

Untreated, urea-enriched and thermal-ammoniated oat grain as supplementary feed for pregnant and lactating South African Mutton Merino ewes grazing wheat stubble¹

T.S. Brand,² A.A. Brand,³ and S.W.P. Cloete

Elsenburg Agricultural Development Institute, Private Bag, Elsenburg, 7607 Republic of South Africa

A. Durand

Langgewens Experimental Farm, Private Bag X2, Moorreesburg, 7310 Republic of South Africa

Received 28 January 1991; revised 9 July 1991; accepted 4 November 1991

Plain (OAT), 1,4% urea-enriched (EOAT) and 3% thermal-ammoniated (NH₃OAT) oat grain were fed to South African Mutton Merino ewes as supplementary feed during late pregnancy and lactation, while grazing wheat stubble at 2 ewes/ha during 1986 and 1987. Blood glucose, urea, calcium, magnesium and zinc levels of the ewes were monitored in 1986 only. Ewes received supplementary feed at 750 g/ewe/d for 16 weeks in 1986, and 550 g/ewe/d for 10 weeks and 750 g/ewe/d for the subsequent 6 weeks in 1987. The crude protein (CP) content of the oats was increased from 9,8% to 12,5% (EOAT) and 15,8% (NH₃OAT) in the first year and from 8,7% to 11,7% (EOAT) and 13,0% (NH₃OAT) in the second year. Ewes which received EOAT and NH₃OAT grain as supplement, tended in both years to maintain higher mean live masses ($P \leq 0.1$) during lactation than ewes which received OAT grain. This improvement was probably due to the higher CP and energy content of the treated grain. Providing ewes with NH₃OAT grain as a supplement, significantly ($P \leq 0.05$) improved 100-day lamb weaning mass and average daily gain (ADG) from birth to weaning by ca 19%, in comparison to the OAT and EOAT treatments in 1986. In 1987, weaning mass and preweaning growth of lambs in the NH₃OAT treatment group were improved by ca 14% in comparison to the EOAT treatment. Lambs from ewes consuming the NH₃OAT supplement were 7,3% heavier ($P \leq 0.05$) at weaning than their contemporaries in the OAT group, but ADG figures for these two treatments did not differ ($P \geq 0.05$). The tendency towards better performance of sheep in the NH₃OAT group could be related to differences in blood glucose levels between groups, which suggests that an improved energy metabolism may be involved. The concentrations of plasma calcium, magnesium and zinc of ewes were unaffected by treatment and within ranges specified in the literature. It was concluded from the study that thermal ammoniation of oat grain led to improved utilization thereof, although the economical application of the procedure has to be elucidated. Satisfactory results in ewe live mass and lamb growth rate were also achieved with plain and urea-enriched oat grain.

Suiwer (OAT), 1,4% ureumverrykte (EOAT) en 3,0% termies-geammonifiseerde (NH₃OAT) hawer is vir twee jaar (1986 en 1987) aan Suid-Afrikaanse Vleismerino-ooie, wat koringstoppel teen 2 ooie/ha gedurende laatdragtigheid en laktasie bewei het, as supplementêre voeding voorsien. Vlakke van bloedglukose, -ureum, -kalsium, -magnesium en -sink in die ooie is slegs in 1986 bepaal. Supplementêre voeding is teen 750 g/ooi/d vir 16 weke in die eerste jaar en teen 550 g/ooi/d (10 weke) en 750 g/ooi/d (6 weke) gedurende die tweede jaar voorsien. Die TRP-inhoud van die hawer is verhoog vanaf 9,8% tot 12,5% (EOAT) en 15,8% (NH₃OAT), en vanaf 8,7% tot 11,7% (EOAT) en 13,0% (NH₃OAT) vir die onderskeie jare. Ooie wat EOAT en NH₃OAT ontvang het, het in albei jare geneig om hoër massas ($P \leq 0.1$) godurende laktasie te handhaaf as die ooie wat suiwer hawer ontvang het. Die verbetering kan moontlik aan die hoër ruproteïen (TRP)- en energie-inhoud van die behandelde graan toegeskryf word. Supplementering met NH₃OAT het 100-dae-speenmassa sowel as gemiddelde daaglikse toename (GDT) in 1986 betekenisvol ($P \leq 0.05$) met ongeveer 19%, in vergelyking met OAT en EOAT, verbeter. Speenmassa en voorspeense groei van lammers in die NH₃OAT-behandeling was in 1987 ongeveer 14% beter as dié van lammers in die EOAT-behandeling. Lammers van ooie in die NH₃OAT-behandeling was 7,3% swaarder ($P \leq 0.05$) met speen as lammers in die OAT-groep, maar GDT tussen die behandelings was nie betekenisvol verskillend nie ($P \geq 0.05$). Die neiging vir beter produksie van skape in die NH₃OAT-groep het verband gehou met die verskil in plasma-glukosevlakke tussen behandelings, wat op 'n moontlike verbeterde energiemetabolisme by dié groep dui. Die konsentrasies van plasmakalsium, magnesium en sink van ooie is nie deur behandeling beïnvloed nie, en was binne die normale grense. Alhoewel termiese ammonifisering die benutting van hawer verbeter het, behoort die ekonomiese aanwending van die tegniek ondersoek te word. Bevredigende resultate in terme van ooi- en lamproduksie is ook met suiwer- en ureumverrykte hawer verkry.

