The effect on protein utilization of feeding different protein supplements via the rumen or via the abomasum in young growing sheep

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1. Sixteen lambs were used to compare two methods of administering various protein supplements to weaned lambs. In one method the protein supplement was mixed with the dry feed, consisting mainly of rolled barley, so that it passed to the rumen. In the second method the supplement was suspended in water which the lambs were trained to suck from a bottle; the suspension then passed directly to the abomasum by way of the oesophageal groove and so escaped rumen fermentation.

2. When the protein supplements were given in amounts that provided less than the estimated protein requirement of the animals, giving the liquid suspension led to significantly lower urinary nitrogen excretion ($P < 0.001$), greater nitrogen retention ($P < 0.05$) and greater live-weight gain ($0.05 < P < 0.1$) than giving the feed in the dry form.

3. The body-weight gain was greater with white fish meal than with casein ($P < 0.05$) and soya-bean meal ($P < 0.001$), whichever method of feeding was adopted. There was no significant interaction between method of feeding and protein source, but the faecal nitrogen excretion was highest when soya-bean meal was given in liquid suspension.

4. From a regression of nitrogen retention on nitrogen intake with lambs receiving the basal ration only, it was calculated that the improvement in retention of the protein supplement effected by giving it in liquid suspension was 31 % for casein, 27 % for fish meal and 24 % for soya-bean meal.

Attempts to reduce the fermentation of high-quality protein in the rumen were stimulated by the discovery that dietary proteins were extensively degraded in that organ (McDonald, 1948; Chalmers, Cuthbertson & Synge, 1954). It has subsequently been shown that the treatment of dietary proteins with formalin decreased this rate of degradation and, when diets containing such proteins were given to Merino sheep, wool growth increased (Ferguson, Hemsley & Reis, 1967).

Recent work at this Institute showed that, by stimulating the oesophageal groove reflex, suspensions of protein could be made to pass directly into the abomasum, thus wholly avoiding degradation within the rumen (Ørskov & Benzie, 1969). A protein supplement given in this way to weaned lambs resulted in increased nitrogen retention and decreased urinary nitrogen excretion when compared with the giving of the same protein in the dry feed (Ørskov & Fraser, 1969).

The experiments reported here were conducted with lambs given diets containing suboptimal amounts of protein to examine the effects on nitrogen retention of giving three different sources of protein in liquid suspension or in dry form.

EXPERIMENTAL

Animals

Sixteen uncastrated male lambs from North Country Cheviot ewes by Suffolk rams were used. They were weaned within 1 week of birth and trained to drink milk from a bottle fitted with a teat. They were also allowed free access to dry food consisting of dried grass and rolled barley. At about 5–6 weeks of age when they weighed about 15 kg they were allocated to the experimental treatments.

Design and treatment

The sixteen lambs were divided into six blocks of two or three according to weight. In each block one lamb was allocated at random to a system of dry feeding and one to liquid feeding. When there was a third lamb it was used as a control and given the basal ration only. The six pairs were then allocated to the six possible sequences of supplementation with three protein sources in three feeding periods of 21 d each. The design was thus a double 3×3 Latin square with split plots, aimed to achieve maximum precision of estimate for the comparison between protein sources and for the interaction between the method of supplementation and the protein source. The comparison between control and supplemented lambs was of subsidiary interest and was not included in the Latin square design. The control diet consisted of rolled barley concentrate with no protein supplement. In the experimental treatments the diets consisted of the rolled barley concentrate together with casein, white fish meal or soya-bean meal, each of these protein supplements being given (*a*) in the dry feed and (*b*) in liquid suspension (see Table 1).

Feed composition and feeding level

The rolled barley concentrate contained 96 % rolled barley, 2 % calcium carbonate, 1 % steamed bone flour, 0·7 % Adisco (1000 i.u. vitamin A/g, 200 i.u. vitamin D/g), and 0·3 % urea. Vitamin E was added to supply 20 i.u./kg; to provide trace minerals, 0·15 g $ZnSO_4.7H_2O$ and 0·08 g $MnSO_4.4H_2O$ were added per kg feed. The concentrate contained 11·5 % crude protein ($N \times 6·25$) in the dry matter. The crude protein in the dry matter of the casein was 97·5 %, of the white fish meal 72 %, and of the soya-bean meal 49 %.

