husbandry farms of the State advisory services. Both these organisations were first downsized and then ultimately dissolved. The science had moved away from the addressing of livestock industry problems and toward medical biotechnology. The people of UK were more frequently suffering from disease and infirmity than from hunger.

Gerald Wiener of ABRO had done well to be part of the trio getting the Journal off the ground in the first place in 1959. He did well again in 1972 separating the Journal from the Proceedings. As Senior Editor of **ANIMAL PRODUCTION** Wiener with his Editorial team of six (J.F.D. Greenhalgh (Rowett), W.G. Hill (Institute of Animal Genetics), L.E. Mount (ARC Animal Physiology), J. Rook (Hannah), J.C. Taylor (GRI)) handled the ever growing influx of papers through until J.A.F. Rook takes over as Senior Editor in 1975. The Journal has doubled the number of original peer-reviewed papers it publishes annually. Rook hands over the Journal with its ten-strong editorial team to T.L.J. Lawrence (Liverpool Veterinary School) in 1984. The number of papers now published annually had gone up again.

It has been a rather wonderful success story – highly profitable both for scientific advance and for BSAP finances. It wasn't to last.

For purposes of present understanding of what was happening to Animal Science through the 75 years of BSAS – and therefore to the types of reports delivered to BSAS publications – some analysis may be helpful to the reader. Broadly there are three major divisions in animal scientific discovery. (A) *Blue Skies* – far from market, and (B) *Applied* at industry level to improve efficiency or address a problem – near market. (C) *Development* trials, instantaneously useful – in the market. For the animal scientist the 'market' is the primary industry – livestock farmers and the breeding, feeding, and veterinary companies who immediately trade with them. (A) tends to be things which are really interesting and when examined may or may not be found to be useful. The big strides forward tend to come from this type of work, but to be useful the applied experimental step (B) is usually needed. (B) tends either to arise from (A), or from the industry itself – as problems requiring solution. (C) tends to examine (i) that which is already known to have application, but ways of delivering the innovation need to be demonstrated, or (ii) that which is not known to have application but industry would like to see it tried. For the first half of the life of BSAS publications it could be said that (B) was predominant, and indeed the perceived reason for the creation of the Society in the first place. (A) was too esoteric for a membership interested in applications, while (C) was somewhat frowned upon as 'not science'. Applied science was mission orientated. After the Thatcher years, Government funding was largely withdrawn from B. Applied science was no longer to be orientated to a mission, but to the requirements of the funders. Government funding was weighted toward (A); while Industry funding was weighted toward (C). Given that the Journal was anxious to improve its reputation in the science publishing forum, it is unsurprising that publications of gripping industry interest have become less frequently published.

To reflect the changes in the nature of the Society's membership (toward science and away from production), in 1995 **ANIMAL PRODUCTION** will become **ANIMAL SCIENCE**. Thirteen years later it will have become **ANIMAL**, to be run not by the British Society of Animal Science, but by the Animal Consortium of INRA, EAAP and BSAS, together with the publishers Cambridge University Press. The BSAS Journal will be found not to be able survive through the nineties and early two-thousands; it had to be (effectively) sold-on into bigger hands, or die. Were ANIMAL SCIENCE to fail there was a danger that the BSAS would fail also, or at least be substantially diminished. To keep the Journal thriving and to have a one-third part in that would be both necessary and shrewd.

The presumed promotion of **ANIMAL PRODUCTION** to **ANIMAL SCIENCE** might have reflected the change in member focus, but it did not have any long lasting positive effect upon the Journal's falling scientific standing. Ten years later, in 2005 the format changes from being approx A5 in page size to being A4 and having a glossy cover – a cover which announces '*Official Journal of the British Society of Animal Science'*. T.L.J. Lawrence (Liverpool Vet School) is the Senior Editor, with 11 scientific editors and two technical editors to help him. The Journal is making money (about £70,000 p.a.), but subscriptions have fallen to around 500, and the standing has dropped from third amongst 'animal science' journals to around thirteenth. It is losing **impact**.

Things are reaching the point where Heads of research Departments are discouraging their staff from publishing in **ANIMAL SCIENCE** because of its low impact factor – a high impact factor being fundamental to the success of any research group entered into the national assessments of research excellence such as the RAE and REF. Nigel Scollan (then Chair of Publications Committee) and Cled Thomas take action by transferring publication (and ownership) out of the direct hand of the BSAS Office and into the hands of a professional publisher, CABI. This will reduce profit margin per subscription, but hopefully increase reputation and sales. At this point, **ANIMAL SCIENCE** was receiving around 250 papers annually, and was rejecting 30-40% of them; but even then, it appears, the standard of science is still not adequate for international accolade. Importantly, the BSAS Office could no longer be expected to handle all the complex elements of aggressive science publishing that the environment of the 2000s demanded.

But even as CABI is taking **ANIMAL SCIENCE** on, Scollan and Thomas are planning for rather more dramatic solutions to the Journal's problems. Which, whilst now having reduced its income generation, is still in trouble on account of lowering quality of submitted papers and the falling impact factor. They are exploring the possibility of creating a Consortium of EAAP (European Federation for Animal Science), INRA (Institut National de la Recherche Agronomique) and BSAS to launch a "**European Journal of Animal Science**". The Consortium will be given both management (Scollan) and Editorial (Thomas) leadership from BSAS. Meanwhile, in 2006, CABI sell **ANIMAL SCIENCE** to Cambridge University Press!

The European Journal is published as **ANIMAL** in 2007. **ANIMAL** ('*An International Journal of Animal Bioscience'*) will bring some £50-80k into the Society every year over the next decade. Total papers published in Volume 1 were 163 of which 20 were reviews (half of these being previous plenary papers from Conferences). In its first few years, of the original papers published, approximately one quarter were on feeding and nutrition, a fifth on breeding and genetics, one sixth each on health and welfare, one tenth on product quality and livestock systems. The Editorial Board's reject rate is 60 – 65 per cent, twice as high as that pertaining in the latter years of **ANIMAL SCIENCE**. **ANIMAL** has a six-person Management Board, an Editor-in-Chief, an Editorial Office, three Technical Editors, and an Editorial Board of around one-hundred persons, (divided into nine sections each with its own senior editor and deputy editor).

ANIMAL has no ambition to be a *Development* journal involved in science transfer into applications. It is a Science Journal. If a Development journal is considered of value, the way is clear for **Advances in Animal Biosciences** to fill that role. However, as discussed above no such intent is yet clear.

There remain the vexed questions. When, if ever, does a conference abstract become a quotable source of scientific information rather than a report of work yet to reach its interpretable end-point? What is the place of the integrated symposium review – is it definitive science output (as publishable in **ANIMAL**) or is it a medium for updating existing knowledge (as publishable in **Advances**). And last, where do 'Development Studies' fit in?

