Diet selection in sheep: the ability of growing lambs to select a diet that meets their crude protein (nitrogen × 6·25) requirements

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To test the proposition that sheep are able to select a diet that meets their crude protein (N × 6·25; CP) requirements, feeds L, A, B, C and H with the same energy content (11 MJ metabolizable energy/kg feed) but different CP contents (78, 109, 141, 172 and 235 g CP/kg fresh feed respectively) were formulated. In addition, feed U, which was feed L plus 21·4 g urea/kg (CP content 132 g/kg), was also made. The feeds were offered *ad lib.* either singly (*n* 4 per treatment) or as a choice between feed H and another feed (pairs LH, AH, BH, CH and UH; *n* 9 per feed pair) to individually penned Suffolk × Scottish mule wether lambs, over the live-weight range 25–45 kg. On the single feeds the rates of live-weight gain were 273, 326, 412, 418, 396 and 407 g/day (SE of difference (SED) 34; $P < 0·01$) and protein (excluding wool) gain were 27, 32, 44, 45, 41 and 39 g/d (SED 4; $P < 0·001$) for feeds L, A, B, C, H and U respectively. When sheep were given a choice between a feed below (L or A) and a feed above their CP requirements (H; as judged by the single-feeding treatments) the CP concentration selected was not different between the two pairs: 131 (SE 4) *v.* 133 (SE 4) g CP/kg feed for pairs LH and AH respectively. On the choices BH and CH (a choice between two feeds above requirements) the feed lower in CP was constantly preferred (874 (SE 33) and 910 (SE 33) g feed B and C respectively per kg total feed intake; CP selected was 157 and 178 g CP/kg respectively). However, this was not the case with the UH choice on which sheep consumed only 599 (SE 61) g feed U/kg total feed intake, resulting in a selection of a higher CP in their diet (173 g CP/kg). The live-weight gains of the animals given a choice between two feeds were 416, 387, 415, 410 and 383 g/d (SED 37) and protein gains were 45, 40, 46, 50 and 43 (SE 7) for pairs LH, AH, BH, CH and UH respectively, which were comparable with the best performance achieved on a single feed. The results suggest that sheep were able to select a diet that meets their CP requirements and avoid, at least to a certain extent, excess of protein intake. It is also possible that sheep discriminate against a property of feed U, such as an excess of urea, when this feed is paired with a feed high in CP.

Appetite: Feed preferences: Growth: Protein intake: Sheep

There are few studies on ruminant animals that test whether such animals, when kept in a controlled environment, can select a diet of adequate composition from a suitable pair of feeds. This might stem from a lack of understanding of the main factors that control feed intake and diet selection in the ruminant animal, but also may reflect the normal husbandry conditions under which such animals are kept. Two recent studies on the diet selection of sheep (Cropper, 1987; Hou, 1991) have suggested that sheep, kept in a controlled environment, are able to make structured choices when they are given a choice between two feeds that differ in their crude protein (N × 6·25; CP) contents. In neither case, however, have the investigators been able to relate the composition of the selected diets to the animals' requirements, as these were not estimated from the performances on single feeds with different protein contents.

Emmans (1991) suggested that the design of an experiment to test whether an animal can select a diet of adequate composition would be much more powerful if, in addition to the choice treatment, like animals were given a series of single feeds which could be made as varying mixtures of the two feeds to be given as a choice. The consequences of the selected diets to the animals, seen as growth rates and food efficiencies, can then be quantified. Such an experimental protocol has been adopted in a series of experiments to test the ability of growing pigs to select a diet that meets their requirements (e.g. Kyriazakis *et al.* 1990, 1991).

The objective of the experiment reported here was to test the proposition that growing sheep when given a choice between a suitable pair of feeds will select a diet that meets their CP requirements. An experimental protocol similar to that proposed by Emmans (1991) was used. In addition, in order to address an aspect of the extent to which sheep make selections between feeds to satisfy digestive (rumen) function, rather than their metabolic needs, urea supplementation of an otherwise low CP feed was also included amongst the feeds offered as a choice.

MATERIALS AND METHODS

Animals and housing

Seventy-six Suffolk × Scottish mule wethers were weaned at 6–8 weeks of age (on 20 May 1991) and moved immediately to the individual pens of the experimental unit. The lambs had a mean live weight of 18·6 (SD 2·6) kg and were given a live-weight-based feed allowance (35 g/kg live weight) of a high-quality commercial feed (Eurolamb diet; Scottish Agricultural College) with 170 g CP and 12 MJ metabolizable energy (ME)/kg dry matter (DM). This allowance was estimated to be just below their *ad lib.* feed intake, thus ensuring that all lambs would reach the experimental live weight with a similar gut-fill.

