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Factors controlling fat deposition in meat animals

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ABSTRACT

The paper takes the view that meat sales are likely to benefit from a reduction in average fat levels, particularly in lamb.

Total fat content is controlled by the mature size of the breed or strain and by the stage of maturity that has been reached. The balance between appetite (energy in) and maintenance requirement (energy lost) seems less important, although there are examples of lean genotypes with low appetites. The partitioning of total fat between carcass (particularly subcutaneous) and abdominal (particularly perirenal) sites is not influenced by mature size but rather by breed itself, especially in cattle. The reason may lie in intrinsic metabolic differences between subcutaneous and abdominal fat tissues.

The number of fat cells in subcutaneous fat, but perhaps not in other fat depots, increases as total fatness increases. Attempts to reduce eventual fat content by reducing the number of cells through underfeeding in early life have not been successful.

Hormonal metabolism can be altered by injecting or implanting active constituents and sex hormone implants are presently available in some countries which aim to confer on females or castrated males the advantages (in terms of low fat and high lean deposition) of the entire male. However their effectiveness in reducing fat content is less than in increasing overall growth. Immunological techniques of growth control are being developed which leave no residues in meat and it is likely that the future will see increasing use of these and other approaches as farmers strive to meet consumers' requirements for lean meat at even lower production costs.

INTRODUCTION

Consumer surveys into meat eating carried out in many countries including Britain over the last few years have indicated a preference for cuts which are easy to cook and can be prepared quickly rather than traditional roasts or stews, and an aversion to fat. The first requirement can be solved by new and imaginative methods of butchery and presentation but the second requires a knowledge of the factors affecting fat deposition and how to control them. This is the subject of the present paper.

TABLE 1 Responses (%) to the question: 'Do you eat the fat on your meat or leave it on the plate?' (MRI, 1977)

Beef		Pork		Lamb	
Eat	Leave	Eat	Leave	Eat	Leave
58	42	57	43	50	50

Consumer attitudes to fat in meat purchased at retail were examined in a recent Meat Research Institute survey (MRI 1977), (Table 1). Of the 1700 people questioned, almost 50% said they left fat on the plate, particularly lamb fat. For children under 16 this figure rose to 60%. Considering that meat purchased at retail has already been trimmed of excess fat these results were a clear indication that average fat levels should be reduced. This should have no adverse affect on eating quality (Dransfield *et al.*, 1979).

FAT DEPOSITION IN THE BODY

The Role of Mature Size, Appetite and Maintenance Requirement

The percentage of fat in the body is increased in all species when energy intake is raised to a high level, although this is more noticeable in non-ruminants than in ruminants fed fibrous diets. The present paper deals with genetic factors in animals fed under similar conditions. Here, the percentage of fat at a particular weight is influenced mainly by mature size. Breeds of small mature size are relatively fat compared with those of large mature size because they are more developed (Table 2). When comparisons were made at the same weight the small Jersey cattle and Gloucester Old Spot pigs had a higher percentage of fat than the larger Friesians and Large Whites. When comparisons were made at the same age, which parallels stage of development under

TABLE 2 Total body fat (% of live weight) in breeds of relatively large and small mature size.

	Same live weight (kg)	Same age (d)
Friesian[1]	15.4 (380)	19.4 (507)
Jersey[1]	22.9	20.8
Large White[2]	19.9 (65)	21.6 (140)
Gloucester Old Spot[2]	24.3	21.5

1 Butler-Hogg and Wood (1982)
2 Lodge *et al.* (1978)

similar feeding conditions, breed differences disappeared. This means that slaughter weight guidelines can be set for different breeds if the objective is to slaughter at a particular 'level of finish' or subcutaneous fat content. Table 3 shows recent results on sire breeds of sheep from the British Meat and Livestock Commission (MLC, 1981). The order of increasing carcass weight was also the order of increasing body size at maturity except for the Texel (see below).

TABLE 3 Carcass weight at a particular 'level of finish' in 5 sire breeds (MLC Ram breed comparison trial).

MLC fat class	2	4
% subcutaneous fat (approx.)	6 to 10	14 to 18
Southdown	15.0	18.5
Dorset Down	16.0	20.0
Suffolk	17.5	22.5
Texel	17.5	22.5
Oxford Down	18.5	23.0

After accounting for mature size, remaining variation in total fat content at constant body weight is probably small, perhaps less than 10% of the whole, and can partly be explained by variation in appetite and maintenance requirement. Fast growing, large mature size breeds have higher appetites and maintenance requirements than their smaller counterparts because of a faster rate of protein deposition but if appetite and maintenance requirement are out of step this can have profound effects of fat deposition. The cause of this unbalance is more likely to be due to appetite than maintenance requirement. Examples of breeds or strains which are leaner than would be expected from their mature size are Pietrain compared with Large White pigs (Perry *et al.*, 1978a), Texel compared with other breeds of sheep (Wolf *et al.*, 1980) and Limousin compared with other breeds of cattle (Koch *et al.*, 1976). In each case low appetite seems to be a cause.

