Fat supplementation in animal production—ruminants

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In 1981, 204 000 tonnes of fat were used by the UK Compound Food Industry in the production of foods for farm animals (Ministry of Agriculture, Fisheries and Food, 1982). Of this, it has been estimated that 65 000 tonnes (Meggison, 1982) were used in the production of ruminant rations (mainly for the dairy cow), the remainder being used for pigs and poultry. Since approximately 5 million tonnes of food were produced for ruminants, this is an average rate of addition of 13 g/kg diet, although, of course, this average conceals very wide variations. Is a further increase in the use of fat desirable?

There are basically two reasons for the addition of fat to the diet of the ruminant animal, first, to act as an energy source and, second, to influence the composition of the final animal product in a particular desired direction.

With the assistance of the microbes in the rumen, the ruminant is able to digest forage materials with a high cellulose content. Many of these materials are of relatively low digestibility and, as a result, the food intake of the animal is often limited by the bulk of the food rather than by its energy content, as is the case in simple-stomached animals (Baile, 1979). Therefore, there may be cases in which it is desirable to increase the mean concentration of metabolizable energy (ME) in the food and the easiest way to do this is to add fat to the diet. For example, a 600 kg dairy cow eating 9 kg/d of silage dry matter (ME content 11 MJ/kg) and 9 kg/d of concentrates (ME content 13 MJ/d) should give a milk yield of 28·3 l/d with a fat content of 4% and a solids-not-fat content of 8·5%. If 0·5 kg of fat is substituted for 0·5 kg concentrates, the yield of the same milk should increase to 31·0 l/d; i.e. by approximately 9%.

This calculation is based on assumptions that the addition of fat does not affect the total food intake or the digestibility or metabolizability of the basal diet and that the ME content of the fat is 34 MJ/kg. It is proposed to discuss each of these assumptions in turn.

Food intake

Johnson & McClure (1973) investigated the effect of adding either animal fat (HEF) or maize oil directly to grass at the time of ensilage: in some silages, 10 g ground limestone/kg were also added. Without limestone, the addition of up to 120 g HEF/kg reduced the voluntary intake by up to 27% in sheep and up to 55% in steers. When limestone was added, the reduction in intake was less at the lower levels of addition of HEF but the same at the higher levels and, overall, the addition of limestone did not affect the food intake. When maize oil was added

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alone, the effects on food intake were almost the same. We have recently carried out a similar experiment in which 80 g/kg of either groundnut oil or beef tallow were added to grass at the time of ensiling. The silages were then offered to dairy cows without any supplement. The addition of the groundnut oil reduced the food intake by 5% and the tallow reduced it by 12%.

It would, of course, be more usual to add the fat to the concentrate part of the diet. Murphy (1982) has reported a series of experiments in which tallow was added to the concentrates fed to groups of cows in addition to grass silage. When 20 g tallow/kg was added to a mixture based on beet pulp, the intake of a moderate-quality silage increased by 15%, but when the tallow was increased to 40 g/kg, silage intake fell slightly (by 3%). In another experiment, this time using a good-quality silage, when a concentrate containing 67·5 g tallow/kg was given at the same rate as the no-fat control concentrate, silage intake increased by 10%. When the fat-containing concentrate was fed iso-energetically (that is, at a lower rate), silage intake was increased by 14% compared with the no-fat concentrate diet. When the experiment was repeated but using a protected tallow mixture, silage intake was reduced by 7%.

We have recently carried out an experiment in which different amounts of tallow were added to the barley-based concentrate offered to cows together with a good-quality grass silage. As the amount of tallow was increased, the weight of supplement given was reduced to keep the supplements iso-energetic. When up to 750 g tallow/d was added, silage dry matter (DM) intake increased from 7·6 to 8·2 kg/d and the total food intake was hardly affected. When the amount of tallow was finally increased to 940 g/d, silage DM intake fell to 7·9 kg/d and the total food intake was reduced by 7% compared with the no-fat control diet. In another experiment, we investigated the effect of adding 450 g soya-bean oil/d to a basal diet of grass silage supplemented with extracted soya-bean meal. When the oil was substituted for part of the meal, so that the supplement was iso-energetic, the total food intake was reduced by 13%, but when the oil was added to the soya-bean meal, so that the supplement was isonitrogenous, total food intake was reduced by only 9%.