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5. Making it all work: Stratagems, tactics, operations

At the beginning, organising meetings of the Society was relatively straightforward. The President, or the Secretary, or a member of the (eight or so person) Executive would make a suggestion which would be agreed or not agreed (invariably the former). Discussions as to forward plans would be held in a quiet moment (often in a bar) at the current conference. The group 'running' the affairs of BSAP was small and well known to each other; it was a club of colleagues. The general topic (or place to visit) for the next meeting would be settled, and speakers proposed. Then it would be a matter of getting things done. Venues booked, speakers invited, letters written, members contacted.

In the fifties and sixties (and to some extent through into the seventies), the general pace at Universities and research institutions was very much slower than became the case after 1990. Working hours were largely self-determined. There was time to do things like attend to the business of your professional society. Indeed, of the senior BSAP members and of the landed farmers, it was expected. Of the less senior, aspirations toward career development would be much helped by a cv which included time spent working on the business of BSAP; one's line managers supported and urged such commitments to outside 'benevolent' institutions such as one's Professional Society. (This would change following the Thatcher years).

Importantly however, until the 1980s, those entrusted with the making of decisions had a veritable army of 'helpers' assisting them to see through the implementation phase. Secretaries, Personal Assistants, Administrators, Technicians, Typing Pools, Janitors, Post-room… Although strictly in the employ of a University, or a Research Council, or Levy or Government-backed body, such people could be readily diverted to carry out the business of the Society; and the Institutions concerned smiled upon it. Public Service was written into the job spec.

This too would change. In 1975 AFRC employed 6732 people on its scientific staffs. In 1990 the number was 3438. There was half the number of people available working twice as hard. Little wonder that the days that BSAP could depend upon the state-backed Institutions to come up with volunteers were over!

The weight of the work of the Society in its early years fell upon the Secretary (Nichols, Maule, and Read were all paid by 'Government'), and upon the President. It was helpful (necessary) for the Secretary and the President to command resources that could be willingly diverted to BSAP business. By the end of the century the reversal of these benefits to the Society was complete. In every respect those resources were gone, and in addition, the paymasters no longer smiled upon their staff/funds being used to the 'Public Good'. Transition by adaptation to changing times has been painful; the road has been made of cobbles – both bumpy and slippery at the same time.

Included into the 1950 **Proceedings** is a list of members and the Constitution. The objects of the Society are *inter alia* to provide opportunities to meet and exchange information, and, importantly, ideas. To support investigation of problems pertaining to animals, to collect and publish information, to encourage the incorporation of research findings into faming practice, to cooperate with other like-minded organisations.

To do all of these properly there would need to be an organised administration…

The Administration

Secretary and Treasurer

The first (1944) Executive Committee comprised Dr John Hammond, Dr A.B. Fowler, Mr Alec Hobson, Mr James Mackintosh, Professor W.C. Miller, Mr W.A. Stewart and Professor R.G.White. The Secretary-Treasurer was Dr J.E. Nichols.

In 1947, the hard work complete, J.E. Nichols goes to the Professorship at Bangor, and passes over both his post at The Commonwealth Bureau of Animal Breeding and Genetics (in the Institute of Animal Genetics, Edinburgh), and his post of Secretary-Treasurer at BSAP, to his successor J.P. Maule.

In 1958, the jobs of Treasurer and Secretary were split, Maule remaining as Secretary and J.L. (Joe) Read (ABRO) as Treasurer. Until that time there were running BSAP; J.P. Maule, the President, a small Executive Committee, and a Publications Committee (to support Mason and Wiener). All positions were, of course, honorary. At this time there were some 600 to 700 members in the Society. Attendances at the Winter Meetings seemed to number something around 200, with 50-100 attending the Summer gatherings. The post of Secretary was passed into the willing and gentlemanly hands of James Walker-Love in 1961 (West of Scotland Agricultural College – DAFS funded). J.P. Maule had been happily running BSAP since 1948.

Blaxter had warned the Society in 1970 that the load upon James Walker-Love (Secretary) and Joe Read (Treasurer) – and their respective offices and employers – was too great to continue to be borne in this way. He recommended setting up a

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Central Office and paying for an administrative secretary to be placed within it. In 1972, Harry Swan of Nottingham University took over as BSAP Secretary for four years, then the next three were looked after by John Southgate (MLC). Ken Deeble was Secretary for the 1979/80 year. Colin Slade (ADAS) was in post from 1980-83, Mrs J Newton was there till 1986, and Grahame Gunn (HFRO) held the fort until 1990. It was no longer a job to be relished. Nobody wanted it for any length of time – continuity was a real issue.

James Walker-Love had been perfect as BSAP Secretary, and he (like Maule) had relished the role. After that however, the work load grew and grew and the work lost its savour, cutting into the day job of incumbents, and testing the patience of their employers. Through these middle years, the Society was steered by the Executive (the implement of the Society's business) and its three sub-committees: *Programmes* which looked after content and organisation of Conferences; *Publications* which looked after the Journals; and *Technical* which did the forward planning, as well as interfacing with the rest of the world when the President was not inclined. Overseeing all was the BSAS Council which 'owned' the functions of the Society and provided governance. The Office delivered the day-to-day hard work.

In 1989, BSAP decided it should bite the bullet and raid its (now substantial) pot of money to fund a permanent (half-time to begin with, then full-time) *paid* post of Secretary. Mike Steele, ready to give up some parts of his previous employment of global itinerant consultant for the life of a part-time Scottish sheep farmer, was appointed. Mike made such a success of running the Society that it was decided to upgrade the post of Secretary to one of CEO, which was confirmed in the late 1990s. In his quiet but effective way he ran BSAP/BSAS until his final retirement in 2017 (an event causing great anguish to his very many friends and colleagues). He was succeeded by Bruce Beveridge.

The Treasurer's job was much less arduous than that of Secretary, indeed, through until recent years it was a bit of a sinecure. The routine work was done in the BSAP Office, while the statutory commitments were covered by a firm of accountants. The Society's income always exceeded its expenditure, and there were ever-growing reserves held in investments. Joe Read handed over to his fellow sheep researcher, A.J.F. Russel (HFRO) in 1973. In 1981 Murray Black (Edinburgh School of Agriculture) took charge and delighted in telling the AGM in what fine shape the finances were. BSAS sadly lost Murray Black, one of its most able and dedicated servants, in 2000 when that dear and much-loved curmudgeon Brian Cooke (recently retired from the animal feed industry, but still a *bon vivant* and the man to be sat next to when the red wine was being ordered) took over, sailing the ship through untroubled waters while threatening dire consequences unless the annual income stream was regularly increased.

