Intensive livestock production; its impact on the cost and nutritive value of food

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Over the 10 years 1966–1976 the total agricultural area in the UK has decreased by some 600 000 hectares (approximately 3%); disproportionately more of this loss has been prime agricultural land, rather than hill or marginal land, and there have been significant increases (239×10^3 ha) of woodland on agricultural holdings. Over the same period the population has increased by 2·8% to 56 million and estimates suggest that it will go on increasing to 57·5 million by the year 2000. It follows that to maintain importations of food, animal feedstuffs and fertilizers at their present level, there has to be an increase in productivity brought about by improvement in efficiency.

The estimated food supply has not changed significantly over the last 10 years (Table 1) nor the proportion that is produced at home (Table 2). If anything, the demand has been for more meat and less sugar and cereal products, but the increase is not of such a magnitude that would trigger an increase in the intensification of farm livestock.

Table 1. *Estimated food supplies in UK (kg/head)*

	1966	1976
Cereal products	76·7	75·0
Sugar	49·6	45·7
Meat	62·1	66·5
Dairy products	152·5	152·0
Eggs	246	237
Fat	25·6	24·6

Table 2. *Self sufficiency nutrients/feed*

Nutrient	1966	1976
Protein	61·1	66·2
Fat	39·8	43·4
Carbohydrate	39·9	39·5
Energy	42·9	44·9
Foodstuffs	51·4	53·7

Intensification is defined here as an increase in the size of the livestock unit, so as to enable benefits to be derived from economies of scale, reductions in capital and labour costs when considered on a per animal basis, and to enable optimum environments to be provided at minimum capital costs. There have been significant reductions in the number of units in some types of livestock production;

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in pigs, for example (Table 3), there has been a 61% reduction in the number of units, and a 12% increase in the sow population.

Table 3. *Change in the nature of pig holdings in UK*

	1966	1976
Herds, $\geqslant$100 sows (%)	12	45
Number of sows ($\times 10^3$)	669	749
Sow holdings	62533	24631
Pig holdings	82127	32337

The justification for intensifying livestock production, in the past 10 years at least, has not been the need to produce more food, indeed sales of farm livestock or livestock products have changed very little (Table 4). Over-all, we are only 51% self sufficient in food production but there would be little point in increasing self sufficiency in meat production within the context of the European Common Market which is virtually (98%) self sufficient in meat and milk production. The justification for intensification lies in the need to maintain our present degree of self sufficiency, but more important, to maintain farm income. Our gross agricultural product, valued at current UK prices, increased from £1034m in 1966 to £2282m in 1976, a factor of two. Over the same period national personal income increased by a factor of four while farm incomes by only a factor of three, despite the economies that have already been achieved by intensification. This relatively lower rate in the rise of farm incomes coupled with disproportionate increases in the price of land and a reduction in the labour force, has forced farmers to intensify further. Indeed the price of land has increased so much that the borrowing capacity of owner farmers based on the value of their land is far in excess of their capacity to service the potential loan from the income the farming enterprise provides.

Table 4. *Sales of agricultural produce and livestock*

	1966	1976
Cereals ($\times 10^3$ ton)	4113	4463
Potatoes ($\times 10^3$ ton)	4776	3340
Milk ($\times 10^6$ l)	21939	27236
Eggs ($\times 10^6$ dozen)	1176	1156
Animals		
Cattle ($\times 10^3$)	3862	4481
Sheep ($\times 10^3$)	13561	12670
Pigs ($\times 10^6$)	13485	13499
Poultry ($\times 10^6$)	282	401

These then are the reasons for intensification. In terms of value for money, the change in agricultural production and its concomitant increase in efficiency has maintained output, sufficient to feed an increasing population and maintain the same degree of self sufficiency and it has provided food at reasonable cost.

I would like to consider in more detail the impact of intensification of animal production on aspects of the value of food for human consumption. In particular,

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the extent to which the nutrient content and quality of food produced for human consumption can be altered by the manipulation of animal feedstuffs.

Effects of intensification on the composition of the animal carcass

One of the objectives of intensive livestock production is to achieve marketable live weights in the shortest possible time. For ruminants, this has led to the use of grain rather than roughages as the main source of feed, as for example in the 'barley beef' system for cattle. The feeding of readily available carbohydrate in the form of cereals increases the efficiency of utilization of feed dry matter, firstly because the concentration of metabolizable energy/kg diet is greater and secondly because it changes the ruminal proportions of short-chain fatty acids, leading to more propionate and less acetate. Table 5 gives examples of this change.

Table 5. *The molecular proportions (mol/100 mol total volatile fatty acids) of short-chain fatty acids in rumen fluid of animals fed on different diets**

	Main dietary constituent	Short-chain acids		
		Acetic	Propionic	Butyric
Sheep	Grass	68	18	14
	Hay	81	13	5
	Flaked maize	51	42	5
	Rolled barley	52	30	12
Ox	Grass	68	18	11
	Mixed cereals	41	37	11

*Garton (1977).

