Substitution of lucerne hay by ammoniated wheat straw in growth diets for lambs

A.A. Brand,† S.W.P. Cloete* and F. Franck
Elsenburg Agricultural Centre, Private Bag, Elsenburg 7607, Republic of South Africa

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Lucerne hay (LH) was substituted by urea-ammoniated wheat straw (AWS) in four lamb-growth diets, all containing 60% roughage. The ratio of LH to AWS was 60 : 0, 40 : 20, 20 : 40 and 0 : 60 in the respective diets, which were composed on an iso-nitrogenous basis. However, cell wall constituents (CWC) increased with increased AWS levels. Results from an 84-day growth study indicated that the voluntary dry-matter intake (DMI) of the lambs declined by 164 g/d per 20% increase in AWS inclusion ($P \leq 0{,}01$). Growth rate (ADG) similarly declined by 64,5 g/d with higher inclusion levels of AWS ($P \leq 0{,}01$). Feed conversion ratio (FCR) was also adversely affected, with an increase of 1,14 kg DMI required per 20% increase in AWS inclusion to give an increase of 1 kg in live mass ($P \leq 0{,}01$). The apparent digestibility of dry matter (DM) and organic matter (OM), as well as the nitrogen balance, tended to decline with increased AWS levels, but no significant differences were recorded. The lower energy intake on the diets including increased levels of AWS was reflected by the decreased deposition of fat by the end of the growth study ($P \leq 0{,}01$), as measured by tritium water space. The economic advantage of the substitution of a high quality roughage like LH with a cheaper source (AWS) must be balanced against the reduction in DMI and ADG, and the adverse effect of increased AWS levels on FCR. Inherent limitations of AWS, like a high CWC and resultant bulkiness, must be recognized and considered in the formulation of diets including AWS as a roughage source.

Lusernhooi (LH) is verplaas met ureum-geammoniseerde koringstrooi (AKS) in lamgroeidiëte wat 60% ruvoer bevat. Die verhouding van LH tot AKS in die onderskeie diëte was 60 : 0, 40 : 20, 20 : 40 en 0 : 60. Die diëte is op 'n iso-stikstofbasis saamgestel, maar die selwandinhoud het met toenemende AKS-insluitingspeile toegeneem. Resultate van 'n 84-dae-groeiproef dui op 'n verlaging van 164 g/d in die vrywillige droëmateriaalinname (DMI) per 20% toename in AKS-insluitingspeil ($P \leq 0{,}01$). Groeitempo (GDT) het ooreenstemmend verswak met 64,5 g/d met toenemende AKS-insluitingspeile ($P \leq 0{,}01$). Voeromsettingsverhouding (VOV) is ook nadelig beïnvloed, met 'n toename van 1,14 kg DMI benodig per 20% toename in AKS-insluitingspeil vir 'n toename van 1 kg in lewende massa ($P \leq 0{,}01$). Die skynbare verteerbaarheid van droëmateriaal en organiese materiaal, sowel as stikstofbalans, het geneig om af te neem met toenemende AKS-insluitingspeile, maar geen betekenisvolle verskille is waargeneem nie. Die laer energie-inname op diëte hoog in AKS is weerspieël in laer liggaamsvetpeile aan die einde van die groeiproef ($P \leq 0{,}01$), soos bepaal met tritiumwaterspasie. Die ekonomiese voordeel van die verplasing van 'n hoë kwaliteit ruvoer, soos LH, met 'n goedkoper bron (AKS), moet opgeweeg word teen die laer DMI en GDT, sowel as die nadelige effek van toenemende AKS-insluitingspeile op VOV. Inherente beperkings van AKS, soos 'n hoë selwandinhoud en gepaardgaande lywigheid, moet erken en in ag geneem word by die formulering van groeidiëte wat AKS as 'n ruvoerbron bevat.

Keywords: Apparent digestibility, body composition, lamb growth, lucerne hay, urea-ammoniated wheat straw, voluntary intake.

† Present address: P.O. Box 101, Laaiplek 7370, Republic of South Africa.
* To whom correspondence should be addressed.

Introduction

The utilization of low-quality roughages in ruminant diets receives considerable attention. The reason for the interest in these roughages lies in the fact that the value of the feed may be enhanced considerably by chemical treatment. Whereas treatment of wheat straw with sodium or calcium hydroxide only improves voluntary intake and digestibility (Barber, Alderman, Adamson, Mansbridge & Williams, 1984), ammoniation may also serve to supplement the nitrogen content of the feed (Sundstøl, Coxworth & Mowat, 1978; Solaiman, Horn & Owens, 1979).

