Short Communications

The effect of thermo-ammoniation on the nutritive value of maize residues

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Thermo-ammoniated maize residues supplemented with 1% urea (Diet 2) or 4.5% fish-meal (Diet 3) and untreated maize residues supplemented with 2% urea (Diet 1), were compared on an iso-nitrogenous base. The *in vitro* dry matter digestibility for Diets 1, 2 and 3 were 56.9, 62.5 and 63.1% respectively. Live mass changes for lambs receiving Diets 1, 2 and 3 respectively were −26.3, 19.9 and 94.0 g/d ($P \leq 0.05$) while feed conversions for Diets 2 and 3 respectively were 33.8 and 9.5 kg dry matter required per kg live-mass gain.

Termies-geammonifiseerde mielie-oesreste wat met 1% ureum (Dieet 2) of 4.5% vismeel (Dieet 3) aangevul was en onbehandelde mielie-oesreste wat met 2% ureum aangevul was (Dieet 1), is op 'n iso-stikstofbasis vergelyk. Die droëmateriaal *in vitro* verteerbaarheid van Diëte 1, 2 en 3 was onderskeidelik 56.9, 62.5 en 63.1%. Massaveranderings van lammers op Diëte 1, 2 en 3 was onderskeidelik −26.3, 19.9 en 94.0 g/d ($P \leq 0.05$) en voeromsetting vir Diëte 2 en 3 onderskeidelik 33.8 en 9.5 kg droëmateriaal per kg lewendemassa-toename.

Keywords: Chemical composition, digestibility, maize residues, nutritive value, protein supplementation, thermo-ammoniation.

Ammonia treatment of straw and other fibrous materials generally causes energy and protein values to improve, accompanied by an increase in dry matter (DM) intake (Sundstøl & Coxworth, 1984). This has also been demonstrated for maize residues (Oji *et al.*, 1977; Morris & Mowat, 1980). Only limited data regarding ammoniated maize residues obtained under South African conditions are available (Pretorius, 1985; Seed *et al.*, 1985), while data regarding thermo-ammoniation of such residues are scarce. Snyman *et al.* (1991) investigated the thermo-ammoniation of non-selected fractions of maize residues. Maize residues are thermo-ammoniated by an increasing number of farmers and the process needs to be quantitatively evaluated under local circumstances.

Maize residues that were grown in the Highveld region during 1986 were obtained by a combine harvester (Slattery) at a kernel moisture content of *ca.* 14%. One third of the residues were hammermilled through a 6-mm screen. The remainder was first thermo-ammoniated (3% NH_3, 85 °C, 20 h) before being milled as described. Conditions for ammoniation corresponded with those used by Fernandez *et al.* to ammoniate corn stalks, as quoted by Muirhead (1985). An 18 m^3 An-stra-verter oven was used for ammoniation. All residues were supplemented with dicalciumphosphate (1%) and elemental sulphur (0.1%). The untreated (non-ammoniated) residues and half of the ammoniated residues were supplemented with 2 and 1% urea respectively. The other half of the ammoniated residues were supplemented with 4.5% fish-meal, in order to raise the crude protein (CP) content of the three diets to an aimed isonitrogenous level of 11% CP.

Thirty-six Dohne Merino ram lambs (4 months old) were stratified according to body mass and randomly allocated to three groups with a comparable body mass distribution. The groups were randomly allotted to each of the diets which were fed on an *ad libitum* basis to lambs individually. Lambs were previously adapted to untreated maize residues supplemented with 2% urea, 1% dicalciumphosphate and 0.1% sulphur, for three weeks. Feed grade sodium chloride was supplied separately (*ad libitum*). Feed was replenished every morning. Refusals were removed and weighed back weekly. The growth trial lasted for 57 days and was succeeded by a 10-day digestion trial. Masses were obtained at the beginning and end of the growth trial, after lambs were fasted overnight.