Howard Simmins (by this time self-employed as a private feed-industry consultant) took over as Honorary Treasurer in 2012 following the untimely death of Brian Cooke.

From the 2000s onwards, the Society would overall make steady gains in its balance of funds carried forward of around £15,000 annually. At the time of the financial crisis of 2008, BSAS had nearly three-quarters of a million pounds of 'available funds' held in investments. Under Howard Simmins careful stewardship (every Treasurer wants that written about them), not only has BSAS financed numbers of conferences and workshops every year, underpinned publications, put in jeopardy all the Society's resources to float EAAP 2016, and gifted all the awards and scholarships, but has done all that in the face of falling membership subscription income. A major part of BSAS's charitable works is the running (at a loss) of conferences and workshops, and providing budgets (spending-money) to its active groups such as the Student Council, the Associations, and Accreditation.

At the time of writing, the 'available fund' of the Society is one million pounds. Given the possibilities for flux in both investment income and in expenditures (viz EAAP) this level of security is considered proper. As a charity, BSAS must ever remain willing to fund its objectives as stated in its constitution. All BSAS activities are charitable in as much as they are planned to lose money. The only money-generating activities are the publications of the Animal Consortium, membership fees and investment returns.

Running conferences normally resulted in losses of £5-25,000. Income from subscriptions could never cover these losses together with the salaries of the CEO and Office staff. While the Journal(s) have given an annual income of around £50-80,000, the importance to Society funds of financial gains from its investments is supreme. Meanwhile, the generosity of industry sponsors supporting in its activities has become of vital importance to the future of BSAS.

That the Society should actively seek sponsorship from the Industry sector as a legitimate part of its funding stream to fulfill the terms of its constitution was first floated in the late 1970s, but was, by-and-large eschewed until the 2000s. From 2010, the Society would be actively and regularly seeking sponsorship from Commercial companies. Extra-mural support would become a *sine qua non* for the running of BSAS conferences. Winning industry sponsorships depends upon the local knowledge of conference organisers together with direct support and co-ordination from the BSAS Office. With projected reductions in income from the Journals and from investments, sponsorship is no longer a nice-to-have add-on; it is a must-have essential.

Office

The BSAP Office was where the Secretary was. Blaxter had warned in 1970 that this could not last, and some more organised provision would have to be made. Kevin O'Connor (MMB) was President in 1980. The Milk Marketing Board had always smiled upon BSAP and the first BSAP Office as such was looked after at the Thames Ditton Headquarters, with Jenny Newton as Secretary. Jenny Newton was supported by an agency which looked after membership subscriptions. This was not efficient. Graham Gunn (HFRO) in 1986 was most happy to have the Office move up to the Edinburgh Bush Estates Farm Office (next door), to be in the capable hands of Joyce Darling, whose domain was adjacent to that of Murray Black – Bush Farms Director and BSAP Treasurer. The three of them ran BSAP with great effectiveness through to 1989. When Mike Steele was appointed as Secretary, things continued in similar vein. Bridget Hilton came to help Joyce in the early nineties, and took over as the BSAS Office manager when Joyce retired in 2003. The BSAS Office continued to be co-located with the Bush farms office until being re-housed in its present premises at Easter Bush. Bridget Hilton would come to have part-time help to handle the membership and the finances (now Frances Reid and Fiona Ferguson).

Through the nineteen eighties and nineties, BSAP was on semi-automatic pilot. The main event was the Winter Conference, which tended to be organised on the basis of 'Scarborough – same again as last year'. Members (and others) submitted their abstracts/summaries to the Programme Committee which reviewed the offered papers and organised the Conference programme into (semi) coherent sessions. The Office produced from the abstracts the Programme and Summaries book for the benefit of the delegates (and the record). The Hammond lecturer, and maybe one or two others would be invited as plenary speakers (usually at the President's behest). Each year there would be one other 'Occasional' meeting, and maybe a workshop, (possibly at the suggestion of Technical Committee) which would be organised by the local group concerned, who would also collate papers and edit into an 'Occasional publication'. The Publications Committee overlooked the strategic affairs of **ANIMAL PRODUCTION**; the day-to-day work being through the Senior Editor (Tony Lawrence) and his editorial team of science and technical editors. The statutory meetings of Council came and went … … Things would change.

Into the 2000s BSAS dependency for many of its office functions upon the goodwill of its members and their organisations had to come to an end. Steele was promoted to BSAS CEO, and his job spec widened to be more than 'running the conferences'. Brian Cooke as Treasurer was required to be more active, not just in looking after the accounts, but in ensuring expenditures was wisely placed. The negotiations to float **ANIMAL SCIENCE** first to CABI and then to CUP were arduous for the Office. Cooke pursued a fraught series of negotiations with EAAP and INRA preparatory to the launch of **ANIMAL** which happily resulted in satisfactory financial arrangements [Thank-you, Brian] and what is proving to be a satisfactory Journal.

Following the implementation of the Strategy Plans of the twenty-teens and the widening out of the Society's activities (see text below), the work of the office increased – not helped by the load resulting from implementation of new labour-saving computer systems! The successes of the initiatives with Accreditation, Associations, Corporate Membership, and Communications etc. have led to more Office activity. To which, over this period of time, was added the increasing involvement of BSAS in running conferences (sometimes with other organisations). Presently the Office delivers around two or three substantial conferences annually, this being the most demanding and embracing office function. Information outreach, both to the membership and the 'outside world' was enhanced by the involvement since 2013 of journalist and tweeter Caroline Stocks, while Leigh Murray's appointment was made full time in 2017. Accreditation, handled from its inception in 2014 by the Accreditation and Governance Group Chair, was in 2017 established with Alison Christie as Accreditation's Executive Manager. Jon Day, whilst not strictly 'Office' has, since 2014, taken on increasing responsibilities for the vital activities of strategy implementation, corporate membership, sponsorship and media.

The present BSAS CEO inherited in 2018 a substantially larger and more complex team, led willingly and ably by Bridget Hilton, than Mike Steele had found thirty years earlier.

Website

In 2006 BSAS had its website up and running. At that time, the website was a means of stating to the world what BSAS was and what it did. Every now and again it would be given a make-over and new information added, such as the dates of next meetings. There were scrollable-through pages to be read. Memberships of Committees could be put up there, Minutes, etc. Nobody much looked at it, but having it was an important part of being an organisation in the public domain.