These factors can not explain breed effects on the location of fat. The various fat depots grow at characteristic rates relative to total fat in a range of cattle breeds even though the amounts in the various depots are quite different (Butler-Hogg and Wood, 1982). In comparisons between Friesian and Jersey and Friesian and Hereford steers (Fig. 1) there was a general association of fat location with the breeds' capacity for milkfat production, high production being associated with partitioning of body fat away from the subcutaneous towards the abdominal fat depots. The Jersey steers had 45% of their body fat within the abdomen, 21% in the perirenal and the rest in the omental and mesenteric depots. The literature shows that in general, 'external depositing' beef breeds are more energetically efficient than 'internal depositing' dairy breeds which tend to have higher maintenance requirements, but the correlation

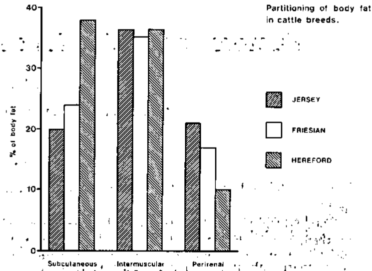

FIG. 1 Partitioning of body fat in cattle breeds. All the animals are steers reared under the same conditions and compared at a total fat content of 20% of live weight. Data on Jerseys and Friesans from Butler-Hogg and Wood (1982) and on Herefords from Truscott (1980).

between maintenance requirement and indices of fat partitioning was non-significant within breeds (Truscott, 1980). The reason for the higher maintenance requirement in dairy breeds was that in most comparisons they were leaner and grew faster than beef breeds and also they had higher proportions of abdominal organs whose protein content and protein turnover make a disproportionately high contribution to maintenance requirement.

Breed effects on fat partitioning, apparently also related to milk production, have been found in sheep breeds (Wood *et al.*, 1980) but breed effects in pigs are small and mainly due to differences in the total amount of fat. As already stated, in all 3 species the fat depots grow at characteristic rates, omental and subcutaneous fat relatively quickly and intermuscular fat relatively slowly and so their proportions at any one time depend on the overall development of body fat (Butler-Hogg and Wood, 1982).

UNDERLYING FACTORS IN FAT DEPOSITION

Number and Size of Fat Cells

Since the fat depots grow by increasing the size and number of fat cells, much research has been done on fat cellularity with a view to reducing fat deposition.

Current findings show that within breeds, percentage fat is quite highly positively correlated with fat cell size (Wood *et al.*, 1978b). Even between breeds which had different numbers of cells because of differences in mature size, cell size was quite similar at the same fat content (Truscott, 1980). This conclusion is complicated, however, by the finding that in some depots the number of recognisable cells is not fixed even in very fat animals and continues to increase during growth. In pigs (Enser *et al.*, 1976), sheep (Broad *et al.*, 1980) and cattle (Truscott, 1980; Robelin, 1981) this occurred in the subcutaneous depot and was probably due mainly to filling of already-formed preadipocytes rather than to new cell replication. In the 3 studies that examined site differences however, the effect was much more marked in subcutaneous than perirenal fat. Truscott (1980) found that between 6 and 20 months of age the increase in size of a single population of cells could account for the growth of perirenal fat in cattle whereas this was not the case in subcutaneous fat, even though both depots had similar relative growth rates. Broad *et al.* (1980) found that between the ages of 1 month and 5 years in sheep, fat cell number increased by 4.3 times in subcutaneous fat but only 1.3 times in perirenal fat and finally Robelin (1981) found that between 15 and 65% of mature weight in cattle, fat cell number increased by 5.6 times in subcutaneous fat and only 1.6 times in perirenal fat.

The normal increase in cell number which occurs in some depots can be arrested by underfeeding at an early age but this does not reduce eventual fat content or cell number if recovery is allowed to occur (Lee *et al.*, 1973; Enser, 1981). Therefore this simple approach to controlling fat cell growth is not likely to be useful. Studies of the process by which preadipocytes are 'switched on' might be more productive and provide information which could be used to suppress this critical step.

Hormones

Since hormones control growth, studies of hormone metabolism have been done with a view to providing indices of growth and composition and to suggest hormonal manipulations that could increase lean and suppress fat growth.