The level of feeding for each period was estimated from the equation $Y = 5·00 - 0·0353\ W$, where Y is the total daily feed (both barley concentrate and supplement) offered, expressed as a percentage of live weight and W is the mean live weight in kg at the beginning of each period. This formula was derived from the *ad lib.* intake of a similar group of lambs. The protein supplements were given so as to achieve a final concentration of 16 % crude protein in the dry matter of the diet. This concentration was chosen because experiments with lambs of similar weight and given similar amounts of feed had shown that it did not allow maximal protein retention and was below the requirement for growth of lambs of this weight (Andrews & Ørskov, 1970).

Management

The lambs were given their concentrate once daily at 11.00 hours. Any uneaten feed was weighed at this time and dried to constant weight at 100°. The protein concentrate allowed for each day for liquid feeding was suspended (and mixed) in a jug of water to give 5–10% dry matter. The suspension was then divided into four equal portions and given at 08.00, 12.00, 16.00 and 20.00 hours. At each feeding the bottles were rinsed with a small amount of water which was returned to the jug. The lambs always consumed the suspension eagerly. Water was always available and the lambs were weighed before and after each collection period.

Nitrogen balance procedure

Each nitrogen balance trial consisted of 10 d of a preliminary period in which the lambs were kept in wooden cages, after which they were put in metabolism cages and the urine and faeces collected for a period of 10 d. The urine was collected in jars containing a solution of acetic acid and formalin to ensure a final pH of below 5 and a final concentration of 1% formalin. The daily output was pooled for the collection period after which it was weighed and samples were obtained for determination of nitrogen. The daily faecal output was also pooled during the collection period and well-mixed samples were taken for determination of dry matter and nitrogen.

The nitrogen content of diets, faeces and urine was estimated by the macro-Kjeldahl method of the Association of Official Agricultural Chemists (1960) with mercuric oxide as catalyst. The ammonia was estimated colorimetrically as the indophenol blue complex using a Technicon AutoAnalyzer.

RESULTS

In Table 1 the growth rates determined during the collection period have been given, together with the intakes of dry matter and digestible dry matter and the apparent digestibility of the dry matter. Regardless of method of feeding there were significant differences between the sources of protein in growth rate. The fish-meal diet gave greater live-weight gain than the soya-bean diet ($P < 0.01$) and casein diet ($P < 0.05$). The difference between the casein and soya-bean diets was also significant ($P < 0.05$).

The increase in live-weight gain in favour of feeding by liquid suspension was 16 ± 7.5%, which was not statistically significant ($0.05 < P < 0.1$). The differences between dry- and liquid-supplement treatments in dry-matter intake, digestibility and digestible dry-matter intake all favoured the dry-supplement treatments but amounted to only about 1, 2 and 4% respectively. There was more uneaten food recorded when the control diet was given, so that the intake was substantially lower and the dry-matter digestibility was also lower. Since the animals receiving the control diet were deliberately excluded from the main change-over design, no reliable estimate can be given of the precision of this comparison.

In Table 2, the nitrogen balance and apparent nitrogen digestibility have been given.

There were no significant differences between the sources of protein in nitrogen intake and urinary nitrogen, but the faecal nitrogen was greater with soya protein than with the other proteins ($P < 0.001$). The differences in nitrogen retention were not significant ($0.05 < P < 0.1$) but were consistent in direction with the differences in live-weight gain between the fish meal, casein and soya-bean treatments.

Table 1. *Effect of method of administration on live-weight gain of groups of six lambs receiving different protein sources and two different methods of feeding the protein supplement; also the mean intake of dry matter, digestibility of dry matter and digestible dry-matter intake*