Through to 2011 the potential of the website was evident, but not realised. It could be an interactive means of better communicating with the membership. And the thing most exercising the minds of members was that they were not being well enough communicated with! The strategy plan of 2015 gave added impulsion to the development of the BSAS web platform that is seen today. Through **bsas.org.uk** the full range of BSAS activities can be accessed. News items, reporting of events past and alerts to events upcoming (within and outside of BSAS auspices), dead-line prompts, access to on-line application to attend conferences, apply for memberships, and the whole panoply of interactive interfaces that now make up the Accreditation and CPD suite of programs. All the BSAS Associations have active sections (Academia, Industry, Student Council), and there are sections dealing with scholarships and awards. Importantly, all BSAS publications, past and present (including **ANIMAL PRODUCTION, ANIMAL SCIENCE, ANIMAL, Proceedings, Animal Bytes**) are

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now available on line through the website. In 2017 a new element was introduced, that of access to numerous presentations made at the Annual Conference and available on the website as videos.

Commemoration of Hammond
The *Hammond Lecture* is the most prestigious presentation to the Annual Conference with a sixty-minute slot. It is considered to be a great privilege to be invited (by the BSAS President) to deliver the Hammond lecture. The first was delivered in 1969 by C.P. McMeekan, a Newzealander who had worked with Hammond on growth in pigs. There have been, over the years, many excellent presentations (and occasionally some dire) from senior international scientists. The quality of these papers, and the undoubted effort put into their preparation, makes them highly appropriate for wider dissemination. The written vehicle for this would naturally be the **Proceedings**, while recently there are video recordings of the full event put out onto the website.

The *Hammond Award* is presented annually (if appropriate) to an outstanding mid-career scientist in recognition of research work of outstanding excellence. The first recipient (1968) was D.G. Armstrong, the nutritional biochemist.

The association of BSAS with John Hammond is not inappropriate, given his reputation as a scientist driven toward industry applications. However, there have been others through the life of the Society equally as deserving of their names being noted. So far, however, apart from the 'awards', there has been no move in this direction.

Scholarships and Prizes
BSAP and BSAS have over the years made a large number of awards; for lifetime achievements, for quality of science and presentation, to support travel and work in distant places.

In 1989 BSAP joined with RSPCA to make an award for innovation in *Animal Welfare*. The first recipient was David Wood-Gush, who amongst other things launched (with the incumbent Professor there) the MSc in Animal Behaviour and Welfare at Edinburgh. The 2017 award was made some thirty years later to the Directors of the programmes that are the inheritors of David's legacy.

The *President's Prize* was initiated originally in the 1970s to be awarded for the best paper at the Annual Conference, open only to those making their first presentation. It has offered encouragement to young scientists (and some rivalry amongst their institutions). The *Industry prize* is given to early career scientists whose paper is judged – by industry members – to be likely to have the highest applications impact. It was initiated in 2014 as part of the strategy plan by industry to re-engage with BSAS.

In recent years it has been assumed that financial support to travel to conferences and to visit research laboratories is most needed by (and best spent on) early-career members (e.g. post-graduate students and post-docs). There are some six awards (amounting to up to £5000 each), associated with past members of BSAP/BSAS. These were begun with donations from members, and by association with their names continue to draw past servants of the Society to the attention of its current members. They are; Alan Robertson (1992), Kenneth Blaxter (1999), Murray Black (2001), Steve Bishop (2012), Kevin Shingfield (2016), Mike Steele (2018).

International
Whilst the Society's record of collaborations with other like Societies world-wide is not especially notable, as has been picked up in every strategic plan (see below), BSAP & BSAS have nonetheless succeeded over the years of their lives in achieving a high profile in international science and science publication, as befits the Society's origins and membership. The Annual Conference (as indicated by attendance and paper authorships) is an international affair. Many members have had strong and lifelong commitments to international livestock science and development; not least the CEO, Mike Steele. Other notable 'Internationalists' have included Gill, Orskov, Hovell, Owen and Simm.

Individual member's contributions have often led to the Society arranging – and subsequently producing fully published proceedings – for Overseas Conferences and workshops. These would include such as those in; Kenya, Mexico, Thailand, Tunisia, Ireland, Netherlands, Greece, Poland, Lithuania…

European Association of Animal Production
At around the same time as BSAP was learning to walk; EAAP was born (in 1949). BSAP Officers had been involved in EAAP proposals since 1939, but BSAP did not join at that time because (a) the annual membership fee was too expensive, (b) delegates would have to be sent at further expense, (c) proposals for a Rome Office were overelaborate, and (d) EAAP notions for organising International Conferences were excessive both in terms of organisation and cost. The other constituent organisations of EAAP were supported by their governments, whilst BSAP was funded (privately) by its membership.

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Nevertheless in 1952 BSAP became members of the European Association of Animal Production and have since played an extremely strong part in its affairs, both scientific and administrative, and contributed fulsomely to the works of its Commissions. The (re-) organisation of EAAP which began in 1958 was strongly influenced by substantial inputs from BSAP senior members (H.R. Davidson, Richard Trehane, Lord Digby) who were stalwart supporters of EAAP, and BSAP's membership of it. Trehane became EAAP President in 1961. BSAP funded the EAAP International Congresses of 1966 (Edinburgh) and 1994 (Edinburgh, 1100 delegates, masterminded by Maurice Bichard), and BSAS the EAAP International Congress in 2016 (Belfast). This latter event should not pass without paying credit to Sinclair Mayne, 66th BSAS President, who has served the Society (like so many other Irish members) tirelessly over many years. Through until the 2000s EAAP had been a significant part of many BSAP members' scientific activities; and reciprocally, BSAP member input to EAAP Commissions was considerable and sustained. Regrettably, such cannot be said of the present day BSAS membership. Maybe EAAP is seen as inadequately scientifically rigourous. The casual observer might be forgiven for failing to understand how BSAS does not see more (not less) of its future lying in cooperative ventures with EAAP.

The total costs of EAAP 2016 marginally exceeded BSAS total available funds - an extremely hazardous position for a society without any Government underpinning to put itself in. Fortunately the EAAP Belfast Conference was a great success (best attended ever, despite bleak warnings two years earlier that nobody would come from Europe to Belfast, and BSAS had made a foolish choice). There were over 1550 delegates from 60 countries; from research science, industry, academia and consultancy services. There were over 70 sessions across 4 days including a rather greater number of applied topics than had come to be experienced at BSAS's own Annual Conference. With the help of substantial sponsorship support from Industry, EAAP Belfast, to everyone's considerable relief just about broke even financially. It was Mike Steele's last hurrah and a triumph. It had been a famous week.

