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Changing the body composition of sheep by feeding

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ABSTRACT

There is a long-standing disagreement about the influence that feeding has on body composition, particularly in ruminants, yet the problem remains of finding ways to produce lean lambs. This paper attempts to revive the view that feeding can alter, independently, the rate of growth and the relative rate of fattening in sheep. A numerical illustration is given of the relationship between a lamb's potential for growth, its feed requirements and the rules it uses to partition feed resources when they are scarce. For simplicity, the feed is considered only in terms of its metabolisable energy: digestible crude protein ratio. Published data are then reviewed to test whether it is reasonable to retain the proposed theory. The review closes with a discussion of our current options and future possibilities for changing body composition by feeding.

Keywords Sheep; growth; body composition; nutrition

INTRODUCTION

In animal production circles, there remains a lack of consensus about the influence that feeding has on the growth and body composition of sheep. Black (1974) presented evidence of appreciable body composition changes associated with nutritional treatment. However, ARC (1980) decided that body composition was not affected by growth rate, a position which was supported by Theriez *et al.* (1982), whilst Greenhalgh (1986) concluded that nutrition had a minor effect on body composition in sheep. This paper reviews the evidence for the effects of feeding on growth and body composition in sheep through the use of a theory described by Emmans (1984, 1985). Ideas from Black (1974, 1983) are also incorporated into the analysis.

APPROACH

Throughout the review, feeds are described in terms of their metabolisable energy (ME, MJ/kg fresh weight) and digestible crude protein (DCP, g/kg) content, where DCP is taken to be the nutrient which first limits protein growth under conditions of adequate energy supply from either the feed or from mobilised lipid reserves. However, any nutrient, that is, a mineral, vitamin or protein (amino acid) component, could be nominated instead of DCP in the analysis: when ME is not limiting to protein growth, the nutrient of greatest consequence to the lamb is that which is first limiting. The responses of the lamb on a particular day are predicted in terms of the net body protein retention (PR, g), the net lipid retention (LR, g) and consequently the

TABLE 1 Growth of lambs given *ad libitum* feed supply.

Case	Thermal environment	Feed DCP content (g/kg)	ME intake (MJ)	DCP intake (g)	Protein retention (PR,g)	Lipid retention (LR,g)	LR:PR (g/g)	Efficiency of use of ME for growth (Kf)
A	Neutral	180	12.2	180	43	94	2.19	0.52
B	Neutral	360	13.3	391	43	94	2.19	0.47
C	Cool	120	18.4	180	43	193	4.49	0.57
D	Warm	120	13.3	130	30	127	4.23	0.57
E	Cold	120	18.4	180	43	94	2.19	0.52

lipid:protein ratio (g/g) in the wool-free empty body gain. Experimental data are used as tests of the expected outcomes. Where the theory fails in its predictions and where experimental evidence is lacking, are indicated. Eight possible types of response are considered (Tables 1,2).

PREDICTED GROWTH RESPONSES

Lambs Grow Protein at their Potential Rate and Fatten Normally when Given Free Access to Feeds of a Balanced DCP:ME Ratio (Case A)

Suppose that a lamb, weighing 25 kg on a certain day, was capable of growing 43 g of protein and gaining 94 g of lipid and that the lamb was given free and continuous access to a feed which satisfied, simultaneously, its total requirement for DCP and ME (case A, Table 1). If the lamb converted DCP to body protein with an efficiency of 0.253 (above a maintenance DCP requirement of 10g) and used ME for growth and fattening with an efficiency of, say, 0.522 (above a maintenance ME requirement of 3.158 MJ) (ARC, 1984), then the lamb would eat 1kg of a feed A which contained 0.18 DCP and 12.2 MJME/kg. Feed A, for this lamb under these conditions, would be balanced and non-limiting to growth. Growth of protein would proceed at the potential rate of 43 g/day and the lipid: protein ratio in the empty body gain would be 94/43 = 2.19.

