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The microbial protein and undegradable essential amino acid requirements for the growth of male Merino and Dohne Merino lambs

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Abstract

The chemical score of microbial protein revealed the order of limiting amino acids for whole empty body growth of Merino and Dohne Merino lambs as histidine, methionine, leucine, arginine and phenylalanine. Microbial protein is unable to provide a similar duodenal essential amino acid pattern or quantity as the whole empty body amino acid composition of Merino and Dohne Merino lambs.

Keywords: Amino acid, whole empty body, microbial protein, chemical score
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Introduction

In ruminants the translation of tissue-level amino acid requirements to dietary amino acid requirements is very complex due to the impact of rumen nitrogen metabolism on the quality and quantity of protein reaching the duodenum (Kung & Rode, 1996). Merchen & Titgemeyer (1992) reported that both the pattern and the levels of essential amino acids supplied to the small intestine are rate-limiting factors for tissue synthesis, and are therefore of critical importance for maximum performance in ruminants (Sloan, 1997). Since the ruminant receives 40 - 80% of its daily amino acid requirements from microbial protein (Sniffen & Robinson, 1987), the degree to which microbial protein supply in the qualitative and quantitative requirement of each essential amino acid has significant implications on animal performance and supplementation strategies.

The present study was conducted to determine the order of limiting amino acids in microbial protein and to establish the extent to which microbial protein of sheep provides in the essential amino acid requirements for growth.

Material and Methods

The experimental design, animals, sampling procedure and laboratory analyses were similar to those described by Nolte & Ferreira (2004a). The whole empty body amino acid composition was calculated from the proportional amino acid patterns of the carcass as well as internal and external offal. Chemical score (the proportion of a single amino acid in microbial protein relative to that of the whole empty body) and the essential amino acid index (the proportion of all the duodenal essential amino acids relative to that of the whole empty body) were used to determine the limiting amino acids in microbial protein (Nolte & Ferreira, 2005). Analysis of variance was done according to the GLM procedure of SAS (2000), with breed as the main effect and the chemical scores of the individual essential amino acids and the essential amino acid index as the response variables.

Results and Discussion

The chemical scores (Table 1) indicate that the relative isoleucine and tryptophan concentrations in microbial protein were in excess of the growth requirements for both Merino and Dohne Merino lambs. Microbial protein supplied inadequate concentrations of all the other essential amino acids to support optimal growth and was first-limiting in histidine, followed by methionine, leucine, arginine and phenylalanine for both breeds. The synthesis of some amino acids, while others undergo deamination, reduces the efficiency of protein synthesis (McDonald *et al*., 1995), which emphasises the importance of the imbalance of microbial protein in comparison to the whole empty body protein of Merino and Dohne Merino lambs. Ferreira *et al*. (1999) determined the order of the most limiting amino acids for growing South African Mutton Merino lambs as histidine, methionine, threonine and arginine. Storm & Ørskov (1984) reported methionine, lysine, histidine and arginine as the first, second, third and fourth-limiting amino acids in microbial protein for the growth of Suffolk x (Finnish Landrace x Dorset Horn) lambs. Given the high order of limitation of lysine for the growth of lambs reported by Storm & Ørskov (1984), the high chemical scores of lysine in microbial protein in both breeds were unexpected.

Table 1 The chemical score[1] and essential amino acid (EAA) index[2] (LS Means ± s.e.m.) of microbial protein for growing male Merino (36.0 ± 7.3 kg) and Dohne Merino (35.8 ± 6.1 kg) lambs

EAA	Merino	Dohne Merino	s.e.m.	P
Arginine	77.84	80.00	0.57	0.06
Histidine	50.21	48.11	0.43	0.01
Isoleucine	124.17	119.92	0.76	0.002
Leucine	71.65	71.98	0.43	0.72
Lysine	99.33	95.24	0.94	0.03
Methionine	52.16	48.43	0.56	0.0001
Phenylalanine	83.44	83.59	0.50	0.88
Threonine	100.46	91.82	1.25	< 0.0001
Tryptophan	139.99	153.35	1.97	< 0.0001
Valine	89.26	92.91	1.12	0.11
EAA Index	82.20	81.13	0.52	0.16