Keywords: Blood metabolites, blood minerals, ewes, lamb growth rate, oat grain, stubble grazing, supplementation, thermal ammoniation.

¹ Part of a Ph.D (Agric.) thesis submitted by TSB to the Department of Sheep and Wool Science, University of Stellenbosch. Promotor Dr J. Coetzee.

² Author to whom correspondence should be addressed.

³ Present address: P.O. Box 101, Laaiplek, 7370 Republic of South Africa.

Introduction

The Swartland area of the Winter Rainfall Region of South Africa is mainly a wheat producing area and cereal monoculture is practiced to a large extent. Sheep production (with an autumn or winter lambing season) normally plays a secondary role in these systems. Pregnant and lactating ewes are mainly dependent on crop residues and stubble grazing during the dry summer and early autumn months, before the first winter rain. Feed supply is normally inadequate for these important physiological stages (Brand *et al.*, 1992a) and rapid live mass losses occur frequently during lactation (Brand *et al.*, 1992b; Cloete & Brand, 1990), which may cause problems such as inadequate milk supply in ewes as well as poor preweaning growth in lambs. This necessitates the provision of supplementary feeding to ewes grazing wheat stubble to provide additional energy and protein (Aitchinson, 1988; Brand *et al.*, 1992a). Previous results suggested that reduced live mass occurred during lactation in ewes consuming urea-enriched, small grain supplements compared to an unsupplemented control group (Cloete & Brand, 1990). Lambs suckled by ewes fed urea-enriched oat or triticale grain also maintained better preweaning growth rates than their contemporaries suckled by control ewes. Weston & Hogan (1986) confirmed that the intake of high-fibre sources is inadequate to provide sufficient nutrients for ewes in late pregnancy and lactation.

Oat grain is an important cereal crop incorporated in the monoculture system, because it is the only cereal grain which reduces the incidence of 'take-all of wheat' (*Gaeumannomyces graminus* var. *tritici*), an important wheat disease (Bester, 1990). It is therefore available on most farms as potential supplementary feed. Oat grain, however, has the lowest energy value of the cereal grains (M.A.F.F., 1976) and a comparatively high crude fibre (CF) content, while protein, varying from 6% to 17%, has a poor quality (Todorov, 1988). Thermal ammoniation of oat grain, however, improved the crude protein (CP) content, digestibility of dry matter (DM), organic matter (OM), neutral detergent fibre (NDF) and CP, as well as N retention (Brand *et al.*, 1985). Enrichment of oat grain with urea and minerals also may have an advantage over plain oat grain (Butler *et al.*, 1987). Enriched oat grain also gave satisfactory results when fed as supplement for pregnant and lactating ewes in a previous study (Cloete & Brand, 1990).

The aim of this experiment was, therefore, to compare untreated oat grain (OAT), urea-enriched (EOAT) and thermal-ammoniated oat grain (NH₃OAT) as supplementary grain sources for ewes in terms of their ability to support live mass as well as their effect on lamb growth rate. Blood metabolites were monitored during part of the study in an attempt to relate biological findings to these parameters. Plasma urea concentrations were monitored, because a close relationship exists between protein intake and plasma urea (Sykes & Field, 1973) and protein intake could possibly be quantified by blood urea concentration (Preston *et al.*, 1965). Plasma glucose was measured as an index of the energy status of ewes. Russel (1977) suggested that a quantitative relation exists between the energy status of the animal and the concentration of glucose in the plasma, while Payne *et al.* (1970) as well as Blowey *et al.* (1973) used plasma glucose levels in metabolic profile tests as the principal index of adequacy of dietary energy. Parr *et al.* (1986) and Brand *et al.* (1992c) accordingly found that plasma glucose concentration changed in accordance with level of nutrition in pregnant and lactating ewes.

