THE INFLUENCE OF DIETARY PROTEIN AND METHIONINE ON THE SULPHUR CONTENT AND GROWTH RATE OF WOOL IN MILK-FED LAMBS

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Summary

The effect of dietary protein and methionine on the sulphur content and growth rate of wool, produced by milk-fed lambs, was studied in an experiment lasting 6 weeks and commencing when the lambs were 3 days old. Measurements were also made on two lambs left with their mothers.

The sulphur content of birthcoat wool was uniformly high, with a mean value of 3·79%. Lambs receiving methionine-supplemented diets, and those left with their mothers, grew wool of a high sulphur content, equivalent to birthcoat values. The sulphur contents of wool grown by lambs receiving three diets, with protein contents between 11 and 39% of dry matter, were similar to each other and were significantly lower than birthcoat values.

Wool growth rate was substantially influenced by the level of protein in the diet. Relative wool growth rates were 42, 100, and 113 with diets containing 11, 27, and 39% protein in the dry matter. Addition of methionine to the latter two diets did not significantly alter wool growth rate.

I. Introduction

Experiments with adult sheep have shown that the administration of casein or sulphur-containing amino acids (*S*-amino acids) directly into the abomasum has a considerable effect on the rate of wool growth (Reis and Schinckel 1964; Reis 1967, 1969). However, because of microbial degradation of proteins and amino acids in the rumen (McDonald 1952; Chalmers and Synge 1954), there is little effect on the rate of wool growth when these supplements are included in the diet. In an experiment with milk-fed lambs, which are essentially non-ruminants, Walker and Cook (1967) found an approximately threefold increase in wool output when the protein content of the diet was increased from 6 to 23% in isocaloric rations.

Wool grown by the lambs in the experiment of Walker and Cook was analysed for sulphur by the present author. The mean sulphur content was 2·87 (S.D. ±0·15)% and was unaffected by the dietary protein level. By contrast, when casein was given per abomasum to adult sheep, there were significant increases in the sulphur content of wool (Reis and Schinckel 1963, 1964; Reis 1969). Moreover, the sulphur values for the lambs' wool were lower than those usually observed in wool from adult sheep (Reis 1965). The low sulphur content of the wool did not appear to be a characteristic of wool grown by these lambs, as the wool collected a few days after birth and before the experiment commenced was consistently much higher in sulphur content, mean 3·53 (S.D. ±0·13)%.

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The present experiment was carried out to determine whether supplements of *S*-amino acids and protein would cause young milk-fed lambs to grow high-sulphur wool, and to measure effects of these supplements on wool growth rate.

II. Experimental

(*a*) *Animals*

Twenty-two crossbred lambs [(Border Leicester × Merino) ♀ × Dorset Horn ♂] were used in the experiment. There were 17 females and 5 males, comprising 7 single-born lambs and 15 twin-born lambs. Birth weights ranged from 3·25 to 5·50 kg. The lambs were born at pasture and, when 3 days old, 20 of the lambs were transferred from their mothers to cages in a room maintained at about 23°C, where they were fed the experimental diets. Two lambs were kept with their mothers.

(*b*) *Plan of Experiment*

There were two consecutive treatment periods, each of 3 weeks, commencing when the lambs were 3 days old. The various treatments given to pairs of lambs are shown in Table 2. Four lambs were used in each of four balanced crossover comparisons of four experimental diets with the whole milk diet (groups 1–8), and two lambs received whole milk in both periods as a time reference (group 9). All diets given to groups 1–9 were isocaloric. Lambs in group 10 also received milk in both periods, but on a more liberal basis. Lambs in group 11 were kept indoors, with their mothers, in a pen maintained at about 25°C. A diet of equal parts chopped lucerne hay and oats was available *ad libitum* to ewes and lambs.