Strategy planning

Forward thinking was the epitome of the Founder Members of BSAS. They founded BSAS! This was a bold and grand plan. Within five years all their aspirations were being successfully played out: the conferences, the symposia, the proceedings, the publications media for exchange amongst scientists, the forum where science met farming, and the promulgation of science in the service of innovative livestock management practices. Through until the mid-nineteen-seventies, the Society had its being, knew what it was doing, and did it very well. Membership and attendances at meetings were never higher. But warning salvos were fired by two heavyweights; K.L. Blaxter and H.P. Donald. Peter Wilson also had a few words to say in 1995, and set up the following year the *Strategic Plan Working Group*. This group was strong on gravitas, travelling to locations of importance and taking expert witness statements from people of importance as to where BSAS should go next. By all accounts a wizard time was had, and a report duly prepared. This comprised broad well-intended conceptual proposals, picking up on the need for actions particularly with regard to 'Overseas', 'PR', Farmer membership, EAAP, and the importance to the Society of serving better the Technology Transfer communities. Wilson (regrettably) advocated "*evolution rather than revolution*", at which point (wholly predictably) the initiative ran into the sand due to a complete lack of mechanisms for implementation. In the later years of the 1990s, matters of strategic concern for the future of the Society would frequently be discussed in Committee. Little if anything would come of them – there was (is) still no effective delivery mechanism.

The drive for better future proofing in the 2000s came from the evident falling away of that vital resource – MEMBERS! Increases in BSAP 'Ordinary' membership had come steadily (from 300 in 1949) through the fifties and sixties (550 in 1959) so that membership numbers exceeded 1100 by 1972 (more than half in ('state') research and ('tertiary') teaching, most of the rest in the trade and state advisory services, with few only involved in primary industries).

By the turn of the century a third of that membership had been lost. In 2004 there were 600 'Ordinary' members; in 2012, 400. One of the current Presidents of that time put it "The only reason I am a member is out of a sense of loyalty to BSAS. I can perceive no actual value in membership itself." His point was there were no evident benefits for paying the subscription fee. Access to the Journals and to the Conferences (the main reasons for being a member) was not restricted to members only! There needed to be more added benefits to BSAS than a small reduction in the Annual Conference fee!

After the farmers had left, for similar reasons (lack of relevance) the technology advisory sector then began to fall away (of course, there were in any event fewer of these following funding withdrawals for both state and industry advisory agencies). Losses were not made good by equivalent gains in members from research and academia. In the Universities the general trend was for Agricultural student numbers to be falling. Further, while in 1981 there were 22 State-funded Premier Agricultural Research Institutions in UK, by 1991, there were just 7. Today, BSAS-orientated livestock research primarily emanates from the Universities and BBSRC strategically supported work at three centres (Rothamsted, Roslin and Aberystwyth). Attendances at conferences had, however by-and-large held up (425 at York in 1992, 500 at Nottingham in 2012).

The perceived need for 'Horizon scanning' and 'Strategy planning' came to the fore at the end of the century. The Presidency of 1998 had a go at it, but apart from there being 'a plan', there was little obvious by way of radical change in the conduct of the Society's affairs.

In 2004 the Student Council had been set up to provide a means of supplying a student to sit on BSAS Council (as was the 'good-practice' of the time). It had the strongest support from President Sandra Edwards, bringing her University experience to bear. What happened next was that not only did the presence of a student considerably smarten up affairs at Council, but the students picked up the ball and ran away with it! With a BSAS budget (£k5) they fixed up a 'Student Meeting' the day before the annual conference, inviting prestigious speakers. They organised a quiz night (and afterwards) during the Conference (old lags invited). They arranged other meetings around the universities on topics-of-the-day (such as experimental analysis). The Student Council, being such a huge success, awoke the Ordinary members to the possibilities of a bit of pro-action on their part too.

The Council had supported the proposition that there should be a forward looking review which took place in 2005/6. Members would be surveyed as to their views on BSAS's future role. The Technical and Ethical Committee commissioned an outside agency for a membership survey which reported strong support for the BSAS Conference organising function, but thought that BSAS was inadequate in its communications with the industry at large. BSAS Council decided that to address the matter of falling membership there should be working groups to consider; (a) raising the profile of BSAS within academia (staff and students), (b) the mission, (c) possibilities for new knowledge transfer focussed on internet communications, (d) development of BSAS involvement in CPD/Accreditation matters. The 2007/8 Presidency (Geoff Simm), with the backing of the Presidents' Committee, commissioned a proper '5-year plan'. The President himself masterminded 'profile raising' by arranging meetings with members of parliament in Westminster, Holyrood and the Senedd. These were well supported, rewarding at the time, but with little longer-term benefit. However, the modern era of forward planning owes much to the original impulsions generated by Simm.

The series '**Animal briefs**' was specially commissioned to give policy makers that for which they had asked – ready and unbiased information on topics of the day. The 'briefs' failed from the outset on account of difficulty in finding writers and having no demonstrable readership! '**Animal bytes**' has been more successful. This series takes from the Annual Meeting selected topics for subsequent re-writing in a popular style. These were (still are) put up onto the website. Whilst sponsored by AHDB (for 3 years) these made effective communication media, but latterly were found more challenging to sustain because of difficulty in finding appropriate writers. Nonetheless **Animal bytes** (in contrast to Animal Briefs) is seen as a successful outcome from strategy planning. The model is sustainable (given hands ready to translate conference presentations into popular science), and the existence of a readership is demonstrated by the number of hits on the website.

This same initiative would lead to the appointment (eventually) of a part-time '**Communications Officer**', the arranging of '**Industry sessions**' at the Annual Meeting for the specific benefit of an 'industrial' audience, and recruitment of '**Corporate memberships**' amongst commercial firms whereby at reduced rates a cohort of new members could be identified. BSAP had asked Janice Harland (an animal nutritionist out of David Armstrong's school working in the animal feed industry) to be the 'Press Officer' in the 1980s to address the issue of the Society's failing interactions with the world at large – a post that she had filled with enthusiasm. However, after her leaving that role (to concentrate better on her consultancy business), the Society had lost the knack, and public relations had again faltered. The cry for the Society to become more attractive to farmers had slowly faded through the sixties when most of the members were happy to see the Society become more attractive to scientists. By 1995, only a faint bleat could be heard (from the older members). The cry that replaced it was one for the society to become more attractive to livestock's allied trades (feed, breeding companies and veterinary) and to the Technology and Knowledge Transfer sectors. The Corporate membership initiative was frowned upon by a significant cohort of those members that attended the AGMs (never a representative sample), and the idea was left to hang for a few years; only being picked up seriously as part of the next strategy plan in 2015 (and now proving its worth).

In 2011 the AGM agreed a re-visited Constitution for the Society. It is not much divergent than that formulated in the early years of the Society, except that there is less emphasis on the duty of BSAS to see the science through to practice – the concept is still espoused, but the feeling of an imperative to do it has gone.

The cynic of 2011, glancing at the stated objectives of the Society, would find nothing in them that could not be reasonably well met by the holding of the Annual Conference and the publication of **ANIMAL** and **Advances in Animal Biosciences, Proceedings of the British Society of Animal Science**. In particular, science transfer would be interpreted as encouraging the involvement of Technology Transfer Agencies in BSAS Meetings and workshops (attendances would indicate success in this). There remained little appetite for cooperative ventures with other like-minded Societies in UK, Europe and Worldwide except those that self-delivered such as EAAP, WPSA, ATVRW.