The concentrations of the minerals, calcium (Ca), magnesium (Mg) and zinc (Zn), in the plasma of the ewes were also monitored. O'Donovan (1983) stated that wheat straw *per se* is low in minerals and vitamins, suggesting that similar deficiencies occur in wheat stubble. Cereal grain is also known to have a low Ca content (Todorov, 1988). Kritzinger (1985) found that ammoniation possibly asserted a negative influence on the utilization of Mg, Zn and Mn in a mineral balance study with sheep fed ammoniated wheat straw and oats.

Experimental Procedure

This experiment was conducted on the experimental farm, Langgewens, in the Swartland area of the Winter Rainfall Region during 1986 and 1987. In 1986, 70 South African Mutton Merino ewes (mated from 15 November 1985 for 6 weeks) were grazed as a single flock at 2 ewes/ha on wheat stubble. A single batch of oat grain was treated as follows:

1. Oat grain (no treatment applied) (OAT).
2. Alkali-ionophore-enriched oat grain (EOAT) (Brand & Cloete, 1990), see Table 1.
3. Oat grain thermally ammoniated in a commercial An-Straverter^R oven (NH₃OAT) at a level of 30 g NH₃/kg DM for 24 h at 90°C (Brand *et al.*, 1985).

Table 1 Physical composition of urea-enriched oat grain

Ingredient	Amount on an as-fed basis
Oat grain	92.5%
Molasses	3.1%
Urea	1.4%
Ca(OH) ₂	2.0%
Na ₂ SO ₄	1.0%
Mineral premix added ^a	1100 g/t
Salinomycin added	320 g/t

^a Containing 1 000 g MgSO₄·7H₂O, 100 g ZnSO₄·7H₂O, 35 g MnSO₄·4H₂O, 45 mg CoCl₂·6H₂O and 1 mg KIO₃.

The dry matter (DM) and crude protein (CP) contents (AOAC, 1984), cell wall constituents [neutral detergent fibre (NDF)] (Van Soest & Wine, 1967) and *in vitro* digestible organic matter (IVDOM) (Engels & Van der Merwe, 1967) of the different processed grains were determined.

Supplementation started in March (6 weeks prior to lambing) when ewes were stratified according to age and live mass and randomly allocated to three experimental groups. Ewes received supplementation at 750 g/ewe/d of plain oat grain, urea-enriched oat grain or thermal-ammoniated oat grain up to the end of June (10 weeks after lambing). Ewes were weighed weekly while information regarding sex, birth type, birth mass and weaning mass (adjusted to 100 days) of the lambs were recorded.

Mid-monthly blood samples (20 ml) were taken from 10 pregnant/lactating ewes per treatment (initially chosen at random) from March to June. The samples were centrifuged for 20 min at *ca* 1 500 g, and the plasma was stored at -4°C.

Plasma glucose (Mercotest Kit Cat. No. 14335) was analysed by spectrophotometry after plasma proteins were precipitated with 0.33 mol/l perchloric acid. Plasma urea concentration (Mercotest Kit Cat. No. 3334 and 14315) was also determined by spectrophotometry, while the concentrations of Ca, Mg and Zn were analysed by atomic absorption spectrophotometry (Van Niekerk & Van Niekerk, 1989).

Continuous data on the lambs and ewes were analysed by least squares procedures (Harvey, 1977) to correct for uneven sub-classes. The fixed model for the analysis on 58 lambs alive on the ewes at weaning, included the effects of treatment, birth type (single or multiple), sex (male or female) and all the applicable two-factor interactions. The interactions between the other main effects and treatments were not significant for the growth data of the lambs and are therefore not discussed. The fixed model for the analysis on the live masses of the ewes included the effects of treatment, number of lambs born (single or multiple) and the two-factor interaction. Only data from 53 ewes that lambed (a poor conception rate was achieved) were retained in the analysis of live masses while blood parameters were derived from the data of 10 ewes per treatment.

The experiment was repeated in 1987 and only production data for 90 ewes and 95 lambs, belonging to the same flock and which were subjected to the treatments described above, were recorded. The experiment differed in 1987 in that supplementation started at the beginning of February (10 weeks prior to lambing) at 550 g/ewe/d, because of a rapid decline in live mass at this stage. Two weeks after the commencement of lambing, supplementation was increased to 750 g/ewe/d and continued up to the end of May (6 weeks after lambing) when sufficient green pasture was available. This difference between 1986 and 1987 in supplementary time after lambing was due to differences in rainfall patterns which, to a large extent, influenced the available pasture. (Precipitation for April and May 1986 amounted to 18.4 and 42.8 mm with respective amounts of 37.8 and 81.9 mm for 1987.)