Protein supplement	Method of administration of protein supplement	Dry-matter intake (g/d)	Digestible dry-matter intake (g/d)	Digestible dry-matter intake ($g/kg^{0.75}$)	Live-weight gain (g/d)	Dry-matter digestibility (%)
Control	Dry feed, no supplement	646	487	52.3	136	77.5
Casein	Dry in concentrate	684	564	54.7	191	82.4
Casein	Liquid suspension	677	553	52.8	223	81.7
White fish meal	Dry in concentrate	690	562	53.8	244	81.5
White fish meal	Liquid suspension	685	550	51.8	270	80.2
Soya-bean meal	Dry in concentrate	688	567	54.4	165	82.2
Soya-bean meal	Liquid suspension	684	550	52.5	203	79.6
SE* of treatment difference		—	—	—	±22	±0.67
All sources	Dry in concentrate	687	564	54.3	200	82.0
All sources	Liquid suspension	682	551	52.3	232	80.5
SE* of difference between methods of administration		—	—	—	±15	±0.65

* Not applicable to control treatment.

Table 2. *Effect of protein source and method of administration on nitrogen balance and apparent nitrogen digestibility of lambs*

(Each value is the mean of six observations, the control treatment is the mean of twelve observations)

Protein supplement	Method of administration of protein supplement	N intake (g/d)	Urinary N (g/d)	Faecal N (g/d)	Retained N (g/d)	Apparent N digestibility (%)
Control	Dry feed, no supplement	12.09	2.97	4.84	4.28	60.0
Casein	Dry in concentrate	17.48	6.94	3.97	6.57	77.2
Casein	Liquid suspension	17.31	5.83	4.29	7.19	75.3
White fish meal	Dry in concentrate	17.82	6.70	3.92	7.20	78.0
White fish meal	Liquid suspension	17.48	5.14	4.48	7.86	74.4
Soya-bean meal	Dry in concentrate	17.38	6.67	4.37	6.34	74.7
Soya-bean meal	Liquid suspension	17.23	5.36	5.11	6.76	70.2
SE* of treatment difference		—	0.46	0.20	0.55	1.21
	Dry in concentrate	17.56	6.77	4.09	6.70	76.6
	Liquid suspension	17.34	5.44	4.63	7.27	73.3
SE* of difference between methods of administration		—	0.20	0.09	0.22	0.48

* Not applicable to control treatment.

The urinary nitrogen was significantly lower ($P < 0.001$) with liquid feeding of the protein than with dry feeding in the concentrate. The faecal nitrogen, on the other hand, was higher with liquid than with dry feeding ($P < 0.01$). The nitrogen retained was greatest with liquid administration ($P < 0.05$). The measurements showed no significant interaction between method of administration and source of protein. The apparent digestibility of nitrogen reflected the differences in faecal nitrogen.

Table 3. *Effect of protein source and method of administration on nitrogen retention in lambs, expressed as percentage of nitrogen intake, percentage of apparent digestible nitrogen intake, and percentage of digestible dry-matter intake, and percentage retention of supplementary nitrogen*

		N retention			
Protein supplement	Method of administration	N intake (%)	Apparent digestible N (%)	Digestible dry-matter intake (%)	Retention of supplementary N (%)
Casein	Dry in concentrate	38·2	49·5	1·20	40·6
Casein	Liquid suspension	41·9	55·6	1·32	53·1
White fish meal	Dry in concentrate	41·2	52·8	1·31	49·4
White fish meal	Liquid suspension	45·3	60·9	1·45	62·5
Soya-bean meal	Dry in concentrate	37·0	49·6	1·14	35·3
Soya-bean meal	Liquid suspension	39·8	56·6	1·26	43·8
SE of difference between treatments		2·7	3·3	0·08	8·5
	Dry in concentrate	38·8	50·6	1·22	41·8
	Liquid suspension	42·3	57·7	1·34	53·1
SE of difference between method of administration		1·2	1·6	0·04	3·9

Table 3 provides various measures of nitrogen retention on percentage bases. Retention of nitrogen from the basal diet, Y, was related to basal nitrogen intake, X, by the regression equation $Y = 0.20X + 1.97$ obtained from twelve nitrogen balances carried out with the control treatment. The equation was applied to basal intakes on the other treatments so that the nitrogen retention attributable to the supplementary nitrogen intake could be estimated by subtraction from the total; thence were derived the percentage retentions of supplementary nitrogen given in Table 3. The percentage retentions were all significantly higher when the protein supplement was given in liquid suspension than when it was given dry ($P < 0.05$ or $P < 0.01$). The values for fish meal tended to be the highest and those for soya bean the lowest, but the differences were mostly not statistically significant. There were no significant interactions.