Daily feed samples were taken from each lamb for analysis. Samples from each lamb taken during the growth and digestion trials, respectively, were pooled. One tenth of total faeces excretion was collected during the digestion trial and weighed after being dried to constant mass at 105 °C in a force draught oven. Feed samples were analysed for dry matter (DM), CP, acid detergent fibre (ADF), acid detergent insoluble nitrogen (ADF-N) and for *in vitro* dry matter digestibility (IVDMD), as referred to formerly (Snyman, 1988). Faeces were analysed for nitrogen only.

Effects of dietary treatments on lamb performance and nutritive value properties were analysed in a completely randomized design, using Anova.exe (Van Ark, H., 1991, personal communication).

The chemical composition and IVDMD of the respective diets are shown in Table 1. The CP contents for Diets 1 and 2 were somewhat lower than the 11.0% aimed at. It can be assumed, however, that the CP contents of all three the diets would be high enough to sustain an optimum rumen ammonia concentration (Snyman, 1991; Satter & Roffler, 1974; Satter & Slyter, 1974). Values of ADF and ADF-N (Table 1) for Diet 2 tended to be somewhat higher than those for Diets 1 and 3.

Table 1 Mean values for the chemical components and IVDMD of the different maize residue diets fed to lambs

	Maize residue diets		
Chemical component and IVDMD	Diet 1 untreated (+ 2% urea)	Diet 2 ammoniated (+ 1% urea)	Diet 3 ammoniated (+ 4.5% fish-meal)
CP (g/100 g DM)	10.2	10.5	11.4
ADF (g/100 g DM)	48.2	54.4	50.2
ADF-N (g/100 g N)*	9.4	11.2	9.5
IVDMD (g/100 g DM)	56.9	62.5	63.1

* Values for residues only, as calculated by correction for urea content, were 21.5 and 15.4% for the untreated and ammoniated maize residues, respectively.

The ADF-N value for the unsupplemented ammoniated residues was 15.4% (Table 1). This value compares well with that of untreated maize residues and *Eragrostis curvula* hay with a comparable CP value (7.8%) (Snyman, 1991), suggesting that heat during the ammoniation process had little effect on CP unavailability (Goering *et al.*, 1972). Thomas *et al.* (1972) found that the ADF-N value of haylage correlated (r = 0.92) with the extent of heating and measured ADF-N values as high as 36% in 33% of haylage samples collected. The IVDMD of Diets 2 and 3 were higher than the IVDMD of Diet 1, reflecting the beneficial effect of ammoniation (Sundstøl & Coxworth, 1984).

The effect of dietary treatment on animal performance and some nutritive value properties during the growth stage, is given in Table 2. The data indicate significant differences between the mass changes of lambs fed on Diets 1, 2 and 3. No significant difference in DM intake was measured between lambs fed on Diet 1 and Diet 2. The results (Table 2) indicate a significant increase in DM intake of ammoniated residues when urea (Diet 2) was substituted for an isonitrogenous amount of fish-meal (Diet 3). This might be due partly to the effect of bypass protein provided by the fish-meal (Kempton, 1982). Untreated maize residues had a low CP (4.4%), and therefore also a low content of bypass protein. Crude protein enrichment by ammoniation was brought about by non-protein nitrogen (NPN) only (Sundstøl & Coxworth, 1984), assuming a low content of bypass protein and available amino acids for Diet 2. The data in Table 2, furthermore, indicate an improved feed conversion for Diet 3, suggesting that the inclusion of fish-meal resulted in an improved efficiency of utilization of ammoniated residues.

The DM and N digestion properties for the respective diets are shown in Table 3. The differences in DM intake resembled those in the growth trial. The mean apparent dry matter digestibility (DMD) of the ammoniated diet supplemented with fish-meal (Diet 3) was higher (P < 0.05) than that of the untreated control diet (Diet 1). A similar tendency was observed for Diet 2. These results are in agreement with the corresponding IVDMD values (Table 1). The differences in *in vitro* (5.6 percentage units) and apparent (3.6 percentage units) DM digestibilities between Diets 1 and 2, however, were smaller than was expected. Oji *et al.* (1977) found an increase of 8.5

Table 2 Mean values for the nutritive value properties of the different maize residue diets fed to lambs (n = 12 per treatment) during the growth period

