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Influence of protein and sulphur amino acid nutrition on hair fibre production by British Angora and Cashmere goats

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SUMMARY – The results from a number of studies are presented which investigated responses in fibre production of British Cashmere and Angora goats to variation in protein and sulphur amino acid nutrition. Requirements for amino acids were considered in the context of the concentration of amino acids, including cysteine and methionine, in rumen microbial protein and in dietary protein supplements compared with the amino acid composition of hair fibre. Increases in fibre yield and diameter were consistently observed in Angora goats given good quality protein supplements or rumen protected intestinally available methionine (Smartamine^{TM} M, Rhone-Poulenc). Cashmere yield was not influenced by protein supplementation but by methonine supplementation in one study, possibly reflecting the smaller quantitative synthesis of this fibre compared with mohair production. Results from an *in vitro* study suggested that methionine could support cashmere fibre growth (approximately 0.75) in the absence of cysteine and cystine providing evidence of transulphuration in isolated hair follicles. However, cysteine and cystine were also required to produce maximum growth. The results confirm the value of a good quality protein supplement or more targeted supply of rumen protected intestinally available methionine to correct a frequently apparent deficiency in sulphur amino acid supply for hair fibre growth by Angora goats, with the possibility of a response to methionine supplementation by Cashmere goats.

Key words: Protein, sulphur amino acids, methionine, hair fibre, goats.

RESUME – *"Influence de l'alimentation protéique et d'acides aminés sur la production de poils chez les chèvres Angora et Cachemire". Un certain nombre d'études présentées ici ont permis d'analyser les réponses de la production de fibre aux variations de la nutrition azotée et en acides aminés soufrés chez les chèvres Cachemire et Angora. Les besoins en acides aminés ont été considérés en relation avec la concentration des acides aminés, y compris la cystéine et la méthionine, dans les protéines microbiennes du rumen et dans les apports alimentaires supplémentaires de protéine par rapport à la composition en acides aminés du poil. Quand on a fourni des apports supplémentaires de protéine de bonne qualité ou de méthionine protégée dans le rumen et disponible dans l'intestin (Smartamine^{TM} M Rhône Poulenc), des augmentations du rendement et du diamètre de fibre ont été généralement observées. Le rendement en Cachemire a été influencé seulement par les apports supplémentaires de méthionine ; ce qui peut indiquer une synthèse plus réduite de cette fibre par rapport à la production de mohair. Les résultats d'une étude* in vitro *ont suggéré que la méthionine pourrait permettre la pousse de fibre (à peu près 0,75) en l'absence de cystéine et de cystine. Ces résultats ont suggéré une transulphurisation dans les follicules de poil isolé. Cependant la cystéine et la cystine sont nécessaires aussi pour obtenir une pousse maximale. Ces résultats confirment l'intérêt d'un apport supplémentaire protéique de bonne qualité ou d'un approvisionnement plus ciblé de méthionine protégée dans le rumen et disponible dans l'intestin pour rectifier un manque souvent apparent d'acides aminés soufrés pour la pousse du poil des chèvres Angora et Cachemire.*

Mots-clés : *Protéine, acide aminé soufré, méthionine, mohair, cachemire, chèvres.*

Introduction

Hair is produced by follicles situated in the skin of animals. The major goat fibre products are mohair produced by the essentially single-coated genetically-distinct Angora goat and cashmere which is produced by the more genetically heterogeneous double-coated Cashmere goat. Both fibre types are produced by secondary hair follicles. Mohair fibres are lustrous, non-medullated, grow at up to 2.5 cm/month and range in diameter from 22 to 45 m, with annual greasy fleece yields of up to 6 kg. Cashmere, which is the fine undercoat, grows at up to 1.5 cm/month, although frequently less, with diameter in the range of 12-18 m, and yields of 50-600 g/year. Growth of cashmere unlike mohair is dependent on photoperiod. Guard hair, the coarse overcoat of the cashmere goat is produced by primary follicles and also grows seasonally with diameters in the range 30-90 m with length 4-20 cm and yields up to 500 g/year. The commercial value of both fibre products is optimised by high yields, small diameters and absence of primary fibres and other contaminants. The physical and biological characteristics of these fibres and the potential for development of fibre-based goat husbandry systems on a larger scale in Europe and Mediterranean regions have been the subject of recent reviews (Laker and Russel, 1995). Additional information on nutritional and hormonal control of hair growth may be found in the review by Galbraith (1998).

The increasing interest in the production of cashmere and mohair in the United Kingdom has resulted in the importation of different genotypes of goats from a number of different countries in recent years. These goats have been used in breeding programmes to improve the yield and quality of commercial fibres. The objective of studies reported in this review was to provide information on the nutrition of these animals and particularly that relating to protein and sulphur amino acids which are known to be important determinants of fibre growth and quality.