The partitioning of feed energy between maintenance and lean and fat deposition is thought to be controlled by growth hormone, insulin, thyroid hormones and catecholamines. In one study, plasma concentrations during periods of controlled underfeeding were measured in Friesian and Hereford steers and pooled averages were related to percentage body fat (Table 4). These typical results show generally low correlations, not strong enough for predictive purposes, but some trends are apparent. For example insulin concentration was positively related to percentage body fat, especially within breeds and growth hormone concentration was negatively related. This suggests that insulin administration will increase fat deposition, as has been found, and growth hormone administration will reduce it. This was demonstrated in pigs by Machlin (1972), (Table 5). Formerly the high cost of growth hormone prevented its use in farm animals although

TABLE 4 Correlations between percentage body fat and plasma hormone concentrations in Friesian and Hereford steers aged 20 months (Truscott, 1980).

Component	Between breeds	Within breeds
Insulin	0.11	0.33
Growth hormone	-0.25	-0.28
Adrenaline	-0.08	0.02
Noradrenaline	0.05	0.22
T_3	0.16	0.31
T_4	0.22	0.26

TABLE 5 Effect of daily intramuscular injection of porcine growth hormone (PGH, 0.13 mg/kg body wt/d) in 18 castrated male and female pigs. The 18 controls were injected with saline (Machlin, 1972).

	Treatment		
	Control	PGH	Significance
Live-weight gain/d (g)[1]	740	860	**
Feed consumed/weight gained[1]	3.3	2.9	*
Back fat thickness (mm)[2]	34.8	27.9	***
Composition of ham(%)			
Fat	21.0	13.6	***
Protein	18.2	19.7	***
Water	59.7	65.7	***

1 From 46 to 94 kg live weight
2 10th rib.

TABLE 6 Growth and composition of 16 boar and 16 castrated male pigs fed on same scale (Wood and Riley, 1982).

	Boar	Castrate	Significance
Final live weight (kg)	88.6	89.6	NS
Live-weight gain/d[1] (g)	748	601	***
Back fat thickness (mm)[2]	7.7	13.3	***
% fat in side	19.9	28.9	***

1 From 27kg
2 Measurement 'C' at last rib.

TABLE 7 Effect of sex hormone implants in steers; 7 pairs of twin calves in each comparison (bull v steer, bull v implanted steer)[1] (Fisher *et al.*, 1982).

	Bulls	Steers	Significance	Bulls	Steers + SH[2]	Significance
Final live weight (kg)	409	379	*	421	409	NS
% lean in side	66.2	60.9	***	65.8	62.4	**
Kg feed/kg lean[3]	22.7	27.0	**	23.2	25.8	*
% fat in side	17.9	24.1	**	18.1	23.2	***

1 Complete pelleted diet fed *ad lib* to 400 days of age
2 140mg trenbolone acetate + 20mg oestradiol implanted as a pellet at base of ear
3 From 180 to 400 days.

if it were produced by genetic engineering and in a slow-release form, treatment might become cost-effective. Another approach is to immunise animals against the growth-retarding peptide hormone, somatostatin. This could increase the secretion of growth hormone and early work by Spencer and Williamson (1981) at MRI found that treatment significantly increased growth rate in sheep.

Clear hormonal effects on growth and fat deposition are exercised by sex hormones. In pigs, sheep and cattle, castration of the male slows growth, especially from fixed inputs of feed (Table 6), and increases fatness. Entire males offer the most cost effective practical route to leaner carcasses in all species although this might be rather too dramatic in some lean pig breeds when energy intake is low, such as to produce undesirably ultra-lean meat.

Adding back sex hormones to steers attempts to restore some of the advantages of the entire male in terms of growth and composition without incurring the behavioural disadvantages, although these are seen as more of a problem in Britain than in New Zealand. However, the effects of currently available sex hormone implants in steers are not dramatic, especially so far as body composition is concerned. We have recently done studies with monozygous and dizygous twin calves in which 1 member of the pair has been left entire and the other castrated or castrated and given a sex hormone implant. It is presently unclear why the maximum effect in steers is achieved with a combination of oestrogen and androgen. Results in Table 7 show the gap between bull and steer was not greatly reduced for any aspect of growth by using these. Other work also shows that sex hormone implants have a greater effect on overall growth than on composition.

Sex hormone implants are a first step in practical hormonal control. As with peptide hormones, immunological control of sex hormone metabolism is also possible (e.g. Perry and McCracken, 1978) which has the advantage of not leaving hormone residues in meat. It is clear that rapid developments are being made in this area and in the future it is likely that more sophisticated and effective hormonal treatments will be available to assist in producing low levels of fat in meat.

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