

# The effect of supplementing untreated, urea-supplemented and urea-ammoniated wheat-straw with maize-meal and/or fish-meal in sheep

A.A. Brand,<sup>1</sup> S.W.P. Cloete<sup>2</sup> & F. Franck

Elsenburg Agricultural Centre, Private Bag, Elsenburg 7607, Republic of South Africa

Received 26 January 1990; revised 2 May 1990; accepted 26 September 1990

Supplementation of untreated, urea-supplemented or urea-ammoniated wheat-straw diets with sources of readily fermentable energy (maize-meal; 0 and 20% of the total diet) and rumen-undegradable protein (fish-meal; 0 and 5% of the total diet) was investigated in a 3×2×2 factorial experiment, involving an intake and *in vivo* digestibility trial with 48 adult S.A. Mutton Merino wethers. Straw dry matter (DM) intake on ammoniated wheat-straw diets was 27 and 22% higher ( $P \leq 0,01$ ) than on untreated and urea-supplemented diets, respectively. No significant difference was found between the latter treatments. The inclusion of 5% fish-meal stimulated ( $P \leq 0,01$ ) straw DM intake by 13% relative to the control diets without fish meal. Incorporation of the 20% maize-meal supplement alone, or in combination with 5% fish-meal, did not result in any further improvement in straw DM intake. The apparent digestibility of organic matter (OM), cell-wall constituents (CWC), acid detergent fibre (ADF) and hemicellulose was higher ( $P \leq 0,01$ ) on the urea-ammoniated wheat-straw diets than on either the untreated wheat-straw diets or the urea-supplemented wheat-straw diets. No differences were obtained between the latter treatments. The apparent OM digestibility of the wheat-straw diets was improved by the inclusion of 5% fish-meal and/or 20% maize-meal. Apparent digestibility of CWC and ADF was not particularly affected by the inclusion of fish-meal or maize-meal. Combined supplementation of the straw diets with both 5% fish-meal and 20% maize-meal tended to suppress the apparent digestibility of CWC and ADF. Apparent hemicellulose digestibility of the wheat-straw diets was increased ( $P \leq 0,01$ ) by 4,5% due to the inclusion of maize-meal. Apparent nitrogen (N) digestibility and N-balance was involved in significant ( $P \leq 0,01$ ) three-factor interactions. Urea supplementation improved ( $P \leq 0,01$ ) N-digestibility compared to untreated wheat-straw diets. Urea ammoniation similarly improved N-digestibility in relation to untreated wheat-straw with or without supplementary maize-meal. The apparent N-digestibility of urea-supplemented wheat-straw tended to be higher than on urea-ammoniated wheat-straw, but the only significant ( $P \leq 0,01$ ) difference occurred between the diets without maize-meal and/or fish-meal. Nitrogen balance was generally improved in sheep receiving diets containing urea-ammoniated wheat-straw, and fish-meal alone or combined with maize-meal. No significant differences in N-balance were found between the untreated wheat-straw diets and corresponding urea-supplemented wheat-straw diets.