The experimental unit was a slatted-floor sheep shed that was naturally ventilated, with the potential to accommodate six rows, each of twenty-four adjustable pens (total 144 pens). Each pen measured 1·29 × 1·53 m and contained one or two (according to the experimental treatment) metal troughs and a bucket for fresh water. The pens with two troughs were chosen randomly within the shed.

Feeds

Two basal feeds with different CP concentrations (low (L) and high (H)), but with the same calculated ME concentration, were formulated and made into pellets (Table 1). The low-protein feed was formulated to be inadequate in CP to support potential growth when offered alone on an *ad lib.* basis (Agricultural Research Council, 1984). It also contained 6 g $NaHCO_3$/kg fresh feed, to reduce the risk of rumen acidosis from such a feed. The protein content of feed H was intended to be above the requirement of the lambs. Both feeds were intended to be non-limiting in minerals and vitamins, but feed H contained a higher amount of macrominerals to maintain suitable ratios to protein.

Mixtures of feeds L and H were made to produce feeds A, B and C. In addition, feed U, which was essentially feed L supplemented with 21·4 g urea/kg fresh feed was also made (Table 1) and resulted in a CP content of 132 g/kg fresh feed. All feeds were supplemented with 5 g NH_4Cl/kg fresh feed as an acidifier to help prevent the formation of urinary calculi.

Design

As a lamb reached 23·5 kg live weight it was allocated to one of three kinds of treatment: initial slaughter group (*n* 6); free and continuous access to a feed (treatments L, A, B, C, H and U; *n* 4 per treatment); or a free and continuous choice between feed H and another feed (feed pairs LH, AH, BH, CH and UH; *n* 9 per feed pair). The lambs were allocated randomly to the treatments taking account of age at 23·5 kg live weight. The experiment

Table 1. *Ingredient and chemical compositions of the experimental feeds (g/kg fresh weight)*

	Feed					
	L	A (L–H; 4:1, w/w)	B (L–H; 3:2, w/w)	C (L–H; 2:3, w/w)	H	U
Ingredients (g/kg)						
Barley	—	41·5	83·0	124·5	207·4	—
Viton*	125	125	125	125	125	125
Molassed sugar-beet pulp	300	301	302	303	305	305
Sweet potato (*Ipomoea batatas*)	439·9	351·9	264·0	175·9	—	401·7
Protected fat	35	31·2	27·4	23·6	16·0	46·4
Fish meal	—	40	80	120	200	—
Soya-bean meal	—	13·4	26·8	40·2	67	—
Urea	—	—	—	—	—	21·4
Molasses	70	70	70	70	70	70
Sodium bicarbonate	6	4·8	3·6	2·4	—	6
Salt	—	0·2	0·4	0·6	1·0	—
Dicalcium phosphate	15·7	12·6	9·4	6·3	—	15·9
Ammonium chloride	5	5	5	5	5	5
Calcined magnesite	0·9	0·9	1·0	1·0	1·0	1·2
Vitamin and mineral mix	2·5	2·5	2·5	2·5	2·5	2·5
Component (g/kg)						
ME (MJ/kg)†	11	11	11	11	11	11
Dry matter	869	878	880	875	874	885
Crude protein‡	78	109	141	172	235	132
Diethyl ether extract	20	24	25	30	37	20
Ash	98	101	105	104	101	98
Ca	15	15·6	16·1	16·9	18·4	16·6
P	3·9	4·1	4·1	4·6	5·0	4·0
Crude fibre	92	92	93	93	91	94
NDF	191	191	199	207	210	189

ME, metabolizable energy; NDF, neutral-detergent fibre.
* Viton-BOCM Silcock; NaOH-treated straw.
† Calculated from food tables.
‡ N × 6·25.

ended when each lamb reached 45 kg live weight, at which stage all single-fed and fifteen choice-fed lambs (*n* 3 per feed pair) were slaughtered.

The lambs to be given a choice between two feeds were given the opportunity to experience both of the two feeds which were subsequently to be given as a choice. The two feeds were offered alone on alternate days for a period of 8 d. This training period was a slight modification of the method described by Kyriazakis (1989) and has been found to be an important part of a choice-feeding training programme both for simple-stomached, e.g. pigs (Kyriazakis *et al.* 1991) and ruminant animals, e.g. sheep (Hou, 1991). The position of the feeds was not changed throughout the experiment, as it had been found that lambs do not select their diet on the basis of the position of the feeds (Cropper, 1987; Hou, 1991); the position of the two feeds, however, was randomized across lambs.