Lambs Grow Protein at their Potential Rate and Fatten Normally when Given Free Access to Feeds of High DCP:ME Ratio (Case B)

The same lamb given free access to a feed B (with the same ME content as feed A but a DCP content of 0.36) would eat 1.00 kg to satisfy its ME requirement for maintenance, growth and fattening, as in case A, but would now require an extra 0.085 kg of feed to supply the 0.983 MJ needed for deamination of the surplus 211 g of DCP intake. Feed B would be non-limiting to growth (43 g) and would support a normal lipid: protein ratio in the gain (2.19). However, relative to case A, feed B would be imbalanced.

Lambs Grow Protein at their Potential Rate but Fatten Excessively when Given Free Access to Feeds of Low DCP:ME Ratio (Case C)

The same lamb given free access to feed C (with the same ME content as feed B but a DCP content of 0.12) would eat 1.50 kg to satisfy its DCP requirement of 180 g. However, in so doing, the lamb would exceed its total requirement for ME by 6.12 MJ, which it could convert to lipid with a marginal efficiency of 0.72 (Emmans, 1984). Consequently, feed C would be non-limiting to growth (43 g) but the lipid protein ratio in the gain would rise above normal to 193/43 = 4.49. In relation to case A, feed C would also be imbalanced.

Lambs are Limited in their Protein Growth when Given Free Access to Feeds of Low DCP:ME Ratio in Relatively Warm Environments (Case D)

In case C, the lamb was able to consume 180 g of DCP for growth by eating more of feed C, depositing 3.921 MJ of the excess ME intake as lipid and losing 2.488 MJ as heat. However, in a relatively warm environment, the ability of the lamb to lose heat could be limited, say, at 7.495 MJ, as it was in case A. Consequently, the need for the lamb to remain thermally neutral would be given priority over the need to acquire DCP for growth. Feed intake would be constrained to 1.08 kg, that is, a feed intake which incurs a heat production of only 7.495 MJ. The supply of DCP up to the point of heat stress would determine the rate of protein growth to be 120 x 0.253 = 30 g. The lipid: protein ratio of the gain (127/30 = 4.23) would also exceed the norm of 2.19. Feed B in a relatively warm environment would be both imbalanced and limiting to growth.

Lambs Grow Protein at their Potential Rate and Fatten Normally when Given Free Access to Feeds of Low DCP:ME Ratio in Relatively Cold Environments (Case E)

Only if the lamb were put in a relatively cold environment (in which the need for the lamb to remain thermally neutral would promote extra

TABLE 2 Growth of lambs given restricted feed supply.

Case	Feed DCP (g/kg)	ME intake (MJ)	DCP intake (g)	Protein retention (PR,g)	Lipid retention (LR,g)	LR:PR (g/g)	Efficiency of use of ME for growth (Kf)
F	360	6.1	180	43	-7	-0.16	0.35
G	180	6.1	90	20	25	1.25	0.50
H	120	6.1	60	13	34	2.62	0.56

heat production of 5.160 MJ), would feed C become balanced and no.ı-limiting to growth once again (case E, Table 1). ARC (1984) regards the heat produced during cold-induced thermogenesis as a cost above maintenance and growth, and therefore the efficiencies for use of ME remain the same as in case C.

Lambs Grow Protein at their Potential Rate, but do not Fatten when Given Restricted Access to Feeds of High DCP:ME Ratio (Case F)

The same lamb given 500 g of feed B which contained 0.36 DCP would receive 180g of DCP and would therefore be able to achieve its potential for protein growth (case F, Table 2). However, the ME supplied would only just meet ME requirements for maintenance and protein growth. Consequently, the lipid-free gain would be energetically expensive to make and Kf would fall to a value of 0.345, better defined as Kp i.e. the efficiency of use of ME for protein gain.