Results and Discussion

The chemical composition of oat grain, EOAT grain and NH₃OAT grain is presented in Table 2. The CP content of oat grain increased by 27% through enrichment and by 61%

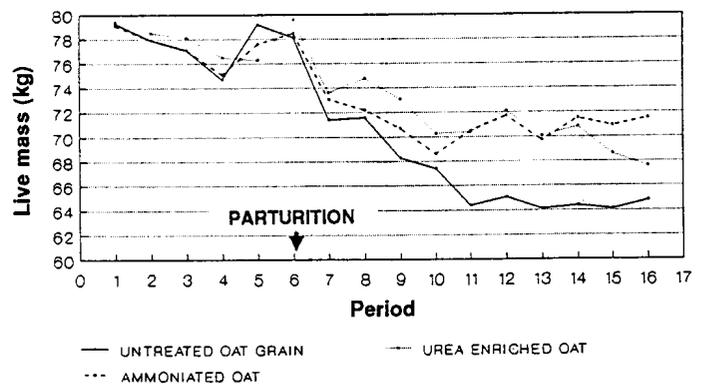
Table 2 Chemical composition of the experimental supplements (DM basis)

Component (%)	Supplement		
	OAT ^a	EOAT ^b	NH ₃ OAT ^c
1986			
Crude protein	9.8	12.5	15.8
Cell wall constituents	39.2	39.0	34.8
<i>In vitro</i> DOM	60.4	62.3	64.5
1987			
Crude protein	8.7	11.7	13.0
Cell wall constituents	40.4	40.6	36.6
<i>In vitro</i> DOM	59.8	62.7	63.8

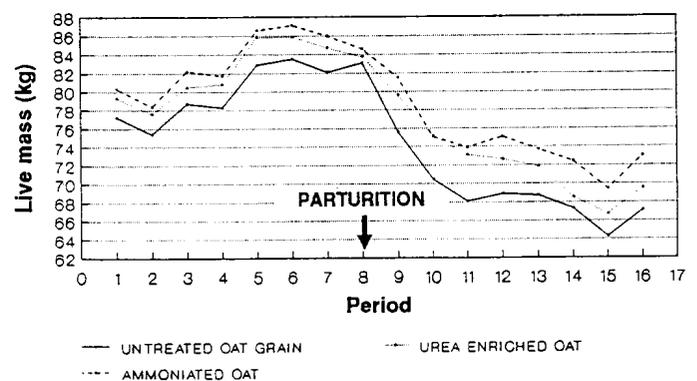
^a Untreated oat grain.
^b Urea-enriched oat grain.
^c Thermal-ammoniated oat grain.

through thermal ammoniation in 1986. The corresponding values for 1987 were 34.5% and 49.4%. In both years, cell wall constituents were slightly lower and IVDOM was slightly higher for the NH₃OAT grain than for the other two treatments. The improvements in CP content and organic matter digestibility and reduction in cell wall constituents were in accordance with findings of Brand *et al.* (1985).

The mean live masses of the ewes for 1986 are presented in Figure 1(a). No significant differences were found between treatments. A trend was, however, observed ($P = 0.07$) for ewes supplemented with EOAT and NH₃OAT to support higher mean live masses at weeks 12 and 14 (weeks 6 and 8 of lactation). The mean live masses of ewes for 1987 are presented in Figure 1(b). The same trends in live masses were observed for 1986 and 1987. Ewes on the NH₃OAT treatment supported significantly ($P \leq 0.05$) higher mean live masses during week 9 to week 16 (the last 7 weeks of lactation) than ewes consuming plain oat supplementation. Similarly, ewes receiving EOAT were heavier ($P \leq 0.05$) than control ewes during weeks 6, 10 and 11. Looking at the results of both years, there appears to be evidence for urea-enrichment as well as ammoniation of oat grain to reduce live mass losses of ewes during lactation. Hodge *et al.* (1980) also reported a response in ewe live mass during lactation due to the enrichment of oat grain with urea. Although not strictly comparable, Butler & McDonald (1986) as well as Butler *et al.* (1987) confirmed that urea-treated oat grain fed to weaners grazing



(a) Ewes supplemented with 750 g/ewe/d for 16 weeks.



(b) Ewes supplemented with 550 g/ewe/d (weeks 1—9) and 750 g/ewe/d (weeks 10—16).