Aanvulling van onbehandelde, ureum-aangevulde en ureum-geammoniseerde koringstrooidiëte met bronne van maklik fermenteerbare energie (mieliemeel; 0 en 20% van die totale dieet) en rumen nie-degradeerbare proteïen (vismeele; 0 en 5% van die totale dieet) is ondersoek in 'n 3×2×2-faktoriaaleksperiment met 48 volwasse SA Vleismerinohamels. Strooi droë materiaal (DM)-inname op die geammoniseerde strooidiëte was onderskeidelik 27 en 22% hoër ( $P \leq 0,01$ ) as op onbehandelde en ureum-aangevulde diëte. Geen betekenisvolle verskille het tussen laasgenoemde diëte voorgekom nie. Die insluiting van 5% vismeel as aanvulling het strooi DM-inname met 13% bo die onaangevulde kontrole gestimuleer. Slegs mieliemeel of mieliemeel in kombinasie met vismeel as aanvulling het geen verdere verhogings in strooi DM-inname veroorsaak nie. Die skynbare verteerbaarheid van organiese materie (OM), selwande (SW), suurbestande vesel (SBV) en hemicellulose was hoër ( $P \leq 0,01$ ) op ureum-geammoniseerde koringstrooidiëte as op onbehandelde of ureum-aangevulde strooidiëte. Geen verskille het tussen laasgenoemde diëte voorgekom nie. Die insluiting van 5% vismeel en/of 20% mieliemeel afsonderlik as aanvulling, het skynbare OM-verteerbaarheid verbeter. Die skynbare verteerbaarheid van SW en SBV is tot 'n mindere mate deur die insluiting van vismeel of mieliemeel beïnvloed. Gesamentlike aanvulling met 5% vismeel en/of 20% mieliemeel het geneig om die skynbare verteerbaarheid van SW en SBV in koringstrooidiëte te onderdruk. Skynbare hemicellulose verteerbaarheid van die koringstrooidiëte is met 4,5% deur die insluiting van mieliemeel verhoog. Skynbare stikstof (N)-verteerbaarheid en N-balans was betrokke by betekenisvolle ( $P \leq 0,01$ ) driefaktor-interaksies. Ureum-aanvulling het skynbare N-verteerbaarheid verhoog ( $P \leq 0,01$ ) in vergelyking met ooreenstemmende onbehandelde koringstrooidiëte. Ureum-ammonisering het ook skynbare N-verteerbaarheid verhoog by die diëte wat geen aanvulling ontvang het nie, en by die diëte wat 20% mieliemeel ingesluit het. Die skynbare N-verteerbaarheid van ureum-aangevulde koringstrooi het hoër geneig as op ureum-geammoniseerde koringstrooi, met slegs die verskil tussen die diëte wat geen mieliemeel of vismeel ingesluit het nie, betekenisvol ( $P \leq 0,01$ ). Stikstofbalans was in die algemeen beter op diëte wat ureum-geammoniseerde koringstrooi ingesluit het, en op diëte waarby vismeel alleen of in kombinasie met mieliemeel ingesluit is. Geen betekenisvolle verskille in N-balans is verkry tussen onbehandelde koringstrooidiëte en ooreenstemmende ureum-aangevulde diëte nie.

**Keywords:** Urea-ammoniation, supplementation, intake, digestibility, nitrogen balance.

<sup>1</sup> Present address: P.O. Box 101, Laaiplek 7370, Republic of South Africa

<sup>2</sup> To whom correspondence should be addressed

## Introduction

The utilization of low-quality crop residues in ruminant nutrition is limited by a number of factors, the most important of which is a low voluntary intake. Physical (Walker, 1984) and chemical (Jackson, 1977; Sundstøl, Coxworth & Mowat, 1978) processing of such low-quality feedstuffs can enhance their utilization by ruminants. The major advantage of chemical over physical processing lies in the improvement of both voluntary intake and digestibility, as opposed to an improvement in voluntary intake alone. As a result of several advantages over caustic

soda treatment, like ease of application, nitrogen addition and absence of undesirable residues, ammoniation is currently also a popular chemical method of upgrading crop residues (Owen, 1981; Sundstøl, 1983/84).

Alternative methods for improving crop residues include supplementation with non-protein nitrogen (Kellaway & Leibholz, 1983), rumen-undegradable protein (Kempton, 1982) or readily fermentable energy (Zorrilla-Rios *et al.*, 1984). The voluntary intake and digestibility of ammoniated wheat-straw can further be improved by strategic supplementation (Perdok & Leng, 1986). Our previous work

suggested that the digestible nutrient intake of ammoniated wheat, oat and barley-straw and oat-hay was inadequate for production functions like growth, pregnancy and lactation (Brand *et al.*, 1989). Strategies for supplementing such roughages so as to improve nutrient intake would therefore appear to be necessary.

The effects of supplementing untreated urea-supplemented and urea-ammoniated wheat-straw with sources of readily fermentable energy (maize-meal) and rumen-undegradable protein (fish-meal) on the voluntary intake, digestibility and nitrogen balance of these diets were therefore investigated.

### Material and methods

Two-hundred-and-fifty bales of wheat-straw were ammoniated (55 g urea/kg and 400 ml water/kg wheat-straw) in a stack, as described by Cloete & Kritzing (1984). The stack was subsequently sealed under a plastic canvass, and treated for a period of 8 weeks. After treatment, the ammoniated wheat-straw was spread on a cement floor to dry to <85% dry matter, before being hammermilled through an 18-mm screen prior to utilization. Untreated wheat-straw of the same batch was similarly milled.