[1]The proportion of an individual amino acid in microbial protein relative to whole empty body protein
[2]The proportion of the total essential amino acids in microbial protein relative to whole empty body protein

Table 2 The essential amino acid requirements of Merino and Dohne Merino lambs at an average growth rate of 250 g/d and the microbial protein and undegradable essential amino acids needed to meet these requirements

EAA[1]	EAA comp: MCP[2] (g/100 g protein)[3]	EAA: required Merino (g/d)[4]	EAA: required Dohne Merino (g/d)[4]	MCP required: Merino (g/d)[5]	MCP required: Dohne Merino (g/d)[5]	Estimated MCP deficiency: Merino (g/d)[6]	Estimated MCP deficiency: Dohne Merino (g/d)[6]	EAA required as UDP[7]: Merino (g/d)[8]	EAA required as UDP: Dohne Merino (g/d)[8]	Maximum ADG[9] from MCP: Merino (g/d)[10]	Maximum ADG[9] from MCP: Dohne Merino (g/d)[10]
Arg	5.54	11.97	11.65	215.96	210.23	98.03	92.30	5.43	5.11	136.52	140.24
His	1.29	4.31	4.49	335.01	349.38	217.07	231.44	2.79	2.98	88.01	84.39
Ile	4.02	5.44	5.63	135.35	140.16	17.42	22.22	0.70	0.89	217.83	210.36
Leu	5.85	13.71	13.66	234.56	233.61	116.62	115.67	6.82	6.76	125.70	126.21
Lys	6.69	11.32	11.82	169.25	176.76	51.32	58.83	3.43	3.93	174.20	166.80
Met	0.79	2.55	2.75	322.34	347.37	204.41	229.43	1.62	1.82	91.47	84.88
Phe	3.41	6.87	6.86	201.49	201.10	83.56	83.16	2.85	2.84	146.33	146.62
Thr	3.85	6.44	7.05	167.38	183.23	49.44	65.29	1.90	2.51	176.15	160.91
Trp	1.54	1.86	1.69	120.25	109.69	2.31	-8.24	0.04	-0.13	245.19	268.79
Val	4.89	9.21	8.88	188.34	181.57	70.41	63.64	3.44	3.11	156.55	162.38

[1]Essential amino acid
[2]Microbial crude protein
[3]From Nolte & Ferreira (2005)
[4]Calculated as Y = (X/100)*Z, where Y = EAA requirement for a growth rate of 250 g/d; X = a crude protein requirement of 168 g/d to allow an average daily gain of 250 g/d (NRC, 1985); Z = the whole empty body amino acid composition for each breed (Nolte & Ferreira, 2004b).
[5]Calculated as Y = X/(Z/100), where Y = microbial protein required (g/d); X = individual amino acid required (g/d); Z = concentration of individual amino acid in microbial protein (g/100 g protein)
[6]Calculated as Y = X - Z where Y = estimated microbial protein deficiency; X = calculated microbial protein requirement and Z = estimated microbial protein production. Z is calculated as 13% of the total digestible nutrient (TDN) intake (NRC, 1996), for an average daily voluntary feed intake of 1.26 kg DM of a diet with a TDN content of 720 g/kg (DM-basis) = 117.94 g/d
[7]Undegradable protein
[8]Calculated as Y = X – (Z/100*A), where Y = UDP requirement for essential amino acid A; X = estimated essential amino acid requirement; Z = estimated MCP production; A = concentration of essential amino acid A in MCP
[9]Average daily gain
[10]Calculated as Y = [(X/100)*Z]/A*250, where Y = maximum ADG supported by essential amino acid B produced by microbial protein, X = estimated microbial protein production; Z = concentration of essential amino acid B in microbial protein and A = requirement for essential amino acid B to allow an ADG of 250 g/d

The essential amino acid index of microbial protein displayed an overall amino acid deficiency for both breeds (Table 1). Animal performance might be even more limited than indicated by the essential amino acid index, due to the measure of constraint by the first limiting amino acid (Chen & Ørskov, 1994). Post-ruminal supplementation of the limiting amino acids is therefore required for optimal animal performance.