Lambs are Limited in their Protein Growth and Fattening when Given Restricted Access to Feeds of Medium DCP:ME Ratio (Case G)

The same lamb given 500 g of feed which contained 0.18 DCP would receive only 90 g of DCP and would therefore be limited to growing only 20 g of protein (case G Table 2). In turn, the lamb's ME requirement for growth would be lower than in case F and what remained of the ME intake would support 25 g of lipid gain. Restricted access to feed A would therefore limit protein growth, but the lipid:protein ratio in the gain would be 25/20 = 1.25, that is, lower than the norm of 2.19.

Lambs are Limited in their Growth and Fatten Excessively when Given Restricted Access to Feeds of Low DCP:ME Ratio (Case H)

The same lamb given 500 g of feed C, which contained 0.12 DCP, would receive only 60 g of DCP and would therefore be limited to growing only 13 g of protein (case H Table 2). Compared with case G more of the ME intake would be surplus to the requirement for maintenance and growth, and the lamb would gain 34 g of lipid. Restricted access of feed C would therefore limit protein growth severely (13g) and the lipid:protein ratio in the gain would be 34/13 = 2.62, that is, higher than the norm of 2.19.

EXPERIMENTAL EVIDENCE

CASE A

At the outset, the theory posited in case A that, in principle, there was a feed that could meet both the requirement of the lamb for ME and for DCP at a certain rate of intake. However, this concept was criticised by Blaxter (1962) who stated that "the term 'balance' of a ration is at least a semantic paradox". Consequently, in this review, attention has been paid to the definition of feed balance, in terms of the DCP:ME ratio, to meet such criticism. Nevertheless, the problem remains of finding, experimentally, balanced feeds for sheep when, presumably, the required DCP:ME ratio in the feed is fixed for a lamb at a time, but decreases as the lipid content of the empty body gain increases with maturity.

One possible way of finding the required ratio of DCP and ME in feeds for sheep is to see whether the lamb selects a balanced and

TABLE 3 Selection of balanced diets by growing lambs.

Trial	Liveweight gain (g/day)	ME intake (MJ/day)	DCP:ME (g/MJ) of diet selected
Ia	288	15.3	10.5
IIb	319	15.2	9.8
IIIc	394	14.2	10.7

a Cropper *et al.*, (1985)
b Cropper,*et al.*, (1986)
c Unpublished data, Lincoln College

non-limiting diet when given free and continuous access to two feeds, one abundant in DCP, the other deficient. Musten *et al.* (1974) with rats and Kyriazakis *et al.* (1988) with pigs have shown that both these species are able to choose a balanced diet under choice feeding conditions. The author has also conducted three similar trials with growing lambs (Cropper *et al.*, 1985; Cropper *et al.*, 1986), the results of which are summarised in Table 3. In the light of this evidence, it is difficult to dismiss the notion that lambs of about 25 kg live weight are capable of consistently selecting a diet with a DCP:ME ratio of 10 g/MJ. However, differences have occurred between trials in rate of live weight gain and feed conversion efficiency. Body composition data are awaited from current choice feeding trials at Lincoln College to clarify this question.

CASE B

That certain, imbalanced feeds, offered *ad libitum*, can supply protein excess to requirements without altering growth and body composition in the lamb is evidenced, for example, by the work of Emmans *et al.* (1987) who recorded non-limited growth in lambs offered a feed with a high DCP:ME ratio of 12.8 g/MJ. Lambs are therefore known to respond to protein rich feeds in the manner predicted in case B

CASE C

In the work of Ranhotra and Jordan (1966), lambs given *ad libitum* access to a feed with a DCP:ME ratio of 8.9g/MJ ate more feed, gained live weight faster, but made that gain less efficiently than lambs offered a feed with 11.8gDCP/MJME. Such a response is comparable to that predicted in case C where the lamb, given free access to an imbalanced feed of lower DCP content than it required, grew protein fast but had an excessively high lipid:protein ratio in its empty body gain.