Thus, the effect of added fat on the voluntary food intake of both sheep and cattle seems to depend on the type of fat used, the way in which it is added and the amount of fat used. However, the picture is very confused and needs further elucidation.

Fibre digestion

In most of the experiments in which fat has been added to the diet of ruminants, there has been a reduction in the apparent digestibility of fibre (Brooks *et al.* 1954; Ward *et al.* 1957; Nottle & Rook, 1963; Steele & Moore, 1968*a*; Kowalczyk *et al.* 1977). In cows, however, Palmquist & Conrad (1980) found an increase in the apparent digestibility of acid-detergent fibre. These workers have suggested that the difference may lie in the low digestibility of fibre in cows (36%) compared with that in sheep (72%, Kowalczyk *et al.* 1977).

The change in fibre digestion is also influenced by the fatty acid composition of the fat added, short-chain fatty acids causing a greater depression than long-chain ones (Steele & Moore, 1968*a*) and unsaturated oils, such as soya bean, causing a larger reduction than saturated fats such as tallow (Macleod & Buchanan-Smith, 1972). Free fatty acids cause a much greater depression in fibre digestibility than the corresponding triglycerides (Macleod & Buchanan-Smith, 1972). Palmquist & Jenkins (1980) have shown that there is no change in fibre digestibility if the fat is added as calcium soaps, which also suggests that there will be no depression if the fat is protected by encapsulation with formaldehyde-treated protein.

The mechanism of this depression is not yet clear. It has been suggested that there may be bactericidal effects or that it may be due to physical coating of the fibre particles in the rumen (Palmquist & Jenkins, 1980). The results of Macleod & Buchanan-Smith (1972) suggest that a free carboxyl group will greatly increase the depression in fibre digestibility which would imply that hydrolysis must first occur.

Digestion and absorption of fat. This subject has recently been reviewed by Noble (1978) and only brief details will be given here.

Ruminants absorb saturated fats more efficiently than do simple-stomached animals (Steele & Moore, 1968*b*) although the reverse situation obtains with unsaturated fats (Andrews & Lewis, 1970*a,b*). The amount of each fatty acid absorbed from the intestinal tract of the ruminant is directly related to its melting point, or its chain length (Steele & Moore, 1968*b*). Although the apparent digestion coefficient of added stearic acid is usually 90% or more (Steele, 1983), if the fat is not well-dispersed throughout the food then digestibility can fall to 50% (Steele & Moore, 1968*b*).

Metabolizability of the diet

Czerkawski *et al.* (1966) showed that the addition of 50 g linseed oil/kg basal diet of hay and concentrates increased the proportion of the gross energy lost in the faeces by 11% but reduced the proportion lost in methane and in the urine by 26 and 15% respectively. As a result, the metabolizability of the basal diet was increased from 67·4% when no fat was added to 69·3% when fat was added. When the same amount of fat was added as free fatty acids, the corresponding figures were an increase of 27% in the faecal loss and reductions of 30 and 11% in methane and urine respectively. In total, metabolizability was reduced by 1%.

Van der Honing *et al.* (1981) gave diets containing up to 70 g/kg of either tallow or soya-bean oil to dairy cows. There were no large effects on the proportions of the gross energy lost in faeces, as methane or in urine, although they all tended to fall. As a result, the metabolizability of the diet was increased from 61·7% when no fat was added to 63·4% when 50 g tallow/kg were added, to 62·6% when 50 g soya-bean oil/kg were added and to 65·8% when 70 g tallow/kg were used.

Wainman *et al.* (1982) have shown that, when up to 50 g/kg of either tallow or 'palm acid oil' were added to a diet fed to sheep, there were only small changes in the energy lost in the faeces, and the loss as methane was reduced as was that lost in urine. In total, the metabolizability of the diet was increased from 53·6% when

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no fat was added to 56·8% when tallow was used and to 56·4% when the palm acid oil was added.