Management and slaughter procedure

The lambs were weighed on one afternoon each week up to 43 kg live weight and then daily during the morning until they reached the target weight of 45 kg. They were offered feed twice daily (morning and afternoon) to minimize spillage, feed refusals were weighed daily and discarded, and water was changed daily. For the choice-fed lambs both troughs were removed at the same time, fresh feed was then placed in the troughs after weighing the refusals so as to offer each lamb similar quantities of both feeds throughout the day. During the first 3 d of the experiment (or the experience period), as the animals were changed from controlled feeding to the experimental feeds, they were given 1000, 1200 and 1400 g/d respectively in two separate allowances before they were given *ad lib.* access to the feed. On the first day of the experiment they were also given a preventative injection of thiamin (Bimeda UK Ltd, Liverpool). The lambs received a daily minimum of 16 h light and the ambient temperature ranged from a mean daily minimum of 10·3 (SD 2·7)° to a mean daily maximum of 20·8 (SD 3·6)°.

On the day of slaughter the lambs were weighed, their wool was sheared very closely and, when cleared from obvious dirt, weighed to give the greasy fleece weight. They were then killed by an injection of pentobarbitol sodium (Euthatal-RMB). In order to minimize blood losses only the liver, stomach and intestines (with the mesenteric fat) were removed. Stomach and intestines were weighed full, stripped of their contents and then weighed empty; gut-fill was calculated by difference. The dissected fractions were then recombined with the remainder of the body and the whole minced, homogenized and subsampled for chemical analysis.

DM was determined by freeze-drying to a constant weight and analysed for CP by a micro-Kjeldhal procedure and ash by burning in a muffle furnace at 550°. The gross energy (GE) of the DM was determined by adiabatic bomb calorimetry. The lipid was calculated from the GE and N values using the equation:

$$\text{lipid} = (\text{GE (kJ/g DM)}) - (23{\cdot}8 \times 6{\cdot}25 \times \text{N (g/g DM)})/39{\cdot}6 \text{ g/g DM}, \qquad (1)$$

which assumes that the energy contents of protein and lipid are 23·8 and 39·6 MJ/kg respectively.

Statistical analysis

The results from the single-fed sheep were analysed by an analysis of variance with feed as a factor. Linear and quadratic effects of the CP content of the feed on the performance and carcass measurements were also tested; from these comparisons the sheep on feed U were excluded. The results from the choice-fed lambs were analysed by a covariance analysis with feed-pair as a factor and live weight at the end of the experience period as a covariate. The rates of live-weight gain were calculated by linear regression in order to make easier the comparisons between single and choice-fed animals. Nine sheep were suspected of suffering from urinary calculi in the early stages of the experiment (when the animals were switched from the controlled feeding to the experimental feeds), and were, therefore, removed. Seven of them were replaced with lambs from the same flock and two, on treatments LH and AH, were treated as missing values.

The path of diet selection was traced by plotting the cumulative difference between the intakes of the two feeds (X − Y) *v.* the cumulative total feed intake (X + Y). The advantages of tracing diet selection this way have been described by Kyriazakis (1989).

RESULTS

Single-fed sheep

The rates of live-weight gain, daily feed intake, and feed conversion efficiency (FCE) of the sheep given access to the single feeds are shown in Table 2. The daily feed intakes are given

Table 2. *The performance and the composition of the gain of lambs given access to a feed with different crude protein (nitrogen × 6·25; CP) contents from 23·5 to 45 kg live weight*

Feed†	L	A	B	C	H	U	SED	Statistical significance of effects of: Treatment	Lin	Quad
CP content (g/kg)	78	109	141	172	235	132	—	—	—	—
Live-wt gain (g/d)‡	273	326	412	418	396	407	34	**	***	**
Feed intake (g/d)	1658	1706	1782	1775	1683	1909	93	NS	NS	NS
FCE (g gain/g intake)	0·167	0·202	0·240	0·236	0·224	0·210	0·016	**	**	**
Protein gain (g/d)	27	32	44	45	41	39	3·5	***	***	**
Lipid gain (g/d)	99	108	97	116	108	125	13	NS	NS	NS
Water gain (g/d)	102	130	175	165	154	157	17	**	**	**
Ash gain (g/d)	8	8	11	11	10	11	1·6	NS	NS	NS
Wool gain (g/d)	9	15	13	17	15	11	3·6	NS	NS	NS

SED, standard error of difference; FCE, feed conversion efficiency; NS, not significant; Lin, linear; Quad, quadratic effects.
** $P < 0{\cdot}01$, *** $P < 0{\cdot}001$.
† L and H are low- and high-crude protein feeds; A, B, C are combinations of L and H; U is L supplemented with urea; for details of diets, see Table 1.
‡ Calculated by regression.

on a fresh weight basis, since the DM content of all feeds was high and did not differ between feeds. Both the rate of live-weight gain and FCE increased significantly ($P = 0{\cdot}01$) with an increase in the level of CP in the feed up to 141 g CP/kg feed (feed B). The rate of live-weight gain on feed U was not significantly different from the maximum growth rate, and the FCE on feed U was similar to that of feed B that had a similar CP content. The daily rate of feed intake was not affected by the level of CP in the feed, although there was an indication that sheep fed on U had a higher rate of daily consumption.