Both the aforementioned factors lead to faster growth, and therefore to greater efficiency because less of the dietary energy is expended on maintenance and the intake of dietary energy is increased. High planes of nutrition achieved by the feeding of grain to cattle, or giving high-energy diets to pigs (for example, when fat is added) generally means there is a surplus of both energy and protein—in cattle the rate of microbial protein synthesis in the rumen is directly related to the carbohydrate fermented. There have been several assessments of the effect of plane of nutrition on carcass composition (Elsley *et al.* 1964; Fowler, 1974; Wallace, 1948) and these indicate that it is the proportion of fat in the carcass, and not fat-free tissue, that is increased as plane of nutrition is increased, thus carcasses contain more fat at given slaughter weights. The extent of this increase varies between breeds of cattle; examples of the magnitude of the effects are given in Table 6. The table, based on results from Kay (personal communication), gives the live weight to which cattle must be raised to obtain given levels of fatness in the carcass; increasing the plane of nutrition reduces this live weight, as does feeding to cattle diets based on barley rather than on grass. Early maturing breeds (Hereford×Friesian) have to be slaughtered at lower live weights than late maturing animals (Friesian). The same results show that the water content of lean tissue is increased as the slaughter weight is reduced (Table 7). It is interesting, however, that irrespective of breed, diet, or plane of nutrition, the water content of

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lean tissue is essentially the same if animals are slaughtered at the same degree of carcass fatness (Table 8).

Table 6. *Live weight (kg) in relation to given levels of carcass fatness*

Breed...	Friesian				Hereford × Friesian			
Plane/Nutrition...	High		Low		High		Low	
Type diet...	Barley	Grass	Barley	Grass	Barley	Grass	Barley	Grass
Fat (%)								
15	390	420	400	470	340	380	400	430
20	470	560	500	600	400	460	480	490
25	590	>700	650	>700	475	590	600	570

Table 7. *Estimates of the water content of the lean tissue in cattle slaughtered at different live weights (g/kg)*

	Carcass weight (kg)				
	200	250	300	350	RSD
Grass feed	764	756	747	738	11·0
Barley feed	756	750	743	736	11·2

Table 8. *Water content of lean meat in carcasses from different breeds of cattle killed at different live weights*

	Friesian				Hereford × Friesian			
	High		Low		High		Low	
Fat content (%)	Concentrates	Grass	Concentrates	Grass	Concentrates	Grass	Concentrates	Grass
15	755	757	759	754	757	753	759	759
25	736	—	731	—	744	737	734	741

Use of grain in livestock feeding

The justification for the use of grain for ruminants lies in the fact that when given alone, or as a supplement, it increases growth rate and there are reductions in money invested in stock, labour and buildings on a per capita basis. However, relative to the use of non-ruminants, feeding grain to ruminants is metabolically inefficient. The feed requirement:kg^{-1} carcass gain is approximately 7:1 cattle, 5:1 sheep, 4:1 pigs, and 3:1 poultry, and it is frequently argued that it is morally wrong to feed grain to ruminants when we could use cellulosic feeds, and thus leave grain for human food or non-ruminant feeding. These arguments may well apply in the context of world food problems, but the cereal grain area of the western world has been expanded to meet the grain demands of the livestock industry; if this demand were reduced then the grain area would contract unless

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there was major government action and economic support to divert the grain to the Third World.

The western world uses grain to intensify livestock production; one such example is the use of grain in sheep production. In the UK the normal level of reproduction in sheep is 1·5 lambs/ewe per year, when the lowland flock is considered. By intensive methods involving light control, the synchronization of oestrus and breed potential, output can be raised to 3·5 lambs/ewe per year (Robinson *et al.* 1975). In such a system, however, demand for grain is increased for it is essential for the adequate nutrition of polytocous ewes and for the rearing of lambs when cellulosic feeds are in short supply. On the one hand, this system increases productivity because it reduces the maintenance cost of the ewe when expressed on a per lamb basis, while on the other hand there are attendant problems. Lambs given diets having a high content of rolled barley produce unusually soft adipose tissue which is unacceptable to the meat trade. This softness is primarily due to the presence of triglycerides with abnormal proportions of branched-chain fatty acids (Duncan *et al.* 1972). For instance the fatty acids of subcutaneous triglycerides of sheep given grass or barley diets contain 2·8 and 15·4% of branched-chain acids respectively and unusually high proportions of odd-numbered fatty acids (Garton *et al.* 1972). The branched-chain fatty acids have lower melting points than those found in lambs on more conventional diets. Both these chemical abnormalities are apparently associated with the failure of the liver to metabolize excess propionate normally (Duncan *et al.* 1974); when propionate as such was included in a barley-based diet given to lambs, the carcass triglycerides contained more odd-numbered fatty acids and branched-chain fatty acids than when acetate or butyrate was included—the fact that grain diets lead to higher proportions of propionate in the rumen was referred to earlier (see Table 5). The effect is due to the utilization of methylmalonyl-CoA which is the normal metabolic product of the carboxylation of propionyl-CoA and therefore in excess under the conditions described above, in place of malonyl-CoA, during the synthesis of fatty acids in adipose tissue from acetyl-CoA or propionyl-CoA as primer units (Garton, 1977).