Figure 1 Mean live mass responses of SAMM ewes grazing wheat stubble at 2 ewes/ha and supplemented with untreated oat grain, urea-enriched oat grain and thermal-ammoniated oat grain during late pregnancy and lactation.

stubble increased growth rate by 30% or more. McDonald & Dunlop (1984) found no differences in the performance of Merino ewes when fed either urea-treated or ammoniated oat grain, provided on an equal CP basis. Performance did, however, improve with increasing amounts of non-protein nitrogen (NPN). The tendency towards higher ewe live masses found in our study might also be attributed to the higher CP and IVDOM contents of the enriched and ammoniated oat grain supplement, although the CP consisted mainly of NPN. The ionophore, included in the urea enrichment formula, might also have played a role in the case of the EOAT group (Sambeth *et al.*, 1984).

The lamb growth data for 1986 and 1987 are presented in Table 3. No significant differences between treatments were found in lamb birth mass in either year. In 1986, the feeding of ammoniated oat grain to ewes significantly ($P \leq 0.05$) improved lamb weaning mass (at 100 days) as well as average daily gain (ADG) from birth to weaning by *ca* 19%, in comparison to the untreated oat grain and enriched oat grain.

Table 3 Mean birth and weaning masses of lambs from ewes receiving plain (OAT), urea-enriched (EOAT) and thermal-ammoniated (NH₃OAT) oat grain while grazing wheat stubble

Particulars	Supplement			SD ¹
	OAT	EOAT	NH ₃ OAT	
1986				
Number of lambs	23	18	17	
Birth mass (kg)	4.5	4.6	4.8	0.89
Weaning mass (kg)	29.6 ^a	29.3 ^a	34.6 ^b	5.12
ADG to weaning (g/d)	249 ^a	248 ^a	298 ^b	50.4
1987				
Number of lambs	36	29	30	
Birth mass (kg)	4.9	4.7	5.2	0.86
Weaning mass (kg)*	31.4 ^a	29.7 ^a	33.7 ^b	3.73
ADG to weaning (g/d)	266 ^{ab}	250 ^a	286 ^b	40.0

^{a-c} Means in the same row with different superscripts differ significantly ($P \leq 0.05$).

¹ Standard deviation for analysis.

* At approximately 100 days.

Compared to the latter treatment, ammoniation of the oat grain supplement led to similar improvements of *ca* 14% in 1987. The average weaning mass of lambs from ewes receiving ammoniated oat grain, was 7.3% higher ($P \leq 0.05$) than control lambs (OAT group), but ADG figures for these two treatments did not differ. No advantages due to enrichment of oat grain were found in either of the years. The lower response due to ammoniation in 1987 compared to 1986, may possibly be ascribed to the lower supplementation rate as well as the lower CP content of the treated grain. The higher growth rate of lambs from ewes receiving the thermal-ammoniated oat grain, was possibly due to the higher CP and IVDOM contents of the grain, which might have improved the milk production of the ewes. Hodge *et al.* (1980) similarly demonstrated an increase in lamb growth rate when oat grain was supplemented with urea or other protein sources. The lack of response in lamb growth rate of the EOAT treatment is, however, difficult

to explain because an increase in lamb growth rate is expected in response to the higher CP contents. This is especially true when taking into account that only one half of the added N in ammonia-treated feeds is utilized by the micro-organisms (Males, 1987), owing to insoluble nitrogenous compounds formed through reaction of ammonia with carbohydrates (Mason *et al.*, 1989). Therefore, the EOAT and NH₃OAT supplements practically supplied equal amounts of available NPN. A possible explanation may lie in the influence of salinomycin on milk production. Mackie & Kistner (1985) stated that ionophores may affect milk production in ruminants by increasing propionate production at the expense of acetate and butyrate. This contention is supported by the fact that the tendency towards reduced live mass losses that occurred during lactation in ewes consuming enriched oat grain supplement was not reflected in better lamb growth.

The plasma glucose and urea concentrations of ewes on the different treatments are presented in Figures 2 & 3. Treatments interacted ($P \leq 0.01$) with month of sampling as far as blood glucose was concerned (Figure 2). Ewes consuming ammoniated oat grain tended to have higher ($P \leq 0.01$) blood glucose levels (69.4 ± 2.7 mg/100 ml) than those given untreated (56.3 ± 2.6 mg/100 ml) or enriched oat grain (61.5 ± 2.3 mg/100 ml) during the first three sampling periods. This tendency was reversed at the last sampling. This lower

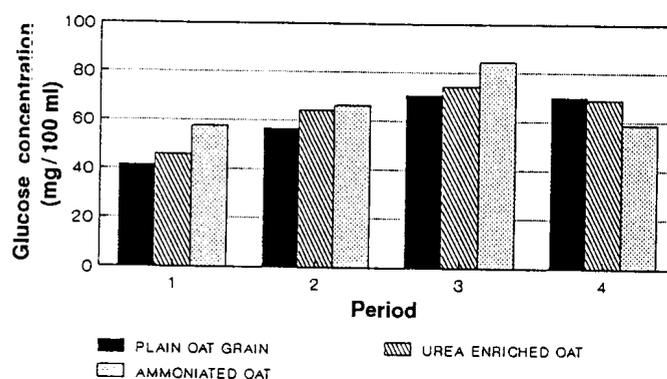


Figure 2 Glucose concentrations in the blood of sheep grazing wheat stubble during late pregnancy and lactation and supplemented with untreated, urea-enriched, and thermal-ammoniated oat grain at 750 g/ewe/d.

