Comparison of different protein sources in enriched grain mixture for fattening lambs

T.S. Brand*
Elsenburg Agricultural Development Institute, Private Bag, Elsenburg, 7607 Republic of South Africa

G.D. van der Merwe
Outeniqua Agricultural Development Centre, P.O. Box 249, George, 6530 Republic of South Africa

Received 24 October 1991; revised 2 April 1992; accepted 18 November 1992

A triticale/oat grain mixture (2:1) was enriched with either a commercially available formula or a locally composed supplement in addition to different protein sources (urea, urea plus fish-meal, urea plus cottonseed oilcake, urea plus bitter lupins or bitter lupins only) to be approximately equal in protein content and *in vitro* organic matter digestibility. Oaten hay (milled through a 12-mm screen) was supplied separately at *ca.* 10% of *ad libitum* intake. The different diets were fed to SA Mutton Merino lambs (4 ram and 4 ewe lambs/diet) on an individual basis from approximately 15 weeks of age (25—40 kg). Values for the grain and hay intake, average daily gain (ADG) and feed conversion ratio (FCR, kg feed/kg gain) of the lambs were monitored over the same growth interval. No significant differences were observed between treatments or sexes in terms of grain intake, hay intake or total dry matter intake. Lambs on the diet containing 30% lupins consumed *ca.* 14% less grain/lamb/d than the mean grain intake of all the lambs (1 147 g/lamb/d) on an absolute basis. No significant differences ($P > 0.05$) in terms of ADG, FCR, or days in the feedlot were observed between diets, while ram lambs performed better than ewe lambs in terms of ADG ($P \leqslant 0.01$), days in the feedlot ($P \leqslant 0.01$) and FCR ($P \leqslant 0.05$). The lack of response to the different protein sources may be explained by the fact that the non-degradable protein (UDP) requirement of lambs over 25 kg was fulfilled by the triticale/oat grain mixture. It was concluded that the protein content of the feed grain as well as the price and availability of different protein sources will determine strategies for inclusion in diets for fattening lambs.

'n Triticale/hawer-graanmengsel (2:1) is met 'n kommersiële of 'n plaasliksaamgestelde verrykingsmengsel, bevattende verskillende proteïenbronne (ureum, ureum plus vismeel, ureum plus katoensaad-oliekoekmeel, ureum plus bitterlupiene of slegs bitterlupiene) op 'n iso-nutriëntbasis verryk. Hawerhooi (deur 'n 12mm-sif gemaal) is apart teen ongeveer 10% van *ad libitum*-inname voorsien. Die verskillende verrykte graanmengsels is aan SA Vleismerino-lammers (4 ram- en 4 ooilammers/dieet) in enkelhokke gevoer vanaf ongeveer 15-weke-ouderdom (25—40 kg). Die graan- en hooi-inname, gemiddelde daaglikse toename (GDT) en voeromsettingsdoeltreffendheid (VOD, kg voer/kg massatoename) van die lammers is oor 'n gelyke massa-interval bepaal. Geen betekenisvolle verskille tussen behandelings of geslagte in terme van graaninname, hooi-inname, of totale droëmateriaal-inname is waargeneem nie, alhoewel lammers wat slegs lupiene (± 30%) as proteïenbron ontvang het, ongeveer 14% minder graan/lam/d as die algehele gemiddelde graaninname (1 147 g/lam/d) van die groep gehandhaaf het. Geen betekenisvolle verskille ($P > 0.05$) in GDT, dae in die voerkraal of VOD is tussen behandelings waargeneem nie, terwyl ramlammers, op 'n konstante massabasis, beter in terme van GDT ($P \leqslant 0.01$), dae in die voerkraal ($P \leqslant 0.01$) en VOD ($P \leqslant 0.05$), as ooilammers presteer het. Die gebrek aan verskille in prestasie tussen die verskillende proteïenbronne word toegeskryf aan die nie-degradeerbare proteïenbehoefte van die lammers, swaarder as 25 kg, wat grootliks deur die graanmengsel alleen bevredig is. Wanneer lammers van hierdie massa afgerond word, sal die proteïeninhoud van die graankomponent en die prys en beskikbaarheid van die verskillende proteïenbronne die aanwending daarvan in heelgraandiëte bepaal.