(*c*) *Diets and Feeding*

The diets are described in Table 1. The dry matter content of the various diets (*c*. 14%) was within the range found by Large (1965) to give equivalent liveweight gains and efficiencies of feed conversion in artificially reared lambs. The low protein milk was supplemented with a trace element mixture. Supplements of vitamins A and D were given to all lambs during the first week of both periods 1 and 2, by adding an emulsion containing 50,000 i.u. each of vitamins A and D_3 to one feed. In addition, all artificially fed lambs received 0·2 ml per day of a proprietary vitamin supplement* to ensure an adequate supply of B vitamins. Chlorotetracycline hydrochloride (17 mg/day) was given with each feed, dissolved in the milk; the product was aureomycin chlorotetracycline soluble powder (Cyanamid D.H.A. Pty. Ltd., Australia).

The daily ration was dispensed from stock mixtures stored at 3°C, and was divided into three equal parts. Lambs were fed from bottles at *c*. 0800, 1300, and 1800 hr each day; the milk was warmed to 38°C prior to feeding. The provision of three feeds per day over a restricted period of 10 hr was considered to be adequate as Walker, Cook, and Jagusch (1967) found that varying the feeding frequency (two, three, or six feeds daily) did not influence liveweight gain or nitrogen retention of milk-fed lambs. No drinking water or solid feed was available. Lambs were weighed daily (to the nearest 10 g) prior to the 0800 feed and the daily ration was calculated on the basis of this weight. Lambs in groups 1–9 received 120 kcal/kg body weight per day, while lambs in group 10 received 240 kcal/kg body weight$^{0\cdot 7}$ per day. The calorific values (kcal/g dry matter) of dried whole milk and casein, measured in a bomb calorimeter, were 5·83 and 5·80 respectively. Values for glucose (3·74) and butter oil (9·24) were taken from Walker and Cook (1967); methionine was assumed to be equivalent to casein.

(*d*) *Wool Growth and Sulphur Analysis*

On the day experimental treatments commenced, the wool from areas (*c*. 25 cm^2) on the right shoulder and right midside was removed with small animal clippers (Oster, size 40). This

* Stated composition per millilitre: vitamin B_1, 1·8 mg; vitamin B_2, 2·2 mg; vitamin B_6, 0·2 mg; niacinamide, 24·0 mg; sodium pantothenate, 0·5 mg.

wool was designated birthcoat wool. The cleared areas were defined by tattooing and a margin was then cleared around the tattooed patch. The mean area of the tattooed patches on the day they were established was 23·4 (S.D. $\pm 2\cdot 69$) cm^2. Wool was subsequently removed from the tattooed patches with small animal clippers at the end of weeks 1, 3, 4, and 6. Wool collected at weeks 3 and 6 was cleaned as described by Reis (1967) to give wool grown (grams clean dry wool) during the last 2 weeks of each treatment period. The areas of the tattooed patches were measured at the end of weeks 1, 3, 4, and 6; the means of the areas at weeks 1 and 3, and at weeks 4 and 6, were taken to represent the patch areas during the last 2 weeks of periods 1 and 2 respectively. These areas were used to calculate wool growth rate per unit area of skin. Sulphur content of clean dry wool was measured as described by Reis and Schinckel (1963). Values for each lamb were calculated from duplicate measurements on wool from each site. The mean difference between duplicate analyses was 0·04 (S.D. $\pm 0\cdot 03$)% sulphur.

Table 1

COMPOSITION OF DIETS

Composition given as grams per 100 g dry matter

Constituent	Milk	Low Protein Milk	High Protein Milk	Methionine Milk	High Protein Methionine Milk
Dried whole milk	100·0	39·2	83·3	98·5	81·8
Casein*	—	—	16·7	—	16·7
DL-Methionine	—	—	—	1·5	1·5
Glucose	—	19·2	—	—	—
Butter oil	—	37·5	—	—	—
Minerals†	—	4·1	—	—	—
Crude protein‡	27·5	10·8	38·9	28·6	40·0
Dry matter content of "milk" mixture (g/100 ml)	14·1	14·4	14·1	14·1	14·1

* Casinal (calcium caseinate; Glaxo-Allenburys).

† NaCl (10%), $CaCl_2$ (57%), KH_2PO_4 (33%).

‡ $N \times 6\cdot 37$; methionine is regarded as protein.

III. Results

All diets, except the low protein diet, supported satisfactory rates of body weight gain, viz. 0·4–1·0 kg/week and 0·8–1·6 kg/week during periods 1 and 2 respectively. Individual differences in the rate of gain were related to the initial weight of lambs. Somewhat higher rates of gain were obtained with lambs in groups 10 and 11.