These roughages were used in a 3×2×2 factorial experiment, in order to investigate the effects of straw treatment (untreated, supplemented with 2% urea or urea-ammoniated), a source of readily fermentable energy (unsupplemented or 20% maize-meal) and a source providing rumen-undegradable protein (unsupplemented or 5% fish-meal; Erasmus *et al.*, 1988).

For this purpose 48 adult SA Mutton Merino wethers, with an average initial mass ( $\pm$ SD) of 72,1  $\pm$ 0,8 kg, were stratified on the basis of live mass, and randomly allotted to 12 experimental diets according to the design described above. After an adaptation period of 14 days, voluntary intake on the respective diets was determined over another 10 day period. This was followed by a 10 day collection period, during which animals were fed at a fixed level of 85% of the voluntary dry matter (DM) intake of the diet ingested at the lowest level. Representative samples ( $\pm$  100 g) of the diets and orts were taken daily for dry matter determinations. Total faeces and urine output were measured daily. Representative urine samples (10% of the daily urine output) were taken and pooled for nitrogen analyses. After thorough mixing of the wet faeces, representative samples were taken and dried at 55°C for 48 h, together with representative feed and ort samples. These samples were milled through a 1-mm screen prior to chemical analyses for DM, organic matter (OM) and nitrogen (N) according to the Weende system (AOAC, 1970). Urinary nitrogen was similarly determined. Cell wall constituents (CWC), acid detergent fibre (ADF), and hemicellulose were determined according to the methods of Van Soest (1963) and Van Soest & Wine (1967). Dry-matter intake and output were determined by the drying of representative feed, ort and faeces samples at 103°C to a constant mass. Standard procedures for the calculation of apparent digestibility coefficients and nitrogen balance were then followed.

Standard statistical procedures for the analysis in a

3×2×2 factorial design were followed (Snedecor & Cochran, 1967). The effects of independent variables and interactions were tested for significance by using the mean square for remainder as error term. Significant ( $P \leq 0,05$ ) two- and three-factor interactions were discussed where they occurred. Significant differences between means were determined by the Bonferoni method (Van Ark, 1981).

## Results and discussion

### Chemical composition

The chemical composition of the untreated, urea-supplemented and urea-ammoniated wheat-straw used in the study are given in Table 1. Ammoniation and urea-supplementation resulted in marked increases in nitrogen content, as was reported previously (Cloete & Kritzing, 1984). Ammoniation generally causes a reduction in the NDF and hemicellulose contents of crop residues (Kiangi *et al.*, 1981; Cloete & Kritzing, 1984, Brand *et al.*, 1989) due to the solubilization of hemicellulose (Solaiman *et al.*, 1979). No conclusive evidence of such a reduction could be obtained from the present investigation.

### Voluntary intake

The effect of straw treatment was not involved in interactions with other main effects as far as voluntary DM intake of the total diet and the straw portion of the diet were concerned. Ammoniation improved ( $P \leq 0,01$ ) the voluntary DM intake of the total diet by 27% and 21%, respectively, in comparison with the untreated diets and the diets containing urea (Table 2). Straw DM intake was similarly improved by 27% and 22%, respectively. The improvement in straw DM intake over the untreated control is smaller than improvements of 47% for urea-ammoniated barley-straw and 47,6% for urea ammoniated wheat-straw reported by Hadjipanayiotou (1982) and Cloete & Kritzing (1984), respectively. The higher intake of ammoniated wheat-straw in comparison with supplemented wheat-straw accords with corresponding improvements in the literature, ranging from 16,4 to 27,3% (Streeter & Horn, 1982; Cloete *et al.*, 1983; Dryden & Kempton, 1983/84; Dias-Da-Silva & Sundstøl, 1986). Other researchers found no difference in voluntary intake between urea-supplemented wheat-straw and anhydrous-ammoniated wheat-straw (Wanapat *et al.*, 1985) or urea-ammoniated wheat-straw (Cloete & Kritzing, 1984).