The deposition rates of the chemical components of the carcass and wool (greasy fleece) gain are also given in Table 2. The rates of protein (Fig. 1) and water deposition responded in a similar manner to that of the rate of live-weight gain to the increase in the level of CP in the feed; the highest rate of body protein deposition was about 45 g/d (feeds B and C). Although the effect of the level of CP was not significant on the rates of ash deposition and wool gain, the tendency was that the former was depressed on feeds L and A, and the latter on feeds L and U. There was no effect of treatment on the rate of lipid deposition, but since animals fed on L and A took a considerably longer time to reach 45 kg live weight, they were also fatter and contained less protein ($P < 0{\cdot}001$) in their bodies at the end of the experimental period.

Choice-fed sheep

Diet selection. The average composition of the diets selected by the sheep on the five feed-pairs during the whole experimental period is given in Table 3. The proportion of feed H chosen declined systematically ($P < 0{\cdot}01$) as the CP content of the other feed was increased (from this comparison the UH pair was excluded). The proportion of feed H chosen was not statistically different when the other feed offered was either L or U (339 *v.* 401 g feed H/kg total feed intake (TFI), SE of difference (SED) 6).

Sheep given the opportunity to choose a feed above the one below their requirements, as judged by their performance on single feeds (feed pairs LH and AH), selected a diet of a similar protein concentration (131 *v.* 133 g CP/kg feed respectively; SED 6). When sheep had a choice between a feed close to their requirements (feed B) or a feed above their CP requirements (feed C) and feed H, which was well in excess of their CP requirements, they tended to avoid the latter feed. On the feed-pair CH they consumed only a very small amount of feed H (176 (SE 65) g/d). This, however, was not the case in the UH pair where the sheep consumed significant amounts of feed H (401 g feed H/kg TFI) and consequently had very high intakes of CP.

Any change in the diet selection over time and live weight would be expected to be seen for the pairs where sheep were able to meet their requirements throughout the experimental period (i.e. pairs LH and AH). When the average proportion of feed H selected by sheep on these two pairs was plotted *v.* time (Fig. 2), a very small decline in the proportion of feed H, and consequently of the CP selected, was observed during the first week but with no subsequent change.

Performance. Because of the 8 d period of experience, sheep had an average live weight of 27·5 (SE 0·19) kg when they were first given access to both feeds as a choice; this live weight was not affected by feed-pair but was used as a covariate in the analysis of the performance data.

The performance of sheep given access to two feeds as a choice is given in Table 4 as rates of live-weight gain, daily feed intake, deposition of the carcass chemical components and feed conversion efficiency (FCE). There was no effect of feed-pair on any of these measurements but there was a significant effect ($P < 0{\cdot}01$) of the covariate on the rate of daily feed intake and FCE. This effect presumably reflected the variation in the live weights of individual sheep (which was not affected by feed pair) at the end of the training period.

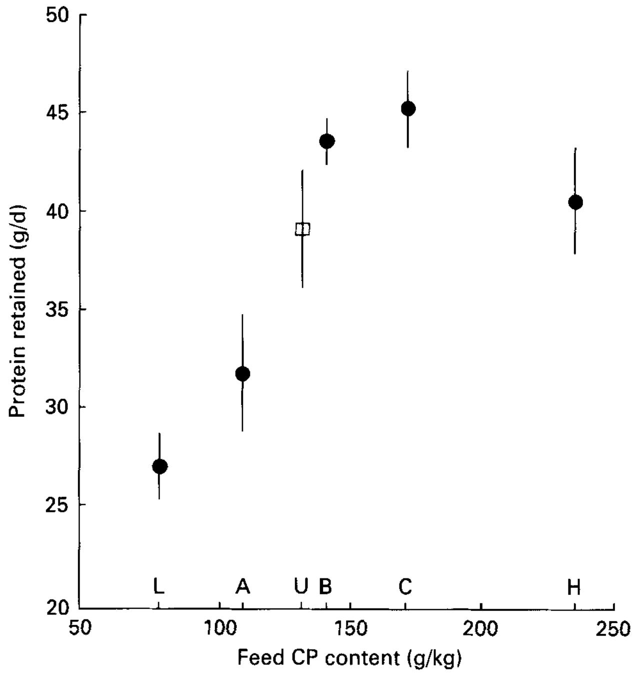

Fig. 1. The daily rates of protein (excluding wool) retention (g/d) of sheep given access to a feed with different crude protein (nitrogen × 6·25; CP) contents from 23·5 to 45 kg live weight. For details of diets, see Table 1.