Keywords: Enriched grain, finishing, lambs, oats, protein source, triticale.

* To whom correspondence should be addressed.

Using enriched, whole-grain mixtures to finish growing lambs appears to be an advantageous practice, and is already used by many farmers in the winter-rainfall region of South Africa. Several advantages are associated with grain-enriched mixtures. The normal cost of processing is greatly reduced without reducting performance (Ørskov *et al.*, 1974a). Feeding whole grain to sheep is not only superior to feeding processed grain (Ørskov *et al.*, 1974b) which is considered to be unnecessary and undesirable (Ørskov, 1976), but also eliminates rumenitis (Ørskov, 1973). Urea is normally included in enrichment mixtures, because the nitrogen content of cereal grain is generally not sufficient to meet the nutrient requirements of ruminal microbes (Ørskov *et al.*, 1972). Microbial protein (MP) synthesized on protein-free diets containing urea is, however, insufficient to satisfy the protein requirements for maximum growth, as high production animals need rumen undegradable protein (UDP; ARC, 1980). The amino acid composition of the UDP is also important, since it may compliment the MP to meet the amino acid requirement of the animal (Mercer *et al.*, 1980; Ørskov *et al.*, 1971), and it was shown that certain protein sources improved microbial efficiency (Cottrill *et al.*, 1982). Microbial species may be influenced not only by the physical nature, chemical composition and quantity of the diet, but in different circumstances, microbial growth may be limited by ammonia, amino acids, peptides, carbohydrates, branched chain fatty acids or minerals. Microbial species also differ in their efficiency to convert fermentable substrate into MP (Bryant, 1973, as cited by Ferguson, 1975). Protein sources are scarce and expensive (Protein Advisory Committee, 1990), necessitating their efficient use, particularly in ruminants where it is used less efficiently than in monogastrics. This study was conducted to compare different local protein sources in a triticale/oat grain enrichment mixture for fattening lambs.

A mixture of triticale and oats (2:1) was used as grain source. Six diets were composed (Table 1) to be approximately equal in energy and protein content. Extra constituents were added as recommended by Ørskov & Grubb (1979). An ionophore and antibiotic were included as feed additives for promoting growth and for coccidiostatic activity (Sambeth *et al.*, 1984) and to prevent abscess formation in the liver, kidneys and rumen walls (Brand & Cloete, 1990). Urea, urea plus fish-meal, urea plus cottonseed olicake, urea plus bitter lupins (*Lupinus angustifolius*), bitter lupins and a commercial mixture were used as protein sources. The diets were prepared as reported by Ørskov *et al.* (1974c) and Ørskov & Grubb (1977). Calcium chloride was dissolved in warm water (40—50°C) at about 1:3 *w/v*. Sodium chloride and urea were then dissolved in the same liquid and poured onto the grain while it was being thoroughly mixed. Thereafter, vitamins and minerals were suspended in water (1:3 *w/v*) and added. Sodium sulphate was added separately, after which the insoluble constituents, namely limestone ($CaCO_3$), ionophore (Salocin[R]) and tylocin (Tylan 100[R]), were bound to the mixture by molasses powder. The protein sources, where applicable, were added subsequently and thoroughly mixed with the grain. The volume of water added amounted to about 3 *l*/100 kg. No storage problems occurred.