**Table 1** The chemical composition of the untreated, urea-supplemented and urea-ammoniated wheat-straw used in the experiment (DM basis)

Composition (%)	Untreated	Urea-supplemented	Urea-ammoniated
Organic matter	95,2	93,3	94,2
Nitrogen	0,55	1,40	1,42
Neutral detergent fibre	78,4	76,8	77,8
Acid detergent fibre	50,9	49,8	50,4
Hemicellulose	27,5	27,0	27,4

**Table 2** Voluntary intake (g DM/kg W<sup>0.75</sup>/day) and apparent digestibility coefficients for untreated, urea-supplemented and urea-ammoniated wheat-straw

	Straw treatment			SE mean
	Untreated	Supplemented	Ammoniated	
<b>Voluntary Intake (g DM/kg W<sup>0.75</sup>/day)</b>				
Total diet	56,8 <sup>1</sup>	59,5 <sup>1</sup>	72,2 <sup>2</sup>	1,83
Straw intake	49,5 <sup>1</sup>	51,5 <sup>1</sup>	62,7 <sup>2</sup>	1,63
<b>Digestibility coefficients (%)</b>				
Organic matter	57,3 <sup>1</sup>	56,7 <sup>1</sup>	61,8 <sup>2</sup>	0,48
Cell wall constituents	55,6 <sup>1</sup>	55,2 <sup>1</sup>	66,1 <sup>2</sup>	0,66
Acid detergent fibre	51,2 <sup>1</sup>	51,3 <sup>1</sup>	58,2 <sup>2</sup>	0,83
Hemicellulose	60,0 <sup>1</sup>	64,3 <sup>1</sup>	81,9 <sup>2</sup>	1,01

<sup>1,2</sup> denote significant differences ( $P \leq 0,01$ )

The lack of an improvement in voluntary DM intake due to the inclusion of urea (Table 2) is in disagreement with most results in the literature (Kempton & Leng, 1979; Kompton, 1982; Stephenson *et al.*, 1983; Cloete & Kritzing 1984). No response in voluntary intake due to urea supplementation was also reported by Barry & Johnstone (1976) and Sudana & Leng (1986) for barley-straw diets including 0,6% urea and wheat-straw diets including 2,5% urea, respectively. The lack of an intake response in the present study could possibly be ascribed to a rather low urea-supplementation level (2%) relative to the optimum level of 2,8% for maximal microbial protein synthesis (Kellaway & Leibholz, 1983). Straw intake on control diets without urea could also be affected by the inclusion of maize-meal and/or fish-meal, as the means depicted in Table 2 are over treatments.

The inclusion of maize-meal as readily fermentable energy with the wheat-straw diets interacted ( $P \leq 0,05$ ) with the inclusion of rumen-undegradable protein (provided by fish-meal) as far as voluntary DM intake was concerned. Both the inclusion of 5% fish-meal and 20% maize-meal stimulated ( $P \leq 0,01$ ) the voluntary intake of the total diet when compared to the control diets including no fish-meal or maize-meal (Table 3). No further improvements were,

however, obtained when both fish-meal and maize-meal were included in the wheat-straw diets. The inclusion of fish-meal in the wheat-straw diets stimulated ( $P \leq 0,01$ ) straw DM intake by 13% relative to the control. Abidin & Kempton (1981) similarly found increased voluntary DM intakes of straw, when fed together with supplements of 240 and 360 g heat-treated protein meal/kg straw. Corresponding improvements in roughage DM intake were reported by researchers providing supplements containing protein from oilmeal products to cattle (Redman *et al.*, 1980; McCollum & Galyean, 1985; Stokes *et al.*, 1988) or sheep (Krysl *et al.*, 1987). Possible reasons for the enhancement of roughage DM intake are an increased rate of passage of particulates (McCollum & Galyean, 1985), or an expansion of gastrointestinal fill (Krysl *et al.*, 1987). The response in straw intake due to the inclusion of undegradable protein in the present study can also be related to an improvement of 72,7% in the intake of the total barley-straw diet following supplementation with 15% cottonseed-meal that was reported by Sudana & Leng (1986). Straw DM intake was unaffected by the inclusion of maize-meal alone, or in combination with fish-meal (Table 3). This result is consistent with reports of a lower roughage DM intake in low-quality fibrous diets containing increasing energy levels