Table 3. *The diets selected by choice-fed sheep: the proportion of feed with high crude protein (nitrogen × 6·25; CP) content (H) as g per kg total feed intake (TFI) and the CP contents of the selected diets*

(Mean values with their standard errors)

		Proportion of feed H eaten (g/kg TFI)		Different from random	CP selected (g/kg feed)	
Feed-pair†	*n*	Mean	SE	selection‡	Mean	SE
LH	8	339	22	**	131	4
AH	8	187	34	**	133	4
BH	9	176	33	**	158	3
CH	9	90	33	***	178	2
UH	9	401	61	NS	173	6
SED		6			6	

SED, standard error of difference; NS, not significant.
** $P < 0{\cdot}01$, *** $P < 0{\cdot}001$.
† L and H are low- and high-CP feeds; A, B, C are combinations of L and H; U is L supplemented with urea; for details of diets, see Table 1.
‡ Proportion of H 500 g/kg TFI.

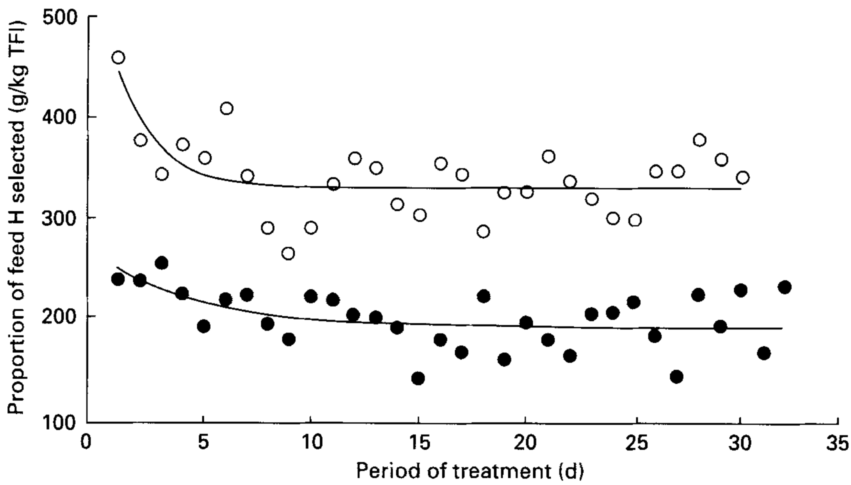

Fig. 2. The average daily proportion of the feed with the high crude protein (nitrogen × 6·25) content (H) selected (g/kg total feed intake (TFI)) during the experimental period by sheep given either a choice between the low crude protein content feed (L) and H (○) or between a mixture of L and H (A) and feed H (●). The lines through the points are fitted by regression. For details of diets, see Table 1.

Table 4. *The performance and the composition of the gain of lambs given access to two feeds with different crude protein (nitrogen × 6·25; CP) contents, as a choice from 23·5 to 45 kg live weight (LWT)*

Feed pair*....	LH	AH	BH	CH	UH	SED
CP selected (g/kg)	131	133	158	178	173	6
Possible range of CP (g/kg)	(78–235)	(109–235)	(141–235)	(172–235)	(132–235)	
Live-wt gain (g/d)†	416	387	415	410	383	37
Feed intake (g/d)‡	1929	1947	1895	2004	1983	89
FCE (g gain/g intake)	0·219	0·200	0·218	0·205	0·198	0·014
Protein gain (g/d)	45	40	46	50	43	7·4
Lipid gain (g/d)	117	103	114	104	102	17
Water gain (g/d)	187	178	176	206	174	34
Ash gain (g/d)	12	12	14	16	10	1·9
Wool gain (g/d)	10	19	16	16	18	3·7

SED, standard error of difference; FCE, feed conversion efficiency.
* L and H are low- and high-CP feeds; A, B, C are combinations of L and H; U is L supplemented with urea; for details of diets, see Table 1.
† Calculated by regression.
‡ From 27·5 to 45 kg LWT.

The performances of these choice-fed sheep were not significantly different from the highest performance observed on a single feed (feed B or C).