Values for the sulphur content of wool are presented in Table 2, both for birthcoat wool and for wool grown during the last 2 weeks of periods 1 and 2 (wool collected at weeks 3 and 6). A comparison of the treatment effects in periods 1 and 2, combined with birthcoat values, is given in Figure 1. The sulphur content of birthcoat wool was consistently high, mean 3·79 (S.D. $\pm 0\cdot 14$)%; the values for groups of lambs varied between about 3·7 and 3·9% (Fig. 1). It is apparent from Figure 1 that the sulphur content of birthcoat wool was substantially higher than that of wool grown during the feeding of low protein milk, milk, or high protein milk. These differences were statistically significant: milk and low protein milk, $P < 0 \cdot 001$; high protein milk, $P < 0 \cdot 05$. The sulphur content of wool grown during the feeding of low protein milk was not significantly lower than that of wool grown with the milk diet. However, there may have been some carry over from period 1 to period 2 due to the low wool growth rates with low protein milk (see Table 2); the lower mean sulphur values for groups 1 and 2 (Fig. 1) may also be related to a carry over effect. The addition of methionine to both milk and high protein milk resulted in marked increases in sulphur content of wool (methionine milk, $P < 0 \cdot 01$; high protein methionine milk, $P < 0 \cdot 05$); the values were not significantly different from birthcoat values. Lambs kept with their mothers produced wool with a high sulphur content similar to that of birthcoat wool, and feeding milk on a more liberal basis (group 10) also appeared to increase the sulphur content of the wool (Table 2; Fig. 1).

TABLE 2

INFLUENCE OF PROTEIN AND METHIONINE ON SULPHUR CONTENT AND GROWTH RATE OF WOOL

There were two lambs per group. Periods were of 3 weeks duration; period 1 commenced when lambs were 3 days old. Groups 1–9 received isocaloric diets, supplying 120 kcal/kg body weight per day. Values for sulphur content and wool growth are on the basis of clean, dry wool and are means for two sites (shoulder and midside) on each of two lambs. LPM, low protein milk; HPM, high protein milk; MeM, methionine milk; HPMeM, high protein methionine milk

Group	Dietary Treatment		Sulphur Content of Wool (%)			Wool Growth ($mg/cm^2/day$)	
	Period 1	Period 2	Birthcoat	Period 1	Period 2	Period 1	Period 2
1	Milk	LPM	3·84	3·35	3·29	1·48	0·60
2	LPM	Milk	3·84	3·05	3·21	0·60	1·35
3	Milk	HPM	3·74	3·36	3·63	1·52	1·75
4	HPM	Milk	3·74	3·24	3·46	2·02	1·80
5	Milk	MeM	3·94	3·50	3·97	1·25	1·46
6	MeM	Milk	3·66	3·78	3·26	1·83	1·84
7	Milk	HPMeM	3·76	3·20	3·81	1·78	2·14
8	HPMeM	Milk	3·66	3·69	3·52	1·80	1·56
9	Milk	Milk	3·74	3·32	3·48	1·65	1·78
10	Milk*	Milk*	3·88	3·54	3·82	1·78	1·97
11	Left with mother	Left with mother	3·91	3·92	4·10	1·64	1·45

* Lambs were fed 240 kcal/kg body weight$^{0 \cdot 7}$ per day.

The amounts of wool grown (g per patch) by lambs receiving the milk diet throughout the experiment were 40% (group 9) and 49% (group 10) greater in period 2 than in period 1. As a result of this time effect, wool growth (expressed as grams per patch) was higher in period 2 than in period 1 for all lambs, except those receiving low protein milk in period 2. However, when wool growth rates were calculated per unit area of skin, these differences were considerably reduced (Table 2). The wool growth rates obtained with lambs fed high protein milk, methionine milk, and high protein methionine milk were not significantly greater than those obtained