**Table 3** Voluntary intake (g DM/kg W<sup>0.75</sup>/day) and apparent digestibility coefficients of straw diets, as affected by supplementation with 20% maize-meal and/or 5% fish-meal

Maize-meal level (%)	0		20		SE mean
	0	5	0	5	
<b>Voluntary Intake (g DM/kg W<sup>0.75</sup>/day)</b>					
Total diet	52,5 <sup>1</sup>	62,7 <sup>2</sup>	68,0 <sup>2</sup>	68,0 <sup>2</sup>	2,11
Straw intake	52,5 <sup>1</sup>	59,2 <sup>2</sup>	54,2 <sup>1,2</sup>	52,2 <sup>1</sup>	1,88
<b>Digestibility coefficients (%)</b>					
Organic matter	54,0 <sup>1</sup>	57,8 <sup>2</sup>	60,9 <sup>3</sup>	61,8 <sup>3</sup>	0,55
Cell wall constituents	58,3	60,0	59,6	57,9	0,77
Acid detergent fibre	52,7 <sup>a</sup>	55,9 <sup>b</sup>	53,6 <sup>a,b</sup>	52,1 <sup>a</sup>	0,96
Hemicellulose	68,1 <sup>a</sup>	70,2 <sup>a,b</sup>	71,5 <sup>b</sup>	73,0 <sup>b</sup>	1,17

<sup>a, b</sup> denote significance ( $P \leq 0,05$ )

<sup>1,2,3</sup> denote significance ( $P \leq 0,01$ )

(Crabtree & Williams, 1971; Lamb & Eadie, 1979; Streeter *et al.*, 1983; Sanson *et al.*, 1990), and could probably be related to the substitution effect. There is also evidence in the literature that straw intake may be improved by the inclusion of a small percentage of starch (Crabtree & Williams, 1971) or molasses (Mbatya *et al.*, 1983). The level of energy supplied in our study (20%) was probably too high to stimulate straw intake to an extent worth mentioning.

#### Apparent digestibility of organic matter and fibre

The effect of straw treatment was not involved in interactions with other main effects as far as apparent digestibility coefficients for OM, CWC, ADF, and hemicellulose were concerned. The apparent OM digestibility of urea-ammoniated wheat-straw was higher ( $P \leq 0,01$ ) than that of the untreated straw diets (7,9%) or the urea-supplemented wheat-straw diets (9,0%; Table 2). These results correspond with previous reports of Cloete & Kritzing (1984), Dryden & Kempton (1983/84), Zorrilla-Rios *et al.*, (1984) and Djajanegara & Doyle (1989). Dias-Da-Silva & Sundstøl (1986) reported comparable improvements in the apparent digestibility of wheat-straw after ammoniation. The apparent OM digestibility of wheat-straw was unaffected by the inclusion of urea, as also found by Cloete & Kritzing (1984).

Apparent digestibility coefficients for CWC, ADF and hemicellulose were improved ( $P \leq 0,01$ ) by urea-ammoniation by respectively 18,9, 13,7, and 36,5% compared to the untreated wheat-straw diets (Table 2). Similar improvements of 19,7, 13,5 and 27,4%, respectively, were obtained in comparison with the diets containing urea. These results are in general agreement with those previously obtained and cited from the literature by Cloete & Kritzing (1984), and subsequently reported by Djajanegara & Doyle (1989).

The inclusion of fish-meal and maize-meal in the wheat-straw diets resulted in respective improvements of 7,0% and 12,8% in apparent OM digestibility ( $P \leq 0,01$ ; Table 3). The inclusion of fish-meal and maize-meal in combination resulted in no further improvement in apparent OM digestibility of the wheat-straw diets, thus causing a significant ( $P \leq 0,01$ ) interaction between the provision of readily fermentable energy and rumen-undegradable protein.