DISCUSSION

Single-feed-fed sheep

The performance of the sheep given access to single feeds (as measured by their rates of live-weight and protein gain) suggested that feed B met the CP requirements of the average sheep for the 23·5–45 kg live weight interval. The average rate of live-weight gain on this feed of 412 g/d was appreciably greater than the performance of wether Suffolk × Scottish mule lambs over a similar live-weight range observed in the experiments of Cropper (1987) and Hou (1991). In the two latter experiments the best performance was achieved by animals given a choice between a low- and a high-protein feed, rather than by feeding a single feed.

The daily rate of feed intake of these sheep was appreciably greater for all the treatments than that predicted by the equation of the Agricultural Research Council (1980), which uses the metabolizability of the energy of the feed and live weight. The protein content of the feeds had no effect on the rate of intake; the animals did not attempt to compensate when offered a feed of low protein content by increasing their rate of feed intake as the protein content of the feed was decreased. Such a compensatory increase in the rate of feed intake is common in simple-stomached animals (e.g. pigs, Kyriazakis *et al.* 1991; chickens, Freeman, 1979) but often absent in ruminant animals offered a range of feeds differing in protein content (Ranhotra & Jordan, 1966; Orskov *et al.* 1971). It has been suggested that such an absence reflects the physical limitations imposed in creating a low-protein diet, since this is usually achieved by diluting a high-protein feed with increasing amounts of a fibrous material (Raven *et al.* 1969). It is unlikely that such a physical limitation was imposed on our lambs by the low-protein feeds since these were made by a sweet potato (starch) dilution. It is, however, likely that either the rapid starch fermentation, which could result in an asynchronous supply of energy and N to rumen bacteria, or the possible decrease in rumen pH (Hespell & Bryant, 1979) had an effect on the microbial growth in the rumen. This could have an adverse effect on organic matter digestion which could again result in a physical limitation imposed on the feed intake of animals on a low-protein feed (Newbold, 1987). The fact that the rate of feed intake appeared to be increased when urea was added to feed L (to result in feed U) provides further support to the above argument.

Choice-fed sheep

Given the performance of the single-feed-fed sheep then the choices offered to the choice-fed ones fall into three distinct classes. The sheep given access to feed-pairs LH and AH were given a choice between one feed below and one above their protein requirements. These animals selected a diet of a certain CP content that allowed them to perform as well as those given feed B alone. An advantage for the choice-feeding treatments over the single-feeding ones was that individual sheep on the same feed-pair could, and did, vary the composition of the diets they selected. It is reasonable, in view of the performance of the choice-fed sheep as a whole, to assume that those individual variations in diet selection reflected individual variation in requirement. Further, individual sheep could change the composition of the diet selected with time, if they wished to, in order to meet any changes in their CP requirements.

The extent to which diet selection is altered by the metabolic state of the ruminant animal has not been studied in any detail, although it has been suggested that in a grazing situation a sheep could conceivably change the composition of its diet by choosing different plants and/or different parts of a plant in order to meet changes in its nutritional requirements (Milne, 1991). There is however, substantial evidence for simple-stomached animals to suggest that their diet selection is affected by changes in their nutrient requirements. With growing pigs given a choice between two appropriate feeds it has been observed that they change the CP of their selected diet with time and weight, and this has been assumed to reflect the decline in their protein requirements as they grow (Kyriazakis *et al.* 1990, 1991). For pigs growing from 12 to 32 kg live weight (for a period of 3 weeks) the change in their CP selected was of the order of 30–40 g CP/kg feed. In this experiment (Fig. 2) the proportion of feed H selected by sheep on pairs LH and AH, and consequently of the CP