Microbial protein production is only able to provide in the quantitative daily tryptophan requirement of growing Merino and Dohne Merino lambs (Table 2). The rest of the essential amino acids have to be supplied by an undegradable protein source. This indicates that microbial protein may not always provide in all the amino acid requirements of high producing animals (Merchen & Titgemeyer, 1992). Ferreira *et al.* (2002) reported increased nitrogen retention when lambs were abomasally infused with amino acids, supporting a contention that post-ruminal amino acid supplementation is needed.

Conclusion

The chemical scores demonstrate that histidine, methionine, leucine, arginine and phenylalanine are the most limiting amino acids in microbial protein for growing Merino and Dohne Merino lambs. Microbial protein does not provide the required profile or quantity of amino acids in the small intestine to support a growth rate of 250 g/d by male Merino and Dohne Merino lambs. Hence, undegradable amino acids supplements are required. Further research on the differences in absorption and utilisation of different amino acids, the response of lambs to the supply of the ideal amino acid pattern in the small intestine, protection of amino acids against rumen degradation and the development of models to predict requirements and estimate subsequent response levels seem justified.

References

Chen, X.B. & Ørskov, E.R., 1994. Amino acid nutrition in sheep. In: Amino acids in farm animal nutrition. Ed. D`Mello, J.P.F., CAB International, Wallingford, U.K. pp. 307-328.

Ferreira, A.V., Van der Merwe, H.J. & Fair, M.D., 2002. Nitrogen retention response to the abomasal infusion of amino acids in South African Mutton Merino lambs. S. Afr. J. Anim. Sci. 32, 106-112.

Ferreira, A.V., Van der Merwe, H.J. & Loëst, C.A., 1999. Amino acid requirements of South African Mutton Merino lambs. 3. Duodenal and whole empty body essential amino acid profile. S. Afr. J. Anim. Sci. 29, 40-47.

Kung Jr., L. & Rode, L.M., 1996. Amino acid metabolism in ruminants. Anim. Feed Sci. Technol. 59, 167-172.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A., 1995. Evaluation of foods (B) Energy content of foods and the partition of food energy within the animal. In: Animal Nutrition (5th ed.). Longman Scientific & Technical, Essex, UK. pp. 238-265.

Merchen, N.R. & Titgemeyer, E.C., 1992. Manipulation of amino acid supply to the growing ruminant. J. Anim. Sci. 70, 3238-3247.

Nolte, J.vanE. & Ferreira, A.V., 2004a. Body-, protein- and essential amino acid composition of male Merino and Dohne Merino lambs. S. Afr. J. Anim. Sci. 34 (6), Supplement 2, 80-82.

Nolte, J.vanE. & Ferreira, A.V., 2004b. The whole empty body essential amino acid profiles of male Merino and Dohne Merino lambs. S. Afr. J. Anim. Sci. 34 (6), Supplement 2, 83-85.

Nolte, J.vanE. & Ferreira, A.V., 2005. The effect of rumen degradable protein level and source on the duodenal essential amino acid profile of sheep. S. Afr. J. Anim. Sci. (accepted).

NRC, 1985. Nutrient requirements of sheep. (6th ed.). National Academy Press, Washington, D.C., USA.

NRC, 1996. Nutrient requirements of beef cattle. (7th ed.). National Academy Press, Washington, D.C., USA.

SAS, 2000. SAS/SAST user's guide, Version 8.2. SAS Institute Inc., Cary N.C., USA.

Sloan, B.K., 1997. Developments in amino acid nutrition of dairy cows. In: Recent advances in animal nutrition. Ed. Garnsworthy, P.C. & Wiseman, J. Nottingham University Press, UK. pp. 167-198.

Sniffen, C.J. & Robinson, P.H., 1987. Microbial growth and flow as influenced by dietary manipulations. J. Dairy Sci. 70, 425-441.

Storm, E. & Ørskov, E.R., 1984. The nutritive value of rumen micro-organisms in ruminants. 4 The limiting amino acids of microbial protein in growing sheep determined by a new approach. Br. J. Nutr. 52, 613-620.