It is interesting however that whilst every forward ambition statement for the Society includes a desire for it to speak better to the 'outside world' on matters of animal science and animal scientists, the constitutional objectives do not explicitly include "Pursue the Professional interests of the Society's members". This is a significant oversight if BSAS is to follow the enjoinder of Blaxter, and others before and after, that BSAS should behave more like a Professional Society and less like an Exhibitions organiser.

What the 2011 AGM had received and accepted was "*BSAS 5-year Strategy Plan Progression – Strategy Report and Road Map*". This was an "*Action Strategy*", its purpose was to brief-out what needed to be done following the plan of 2007. Needless to say, it began with both a "*vision*" and a "*mission*" statement!

"The vision is for a Society that functions as the authoritative and professional body for governance and oversight of Science impacting upon farm, companion and leisure animals. A Society that is visibly the professional forum for discussion and dissemination of Animal Science R&D, through meetings, publications and accessibility to industry end-users and public bodies in their widest senses.
The mission is to deliver science with the impact to give us food, fibre, and animal companionship with minimum detriment. The agenda for the mission is: Food Security, Food Quality, Animal Well-being and Environmental Protection".

[The report of the Council, 30th November 2017, confirms as the objectives and activities of BSAS:

The British Society of Animal Science (formerly The British Society of Animal Production) was formally constituted on 6th January 1944 and amended at the Annual General Meeting in 2010 in order to:
Provide opportunities for those interested in and concerned with the science relating to animals and its application to meet and exchange information, ideas and experiences.
Encourage the investigation of problems and matters pertaining to the science related to animals and its application.
Collect and publish information about the science relating to animals and its application; to print and publish any periodicals, books and leaflets which the Society may think desirable.
Stimulate the incorporation into practice of advances resulting from research, experimental work and practical experience.
Co-operate with any other organisation in furthering of the objectives of the Society.
Do all such things as may be incidental or conducive to the attainment of the objects or any of them.]

The 2011 Strategy Report document saw its own objective as dealing with "Two related problems: *Falling membership and reduced visibility"*. It saw BSAS as being in danger of *losing its importance and relevance*. That report had resulted from a team of ex-presidents led by Colin Whittemore which had looked at the various elements of the Simm report and come to the conclusion that actions were needed in the following general areas; collaboration with other organisations, projection to the lay community, increasing membership, creating relationships with end users, developing member benefits, and increasing back office and front office functionality (the latter with particular regard to the Society presenting to legislators and policy drivers views representing the best interests of its members and their science).

The Plan was endorsed at the 2012 AGM. What resulted was a restructured committee framework, the setting up of two new functional groups, one for industry (**Industry Association**), and one for academia (**Academia Association**), and later one for overseas members (**Global Association**). These Associations were to bring their respective sectors closer to the work of the Society. Primarily to give members from the feeding, breeding, equipment and veterinary sectors; the post-grad and post-doc students; and the overseas members, a more direct stake in the organising of conferences, setting of agendas, and determining future policy and initiatives. One step toward making BSAS a 'Professional body' was achieved with setting up with the Society of Biology the **Accreditation Scheme**.

What however was not achieved was any formal mechanism for The Society to 'Speak for its members'. Nor had anything much happened regarding liaisons with other like-minded organisations – either at home or abroad. Particularly disappointing were the failures regarding closer relationships with veterinarians and with Societies of Animal Science worldwide.

The Strategic Planning paper ends "Failure to action previous plans has often been due to BSAS depending upon a decreasing pool of increasingly time-constrained office bearers." It has often been remarked that the Presidents and the Committees of BSAS are quick to propose actions that might benefit the Society, but the actual delivery of these opportunities is poor. It is evident from the experiences following the action plan that success is likely only when an individual is identified to complete a particular task and is recompensed for the time spent in carrying it out.

In 2013, President Peter Williams revisited the 2011/12 strategy. The Society is reminded that what should come first is those things it does best (and easiest; mostly through the permanent Office staff). These are (i) Publish scientific literature with EAAP and INRA (**ANIMAL, Advances**, etc.), and (ii) Run the Annual Conference and other Occasional meetings and Workshops.

In 2015/16, President Alistair Carson, asked Colin Whittemore (again!) to do a further 'Strategic review'. This would take the form of a wide-ranging survey of all BSAS members, and the setting up of eight special groups to consider specific topics. It was not a trivial task! (But then neither was the 2011 operation).

In that last review, the members re-asserted that for them BSAS was about the Annual Conference and the other meetings like the workshops. They wished more symposia sessions with outside speakers and more industry-related content. They were in agreement with the Society moving faster towards conducting its affairs in ways akin to a 'Professional body'.

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They were looking for BSAS to be a more influential voice amongst 'policy-makers'. Members saw the **Accreditation Register** as an important part of fostering 'Professionalism', but regretted the lack of any Governmental *imperative* for animal scientists to *require* certification just as do other like professionals.

The most persistent and forcibly put message from the membership was however that BSAS did not communicate with its members well enough. Not just about its activities, but also about what was going on in research, technology and knowledge transfer. Neither did it communicate well on behalf of its members with the outside world of industry, politics and policy. In brief, it was not behaving like a 'Professional Society'! More resources were needed to be put into communications; both persons, and information technology. This resulted (in due course) with the appointment of another member to the **Communications team**, and a stream of Facebook, Linkedin and Twitter feeds, as well as snappy items on the (to be modernised and upgraded) **BSAS Website**. The ambition for the website was that it should be the regular 'go to' place for all BSAS members. The usefulness of the web site for communicating conference activities (e.g. by **videoed presentations**) to those unable to attend, especially overseas members, is clearly evident. Many of these initiatives are still in process of being satisfactorily developed.

Despite the ease with which the Society finds it can come up with ideas and solutions to its problems, there remains the all-pervading difficulty of getting things done by a volunteer workforce under extreme pressure from their 'day-job' employers. It is not the strategy *planning* – it is the strategy *actioning*! Where success has come (and the above account tells of some very real successes), it has often only been as a result of matters being taken forward by individuals highly motivated toward the well-being of the Society.

The Associations

The **Academia Association** and an **Industry Association** were set up in 2013 to involve respectively the University Post-graduate community and the Animal Industries (especially Feed) in working closer with the Society. Each have about 15-20 corporate members, each member with their own representative (or 'ambassador'). The **Industry Association** has been key to creating industry-useful sessions within the Annual Conference and encouraging post-graduate students to be 'Industry aware'. Industry has seen the Association as a fertile recruiting ground, and has created strong liaisons with their sister Association. Through IA, BSAS has been able to act as a broker helping to bring together Academia and Industry to secure funding within the Government Agritech programme for CIEL.