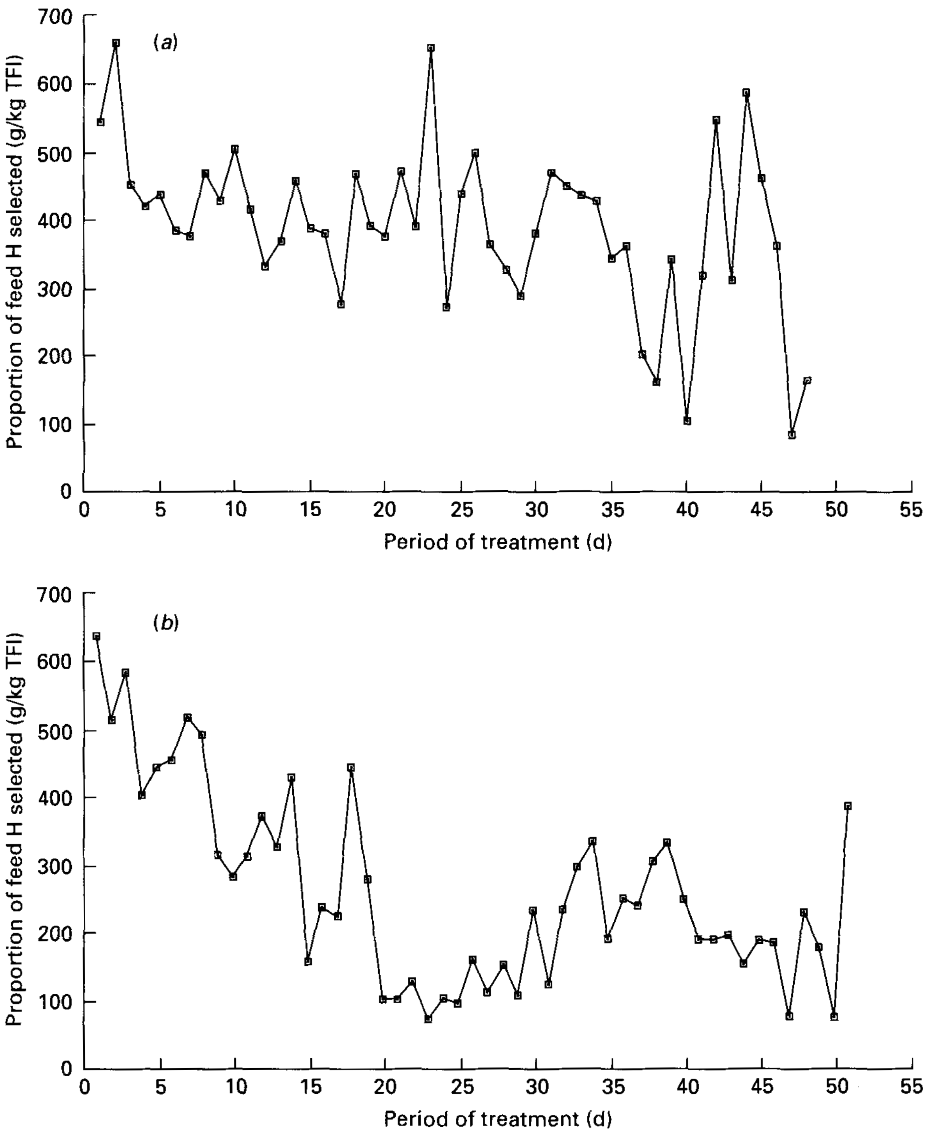

Fig. 3. Two examples of the change with time of the daily proportion of the high crude protein (nitrogen × 6·25) feed (H) selected (g/kg total feed intake (TFI)) by (a) a sheep (no. 87) given a choice between the low crude protein feed (L) and feed H and (b) a sheep (no. 75) given a choice between a mixture of L and H (feed A) and feed H. For details of diets, see Table 1.

selected, changed very little with time. There were individual animals that changed their diet selection over time (for examples, see Fig. 3), but the average change was nowhere near the magnitude of that observed with pigs. It is suggested that such a difference reflects the fact that sheep are much more slowly growing animals and, therefore, any changes in their diet selection could not be seen over the time-scale of the present experiment. Hou (1991) gave sheep a choice between two feeds of different protein content over a much larger period of time (exceeding 2 years) and observed systematic changes in their diet selection that were probably related to changes in their requirements.

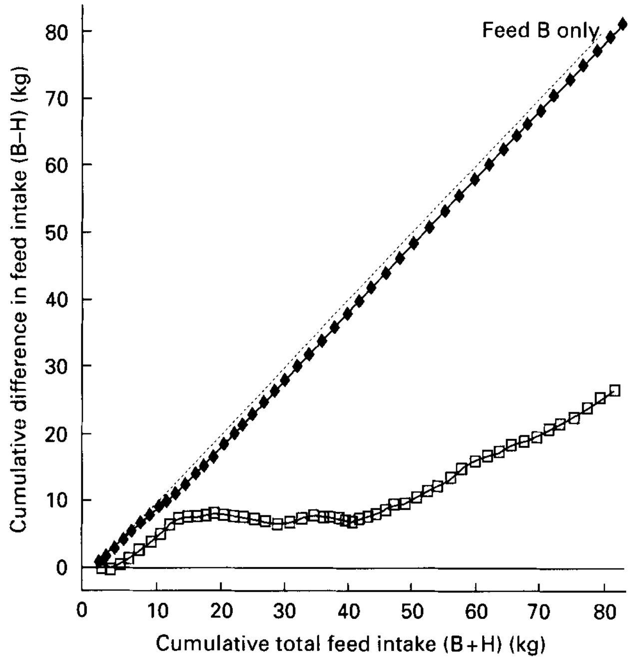

Fig. 4. Two examples of the paths of diet selection of sheep given a choice between a mixture of high (feed H) and low crude protein (nitrogen × 6·25) (B) and feed H. (---), That expected for sheep showing a complete preference for feed B only and, therefore, a path of diet selection parallel or towards this line (e.g. lamb no. 91) reflects a preference for this feed. Any path of diet selection parallel to the *x* axis indicates an equal preference for both feeds B and H. (□—□), Lamb no. 31; (◆—◆), lamb no. 91.