The problem appears to be specific to sheep and to goats, small ruminants, and does not occur in cattle (Duncan & Garton, 1978), and it has been overcome by the use of whole, rather than processed grain as feed. The change in processing of grain also prevented the problem of rumenitis which occurs in animals given diets with a high grain content. This latter problem has been attributed to the high acidity in the rumen (Kay *et al.* 1969) and recent experiments at the Rowett Research Institute have shown that rumen acidity is reduced and the proportions of acetate increased when whole, rather than processed, grain is given as feed (Table 9) (Ørskov *et al.* 1974); growth rates were not affected. The reason for the differences between cattle and smaller ruminants have not yet been fully investigated. Certainly there are differences in the intake of the two species relative to body size, and in the rate of deposition of adipose tissue in cattle and sheep when they approach conventional slaughter weights. The capacity of sheep liver mitochondria to metabolize propionate is specifically limited by the rate of oxidation of endogenously-generated succinate (Smith & Russell, 1967); it seems that when this capacity is exceeded methylmalonate and propionate are transported to tissues which are active sites of fatty acid synthesis and thus become incorporated into fatty acids being synthesized *de novo* (see Garton, 1977).

Table 9. *Effect of processing of different cereals in lamb diets on rumen pH and proportion of acetic and propionic acid*

			Molar proportion	
Cereal	Form	Rumen pH	Acetic acid	Propionic acid
Barley	Whole	6·4	52	30
	Ground*	5·4	45	45
Maize	Whole	6·1	47	39
	Ground*	5·2	41	43
Oats	Whole	6·7	65	19
	Ground*	6·1	53	37
Wheat	Whole	5·9	52	32
	Ground*	5·0	34	43
SE of means		0·14	2·4	3·2

*Pelleted.
Taken from Ørskov *et al.* (1974).

Taints in animal tissues

Boar taint. A recent development in intensive pig production is based on the realization that there are differences in the responses of boars, male castrates and gilts to given levels of nutrition. This has led to the practice of separating the sexes at feeding, and because of the superiority of the boar in growth rate and efficiency, to leaving males entire. There are, however, problems of taint in boar meat (commonly referred to as the sex odour) and which is most evident on cooking. The substance primarily responsible for this taint in cooked flesh is 5α-androst-16-en-3-one (Patterson, 1968) and it is primarily associated with adipose tissue. The concentration of androstenone varies and it increases with age. At 6 months of age young males may have concentrations as low as 1 μg/g fat or less, while old boars can have ten times this amount.

The ability of the general public to detect sex odour varies enormously, from those who can detect small amounts, 1 μg/g fat (Patterson, 1969) to those, in the minority, who find the odour pleasant. In Danish work (Wismer-Pederson *et al.* 1969), boars representing extremes in age were studied and strong and weak odour was detected in young and old boars alike. In their study of some 2000 boars, no significant relationship was found between age and sex odour. The same workers put forward the proposition (supported by Green & Winters, 1945) that boars with strong sex odour could be those which are most active in reproduction. The Danish workers also reported considerable taint in some 5% of the gilts they examined and believed there was androstenone in gilts. This is not generally

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accepted, however, and an alternative explanation put forward by Bishop (1969) is that taint in the carcasses of gilts and castrated pigs may be attributed to abnormal sex phenotypes which occur from time to time. The effect of plane of nutrition on the incidence of taint has been studied at the Rowett by Elsley & Livingstone (1969); there was no significant effect of plane of nutrition on the incidence of taint, although there was a tendency for more boars with strong taint to come from those on a low level of nutrition.

Most of the work on taint has been undertaken with selected panels. Extensive trials have been carried out by Rhodes (1971, 1972) on the acceptability of boar meat, and these indicate no major problems with boars slaughtered before 110 kg.

The use of androgens and oestrogens

The superiority in growth of entire males over castrates has promoted experiments to examine the effects of the inclusion in diets of androgens and oestrogens on efficiency and carcass quality. It appears that the over-all effect is to reduce carcass fatness at given slaughter weights, and therefore improve efficiency in terms of lean meat production; these effects, however, are small in females (Fowler *et al.* 1978). A commercial product added to the diet providing 2 mg/tonne methyltestosterone and 2 mg/tonne diethylstilboestrol can be used to increase growth and improve carcass quality. Recently colleagues have examined taints in carcasses at the local factory following complaints by the company that there appeared to be an increase in taint problems. In these studies (Fowler, personal communication) pigs were examined which came from units in which the manufacturers currently recommended dietary additions (2 mg/tonne methyltestosterone and 2 mg/tonne diethylstilboestrol) were used or from units in which half this allowance was employed, or none. In 1000 samples, 228 from the first group, 38% had a strong skatole-indole odour, only 36% were clear, while the other groups were relatively clear of taint.

It is apparent that in intensive pig production there are substantial benefits to be derived from the exploitation of the potential of boars, and from the use of growth promoters, but there are attendant problems.

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