DISCUSSION

Influence of method of administration

The results reported here fully support the results obtained earlier when a mixture of protein concentrate was given in liquid suspension compared with giving it in dry form (Ørskov & Fraser, 1969). A highly significant reduction in the urinary nitrogen excretion was obtained and a smaller increase in faecal nitrogen depending upon protein source, with subsequent increase in nitrogen retention and live-weight gain. It must be re-emphasized here that the feeding of the liquid suspension must rely on the function of the oesophageal groove and must therefore be fully integrated with the behavioural pattern of the animal and be given in a manner similar to that on which the animals were reared (Ørskov & Benzie, 1969).

The levels of protein used in the experiment were estimated to be below requirement for optimum utilization and this allowed differences resulting from different methods of administration to be measured. Employing a similar level of feeding, Andrews & Ørskov (1970) showed that lambs given dry feed responded by increased nitrogen retention to levels of protein higher than those used here. If the lambs were given protein in excess of their requirement or optimum utilization, differences resulting from different methods of administration might well disappear.

Influence of source of protein

The results showed differences between sources of protein in the result for live-weight gain. This was apparent both with liquid feeding and with feeding the protein incorporated in the concentrate, and there were no significant interactions between method of administration and source of protein. An interaction between method of administration and source of protein was expected because it had been shown that ammonia formation from casein in rumen fluid was much greater than when herring meal was used (Chalmers & Synge, 1954) but the precision of detecting such interaction in the present work may not have been sufficient. While an interaction could not be detected, the advantage of liquid feeding of soya-bean meal was slightly less than it was with casein and fish meal owing to the increase in the faecal nitrogen excretion when soya-bean meal was given in the liquid form. This emphasizes the point mentioned by Ørskov & Fraser (1969) that protein used in this way must be highly digestible. The differences noted here between sources of protein may well be associated with differences in their amino acid composition and therefore may be an expression of how the combination of microbial protein formed in the rumen, and the source of protein used, approach the optimum amino acid composition for growth.

The expression 'net protein utilization' (NPU) normally determined with monogastric animals cannot be directly compared with the utilization of protein noted here because the values given in Table 3 are the expression of the utilization of the protein supplements with the protein entering the abomasum from the rumen. It is interesting, however, to note that Eggum (1968) with rats reported an NPU for white fish meal of 64·9%. This compares with a supplementary protein utilization of 62·5% obtained in this experiment, so that feeding of the protein supplement in liquid suspension may give a protein utilization similar to that observed with monogastric animals.

The results here may suggest that the sulphur-containing amino acids may have been limiting since the soya-bean meal contained less cystine and methionine than the casein and fish meal (Ørskov & Fraser, 1969). In the previous work, however, no significant difference in nitrogen retention between casein and fish meal was detected. An experiment is now in progress which involves feeding with individual amino acids which may help to clarify this.

Quantitative deductions

The basal ration used was formulated in an attempt to provide sufficient nitrogen to satisfy the requirement of the rumen micro-organisms by the addition of a small amount of urea to the rolled barley. The concentration of nitrogen in the basal diet (1·87% in the dry matter) was in excess of the microbial requirement according to estimates by Hungate (1966) who quotes values from 0·7 to 1·7 g/100 g of carbohydrate fermented for the nitrogen incorporated into microbial cells. In some recent work conducted here (E. R. Ørskov, C. Fraser & I. McDonald, unpublished) it was shown, furthermore, that no increase took place in the amount of non-ammonia crude protein entering the abomasum as a result of adding urea to a barley diet containing 1·6% nitrogen in dry matter. If the basal ration, therefore, contained sufficient nitrogen to meet the microbial requirement, some deductions can be made about the extent of rumen degradation of protein when the protein supplements were given. If the value for nitrogen retention noted when the liquid supplement was given represented maximum utilization, then it can be calculated that between 70 and 80% of dietary protein passed through the rumen undegraded when it was given in dry form. The advantage of feeding in liquid suspension gave an average increase in utilization of 27%, and, for the individual proteins, 31% for casein, 27% for fish meal and 24% for soya-bean meal.

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