Fibre digestibility of the wheat-straw diets was not markedly affected by the inclusion of fish-meal and/or maize-meal (Table 3). With regard to apparent CWC and ADF digestibility, there was a tendency for diets including fish-meal to have a higher digestibility than the control. When maize-meal was provided together with fish-meal, CWC and ADF digestibility tended to decrease, resulting in a significant ( $P \leq 0,05$ ) two-factor interaction between the inclusion of maize-meal and fish-meal. Hemicellulose digestibility was improved ( $P \leq 0,01$ ) by 4,5% due to the inclusion of maize-meal. Evidence from the literature suggests that the inclusion of protein and energy at low levels may improve fibre digestibility (Williams, 1983/84). High levels of soy bean meal and maize gluten meal were, however, found to suppress the cellulose and hemicellulose digestibility of wheat-straw diets (Streeter *et al.*, 1983). The

apparent ADF digestibility of low quality roughages was also adversely affected by high levels of barley (Lamb & Eadie, 1979) and molasses (Williams, 1983/84). These findings may possibly be related to rumen pH levels lower than 6,2, thus suppressing the activity of cellulotic microbes (Ørskov, 1982; Williams, 1983/84). Rumen pH levels of 6,31 and 6,26, respectively, were observed 8 h after feeding on the diets including maize-meal only, and maize-meal together with fish-meal, indicating that the level of readily fermentable energy supplied was possibly high enough to influence fibre digestibility.

#### Apparent nitrogen digestibility and nitrogen balance

Apparent nitrogen (N) digestibility was affected by a significant ( $P \leq 0,01$ ) three-factor interaction between straw treatment, the inclusion of maize-meal as a source of readily fermentable energy, and fish-meal as a source of rumen-undegradable protein. In untreated wheat-straw, the inclusion of maize-meal and/or fish-meal resulted in marked improvements ( $P \leq 0,01$ ) of apparent N-digestibility, ranging from 40,1 to 62,6 percentage units (Figure 1). Much smaller improvements were observed in urea-supplemented wheat-straw and urea-ammoniated wheat-straw, where only the provision of fish-meal and fish-meal in combination with maize-meal succeeded in improving ( $P \leq 0,05$ ) apparent N-digestibility by 11,1 to 21,1 percentage units. The apparent N-digestibility of urea-supplemented wheat-straw was higher ( $P \leq 0,01$ ) than untreated wheat-straw regardless of the inclusion of fish-meal and maize-meal, differences ranging from 14,1 to 61,6 percentage units. This result is understandable when the contribution of urea to N-digestibility of urea-supplemented wheat-straw is considered (Cloete & Kritzing, 1984). The apparent N-digestibility of urea-ammoniated wheat-straw, in contrast, was not significantly different from that of untreated wheat-straw when either 5% fish-meal, or 5% fish-meal combined with 20% maize-meal, was included in the diet. Urea-ammoniation of wheat-straw tended to decrease apparent N-digestibility in comparison with urea-supplementation, the difference of 15,4 percentage units between the diets not including maize-meal and/or fish-meal being significant ( $P \leq 0,01$ ). This finding is consistent with previous results (Cloete *et al.*, 1983, Cloete & Kritzing, 1984). Results previously cited from the literature suggest the possibility of

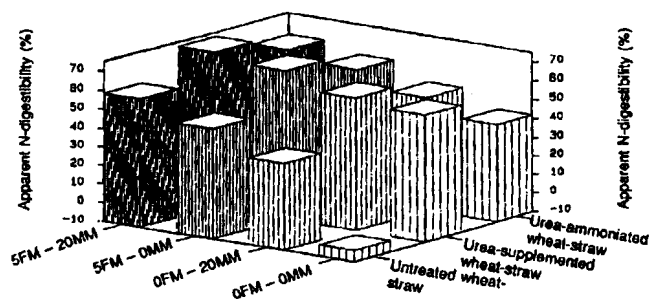


Figure 1 The effect of supplementation with 20% maize-meal (MM) and/or 5% fish-meal (FM) on the apparent digestibility of nitrogen (N) in untreated, urea-supplemented, and urea-ammoniated wheat-straw.

hindgut fermentation and bonding of nitrogen via the Maillard reaction (Cloete, *et al.*, 1983). Unidentified aromatic amines in treated straw may also be involved (Dryden & Kempton, 1983/84).