Composition of hair fibres

Hair is produced by follicles situated in the skin of animals. The hair product is composed largely of cells of the cortex which contain large amounts of intermediate filament proteins (IFPs) (including keratins) and a non-filamentous matrix. The IFPs are considered to contain concentrations of the sulphur amino acid cysteine (residues per 100 residues of amino acids) of 6.0 and up to 20 in the high sulphur cysteine – rich fraction of the matrix proteins. Overall concentrations of cysteine (including that present in its dimer form cystine) for sheep wool in comparison with muscle and sources of dietary supply are shown in Table 1. The main points to note are the greater concentrations of cysteine in wool than muscle, rumen microbial protein and the examples of dietary protein supplements soya bean meal and white fish meal. The supply of sulphur amino acids above that supplied by microbial protein also depends on the digestibility of the rumen-undegraded fraction of the dietary supplement. The studies reported in this paper will describe responses of Angora and Cashmere goats to supplementation of the diet with: (i) protein supplements; and (ii) rumen-protected intestinally available methionine which is known to provide the sulphur moiety which can be transferred to form cysteine by transulphuration in certain tissues.

Table 1. Relative composition of selected amino acids in tissues and dietary protein sources (modified from Galbraith, 1995)

Amino acid	Wool	Muscle	Rumen microbial protein	Extracted soyabean meal	White fishmeal
Threonine	5.5	3.9	5.2	4.2	4.2
Leucine	6.5	5.8	7.4	8.2	6.7
Phenylalanine	4.6	3.1	5.5	5.5	3.9
Lysine	3.5	5.9	8.1	6.8	5.7
Methionine	0.6	1.8	2.5	1.4	3.0
Cyst(e)ine	9.1	1.1	1.0	1.4	0.9

Responses to dietary protein supplements

The effect of two levels of dietary protein and energy (see Table 2) was studied for 112 days in 24 Australasian-type yearling castrate male Angora goats. Protein supplementation was provided by a mixture of equal quantities of white fish meal and soya bean meal to give estimated concentrations [g/kg dry matter (DM)] for rumen undergradable protein (UDP) of 26 (LP) and 79 (HP) and for rumen degradable protein (RDP) 82 (LP) and 101 (HP) respectively. Positive responses in mid-side raw fibre yield to protein occurred in the first four weeks and were maintained throughout. There was no significant response to energy until the final 3 weeks. Their data confirm earlier reports and also show the commercially undesirable increase in fibre diameter.

The question of optimising dietary protein concentration to balance benefits in fibre yield against increases in diameter was investigated in a further study (Table 3). In this 63 day study, 20

Australasian type male castrate Angora goats, aged about 16 months were offered diets containing an estimated 9.6 MJ/kg DM metabolisable energy with variations in crude protein (CP) achieved by replacing dietary sugar beet pulp with a mixture of soya bean meal and fish meal. The data were examined by analysis of variance and the significance of linear (L) quadratic (Q) and cubic (not shown) relationships between treatments determined. The clean fibre yield was significantly affected (Q; $p < 0.05$) between day 1 and 56 with increases up to 165 g CP per kg dietary DM and a decrease at the highest concentrations of 185 g CP per kg DM. Fibre diameter increased linearly (L; $p < 0.05$) as the protein intake was raised. The data suggests that a concentration of 165 g/kg DM may be most appropriate for optimising fibre yield, but not diameter. Under the conditions of the experiment it is seen that protein supplementation reduced the quality of the fibre as a result of increases in diameter. The results suggest that the relative economic importance of mohair yield and fineness will require to be considered where controlled protein nutrition can be achieved.

Table 2. Raw yield (g/100 cm^2) and diameter of mid-side mohair fibre of Angora goats given diets containing (per kg DM) 10 MJ (LE) or 11.9 MJ (HE) and 108 g (LP) or 180 g (HP) crude protein (adapted from Shahjalal *et al*., 1992)

	Treatment				SED	Significance of contrasts†	
	LE-LP	LE-HP	HE-LP	HE-HP		P	E
Period of treatment (weeks)							
1-4	1.68	2.49	1.65	2.11	0.357	*	NS
5-8	2.88	3.97	3.05	3.53	0.335	**	NS
9-12	2.50	3.74	3.19	3.75	0.319	**	NS
13-16	1.74	3.14	2.59	3.31	0.279	***	**
1-16	8.91	13.3	10.5	12.7	1.08	***	NS
Fibre diameter (m) day 112	29.9	35.6	32.4	35.8	1.49	***	NS

†P = protein; E = energy (no interaction effects were recorded).
*P < 0.05, **P < 0.01, ***P < 0.001, NS = non significant.