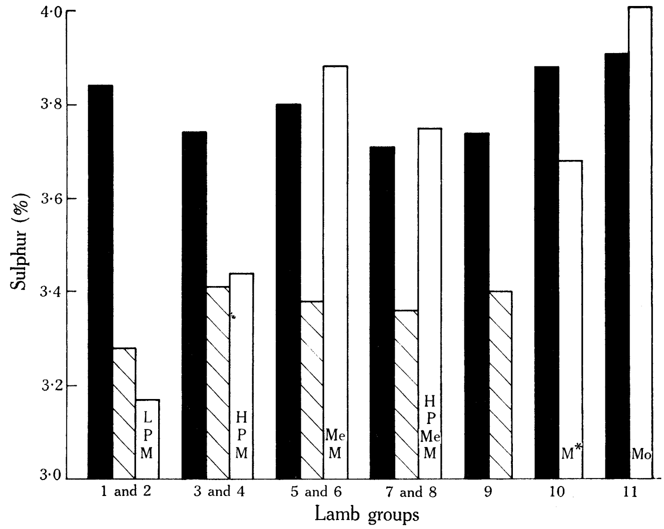

Fig. 1.—Influence of diet on the sulphur content of clean dry wool from milk-fed lambs. See Table 2 for details of the experiment. The shaded areas represent birthcoat values and the hatched areas are values for lambs receiving milk. Other treatments are LPM (low protein milk), HPM (high protein milk), MeM (methionine milk), HPMeM (high protein methionine milk), M* (lambs fed 240 kcal/kg body weight$^{0\cdot7}$ per day), and Mo (lambs left with their mothers). For lamb groups 1–8 each value is a mean for four lambs; experimental treatments were given in either period 1 or 2. For lamb groups 9–11 each value is a mean for two lambs; experimental treatments were given in both periods 1 and 2.

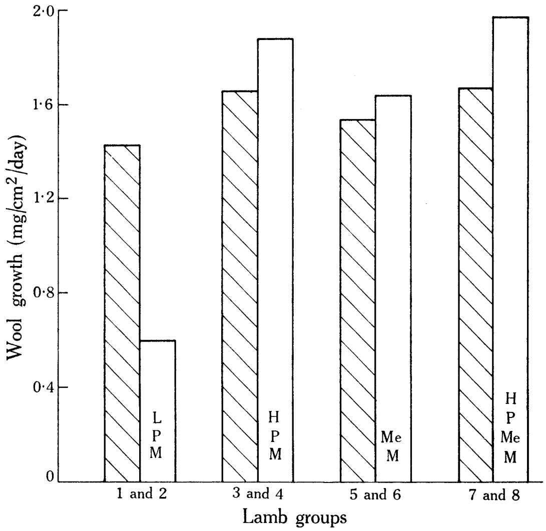

Fig. 2.—Influence of diet on the wool growth rate of milk-fed lambs. See Table 2 for details of the experiment. The hatched areas are values for lambs receiving milk; other treatments are LPM (low protein milk), HPM (high protein milk), MeM (methionine milk), and HPMeM (high protein methionine milk). Each value is a mean for four lambs receiving the experimental diets in either period 1 or 2. Values are on the basis of clean, dry wool.

with the milk diet, although the two high protein diets produced higher wool growth rates than the milk diet irrespective of the order of treatments (Table 2). Larger numbers of lambs would be needed to establish the reality of the effects of additional protein. Lambs given low protein milk grew considerably less wool ($P < 0 \cdot 001$) than they did when fed the milk diet (Table 2, Fig. 2). Figure 2 illustrates the mean wool growth rates (wool per unit area) obtained with each experimental diet fed to groups 1–8; almost identical results were obtained when wool growth was expressed as grams per patch. Expressed as a percentage of the wool growth rates obtained with the milk diet, relative rates for the other diets were: low protein milk 42, high protein milk 113, methionine milk 106, high protein methionine milk 118.