Disappointing results were obtained from investigations where ammoniated straw was included as roughage in the diets of reproducing ewes (Orr, Treacher & Mason, 1985). Local results also suggested that diets containing 50—60% urea-ammoniated wheat straw, resulted in a low voluntary intake by ewes in late pregnancy and lactation. As a result, inadequate mass gains in late pregnancy, loss of live mass and condition in lactation, and suboptimal lamb growth were recorded in these animals (Brand, Cloete & Vosloo, 1988). Because of a shortage, as well as the high cost of high-quality roughages like lucerne hay, it was decided to investigate the possibility of incorporating ammoniated wheat straw as a roughage component in production diets for sheep. The present experiment was thus designed to investigate the substitution of lucerne hay by ammoniated wheat straw in growth diets for lambs. A roughage level of 60% was chosen for this investigation, as no definite advantage of ammoniation over urea supplementation of maize residues could be demonstrated at lower roughage levels (Seed, Hofmeyr & Morgan, 1985).

Procedure

Experimental diets

Wheat straw (200 bales; average mass ± 8 kg each) was treated with 75 g urea and 400 g water/kg straw for a period of 8 weeks, as described by Cloete & Kritzinger

(1984). After treatment, the bales were spread on a cement floor to dry, before being hammermilled together with the other diet components through a 18-mm screen, and thoroughly mixed in a horizontal mixer. The control diet consisted of 40% concentrates and 60% lucerne hay (LH). The lucerne hay was substituted in a stepwise fashion by urea-ammoniated wheat straw (AWS), resulting in the four diets containing 0, 20, 40 and 60% AWS (Table 1). Minerals were added to the diets in accordance with NRC (1985) standards, in such a fashion as to render the diets comparable.

Experimental animals

Thirty-two SA Mutton Merino wethers were used in the investigation, which included a growth study and a balance trial. The wethers were stratified into eight blocks on live mass, and randomly allocated to the experimental diets within blocks. The mean live mass of the wethers at the beginning of the trial was 27,3 ± 4,3 kg. A week before the growth study commenced, all the animals were innoculated against enterotoxaemia and treated with a broad-spectrum anthelminthic. After an adaptation period of 14 days on the respective diets, all the lambs were injected subcutaneously with a solution containing vitamins A, D and E, before the growth study commenced.

Growth study

The growth study was conducted over a period of 84 days. The wethers were kept in individual pens and fed twice daily, at 08h00 and 16h00. Dry matter intake was determined daily and the live mass of the wethers was recorded every 14 days.

Body composition

The tritium water space technique, as described by Coetzee (1977), was used to determine the body composition of the lambs after the adaptation period and at the end of the growth study. The radioactivity of body water was measured on a pure water aliquot, derived from vacuum distillation of a blood sample, as described by Boshoff (1973). The following equation (Boshoff, 1973; Coetzee, 1977) was used for the determination of total body water:

$$\text{Tritium water space (kg)} = \frac{(c-d)\cdot 50\cdot e}{(b-a)\,1\,000} = \frac{(c-d)\cdot e}{(b-a)\cdot 20}$$

where a = counting rate of background blood sample in impulses per minute (i.p.m.); b = counting rate of active blood in i.p.m.; c = counting rate of a 0,02 dilution of the tritiated water in i.p.m.; d = counting rate of the sintillator fluid in i.p.m. (correction); and e = volume of tritiated water injected.

The regression equations of Searle (1970) were used to calculate total body water, fat, protein and ash from the tritium water space.

In vivo digestibility and nitrogen balance

The diets were used for an *in vivo* digestibility and nitrogen (N) balance trial following the growth study, using four wethers on each diet. The total dry matter (DM) intake and faeces and urine excretion were measured over a 10-day collection period, during which time the wethers were fed at a level of 15% under voluntary intake. Representative feed, faeces and urine samples were taken daily and pooled for the determination of DM, organic matter (OM), and crude protein (CP) contents (AOAC, 1970), as well as for the cell wall constituents (CWC), acid detergent fibre (ADF) and hemicellulose (Van Soest, 1963; Van Soest & Wine 1967). Apparent digestibility coefficients were subsequently calculated for DM, OM, CP, CWC, ADF and hemicellulose, while the N-balance results were also obtained.