CASE D, E

The relationship between *ad libitum* feed intake and environmental hotness has been reviewed by NRC (1981). Soderquist and Knox (1967) and Ames and Brink (1977) showed that rate of feed intake and liveweight gain decreased when the lambs were exposed to high ambient temperatures (case D) and that the lambs' rate of feed intake increased in the cold (case E). Furthermore, Musten *et al.* (1974) demonstrated that choice-fed rats increased their rate of total feed intake, but selected a diet with a lower DCP:ME balance when the ambient temperature was 8°C than they did when it was 23°C. This result provides independent evidence to support the theory that the required DCP:ME ratio in the feed is intimately related to environmental temperature (cases A and E). The data of Ames and Brink (1977) suggested that there was a particular temperature (13°C) at which the single feed they offered (10.9 g DCP/MJME) to lambs was used most efficiently for protein gain. Current trials at Lincoln College are investigating the relationship between feed DCP:ME ratio and environmental temperature in growing lambs.

CASE F

Under restricted feeding conditions there are no recorded instances of lambs growing protein at their potential rate, as was predicted in case F, and the data in Table 4 indicate that limited DCP supply was not always the cause. Consequently, alternative scales to DCP for predicting protein supply in sheep have had to be developed (e.g. ARC, 1984). However, Barry (1981) recorded a protein growth response in clover-fed lambs infused with casein and methionine and Poppi *et*

TABLE 4 Recorded growth of lambs given restricted feed supply.

Feed	Feed DCP:ME (g/MJ)	DCP intake (g/day)	Protein retention (g/day)	Lipid retention (g/day)
White clover [a]	24	190	7	-6
Perennial ryegrass [a]	23	159	9	-7
Lucerne [b]	22	175	31	-27

[a] Joyce and Newth (1967)
[b] Mitchell and Jagusch (1972)

al. (1988) obtained similar results with fishmeal supplementation of grazed forages. From these results it could be concluded that single amino acids were limiting growth in the experiments in Table 4 and that DCP is still a useful concept provided the amino acid composition is also known. The possibility therefore remains that lambs have never grown as predicted in case F because they have never been fed in a way which permitted such growth. Trials addressing this problem are underway at Lincoln College.

CASES G, H

The most commonly reported response to restricted feeding is that in which the rate of protein growth is slowed by DCP supply, as described in cases G and H. Moreover, in line with the expectation that lipid retention is dependent on the ME surplus to the lamb's requirements for maintenance and protein growth, the lipid:protein ratio in the gain has been shown to be lower than normal (Boccard and Duplan, 1961; Andrews and ørskov, 1970; Joyce *et al.*, 1972; Fattet *et al.*, 1984) as in case G, and higher than normal (Meyer and Clawson, 1964; Andrews and ørskov, 1970), as in case H. In turn, Burton and Reid (1969), Ferrell *et al.* (1979) and Theriez *et al.* (1982) have reported no differences in the lipid:protein ratio in the gain of lambs growing at different rates and have thus concluded that body composition is not affected by nutrition. The works reviewed here suggest that such conclusions are based on limited experience and cannot be of general application.

CONCLUSIONS

Above maintenance, feeding has been found to affect growth and body composition in sheep by governing protein growth through supply of DCP and by determining the lipid content of the empty body gain through the supply of DCP relative to the supply of ME.

Consequently, it is suggested that the problems of poor growth performance and overfatness in commercially reared lambs could be solved by one or more of the following methods, some of which have already been investigated in New Zealand:

(a) avoiding feeds of low protein content especially in warm environments.
(b) supplementing pasture with high quality protein (Poppi *et al.*, 1988; Muir *et al.*, 1989).
(c) reducing heat stress, and therefore stimulating feed intake, by shearing (Bray *et al.*, 1985) or winter finishing (Bray and Taylor, 1987).
(d) improving protein availability from forages, especially legumes (Cruickshank *et al.*, 1985).
(e) breeding inherently leaner sheep.

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