Nitrogen balance results were also influenced by the three-factor interaction ( $P \leq 0,01$ ) between straw treatment, the inclusion of maize-meal as a source of readily fermentable energy and fish-meal as a source of rumen-undegradable protein. Urinary N-losses largely cancelled the higher apparent N-digestibility coefficients consistently obtained for the urea-supplemented wheat-straw diets in comparison with untreated wheat-straw diets and ammoniated wheat-straw diets (Figure 2), as also found previously (Cloete & Kritzing 1984). The provision of maize-meal only did not influence the N-balance of untreated and urea-supplemented wheat-straw, but it improved ( $P \leq 0,01$ ) the N-balance of urea-ammoniated wheat-straw from 0,17g/day to 2,78g/day. The latter result is consistent with results published by Zorrilla-Rios *et al.*, (1984). When compared to the respective diets containing neither fish-meal nor maize-meal, the inclusion of fish-meal led to improvements ( $P \leq 0,01$ ) in the N-balance of untreated and urea-ammoniated wheat-straw but not in urea-supplemented wheat-straw. The poor N-balance figures on the latter diets, despite the observed high apparent N-digestibility coefficients (Figure 1), seem to imply protein utilization for energy or a lack of protein synthesis both probably owing to limited energy intake. As no response in N-utilization was observed on the urea-supplemented diet containing maize-meal alone, protein intake also appeared to be a limiting factor. The improved N-utilization on urea-supplemented wheat-straw including fish-meal and maize-meal in combination, supports the contention that both energy and protein were limited (Clanton & Zimmerman, 1970). The provision of fish-meal and maize-meal in combination also resulted in marked improvements ( $P \leq 0,01$ ) in N-balance on untreated and urea-ammoniated wheat straw. Sheep on urea-ammoniated wheat-straw generally had higher ( $P \leq 0,05$ ) N-balance figures than those on untreated or urea-supplemented wheat-straw receiving similar supplements. The only exceptions were relative to urea-supplemented wheat-straw, when fed either diets containing no fish-meal or maize-meal, or when fish-meal and maize-meal were both supplied. The higher N-balance on unsupplemented urea-ammoniated wheat-straw in comparison with the untreated control diet is consistent with previous results (Cloete & Kritzing 1984; Djajanegara & Doyle, 1989). Nitrogen utilization on urea-ammoniated wheat-straw appears to be more efficient than on untreated wheat-straw or urea-supplemented wheat-straw (Figure 2). This observation could possibly be related to the higher energy content of the diets containing urea-ammoniated wheat-straw as reflected by higher apparent OM digestibility coefficients (Table 2).

### Conclusions

Voluntary DM intake of straw was markedly improved by urea-ammoniation. There is, however, evidence indicating that voluntary intake levels on diets containing 50 to 60% urea-ammoniated wheat-straw were not sufficient to sustain optimal levels of production in pregnant and lactating ewes

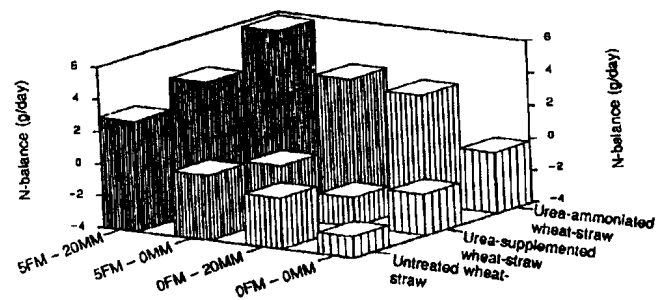


Figure 2 The effect of supplementation with 20% maize-meal (MM) and/or 5% fish-meal (FM) on the nitrogen (N) balance of sheep on untreated, urea-supplemented, or urea-ammoniated wheat-straw.

(Brand *et al.*, 1988) or in growing lambs (Brand *et al.*, 1990). Supplementation of straw diets with fish-meal as source of undegradable protein also resulted in increased voluntary straw DM intake levels in this investigation. It is, however, doubtful if the voluntary DM intake of low quality crop residues can be increased to levels where it can be applied in production diets for sheep. Low quality roughage diets such as those included in this experiment may therefore play an important role in the maintenance nutrition of sheep, but there appears to be limited scope for these as part of production diets when fed at levels higher than 30% of the total diet (O'Donovan, 1983). The ammoniation of the roughage portion in such diets appears to be of limited value (Seed *et al.*, 1985; Brand *et al.*, 1991).

### Acknowledgement

The authors wish to thank the staff of the Animal Production Laboratory for the preparation and chemical analysis of samples.

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