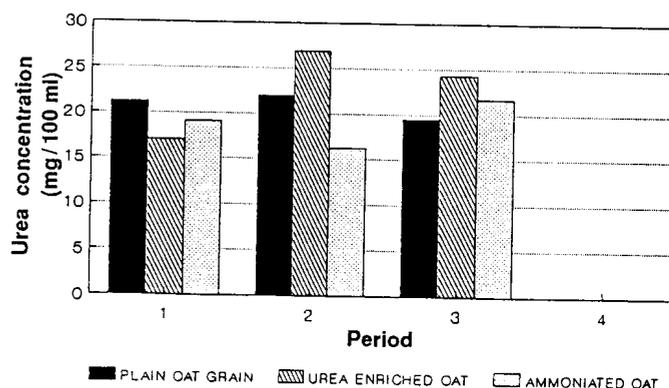


Figure 3 Plasma urea concentrations of sheep grazing wheat stubble during late pregnancy and lactation and supplemented with untreated, urea-enriched, and thermal-ammoniated oat grain at 750 g/ewe/d.

glucose level could possibly be attributed to higher milk production of these ewes (Reid & Hinks, 1962) as reflected by the higher growth rate of their lambs. The higher glucose levels found with the NH₃OAT group was probably related to the higher energy content of the grain (Parr *et al.*, 1986). The glucose levels found in this study were, however, in agreement with normal values reported by Bowden (1971), although somewhat lower during late pregnancy for the OAT (41.5 ± 1.3 mg/100 ml) and EOAT (46.0 ± 1.9 mg/100 ml) groups in comparison to values quoted by Bowden for ewes in late pregnancy (59 mg/100 ml). Overall, it seemed that blood glucose yielded satisfactory results as an index of nutritional status of the ewes in this study. Although blood glucose concentrations are subjected to homeostatic control and were described by Lindsay (1977) as one of the poorest indicators of nutritional status, Reid & Hinks (1962) found that the maintenance of homeostasis in undernourished pregnant and lactating ewes is impeded, due to the high requirement of glucose for the foetus and for lactose synthesis.

No significant differences ($P \leq 0.05$) in plasma urea concentrations were found between treatments (Figure 3). Plasma urea levels, however, were significantly ($P \leq 0.05$) lower (18.9 ± 0.8 mg/100 ml) during late pregnancy in comparison to the first (22.4 ± 1.3 mg/100 ml) and second (21.8 ± 1.1 mg/100 ml) months of lactation. The higher plasma urea concentrations during lactation may be related to the supply of nutrients selected from the stubble land, due to the precipitation recorded in April and May. The plasma urea levels found in this study between treatments were, however, unexpected, since they seem to be unrelated to the protein content of the supplements. The higher milk production of the NH₃OAT group (as reflected by the higher growth rate of their lambs) may have influenced plasma urea concentrations, as these animals may have had lower concentrations during peak lactation (NRC, 1985), thereby confounding the results. The urea concentrations in the plasma found in this study were, however, in accordance with values found by Sykes (1978) (14.0—19.0 mg/100 ml).

Plasma minerals were unaffected by treatment or sampling period. The overall mean concentration of plasma Ca (14.3 ± 0.2 mg/100 ml) was higher than the value of 9—10 mg Ca/100 ml regarded as normal by Underwood (1981). The overall mean concentrations of plasma Mg (2.3 ± 0.02 mg/100 ml) and Zn (1.09 ± 0.02 p.p.m.) were within the normal range of values for sheep compiled by Church (1979) (1.8—3 mg Mg/100 ml and 0.8—1.2 p.p.m. Zn). Therefore it seemed that no measurable mineral deficiency occurred on the stubble with the supplements provided.