The growth trial was carried out with 48 South African Mutton Merino (SAMM) lambs, approximately 15 weeks of age and with a mean, initial live mass (± *SD*) of 24.6 ± 0.1 kg. Prior to the trial, the lambs were drenched with a broad-spectrum anthelmintic, vaccinated against *Clostridium ovitoxicum* and adapted for three weeks to the respective diets. Each sheep was individually housed in indoor pens equipped with feed and water trays. The lambs were randomly allotted to the six experimental diets, with four ram and four ewe lambs per diet. The six experimental diets were fed *ad libitum* to the lambs while oaten hay (milled through a 12-mm screen) was supplied separately at *ca.* 10% of *ad libitum* intake. The trial ended when the lambs were slaughtered at a mean live mass (± *SD*) of 40 ± 0.2 kg at approximately 25 weeks of age. Feed intake and live mass were measured weekly. Dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) were calculated for each lamb, and differences between treatment means were tested for significance by a multifactor analysis of variance (with diet, sex and the interaction between this as factors), accommodating uneven subclass sizes (because one lamb died from a lung disease and another two died of thiamine deficiency) (NCSS, 1987). The dry matter (DM), organic matter (OM), crude protein (CP), calcium (Ca) and phosphorus (P) content of the individual ingredients as well as the experimental diets were determined according to procedures described by the AOAC (1984). *In vitro* organic matter digestibility (Engels & Van der Merwe, 1967), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (Van Soest, 1963; Van Soest & Wine, 1967) of the corresponding samples were also determined.

The chemical composition of the individual ingredients is presented in Table 2. The CP content of triticale grain was extremely low (9.2%) in comparison to literature values (Van der Merwe, 1980, 15.5%; Ensminger & Olentine, 1978, 16.5%), although similar CP values for the five locally

Table 1 The composition of the experimental diets on an air-dry basis

	Experimental diets					
Ingredient (%)	1	2	3	4	5	6
Triticale/oat grain (2:1)	89.4	94.8	92.2	90.7	84.9	65.9
Commercial concentrate	10.6	–	–	–	–	–
Urea	–	1.5	1.0	1.0	1.0	–
Fish-meal	–	–	3.1	–	–	–
Cottonseed oilcake	–	–	–	4.6	–	–
Lupins (*L. angustifolius*)	–	–	–	–	10.4	30.4
Feed lime	–	1.5	1.5	1.5	1.5	1.5
Calcium chloride	–	1.2	1.2	1.2	1.2	1.2
Molasses powder	–	0.4	0.4	0.4	0.4	0.4
Sodium sulphate	–	0.3	0.3	0.3	0.3	0.3
Salt	–	0.3	0.3	0.3	0.3	0.3
Mineral/vitamin premix *	–	+	+	+	+	+
Salocin[R] **	–	+	+	+	+	+
Tylan 100[R] ***	–	+	+	+	+	+

* 457.82 5 g/t (200 g MgO; 150 g $ZnSO_4.7H_2O$, 80 g $MnSO_4.4H_2O$, 5.3 g $CoSO_4.7H_2O$, 1.0 g KIO_3, 1.5 g retinol palmitate, 20 g D-L tocopherol acetate, 0.025 g cholecalciferol).

** 320 g/t.

*** 100 g/t.

Table 2 The chemical composition and *in vitro* organic matter digestibility of the feed ingredients used in the experimental diets (DM basis)

	Chemical composition (%)							
Ingredient	DM	OM	CP	ADF	NDF	Ca	P	IVOMD (%)
Triticale	88.9	98.3	9.19	3.89	21.08	0.07	0.39	90.1
Oats	91.6	97.2	11.55	18.46	18.46	0.12	0.42	55.6
Fish-meal	90.95	87.31	69.55	2.84	20.10	3.36	2.16	75.8
Cottonseed oilcake	91.2	92.6	37.98	24.80	34.69	0.56	1.32	64.0
Lupins	91.8	96.7	25.72	27.70	38.91	0.35	0.40	84.4
Commercial mixture*	94.5	50.5	58.71	0.61	2.20	11.52	1.57	83.4
Urea	–	–	287.0	–	–	–	–	–
Molasses powder	92.2	77.0	4.06	–	–	8.83	0.15	97.7
Oaten hay	91.7	94.9	7.05	36.96	63.70	0.32	0.24	58.3

* Maximum of 86.2% of CP content provided by NPN.

available cultivars were found by Brand (1991; unpublished results – variation between 9.5% for Usgen 10 and 8.6% for Usgen 14 with a mean value of 9.2 ± 0.4%). The CP contents of the protein sources were within normal ranges, except for cottonseed oilcake (38.0%) and bitter lupins (25.7%) which had lower than normal values (Van der Merwe, 1980, 46.7% and 31.1% respectively).