Statistical analysis

The allometric-autoregressive model for the description of growth as described by Roux (1974; 1976) and applied by Kemm, Siebrits & Ras (1982), was used to determine daily dry matter intake (DMI), average daily gain (ADG)

Table 1 Physical composition of the experimental diets on an 'as fed' basis

	Diet			
	60LH:0AWS	40LH:20AWS	20LH:40AWS	0LH:60AWS
Lucerne hay (%)	60	40	20	0
Ammoniated wheat straw (%)	–	20	40	60
Wheat (%)	38,5	37,9	37,1	36,4
Feed lime (%)	–	0,6	1,4	2,1
Salt (%)	1	1	1	1
Ammoniumchloride (%)	0,5	0,5	0,5	0,5
Sodium sulphate (g/t)	–	–	1510	2809
Magnesium sulphate (g/t)	–	–	–	965
Zinc sulphate (g/t)	–	–	14,3	31,3
Cobalt sulphate (g/t)	–	–	–	19,3
Salinomycin (g/t)	320	320	320	320

and feed conversion ratio (FCR) via the relationship between ln (cumulative ME intake) and ln (live mass), for the interval 20—55 kg. An initial value for *mu* was estimated from results published by Meissner (1977).

The digestibility and N-balance results were analysed according to a randomized block design with four replications. One wether on the diet containing 60% AWS sustained a net mass loss over the experimental period, and no DMI, ADG and FCR results could thus be computed for this individual. Body composition data for only seven lambs on each of the diets containing 40 and 60% AWS were included, since negative fat values were calculated from the regression equation for these individuals. The growth and body composition studies were thus analysed according to a completely randomized design. The degrees of freedom for diets were partitioned into orthogonal polynomials, depicting linear, quadratic and cubic trends in the analyses on growth parameters and body composition. Differences between means were tested by the Sidak method (Van Ark, 1981).

Results and Discussion

Chemical composition

The chemical composition of the experimental diets is given in Table 2. The CP content of the LH did not differ from that of the AWS, thus allowing the diets to be composed on an iso-nitrogenous basis. The CP content of AWS varied between 7,6 and 11,8% (Males & Gaskins, 1982; Eng, 1984) depending on the ammoniation level. The relatively high CP content of the AWS in this case, may possibly be related to unchanged urea.

The CWC and hemicellulose contents of the diets increased as the level of AWS increased, whereas only a small increase was observed in ADF content. These trends may be related to the large difference in CWC between LH and wheat straw (21 percentage units), while a comparatively small difference (10 percentage units) existed in ADF (Preston, 1986).

Growth study

Average DMI, ADG and FCR of the lambs on different diets, as obtained from the allometric-autoregression model, are presented in Table 3. DMI of the lambs on the diets containing 40 and 60% AWS were respectively 16,8 and 31,3% lower ($P \leq 0{,}01$) than the diet containing LH as roughage. By partitioning the degrees of freedom into orthogonal polynomials, it was evident that the DMI decreased linearly by 164 g for a 20% increase in AWS inclusion, with the linear trend accounting for 97,5% of the variance associated with diets (Table 3). The ADG of the lambs was correspondingly decreased ($P \leq 0{,}01$) by 35% as a result of the inclusion of 40% AWS in the diet. A further significant ($P \leq 0{,}01$) decrease was observed in the diet containing only AWS as roughage. The linear trend associated with increased AWS levels amounted to a decrease of 64,4 g/d per 20% AWS, accounting for 98,9% of the variance introduced by diets. The inclusion of 40% AWS adversely affected FCR by 32,5% ($P \leq 0{,}05$). A further increase in FCR of 30,2% ($P \leq 0{,}05$) was observed when LH was entirely replaced by AWS. A linear trend, involving 1,14 kg DMI/kg mass gain per 20% increase in AWS inclusion, accounted for 93,4% of the variance in FCR associated with diets.