However, little progress had been made with regard to linkages with other like-minded overseas organisations. International outreach was judged 'poor' in the 2016 review. The call for action resulted in the setting up of the **Global Association**. To date there is no evidence that this 'Association' (in contrast to Academia and Industry) has had any beneficial effects.

Left pending, however, is the matter of the involvement of the veterinary professions. If the BSAS was a Society for the Animal Sciences, how was it that there were so few members with direct interests in animal health? The inclusion of those in animal health research, teaching, technology transfer, and practice was called for by the 2016 review as a matter of priority for all parts of the Society – organisers of conferences, planners of workshops, members of Associations…

Accreditation

As a part of '*developing the benefits of membership through the Society having a governance role in maintaining science standards and integrity'*, tentative exploration of various CPD schemes was suggested; it was noted that the Nutrition Society had one such. In 1999 BSAS Council (with CW in the Chair) had opined that "CPD was one area in which the Society might provide Accreditation, and Cled Thomas was asked to look into the matter. A few years later another report was asked for, the objective of which would be to provide evidence to the effect that such schemes were neither beneficial nor necessary! Unfortunately, the report's author (CW), whilst confirming the shortcomings in many existing schemes, came to the conclusion that a CPD-based Accreditation scheme was a rather good thing for professional animal scientists to belong to. As for example was already the case for veterinary surgeons. Further, an Accreditation scheme for all professionals was urged by the Government of the day, and BSAS was well placed to deliver. As is normal, the strength of advocacy of the report's writer ensured that it would be he who would get the job to do!

In 2012, a potential scheme was outlined to the Society that would be run with, overseen, and audited by, the Society of Biology (the newly constituted replacement for the defunct Institute of Biology) and through SB by the Science Council of Great Britain (giving international and independent status to the scheme).

The *Royal Society of Biology & British Society of Animal Science Accreditation Register* was to be available to be joined at either Certified or Associate level, and as an Animal Scientist or an Animal Technologist (with appropriate post-nominals). Continuing Profession Development was to be embedded as an integral element of the scheme.

The scheme would become fully functional by 2014. Early problems with the on-line applications interface would involve a large (unnecessary) administrative burden, but would be resolved by 2016. Thus was created a substantial new dimension to the business of the British Society of Animal Science. To administer it the **BSAS Accreditation and Governance**

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Group was formed**.** The taking of responsibility for the *Certification of competence* – not just for its members, but also for the wider Animal Science community – represents a landmark step in (i) the Society acting as a *Professional organisation* in the wider world sphere (as opposed to being simply a body running conferences and publishing scientific literature), and (ii) the Society giving its members additional benefits of membership.

Committee Frameworks

At its beginnings the British Society of Animal Production was a gathering of like-minded people; a Club. But soon it had accumulated funds that required accountability. The British Society of Animal Science had become a Registered Charity in Scotland in the 1980s. Properly constituted organisations require responsible persons named as accountable for their governance and conduct. There being no management structure as such, this function was taken on by the Council. BSAP Council was formed in 1978 (J.M.M. Cunningham in the chair). The named members of Council became the Trustees responsible to the Charity Commission for the conduct of affairs – Council being appointed by the Membership at the Annual General Meeting.

Before the appointment of a CEO (Mike Steele in 1989), the affairs of BSAP were managed by the Secretary as the only post with presumptive continuity. The Office effectively saw to it that things happened. Toward the Society's middle years, meetings would be organised by members most interested in holding them. Programmes for Winter and Summer Meetings came to be organised by a 'Programme Committee', the Journals were looked after by the Publications Committee (aka their Editors), Ideas came from the Technical Committee, while the Council presided over all, chaired by the President. The only 'statutory' bodies making up the Society were the Council as Trustees, and the AGM. All the other committees could come and go at will!

Subsequently it was decided that the Council was too large a body to be held responsible as Trustees. In the 2000s this body was reduced to the four Presidents (Past, Current, Vice, Junior Vice) and the Treasurer. In 2017 this was judged too few people, so in future there will be added back a small number of members of Council.

Come 2005 there were 3 standing Committees in addition to Council; Programme, Publications, Technical & Ethical. Arrangements for the Journals changed through the early 2000s, with **ANIMAL** and **Advances in Animal Biosciences** coming to be handled by their own administrations (with BSAS representation) and the publishers (Cambridge University Press). In 2009 Publications had become 'Education and Communications Group', and there was a new Group – Marketing (short-lived, unsurprisingly).

The Strategy plan of 2011/12 suggested that the Committee structure was no longer fit for purpose. But the changes that followed do not appear (in retrospect) especially coherent. In 2011 T&E becomes Strategy and Innovation and will be the 'Ideas (for Conferences) and Development (strategy) Group', also attending to relationships with other Societies, and reviewing scholarships, awards and prizes. By 2016 it was noticed that the main item here was now being done by the Presidents' Committee, the second (relations with other societies) did not seem to have a mechanism for its enactment, leaving only the last function.

In 2013 the Education and Communications Group became the Communications Group. A new Stakeholders group is formed which mostly concerns itself with the affairs of the Academia and Industry Associations. By this time, organising the activities of BSAS employed a secretariat of four staff, (Chief Executive, Senior Executive Officer, Executive Assistant, Finance Officer) and a number of dynamic (as in short-lived) working groups/committees made up of office bearers and staff. These are Council (the main representative body of members), Science and Technical Events, Strategy and Innovation, Communications, Stakeholders, and Accreditation. The President's Committee was started to provide continuity-support to the current President from the other three Presidents (past, next, and next after), the CEO and the Treasurer. It was soon found helpful to add into this group Chairs of other Groups (giving co-ordination between Groups). The Presidents' Committee became the effective forward planning group for the generation and implementation of operational strategy. Presidents' had the unhappy knack of duplicating the work of other committees (including Council); however, it seemed to get some things done!

So who runs BSAS? The Society has four imperatives in its bag of things to be done: Conferences and Workshops organisation, Publications, Accreditation, and Awards. Fiducial responsibilities lie with the Trustees, backed by the Council and the AGM. Functional operations are delivered from the Office (now including the Communications duo and the Accreditation Executive) and from the CEO. Delivered to the AGM in 2018 were the reports of the CEO and the Hon Treasurer, and the activities of Science and Technology Events, Education and Training, Communication, Stakeholders, Accreditation and Student's Council.

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Concluding reflections

In reading through the volumes of archived papers generated over 75 years, one cannot help but suggest in the past the membership was more committed and pro-active; less pre-occupied with the trivial round, the common task. Within working hours' time was put aside to spend to the benefit of the Society.