Table 3. Mid-side clean fibre yield (g/100 cm^2) and fibre diameter of Angora goats given diets differing in crude protein concentration (modified from Shahjalal *et al*., 1991)

	Treatment means† dietary crude protein (g/kg DM)				SED	Statistical significance††	
	102	126	165	185		L	Q
Clean fibre yield (g/100 cm^2)							
Day 1 to 56	3.43	3.99	4.89	3.20	0.547	NS	*
Fibre diameter (m)							
Day 56	29.8	31.5	36.1	33.6	1.77	*	NS

†Data have been adjusted for initial fibre yield (day 0) as covariate.
††See text.
*P < 0.05, NS = non significant.

Cashmere is an economically more valuable fibre than mohair and there is considerable interest in means of improving yield. The effect of protein nutrition was studied in 24 male castrate Cashmere goats [12 Siberian (S) x Irish feral and 12 Australasian (A) x Irish feral] in a 102-day study. Within genotypes the goats were allocated to receive nitrogen supplementation either based on urea + sodium sulphate (U) or white fish meal (F) to give estimated concentrations (g/kg DM) of RDP and UDP of 86 and 64 and 117 and 32 for diets F and U respectively with an estimated ME concentration of 11.0 MJ/kg DM for the basal diet. Mid-side total fleece growth measurements indicated no significant effects due to protein supplementation (Table 4, selected data shown) with no significant alteration in the proportions by weight of guard hair to cashmere. There were similarly no effects of source of protein supplement on the average diameter of cashmere fibres. These results confirm others in the literature (see Souri *et al.*, 1998a) that under these or similar nutritional conditions, and unlike mohair production by Angora goats, cashmere growth is usually not limited by protein nutrition.

Table 4. Fleece growth (cashmere + guard hair) proportion of yield and fibre diameter of Siberian (S) and Australasian (A) cross Irish feral goats given dietary supplements of urea (U) or white fishmeal (F) (modified from Galbraith *et al.*,1994)

	Treatments				SED
	SU	SF	AU	AF	
Mid-side fleece yield (g/100 cm^2)					
Day 49 to 97	0.93	1.26	1.31	1.19	0.577
Estimated proportion of yield (g/kg)					
Day 97 guard hair	645	729	869	773	139
Cashmere	355	271	131	227	139
Cashmere fibre diameter (m)					
Day 97	17.4	17.7	16.5	17.4	0.58

Responses to rumen-protected methionine

One disadvantage of meeting the requirement for one amino acid by means of protein supplementation is the over-provision of other amino acids, the disposal of which places a metabolic burden on the animal. With this in mind, we have studied the response of both Cashmere and Angora one year old goats to rumen protected intestinally available methionine (Smartamine^{TM} M, Rhône-Poulenc, Paris, France) supplementation. At inclusion rates of 2.5 g/day, in addition to a basal diet containing (per kg DM) 9.9 MJ ME and 107 g CP, methionine stimulated (Table 5) raw fibre yields and fibre diameter (with some reduction in quality) of Angora goats in both treatment periods, whereas responses (increases in yield, without affecting diameter) to cashmere were obtained from days 31 to 58 only. Guard hair was not affected by supplementation. The results suggest that responses obtained were most likely due to limitation of sulphur amino acid supply in the present study. It was also interesting to note that methionine stimulated liveweight gain and nitrogen retention (as a proportion of dietary N intake) in both genotypes, with a greater response in N retention in Angora goats which may be partially attributable to the greater retention of N for fibre production by Angora goats. Certain differences between genotypes were also recorded for intake and apparent digestibility of dry matter. Souri *et al.* (1997) also showed that 10-month old Angora goats given basal diets containing approximately 100 g crude protein per kg DM and supplemented with rumen-protected methionine (Smartamine^{TM} M) grew more quickly and had greater retention of dietary N, than controls. However, the relative partitioning of dietary N to mohair N was unchanged at approximately 0.40. These results suggest that the animals were deficient in methionine/cysteine in both fleece and non-fleece tissues and that relative partitioning was unchanged in response to improved supply.

The results did not explain the relative importance of methionine and cysteine for hair growth and the question of whether methionine can convert to cysteine in the hair follicle. This question was tested *in vitro* using our follicle explant system (Ibraheem *et al.*, 1994). Small skin samples were obtained by approved technique from the mid-side area of three 18-month old Scottish male castrate Cashmere goats in the time period August to September at 57^{o}N. Cashmere follicles were isolated and incubated in Williams E medium without cystine, cysteine or methionine (O) and then supplemented to give final concentrations as follows: 100 M methionine + 330 M cysteine + 83 M cystine (MC); 100 M methionine without cysteine or cystine (M); 330 M cysteine + 83 M cystine without methionine (C).