Results corresponding to those obtained for the diet including AWS as roughage, were reported by Al-Rabbat & Heany (1978) who found that lamb growth averaged 110 g/d with a FCR of 15:1 on a growth diet containing

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

Component (%)	Diet			
	60LH:0AWS	40LH:20AWS	20LH:40AWS	0LH:60AWS
Moisture	8,6	8,6	8,4	7,3
Crude protein	16,2	16,4	16,8	16,4
Cell wall constituents	37,2	38,0	45,1	55,5
Acid detergent fibre	26,0	25,1	28,5	28,6
Hemicellulose	11,3	12,9	16,5	26,9

Table 3 Average voluntary dry matter intake (DMI), average daily gain (ADG), and feed conversion ratio (FCR) of the lambs

Parameter	Diet				Regression
	60LH:0AWS	40LH:20AWS	20LH:40AWS	0LH:60AWS	b ± *SE*
DMI (g/d)	1597^{3}	$1481^{2,3}$	1329^{2}	1098^{1}	–164 ± 22
ADG (g/d)	331^{3}	$266^{2,3}$	216^{2}	132^{1}	–64,5 ± 6,35
FCR (kg DMI required/ kg mass gain)	$4{,}87^{c}$	$5{,}59^{b,c}$	$6{,}46^{b}$	$8{,}41^{a}$	1,14 ± 0,17

$^{a—c}$ Denote significance in rows ($P \leq 0{,}05$).
$^{1—3}$ Denote significance in rows ($P \leq 0{,}01$).

64% AWS. Seed *et al.* (1985) similarly obtained an ADG figure of 153 g/d, with a FCR of 5,5 kg DMI required per kg gain, on a diet containing 60% ammoniated maize residue and 40% concentrate.

The marked effect of the inclusion of AWS on the DMI and ADG of the lambs in the growth study may be related to the bulkiness and/or palatability of AWS in comparison to LH. Levy, Holzer, Drori & Folman (1983) suggested that the depression of voluntary intake on diets containing wheat straw can be related to rumen fill. Mbatya, Kay, Smart & Milne (1983) found that the replacement of wheat straw with dried grass in growth diets resulted in increases in DMI. The bulkiness of AWS (as reflected by higher CWC levels in the diets including increasing AWS levels) may play an important role in the results obtained in the present study, for acceptable voluntary intake and growth results were obtained on a diet containing 38,6% AWS that was balanced to contain 16% crude fibre (S.W.P. Cloete & A.A. Brand; unpublished results). In diets containing this level of roughage, however, there appears to be uncertainty as to whether ammoniated roughage has an advantage over untreated urea-supplemented roughage, at least in regard to maize residue (Seed *et al.*, 1985).

Body composition

Body composition of the lambs was determined after the adaptation period and at the end of the growth study, and the results are given in Table 4. At the end of the 14-day adaptation period, a decreasing tendency with increased AWS levels was already discernable in the average fasting mass of the lambs, although no significant differences were observed. By the end of the growth study, the bodies of the lambs consuming the diet including 60% AWS, contained more ($P \leqslant 0{,}01$) water than those lambs consuming the diets including 60 and 40% LH. The partitioning of the degrees of freedom for diets into orthogonal polynomials, suggested a 2,47% increase in body water for a 20% increase in AWS inclusion. This tendency accounted for 88,7% of the variance associated with diets. Body fat was markedly reduced ($P \leqslant 0{,}01$) by 51,3% as LH was entirely replaced by AWS as roughage. The linear trend that was found, suggested that a reduction of 3,4% in body fat occurred for every 20% increase in AWS, and accounted for 88,3% of the variance introduced by diets. The average fasting masses of the lambs at the end of the growth study followed the same trend as the ADG results.

In vivo digestibility

The inclusion of AWS at levels up to 40% did not affect apparent DM or OM digestibility, but the diet containing 60% AWS tended ($P \leqslant 0{,}10$) to have a lower apparent digestibility (Table 5). The decreasing trend in apparent digestibility may possibly have been related to a lower energy content of AWS compared to LH. The apparent digestibility of CP was unaffected by AWS inclusion. The apparent digestibility of CWC was increased ($P \leqslant 0{,}05$) by 14,9 percentage units by the total replacement of LH by AWS (Table 5). The apparent digestibility of hemicellulose was correspondingly increased ($P \leqslant 0{,}05$) by up to 25 percentage units. Apparent ADF digestibility was not markedly affected by AWS inclusion.