Conclusions

It can be concluded from this study that thermal ammoniation of oat grain improved the utilization thereof, as was reflected by reduced live mass losses in ewes and the improved performance of their lambs. Enhanced plasma glucose levels in this group seemed to imply that the improved performance may have been related to an increased energy metabolism. The economical application of this procedure must, however, be elucidated. Satisfactory results in ewe live mass and lamb growth rates were also achieved with plain and urea-enriched oat grain. The lack of response in lamb growth rate to supplementation with urea-enriched oat grain is, however, unexpected against the background of the better performance of the ewes when compared to ewes supplemented with plain oat

grain. The effect of the ionophore on milk production seems to be the most logical explanation for this discrepancy (Mackie & Kistner, 1985). On the other hand, taking into account the results of Brand *et al.* (1992b) who concluded that NPN supplementation *per se* would be of little use to sheep grazing wheat stubble, the addition of easy fermentable energy to the enriched grain mixture might have resulted in entirely different findings. It is, however, difficult to make definite conclusions owing to the relative small difference in IVDOM contents of the EOAT and NH₃OAT supplements. Satisfactory results with glucose as indicator of nutritional status of the ewe were found in the study. Blood metabolites may thus assist in the assessment of the adequacy of nutrition on an objective basis, and standards for local conditions are urgently needed.

Acknowledgements

The authors thank Messrs G. Buchholtz and N.P. Dippenaar and their staff for help with the practical execution of the experiment.

References

- AITCHINSON, E., 1988. Cereal straw and stubble as sheep feed. *J. Agric. W. Aust.* 29, 96.
- AOAC, 1984. Official methods of analysis (11th edn.). Association of Official Analytical Chemists, Washington, DC.
- BESTER, F.J., 1990. Beheer van vrotpootjie en oogvlek van koring in Wes-Kaapland. M.Sc. thesis, University of Stellenbosch, Republic of South Africa.
- BLOWEY, R.W., WOOD, D.W. & DAVIS, J.R., 1973. A nutritional monitoring system for dairy herds based on blood glucose, urea and albumin levels. *Vet. Res.* 92, 69.
- BOWDEN, D.M., 1971. Non-esterified fatty acids and ketone bodies in blood as indicators of nutritional status in ruminants. Review. *Can. J. Anim. Sci.* 51, 1.
- BRAND, A.A. & CLOETE, S.W.P., 1990. Benutting van verrykte gars en gars plus koring as afrondingsrantsoene vir vroegspeenlamers. *S.-Afr. Tydskr. Veek.* 20, 93.
- BRAND, A.A., CLOETE, S.W.P. & KRITZINGER, N.M., 1985. The effect of anhydrous ammoniation on the nutritive value of whole oat grain. *S. Afr. J. Anim. Sci.* 15, 43.
- BRAND, T.S., FRANCK, F., DURAND, A. & COETZEE, J., 1992a. The nutritional status of South African Mutton Merino ewes grazing wheat stubble during different physiological stages. 1. Chemical composition of the grazing and intake of the ewes. Submitted to *S. Afr. J. Anim. Sci.*
- BRAND, T.S., FRANCK, F., DURAND, A. & COETZEE, J., 1992b. The nutritional status of South African Mutton Merino ewes grazing wheat stubble during different physiological stages. 3. Production data and wool characteristics. Submitted to *S. Afr. J. Anim. Sci.*
- BRAND, T.S., FRANCK, F., SCHOLTZ, A.J. & COETZEE, J., 1992c. Nutritional status of South African Mutton Merino ewes grazing wheat stubble during different physiological stages. 2. Blood metabolites and rumen parameters. Submitted to *S. Afr. J. Anim. Sci.*
- BUTLER, L.G., KING, W.R. & McDONALD, C.L., 1987. Growth of young Merino sheep grazing cereal stubbles and supplemented *ad libitum* with oats, of different crude protein contents, sprayed with various amounts of urea. *Aust. J. Exp. Agric.* 27, 339.
- BUTLER, L.G. & McDONALD, C.L., 1986. Growth responses of young Merino wethers to *ad libitum* feeding of oat grain mixed with either lupin seed or urea solution. *Aust. J. Exp. Agric.* 26, 643.
- CHURCH, D.C., 1979. Digestive physiology and nutrition of ruminants. Vol. 2. Ed. Church, D.C., O & B Books Inc., USA.
- CLOETE, S.W.P. & BRAND, A.A., 1990. Response of SA Mutton Merino ewes and their lambs to supplementation with enriched oat, barley or titalace grain on wheat stubble grazing. *S. Afr. J. Anim. Sci.* 20, 96.