IV. Discussion

It is apparent that young lambs are able to grow high-sulphur wool in response to changes in nutrition or supplements of methionine, as has been found with adult sheep (Reis 1965, 1967). Synthesis of high-sulphur wool is due to increased synthesis of certain components of the high-sulphur proteins (Gillespie and Reis 1966), and there is evidence that these proteins are amongst the last to be synthesized in the follicle bulb (Downes *et al.* 1966). Thus, any restriction of the cyst(e)ine supply to the wool follicles would tend to result in wool with a low sulphur content. In view of the present results and those of Walker and Cook (1967), it would appear that the *S*-amino acid requirements for body growth and for the synthesis of wool proteins in the young lamb may restrict the supply of cyst(e)ine available for incorporation into the specific protein components present in high-sulphur wool. Thus, Walker and Cook (1967) observed no effect of increasing amounts of protein in the diet on the sulphur content of wool, although wool growth rate was increased markedly. In the present experiment, even a diet containing 39% protein (which would provide approximately 80 g protein per day for a 10 kg lamb) failed to induce the growth of high-sulphur wool, especially in the first few weeks of life. Only the addition of methionine to the diet, or a presumably high intake of *S*-amino acids by the lambs receiving milk and solid feed *ad libitum* with their mothers, resulted in the production of high-sulphur wool throughout the experiment.

It has been observed with adult sheep that an abomasal supplement of 2 g/day of cysteine or methionine produces maximum stimulation of synthesis of specific high-sulphur proteins and hence a maximum sulphur content in wool (Gillespie and Reis 1966; Reis 1967). The maximum values obtained varied between about $3 \cdot 7$ and $4 \cdot 3$% sulphur for individual sheep (Reis and Schinckel 1963; Reis 1965, 1967). As the sulphur content of wool grown by lambs receiving methionine-supplemented diets varied between $3 \cdot 73$ and $4 \cdot 00$%, it is likely that these values are approaching the maximum for these lambs. Although intakes by adults and lambs cannot be compared directly, methionine intakes of methionine-supplemented lambs were quite high (5–6 g/day for a 10 kg lamb). As the sulphur content of birthcoat wool from all lambs was high and was not significantly different from that of wool grown during methionine supplementation, these values may also be approaching the maximum for each lamb. Further evidence supporting this supposition is that the birthcoat sulphur values were either equal to or greater than the sulphur content of wool grown when the animals were 6–7 months old and receiving an *ad libitum* intake of a diet containing 18% crude protein. The mean sulphur content of wool grown during this period was $3 \cdot 62$ (S.D. $\pm 0 \cdot 13$)%. The relationship between the sulphur content of birthcoat and adult wool may warrant further study in view of the possibility that the sulphur content of wool may be used to distinguish between high and low wool producers, at least in genetically selected groups of sheep (Piper and Dolling 1966; Reis *et al.* 1967).

In agreement with results obtained with adult sheep (Reis 1969) and milk-fed lambs (Walker and Cook 1967), there was a substantial effect of the amount of intestinally digested protein on wool growth rate in these experiments. Due to the short experimental periods necessary with young lambs, the differences in wool growth rate obtained with the various diets would not have been measured precisely, because further changes in wool growth rate would be expected if protein or amino acid supplementation was continued for more than 3 weeks (Reis 1969). The removal of wool grown during the first week of a period should allow for emergence time of wool with the various high protein diets (Reis 1969), but the wool growth rate measured with the low protein diet may still be partly influenced by the previous nutrition and therefore be overestimated. The failure to demonstrate a significant increase in wool growth rate with the high protein diet relative to the milk diet was not surprising, as protein intakes were already high. Thus, a 10 kg lamb would receive *c.* 60 g protein per day from the milk diet and *c.* 80 g protein per day from the high protein diet. The lack of effect of methionine supplementation on wool growth may be due to an already adequate intake of *S*-amino acids, or the supplements may have resulted in an excessive methionine intake. Methionine added was $1 \cdot 5$% of the dietary dry matter and approximately doubled the methionine intake.

The same conclusions were drawn regarding treatment effects whether wool growth was expressed as wool per patch or wool per unit area of skin. The increase, with time, in the amount of wool grown per patch was presumably related to an increase in the number of active follicles (Schinckel 1963) and to an increase in the synthetic capacity of active follicles. The calculation of wool growth as wool per unit area largely removed the effect of time, due to the increasing patch areas, and allowed comparisons to be made between lambs. However, these rates should not be compared with published values for adult sheep, because factors other than synthetic activity of the wool follicles influence the rates obtained in young lambs.

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