The chemical composition and *in vitro* organic matter digestibility (OMD) of the enriched grain mixtures are presented in Table 3. The *in vitro* OMD of the diets varied between 79.0% and 83.4% with corresponding CP contents which varied between 13.8% and 17.0%. The ADF and NDF contents of the diets were found to have a mean value of 8.7% and 28.9%. The calcium: phosphorus ratios of the different diets varied between 3.2:1 (Diet 2) and 2.1:1 (Diet 5). Although the diets differed in CP content due to the unexpected low CP content of the triticale grain, these differences were neutralized to some extent by the actual oaten hay intakes. The CP content based on actual intake of concentrate and hay was 14.2%, 13.7%, 14.4%, 13.8%, 16.2% and 15.4% for Diets 1 to 6 respectively. The percentage oaten hay intakes of the lambs of the experimental diets as percentage of the total intakes were found to be respectively 7.4% (Diet 1), 8.2% (Diet 2), 6.4% (Diet 3), 6.6% (Diet 4), 8.3% (Diet 5) and 10.1% (Diet 6).

The average DMI, ADG, FCR and days in the feedlot of lambs consuming the respective diets and the dressing percentages of the lambs are presented in Tables 4 and 5. In the absence of significant interactions between sex and diet, means are given for the main effects only. No significant differences (P > 0.05) were observed between diets or sexes in terms of grain intake, hay intake or total DMI. It was, however, evident from the data that the lambs on Diet 6, with 30.4% bitter lupins in their diet, consumed less grain/lamb/d in absolute terms, than the mean grain intake of all the lambs (1 147 g/lamb/d). This lower intake was most probably related to the palatability of the lupins, because most of the

Table 3 The chemical composition and *in vitro* organic matter digestibility of the enriched grain mixtures (DM basis)

	Diet					
	1	2	3	4	5	6
Item (%)	Commercial	Urea	Fish-meal	Cottonseed oilcake	10% Lupin	30% Lupin
Dry matter	88.1	87.8	88.0	88.4	87.6	88.0
Organic matter	93.0	93.9	94.3	94.1	94.8	94.3
In vitro organic matter digestibility	81.0	82.4	80.2	83.8	81.6	79.0
Crude protein	14.70	14.24	14.87	13.81	17.03	16.33
Non-degradable protein*	–	2.20	3.69	2.86	2.29	2.47
Acid detergent fibre	8.25	6.82	6.98	7.47	9.74	12.99
Neutral detergent fibre	27.85	29.44	30.61	30.96	27.30	26.94
Calcium	1.33	1.26	1.08	1.07	0.82	0.99
Phosphate	0.50	0.39	0.43	0.36	0.39	0.39

* Calculated from Preston (1988) and Brand *et al.* (1992).

Table 4 Means ± *SE* for dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR), days in the feedlot and dressing percentage of lambs (growth interval from *ca.* 25 kg to *ca.* 40 kg) fed grain-enriched mixtures with different protein sources