Thus, although the addition of fat will generally increase the metabolizability of the total diet, the magnitude of the change will probably depend on the basal diet and on the type and amount of fat used.

Metabolizable energy value of fat

In formulating rations, it is obviously desirable to have a standard value for the ME content of fat. However, as already shown, the addition of fat to the diet will affect the partition of energy between the various pathways of loss and so a single value for the ME of fat is not really feasible.

Wainman *et al.* (1982) have published values of 34·2 MJ/kg for tallow and 32·3 MJ/kg for palm acid oil. A table of ME values published by Vitamealo Ltd gives a value of 35·2 MJ/kg for tallow. The values of Van der Honing *et al.* (1981) can be recalculated to give ME values for tallow of 27·2 and 36·6 MJ/kg and for soya-bean oil of 21·8 MJ/kg. Finally, the values of Czerkawski *et al.* (1966) can also be recalculated and they give values of 25·9 MJ/kg for linseed oil and 17·9 MJ/kg for linseed oil fatty acids. Obviously, there seems to be a very wide scatter in the values and much more work will be needed to define more closely the value to be used under any particular set of conditions.

Modification of the fatty acid composition of the final product

Cook *et al.* (1970) introduced the use of protected fat into the feeding of ruminants. This is a fat coated with a protein which is then treated with an aldehyde to render it insoluble in the rumen. Initially, they protected sunflower-seed oil and fed it to lambs in order to increase the proportion of polyunsaturated fatty acids in the depot fat. On average, the linoleic acid content of the depot fats could be increased from approximately 3% to over 14%. Garrett *et al.* (1976) found that, by incorporating protected sunflower seeds into the diet of fattening cattle, it was possible to increase the linoleic acid content of the depot fats from 5·3 to 15·7%. Mills *et al.* (1979) showed that if a supplement of protected sunflower oil was fed for 112 d to lambs, the linoleic acid content of the depot fats could be increased to 25%.

Cook *et al.* (1972) gave the same material to dairy cows and found that the linoleic acid content of the milk fat could be increased to over 30%. Recently, Clapperton (1982) showed that adding 500 g/d of protected sunflower oil to the diet of cows given a low-roughage diet of dried grass cubes and flaked maize could increase the linoleic acid content of the milk fat from 4 to 22% and that, when 540 g/d of the same oil was added to the diet of cows fed on grass silage, the linoleic acid content of the milk fat could be increased to 14%. There have been many other experiments and the subject has recently been reviewed by Palmquist & Jenkins (1980).

The minimum amount of fat needed by the dairy cow

Virtanen (1966) showed that, when the amount of fat added to an artificial diet was increased from 37 to 129 g/d, the milk yield was increased by 41% and that of fat by 56%. Later, Banks *et al.* (1976) found that the addition of 400 g/d of fat to a basal ration containing 81 g/d of fat caused average increases of 36% in milk yield and 55% in the yield of milk fat. Both these results show that it is necessary to have a certain amount of fat in the total diet of the dairy cow if a satisfactory milk yield is to be obtained. The minimum is probably 100 g/d, although it may depend on the potential milk yield of the cow. With most practical rations, however, this minimum is likely to be exceeded.

Fat-feeding in early lactation

Early in the lactation, the cow is not able to eat sufficient food to supply her energy requirement (Bauman & Currie, 1980). Smith *et al.* (1978) fed protected tallow to dairy cows during the first 15 weeks of lactation. The total food intake was depressed and there was no increase in the milk yield. Bines *et al.* (1978) fed protected tallow to cows for the first 13 weeks of lactation. When approximately 520 g/d of fat was given, the total milk yield was increased by 14%, but when more fat was added, the food intake and the milk yield began to fall and, at the highest level of addition, 1200 g fat/d, milk yield was less than when no fat was added. Brumby *et al.* (1978) concluded that the optimum fat concentration for dairy cows was when fat supplied 15% of the total ME. Yang *et al.* (1978) fed protected sunflower seeds continuously after the first month of lactation and found that although there was an increase in the peak yield of the cows, the lactation was shortened from 302 to 255 d and that the lactation yield of the cows was depressed.