- ENGELS, E.A.N. & VAN DER MERWE, F.J., 1967. Application of *in vitro* technique to South African forages, with special reference to the effect of certain factors on the results. *S. Afr. J. Agric. Res.* 10, 983.
- HARVEY, W.R., 1977. User's guide to LSML76 - Mixed model least squares and maximum likelihood computer program. Ohio State University, Columbus, USA.
- HODGE, R.W., BOGDANOVIC, B., KAT, C. & SWEATMAN, D., 1980. The response of Merino ewes fed oats supplemented with urea, fish-meal or lucerne chaff. *Proc. Aust. Soc. Anim. Prod.* 13, 273.
- KRITZINGER, N.M., 1985. The effect of ammoniation on mineral absorption and excretion. Poster S.A.S.A.P. Congress, Stellenbosch, 1985.
- LINDSAY, D.B., 1977. The effect of feeding pattern and sampling procedure on blood parameters. Blood profiles in animal production. Occasional Publications No. 1. *Brit. Soc. Anim. Prod.* 13, 99.
- MACKIE, R.I. & KISTNER, A., 1985. Some frontiers of research in basic ruminant nutrition. *S. Afr. J. Anim. Sci.* 15, 72.
- M.A.F.F., 1976. Energy allowances and feeding systems for ruminants. H.M.S.O., London.
- MALES, J.R., 1987. Optimizing utilization of cereal crop residues for beef cattle. *J. Anim. Sci.* 65, 1124.
- MASON, V.C., KEENE, A.S., COOK, J.E., COOPER, E.M. & HARTLEY, R.D., 1989. Oven and stack ammoniation of grass hays. 1. Changes in chemical composition in relation to digestibility *in vitro* and cell wall degradability. *Anim. Fd Sci. Tech.* 24, 299.
- MCDONALD, G.L. & DUNLOP, A.C., 1984. A new technique for adding non-protein nitrogen to oat grain. *Proc. Aust. Soc. Anim. Prod.* 15, 456.
- NRC, 1985. Ruminant nitrogen usage. National Academy Press, Washington, DC
- O'DONOVAN, O.B., 1983. Untreated straw as livestock feed. *Nutr. Abstr. Rev.* 53, 441.
- PARR, R.A., MILES, M.A. & LANGDON, P.J., 1986. The glucose test and nitrogen of ewes in late pregnancy. *Proc. Aust. Soc. Anim. Prod.* 16, 299.
- PAYNE, J.M., DEW, S.M., MANSTON, R. & FAULKS, M., 1970. The use of metabolic profile test in dairy herds. *Vet. Rec.* 87, 150.
- PRESTON, R.L., SCHNAKENBERG, D.D. & PFANDER, W.H., 1965. Protein utilization in ruminants. 1. Blood urea nitrogen as affected by protein intake. *J. Nutr.* 86, 281.
- REID, R.L. & HINKS, N.T., 1962. Studies on the carbohydrate metabolism of sheep. XVIII. The metabolism of glucose, free fatty acids, ketones, and amino acids in late pregnancy and lactation. *Aust. J. Agric. Res.* 13, 1112.
- RUSSEL, A.J.F., 1977. The use of measurements of energy status in pregnant ewes. Blood profiles in animal production. Occasional publications. No 1. *Brit. Soc. Anim. Prod.* 13, 31.
- 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.
- SYKES, A.R., 1978. An assessment of the value of plasma urea nitrogen and albumin concentrations as monitors of protein status of sheep. Blood profiles in animal production. Occasional publications. No. 1. *Brit. Soc. Anim. Prod.* 13, 143.
- SYKES, A.R. & FIELD, A.C., 1973. Effects of dietary deficiencies of energy, protein and calcium on the pregnant ewe. IV. Serum total protein, albumin, globulin, transferrin and plasma urea levels. *J. Agric. Sci., Camb.* 80, 29.
- TODOROV, N.A., 1988. Feeds and feedstuffs in Europe. 2.3. Cereals, pulses and oilseeds. *Livest. Prod. Sci.* 19, 47.
- UNDERWOOD, E.J., 1981. The mineral nutrition of livestock. Commonwealth Agricultural Bureaux, Slough, England.
- VAN NIEKERK, F.E. & VAN NIEKERK C.H., 1989. Effect of high levels of dietary molybdenum and sulphate on S.A. Mutton Morino sheep. 1. Mineral status and haematological parameters. *S. Afr. J. Anim. Sci.* 19, 107.
- VAN SOEST, P.J. & WINE, R.H., 1967. Use of detergents in the analyses of fibrous foods. IV. Determination of plant cell wall constituents. *J. Assoc. Off. Agric. Chem.* 50, 50.
- WESTON, R.H. & HOGAN, J.P., 1986. Nutrition of herbage fed ruminants. In: The pastoral industries of Australia. Eds. Alexander, G. & Williams, O.B. Sydney University Press, Sydney, Australia.