Nitrogen balance

The replacement of 40% LH with AWS resulted in a decrease ($P \leqslant 0{,}05$) of 6 g/d in N intake (Table 6), which decreased further by 7 g/d ($P \leqslant 0{,}05$) when the remaining 20% LH was also replaced. Urinary N excretion of the lambs on the respective diets varied between 24,8 and 18,5 g/d, with a tendency to decrease with increasing AWS levels. Faecal N excretion also tended to decrease

Table 4 Body composition of the lambs after the adaptation period (initial values) and at the end of the growth study (final values), measured according to the tritium water space technique

Component	Diet				Regression
	60LH:0AWS	40LH:20AWS	20LH:40AWS	0LH:60AWS	b ± *SE*
Initial values					
Body water (%)	65,8	66,2	67,6	69,1	1,13 ± 0,97
Fat (%)	15,3	13,3	13,5	13,3	−0,62 ± 0,76
Crude protein (%)	15,0	15,3	15,3	15,4	0,13 ± 0,12
Ash (%)	3,2	3,6	3,6	3,7	0,15 ± 0,08
Fasting mass (kg)	33,6	31,7	30,1	28,4	−1,71 ± 0,73
Final values					
Body water (%)	62,8[1]	62,1[1]	66,4[1,2]	69,6[2]	2,47 ± 0,65
Fat (%)	18,8[2]	19,1[2]	14,1[1,2]	9,3[1]	−3,36 ± 0,63
Crude protein (%)	14,8[a,b]	14,4[a]	15,2[b]	15,6[b]	0,30 ± 0,11
Ash (%)	3,7	3,6	3,6	3,7	0,03 ± 0,03
Fasting mass (kg)	52,6[3]	48,0[3]	42,1[2]	35,3[1]	−5,80 ± 0,76

[a—c] Denote significance in rows ($P \leqslant 0{,}05$).
[1—3] Denote significance in rows ($P \leqslant 0{,}01$).

Table 5 Apparent digestibility of the lambs on the experimental diets

Digestibility coefficient (%)	Diet			
	60LH : 0AWS	40LH : 20AWS	20LH : 40AWS	0LH : 60AWS
Dry matter	70,2	70,0	69,4	66,9
Organic matter	71,8	71,3	70,6	68,2
Crude protein	77,5	77,1	76,9	78,9
Cell wall constituents	46,2[a]	47,4[a]	55,2[a,b]	61,3[b]
Acid detergent fibre	43,8	45,9	50,6	47,9
Hemicellulose	50,7[a]	50,4[a]	63,9[b]	76,1[c]

[a—c] Denote significance in rows ($P \leqslant 0,05$).

Table 6 Nitrogen balance of the lambs on the experimental diets

Component	Diet			
	60LH : 0AWS	40LH : 20AWS	20LH : 40AWS	0LH : 60AWS
N intake (g/d)	43,5[c]	40,9[b,c]	37,5[b]	30,5[a]
N excretion (g/d):				
Urine N	24,8	24,2	21,4	18,5
Faecal N	9,8[b]	9,4[b]	8,6[a,b]	6,4[a]
N balance (g/d)	8,9	7,3	7,6	5,6

[a—c] Denote significance in rows ($P \leqslant 0,05$).

with increased AWS inclusion, the differences between the diets containing 0 and 20% AWS and the diet containing 60% AWS being significant ($P \leqslant 0,05$). No significant differences were found in the N balance of the lambs on the respective diets, but it tended to decline with increased AWS inclusion. According to the ARC (1980), ram lambs require 6,4 to 8,8 g N/lamb/d for daily gains of 200—300 g. The absolute values in Table 4 indicate that the lambs on the diet containing 60% AWS might have received insufficient N for optimal production, mainly due to a lower N intake on this diet.

Conclusions

It is evident from these results that the replacement of LH with AWS was associated with a lower DMI, resulting in lower growth rates and a poorer FCR. Seeing that the energy content of the diets – as reflected by the apparent digestibility of DM and OM – did not differ largely, the main cause of the reduced performance of lambs consuming diets with high levels of AWS, appears to be a lower intake of energy, resulting in less body fat being deposited. The low energy intake could be related to the inherent bulkiness and/or reduced palatability of roughages like wheat straw in comparison with LH. A lower N intake, resulting in inadequate N-balance results, could also be a limiting factor on the diet containing 60% AWS.

The economic advantage of the replacement of a high-quality roughage, like lucerne hay, with a cheaper source must be balanced against the reduction in growth rate and the poorer feed conversion of diets high in AWS. The difference in the price of the two roughages and the availability of LH will be the most important considerations in the decision. When AWS is included in growth diets, satisfactory results can be obtained if the inherent limitations of AWS, like a high cell wall content, are recognized and considered in the formulation of diets (S.W.P. Cloete & A.A. Brand, unpublished results). At this level of roughage inclusion, ammoniation offered no advantage over urea supplementation in the study reported by Seed *et al.* (1985). The inclusion of ammoniated roughages in diets for growing lambs can thus not be recommended unconditionally.

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