	Diet					
	1	2	3	4	5	6
Parameter measured	Commercial *n* = 8	Urea *n* = 7	Fish-meal *n* = 7	Cottonseed oilcake *n* = 8	10% Lupin *n* = 7	30% Lupin *n* = 8
Grain intake (g/d)	1236 ± 76	1080 ± 82	1180 ± 82	1244 ± 76	1159 ± 82	982 ± 76
Hay intake (g/d)	99 ± 7	95 ± 8	85 ± 8	88 ± 7	104 ± 8	106 ± 7
Total DMI (g/d)	1335 ± 82	1175 ± 89	1265 ± 89	1333 ± 82	1263 ± 89	1088 ± 82
ADG (g/d)	236 ± 15	200 ± 16	225 ± 16	219 ± 15	214 ± 16	194 ± 15
FCR (kg DMI/kg gain)	5.64 ± 0.41	5.98 ± 0.44	5.81 ± 0.41	6.20 ± 0.44	6.04 ± 0.44	5.80 ± 0.41
Days in feedlot	72 ± 4	79 ± 4	68 ± 4	71 ± 4	73 ± 4	80 ± 4
Dressing percentage*	46.3 ± 1.3	45.2 ± 1.3	45.1 ± 1.3	46.4 ± 1.3	43.4 ± 1.3	46.4 ± 1.3

* Only measured on ram lambs (*n* = 4).

No significant differences between treatments were observed.

Table 5 Means ± *SE* for dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR) and days in the feedlot for ram and ewe lambs (growth interval *ca.* 25 kg to *ca.* 40 kg), fed grain enriched mixtures with different protein sources

	Sex		
Parameter measure	Rams $n = 24$	Ewes $n = 21$*	Level of significance
Grain intake (g/d)	1180 ± 42	1114 ± 48	$P = 0.32$
Hay intake (g/d)	100 ± 4	92 ± 5	$P = 0.26$
Total DMI (g/d)	1280 ± 45	1206 ± 51	$P = 0.30$
ADG (g/d)	239 ± 8	190 ± 9	$P = 0.0005$
FCR (kg DMI/kg gain)	5.44 ± 0.23	6.39 ± 0.26	$P = 0.01$
Days in feedlot	66 ± 2	81 ± 2	$P = 0.0001$

* One ewe lamb died from a lung disease (Diet 2) and another two ewe lambs died from thiamine deficiency (Diets 3 and 5).

rejected feed consisted of lupins. This phenomenon is probably related to the alkaloid content of lupins, which is known to suppress intake (Ruiz *et al.*, 1977). No noticeable effect on grain intake was observed at the low level of lupin inclusion (Diet 5). Days in the feedlot, ADG and FCR were unaffected by diet, while the differences between rams and ewes were significant. Ram lambs grew faster than ewe lambs ($P \leqslant 0.01$), resulting in a shorter ($P \leqslant 0.01$) time in the feedlot. Ram lambs also used their feed more efficiently for live weight-gain ($P \leqslant 0.05$) than ewe lambs. The tendency towards lower ADG values found in the lambs receiving only lupins as protein source (194 g/lamb/d) was related to the fact that most of the rejected feed consisted of lupins. These lambs therefore consumed a poorer diet in terms of CP and energy content. Little differences were observed in the ADG values of lambs consuming the diets which contained the different protein sources plus urea, while lambs which consumed the diet with urea as sole protein source, also performed a little worse (200 g/lamb/d) than the mean ADG (218 g/lamb/d) of all the other treatments. No differences between diets were observed in terms of FCR. Lambs which consumed cottonseed oilcake as protein source had the poorest feed conversion ratio (in absolute terms), which was in agreement with a feeding trial conducted by Meyer *et al.* (1990). They also found the poorest feed conversion on cottonseed oilcake when a range of protein sources were tested in a growth trial with lambs. No significant differences occurred in the dressing percentage of ram lambs on the respective diets.