In the 60s, 70s and 80s, BSAP Committees and members were busily forming *ad hoc* groups to respond to consultations and to lead in initiating National level discussions in matters such as breeding targets, feed requirements and safety, and animal welfare and management. BSAP opinion was sought as a professional body whose position on livestock issues mattered, and was considered by others to have a significant voice. Those 'others' included Government Ministers, Senior Civil Servants, Industry leaders, and professional groups (such as the Vets and the Institute of Biology). The Society was outward looking and international in its demeanor. It was, in a word, *important*. So also were its Conferences and its published organs; such as the Proceedings, Animal Production, Occasional publications. BSAP *led*.

For all its re-named Committees and Initiatives not only is there much unfinished business pending in this 75th year of BSAS, but it is not obvious how this business is to be completed within the society's current framework.

Looking inwards at the Society, it is not for the want of knowing what needs to be done. In the modern era it is for the want of incisive people with the time to do it. That, above all things, is what has changed in 75 years.

Looking outwards, what has changed is that the imperative to feed hungry mouths and foster the second agricultural revolution has long gone. So what is the British Society of Animal Science to be for?

Perhaps most importantly is the Society's part in Information Transfer and Information Exchange through science publishing; of proceedings, symposia plenary papers, original research and development. But here there are issues to be addressed. The science *generating* community is well served by modern day publishing, but the science *user* community is not. This was a major reason why the Society was formed 75 years ago, and maybe it is time this matter be re-visited. Science publication itself is changing with the digital age, and in future the Society will need to plan without an income flow from this source. BSAS has a voice on the Consortium Board for **ANIMAL** and **Advances in Animal Biosciences**, but in the absence of a Publications Committee, the means by which ownership and influence upon the development of those publications (so vital to the future of the Society) is now insecure.

Is the Society to be seen as an appropriate Professional body for pursuing the interests of its members? If it is to do this directly then substantial investment is needed to fund public outreach in all its forms and to all sectors. This will require an expanding membership – a virtuous circle of expanding subscription income being spent on expanding services. The Society may choose to action this element of its work in-house, or expend more energy in making other organisations (such as the Royal Society of Biology and EAAP) work more effectively on its behalf.

Incontrovertibly, BSAS has to be for the organising of conferences and workshops, at which it is very good. Further, the Society is developing new mechanisms for the promulgation of the outputs from such events using modern technologies. Perhaps this will be the way in which the issues of the future be addressed.

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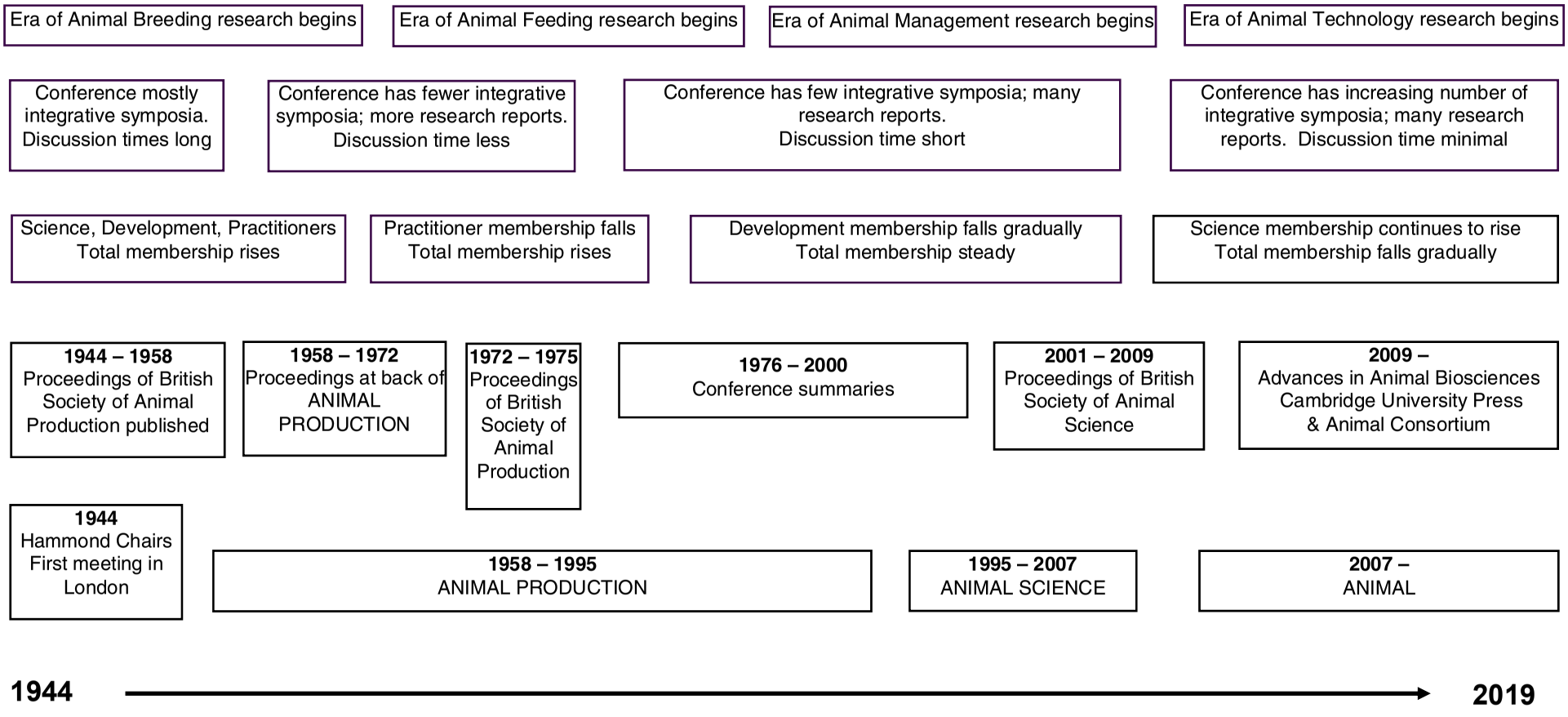
British Society of Animal Production / British Society of Animal science
75-Year timeline 1944-2019



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Animal Science Fit for the Future

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British Society of Animal Science

The British Society of Animal Science aims to provide an opportunity for those with an interest in animals and animal science to exchange views, ideas and information. It is an energetic and active society with about 700 members from over 40 countries throughout the world. Today, as ever, the Society is the natural meeting point for all of those with an interest in animal science. Its membership is drawn from research, education, advisory work, commerce and practical animal keeping.

The Society's Journal is *Animal* which publishes high quality fundamental and applied research and is an exciting international journal of animal bioscience. Animal publishes cutting edge research, hot topics and horizon-scanning reviews on animal-related aspects of the life sciences.

The Society organises major scientific and specialist conferences on key issues facing the science related to animals.

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