The results (Table 6) indicated that the follicles in treatment MC (containing all of the sulphur amino acids) exhibited typical hair growth rates for up to 120 h incubation. Follicle growth and viability at 72 hours was significantly reduced in the absence of methionine with cystine and cysteine present (treatment C). In addition, methionine supported growth of follicles in the absence of cysteine and cystine to about 0.75 of that recorded in its presence. It is concluded that methionine is essential to support hair growth and viability and that cysteine/cystine are not essential provided that methionine is present. The results also provide strong evidence for the presence of a transulphuration pathway within the cashmere secondary hair follicle.

Table 5. Mid-side fibre yields (mg/100 cm^2/day), proportion of cashmere and guard hair and diameter of cashmere and mohair in response to methionine supplementation (modified from Souri *et al.*, 1998a)

	Treatment groups†				SED	Significance of contrasts††	
	CO	CS	AO	AS		D	G
Days 0 to 30							
Total raw fibre yield	42.0	53.0	96.3	141	8.0	**	***
Guard hair yield	29.0	33.0			2.4		
Cashmere yield	13.0	19.0			1.7		
Proportion	0.31	0.37			0.02		
Diameter (day 30) (m)	19.7	19.2	27.6	32.9	1.9	***	***
Days 31 to 58							
Total raw fibre yield	46.0	54.0	87.0	156	7.0	***	***
Guard hair yield	33.0	35.0			2.9		
Cashmere yield	12.0	19.0			1.5	*	
Proportion	0.27	0.35			0.02	*	
Diameter (day 58) (m)	18.9	19.7	28.3	32.6	1.7	***	***

†C = Cashmere; A = Angora; O = no supplementation; S = methionine supplementation.
††Contrast D (diet), contrast G (genotype).
*P < 0.05, **P < 0.01, ***P < 0.001.

Table 6. Elongation (E, mm) and number of viable cashmere hair follicle (V) in 24 h growing periods *in vitro* (modified from Souri *et al.*, 1996)

Hours		Treatments†				PSD††
		CM	M	C	O	
24	E	0.11^{a}	0.09^{a}	0.05^{b}	0.03^{b}	0.07
	V	89^{a}	70^{a}	54^{a}	41^{a}	9.6
48	E	0.11^{a}	0.08^{b}	0.04^{c}	0.03^{c}	0.06
	V	83^{a}	58^{a}	26^{a}	25^{a}	10.0
72	E	0.13^{a}	0.09^{b}	0.02^{c}	0.02^{c}	0.07
	V	62^{a}	42^{a}	9^{b}	2^{b}	6.0
120	E	0.12^{a}	0.10^{a}	0.00	0.00	0.07
	V	54^{a}	38^{a}	0	0	7.4

†See text for treatments.
††Values are means with Pooled Standard Deviation (PSD).
a,b,cValues in the same row with different superscripts are significantly different (P < 0.05).

More recent studies (Souri *et al.*, 1998b) have demonstrated the transfer of radioactivity-labelled sulphur from methionine to form cysteine in isolated mohair follicles. These results suggest that cashmere and mohair secondary follicles are at least partially independent of the synthesis of cysteine/cystine in, and supply from, other tissues. However, the studies do suggest that maximum hair follicle growth requires the presence of methionine and cysteine/cystine.

Conclusions

The amino acid composition of the hair fibre creates particular demands for sulphur amino acids on the normal supply mechanisms within the animal. These may be supplied in protein supplements or by rumen-protected methionine as a more targeted single amino acid form. Angora goats respond to a greater extent than Cashmere goats, an effect associated with the greater quantitative synthesis of mohair. Commercially desirable increased yields of mohair are associated with undesirable increases in fibre diameter. Feeding strategies for Angora goats could usefully consider the provision of good quality protein supplements, if the economic costs of such supplementation are less than the financial returns obtained from increases in yield. The small or absent responses currently indicate that protein supplementation may not produce financial returns in cashmere production. Further work is required to confirm responses to rumen-protected methionine supplements, particularly where genetic selection results in greater quantities of fibre production. The results from studies reported here provide evidence of transulphuration in both cashmere and mohair follicles and emphasise the need for an effective dietary supply of sulphur amino acids for absorption at the small intestine. The response to the rumen-protected intestinally-available methionine product confirms the value of a targeted supplement which supplies an otherwise potentially deficient amino acid without providing additional amino acids in quantities above those required by the animal.

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