The lack of response of the lambs to the different protein sources accorded with results of several other researchers. Meyer *et al.* (1990) also found no significant differences in performance of lambs (25—40 kg) which received iso-nutrient diets with either fish-meal, cottonseed oilcake, cottonseed, sunflower oilcake, sunflower seed, soybean seed, lupins or urea as nitrogen source in grain sorghum based diets. Andrews & Ørskov (1970) showed that lambs over 30 kg live mass did not respond to additional protein added to barley-based diets, while Ørskov & Grubb (1977) showed that early weaned lambs, between 23 and 30 kg in live mass, showed no difference in live mass-gain when fed grain sprayed with a urea solution or a fish-meal supplement. These findings could be related to the UDP requirements of the fattening lamb. The triticale/oat grain mixture (2.32% UDP as percentage of the DM as calculated from the values presented by Preston, 1988) supplied 26.6 g UDP/lamb/d (calculated from the mean grain intake of 1 147 g/lamb/d). When compared to the estimated UDP requirements (McDonald *et al.*, 1988) for 35 kg lambs growing at 150 g/d (16 g/d), no UDP deficincies were suspected. No significant effect of the different true protein sources was reflected in the production parameters of the lambs.

Overall, grain enrichment mixtures were practical for the preparation of grain-based diets for the fattening of lambs, resulting in reduced processing costs. Considering that two lambs died from thiamine deficiency (in Diets 3 and 5 respectively), it may be necessary to include thiamine in the mineral/vitamin premix (5 mg thiamine hydrochloride/kg feed, E.W. Seed, personal communication, Roche Products (Pty) Ltd., 4 Brewery Street, Isando 1600).

The inclusion of additional true protein and/or rumen undegradable protein to that supplied by the triticale/oat mixture therefore had little effect on the growth performance and feed conversion of these lambs at a growth rate of *ca.* 200 g/d for the growth interval above 25 kg. The inclusion of the different protein sources in such fattening diets will be determined by price, availability and the crude protein content of the grain used. Precautions have to be taken when including bitter lupins, because high levels may result in inadequate voluntary intake levels.

Acknowledgements

The authors thank Miss Dalene Young for assistance with the practical execution of the trial. Mr S.W.P. Cloete is thanked for editing the manuscript.

References

ANDREWS, R.P. & ØRSKOV, E.R., 1970. The nutrition of the early weaned lamb. 1. The influence of protein concentration and feeding level on rate of gain in body weight. *J. Agric. Sci., Camb.* 75, 11.

AOAC, 1984. Official methods of analysis (13th edn.). Association of Official Analytical Chemists, Washington DC.

ARC, 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, London.

BRAND, A.A. & CLOETE, S.W.P., 1990. Benutting van verrykte gars en 'n koring/garsmengsel as afrondingsrantsoene vir vroegspeenlammers. *S.-Afr. Tydskr. Veek.* 20, 93.

BRAND, T.S., FRANCK, F., BRAND, A.A. & DURAND, A., 1992. An evaluation of fababean (*Vicia faba*) and lupin (*Lupinus albus*) stubble and seed for sheep. *S. Afr. J. Anim. Sci.* 22, 170.

COTTRILL, B.R., BEEVER, D.E., AUSTIN, A.R. & OSBOURN, D.F., 1982. The effect of protein- and non-protein-nitrogen supplements to maize silage on total amino acid supply to young cattle. *Br. J. Nutr.* 48, 527.

ENGELS, E.A.N. & VAN DER MERWE, F.J., 1967. Application of an *in vitro* technique to South African forages with special reference to the effect of certain factors on results. *S. Afr. J. Agric. Sci.* 10, 983.

ENSMINGER, M.E. & OLENTINE, C.G., 1978. Feeds and nutrition complete. The Ensminger Publishing Company, California, USA.

FERGUSON, K.A., 1975. The protection of dietary proteins and amino acids against microbial fermentation in the rumen. In: Digestion and metabolism in the rumen. Eds. McDonald, I.W. & Warner, A.C.I., Proc. IV Int. Symp. Ruminant Physiology. Sydney, Australia, August 1974. University of New England.

McDONALD, P., EDWARDS, R.A. & GREENHALGH, J.F.D., 1988. Animal nutrition. Longman, New York.