Obviously, more work is required to define the amount of protected fat which should be added early in lactation and the length of time during which it can be given before it has an adverse effect on the length of lactation. Work is also needed on the effect of free fat given at the start of lactation.

Fat-feeding during the main part of lactation

Fat can be incorporated into the diet in three ways. First, the fat can be added and the diet fed iso-energetically; this requires that the total food intake be reduced. Secondly, the fat can be substituted for part of the ration and the total intake maintained at the same level which means that the energy intake has been increased. Finally, the fat can be added to the basal diet and intake kept constant; this means an even greater increase in the energy intake. The first method has been widely used but, if the calculations have been done correctly, there should be no response in the milk yield. Only experiments in which *ad lib.* intake has been measured will therefore be discussed.

Murphy & Gleeson (1979) found that approximately 500 g/d tallow added to the diet of group-fed dairy cows gave only a very small increase in the milk yield. Stull *et al.* (1957) found an increase of 10% in milk yield when 70 g tallow/kg was incorporated into concentrates given to dairy cows. We recently found that the

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iso-energetic addition of 350 g/d of beef tallow to the concentrates given to cows receiving grass silage *ad lib.* gave an increase of approximately 8% in milk yield but that the addition of more tallow did not increase the milk yield further. This lack of additional response may indicate that the particular cows used were not able to respond, but cows with a higher yield potential might have been able to do so. Steele *et al.* (1971) obtained an increase of 24% in milk yield when 8% soya-bean oil was used to replace starch in the concentrates, but the fatty acid content of the basal diet was very low.

Steele *et al.* (1971) found that the addition of ground soya beans to the diet increased milk yield by 13%. Conversely, Hutjens & Schultz (1971) found that 29% of whole soya beans in the concentrates reduced milk production by 16%. Palmquist & Conrad (1978) found that 35% of whole soya beans reduced milk yield by 6% in Holsteins and by 8% in Jerseys. We found that when soya-bean oil or soya beans were added to the diet of cows given grass silage and soya-bean meal, milk yield was always reduced. On average, the soya-bean oil reduced the intake by 8% and the soya beans reduced it by 17%.

Recently, Palmquist & Conrad (1980) have investigated the effect of feeding diets in which either the energy intake or the intake of fibre was kept constant. They did not find any major differences in the milk yield.

Obviously, the effect obtained depends very much on the basal diet used and on the level of fat addition. Much more work will be needed to unravel the various interactions.

Milk fat content

Storry *et al.* (1974) showed that free cod-liver oil markedly depresses milk fat content although protected cod-liver oil has a much smaller effect. The fat content is also depressed, on average, by free vegetable oils such as soya-bean, sunflower or cottonseed oils (e.g. Banks *et al.* 1976; Goering *et al.* 1977).

Milk fat content is not usually affected by the feeding of free saturated fats such as tallow (e.g. Palmquist & Conrad, 1978) but free palm oil and palmitic acid increases the fat content of milk (e.g. Banks *et al.* 1976).

Unextracted vegetable seeds such as soya beans or sunflower seeds increase the milk fat content (e.g. Rafalowski & Park, 1982) and, finally, both protected vegetable oils and protected animal fats usually, though not invariably, increase milk fat content (e.g. Sharma *et al.* 1978; Clapperton & Steele, 1982).

It is important to stress that these changes in milk fat content are primarily due to the balance between the reduced *de novo* synthesis of fatty acids in the udder caused by the addition of the fat and the increased transfer of fatty acids from the food to the milk. This is essentially different from the situation in the 'low-fat-milk syndrome' which is probably due mainly to changes in rumen fermentation (Davis & Brown, 1970).

Summary

The effect of adding fat to the diet of the ruminant is a very complex subject. For animals with a low production potential, the role of fat is probably limited but,

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as the potential output is increased, energy intake becomes a more important limiting factor and the use of more fat may then be justified.

If this is so, certain problems require solution. These include the effects on food intake and its metabolizability and the ME value to be assigned to the fat itself. In dairy cows, the best way to feed fat, either early in lactation or throughout, needs to be assessed together with any effects in later lactations. Finally, the best form of fat to use and the method of incorporating it into the diet also needs to be investigated.

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