The choice between feed pairs BH and CH falls into the class of choices between a feed at about (feed B) or above their requirements (feed C) and a feed well in excess of their requirement (feed H). It has been suggested that in such cases, once the animal has met its requirements for protein, further intake has no advantage (i.e. the animal has no obvious advantage in overloading its deaminating system (Harper, 1974)). This rule seems to have applied to such choices given to rats (Musten *et al.* 1974), pigs (Kyriazakis *et al.* 1990) and sheep (Cropper, 1987). However, in all these cases the avoidance of the feed over-abundant in CP was not complete, but some small amount of it was consumed. It has been suggested that such a behaviour is a sampling behaviour, since an animal has an obvious advantage in monitoring its environment (e.g. foraging animals need to be informed about the quality of their foraging patches; Shettleworth, 1978; Lea, 1979). This rule seems to explain completely the behaviour of sheep given a choice between feeds C and H (almost a complete preference for feed C). However, it does not seem to apply very tightly to the BH pair (where the animals consumed some more substantial amounts of feed H). This could be accounted for by the fact that feed B approximated to the animals' requirements and, at least for some sheep in the beginning of the experiment, was below their requirement. This would imply that the preference for feed H, for some animals at least, should change with time. In Fig. 4 the pathways of two sheep that represent the two extremes on this treatment are shown. Sheep no. 91 showed almost a complete preference for feed B that did not change with time (average proportion of feed B selected was 988 g B/kg TFI). For sheep no. 31, its initial diet selection, an equal preference for both feeds, changed with time towards a substantial preference for feed B (average proportion of B selected was 737 g B/kg TFI).

Such an avoidance of excess protein intake did not seem to apply when sheep were given a choice between feeds U (a feed designed to satisfy rumen function) and H. In terms of its CP content, feed U was similar to feed B (131 *v.* 142 g CP/kg feed respectively) and, therefore, the diets selected might have been expected to be similar between pairs UH and BH. However, animals of the UH pair consumed a higher proportion of feed H and, consequently, overconsumed CP. There are two hypotheses that could explain the feed choice of these animals. The first is that sheep did not select their diet according to the CP content of the feeds offered as a choice, but according to another nutrient present in the feed (e.g. a macromineral or an amino acid). This view is supported by the fact that sheep given a choice between feed L or feed U (which was essentially feed L supplemented with 21·4 g urea/kg feed) and feed H selected diets with similar proportion of feed H (339 *v.* 401 g/kg TFI; SED 6). This implies that sheep equated feeds L and U in a nutritional dimension other than the CP content of the feed. Such an hypothesis, however, does not account for the larger individual variation in diet selection for pairs UH compared with any other pair (the standard error was twice as high on UH), which was reflected in the wide range of the proportion of feed H selected (range 176–780 g feed H/kg TFI). The second hypothesis suggests that sheep chose to avoid (in relative terms) one or some properties of feed U (other than its CP content) when the alternative was a high-protein feed. Such a property of feed U will have to be related to the excess of urea (or rapidly degradable protein) present in this feed. Such an avoidance hypothesis could account for the variation in individual diet selection, since it has been shown that individuals have different tolerance levels for feeds with detrimental or toxic properties (Robinson, 1974, 1975). Consequently, when given a choice between such a feed and another one, an animal may select a diet according to its tolerance level and its properties (Chesters & Quarterman, 1970). The avoidance of excess of rapidly degradable protein has a rational justification (Newbold, 1987), but cannot be confirmed at this stage by the results of a single treatment. The results of the present experiment do not rule out the possibility that some organoleptic property of diet U was important in determining the selection observed when feeds U and H were offered as a choice. However, if such properties of feed U were important they were not sufficient to cause a reduction in intake when U was offered as a single feed.

The experiment described here was an investigation into the rules of one aspect of diet selection. It is concluded that sheep selected their diets from the pairs of feeds offered in a directed manner. The quantity eaten and, hence, the compositions of the diets selected appeared to reflect the sheep's requirements for CP for maintenance and growth.

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