MERCER, J.R., ALLEN, S.A. & MILLER, E.L., 1980. Rumen bacterial protein synthesis and the proportion of dietary protein escaping degradation in the rumen of sheep. *Br. J. Nutr.* 43, 421.

MEYER, J.H.F., SWART, D., OSLER, I. & BOLT, M., 1990. Kombinasie van graansorghum en proteïenbronne vir volledige voerkraaldiëte vir intensiewe slaglamproduksie. *Handl. 29ste Kongres S.-Afr. Ver. Diereprod.* 27—29 Maart 1990, Stellenbosch.

NCSS, 1987. Number Cruncher Statistical System. J.L. Hintze, Kaysville, Utah 84037, USA.

ØRSKOV, E.R., 1973. The effect of not processing barley on rumenitis in sheep. *Res. Vet. Sci.* 14, 110.

ØRSKOV, E.R., 1976. The effect of processing on digestion and utilization of cereals by ruminants. *Proc. Nutr. Soc.* 35, 245.

ØRSKOV, E.R., FRASER, C. & McDONALD, I., 1971. Digestion of concentrates in sheep. 2. The effect of urea or fishmeal supplementation of barley diets on the apparent digestion of protein, fat, starch and ash in the rumen, the small intestine and the large intestine, and calculation of volatile fatty acid production. *Br. J. Nutr.* 25, 243.

ØRSKOV, E.R., FRASER, C. & McDONALD, I., 1972. Digestion of concentrates in sheep. 4. The effect of urea on digestion, nitrogen retention and growth in young lambs. *Brit. J. Nutr.* 27, 491.

ØRSKOV, E.R., FRASER, C. & GORDON, J.G., 1974a. The effect of processing of cereals on rumen fermentation, digestibility, rumination time and firmness of subcutaneous fat in lambs. *Brit. J. Nutr.* 32, 59.

ØRSKOV, E.R., FRASER, C. & McHATTIE, I., 1974b. Cereal processing and food utilization by sheep. 2. A note on the effect of feeding unprocessed barley, maize, oats and wheat on food utilization by early weaned lambs. *Anim. Prod.* 18, 85.

ØRSKOV, E.R. & GRUBB, D.A., 1977. The use of whole barley diets fortified with solutions of urea, minerals and vitamins for lambs. *Anim. Feed Sci. Technol.* 2, 307.

ØRSKOV, E.R. & GRUBB, D.A., 1979. The minimal nitrogen metabolism of lambs. *Proc. Nutr. Soc.* 38, 24A (Abstr).

ØRSKOV, E.R., SMART, R.I. & MEHREZ, A.Z., 1974c. A method of including urea in whole grains. *J. Agric. Sci., Camb.* 83, 299.

PRESTON, R.L., 1988. Typical composition of feeds for cattle and sheep, 1988—89. *Feedstuffs* 60, 17.

PROTEIN ADVISORY COMMITTEE, 1990. Memorandum on protein supply and demand for animal production. Compiled by Dr J.G. Cloete, Animal and Dairy Science Research Institute, Private Bag X1, Irene 1675, RSA.

RUIZ, L.P., WHITE, S.F. & HOVE, E.L., 1977. The alkaloid content of sweet lupin seed used in feeding trials with pigs and rats. *Anim. Feed Sci. Technol.* 2, 59.

SAMBETH, W., BAHRECKE, G. & SCHLOLAUT, W., 1984. Salinomycin-Na, a new feed additive with growth promoting and coccidiostatic activity for fattening lambs. International symposium on sheep production on big farms. Debrecen, 14—16 August 1984.

VAN DER MERWE, F.J., 1980. Dierevoeding. Kosmo-uitgewery Edms. Bpk., Stellenbosch.

VAN SOEST, P.J., 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method of determination of fibre and lignin. *J.A.O.A.C.* 46, 82.

VAN SOEST, P.J. & WINE, R.H., 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell wall constituents. *J.A.O.A.C.* 50, 50.