Nutritive value properties	Maize residue diets: Diet 1 untreated (+ 2% urea)	Diet 2 ammoniated (+ 1% urea)	Diet 3 ammoniated (+ 4.5% fish-meal)	SEM
Beginning mass (kg)	26.3	26.2	26.3	0.51
Final mass (kg)	24.8	27.4	31.7	0.74
Mass change (g/d)	–26.3^{a}	19.9^{b}	94.0^{c}	17.7
DM intake (% of body mass)	2.53^{a,b}	2.49^{a}	3.09^{b}	0.10
Feed conversion*	–	33.8	9.49	–

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

* DM intake (kg) /kg mass increase.

Table 3 Mean values for the DM and N digestion properties of the different maize residue diets fed to lambs (n = 12 per treatment)

Digestion and N-retention properties	Maize residue diets: Diet 1 untreated (+ 2% urea)	Diet 2 ammoniated (+ 1% urea)	Diet 3 ammoniated (+ 4.5% fish-meal)	SEM
DM intake (kg/100 kg body mass)	2.83^{a}	3.08^{a}	3.79^{b}	0.10
Apparent DM digestibility (%)	58.7^{a}	62.3^{a,b}	63.6^{b}	0.77
Nitrogen:				
intake (g/d)	11.6^{a}	14.2^{a}	22.5^{b}	0.95
faeces excretion (g/d)	4.12^{a}	6.19^{b}	8.95^{c}	0.41
apparent digestibility (%)	64.5^{a}	56.2^{b}	59.5^{a,b}	1.26

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

percentage units in apparent DM digestibility when corn stover with an initial digestibility of 51.6% was treated with 3% ammonia at normal temperature. Snyman *et al.* (1991) thermo-ammoniated non-selected maize residues with an IVDMD of 51.8% under the same conditions as in this trial and found an increase of 7.9 percentage units. Results from Seed *et al.* (1985) showed a difference in DMD of 4.4 percentage units when a diet containing untreated maize residues (DMD = 62.4%) was compared with a diet containing the ammoniated maize residues (DMD = 66.8%). The low response in the present trial might be explained by the initial high digestibility (IVDMD = 56.9%) of the untreated maize residues. (Kernan *et al.*, 1979). Nitrogen intake was higher ($P < 0.05$) on Diet 3 compared to Diets 1 and 2. Faecal N excretion was higher ($P < 0.05$) for ammoniated diets (Diets 2 and 3) compared to Diet 1. This resulted in a lower ($P < 0.05$) apparent N digestibility on Diet 2 compared to Diet 1. An increased faecal-N excretion by animals fed on ammoniated maize residues was also measured by Seed *et al.* (1985) and Snyman *et al.* (1991). Borhami & Johnsen (1981) concluded that a proportion of the ammonia, resulting from ammoniation, was tightly bound to the straw and not released during passage through the alimentary tract. The results of this investigation suggested that the lower apparent CP digestibility of Diet 2 was not merely due to a greater extent of nitrogen unavailability in terms of ADF-N.

It is concluded that the nutritive value of maize residues was improved by thermo-ammoniation. Supplementation of ammoniated residues with fish-meal led to an increased efficiency of utilization. The improvement in DM digestibility due to ammoniation seemed to be influenced by the initial digestibility of the untreated residues. More research is needed to quantitatively relate the effect of ammoniation to the initial IVDMD of maize residues produced under varying conditions. Such data are needed for an economic evaluation of thermo-ammoniation. The eventual economical justification for thermo-ammoniation will depend on the cost of thermo-ammoniated residues compared to alternative roughages with the same feeding value or to the cost of concentrate required to supply the same improvement in nutritive value. During severe droughts when good quality roughage and concentrates are scarce, ammoniation of stored maize residues may also be of strategic importance.

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Prediction of the chemical composition and *in vitro* dry matter digestibility of a number of forages by near infrared reflectance spectroscopy

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The chemical composition and *in vitro* dry matter digestibility of a number of forages, namely lucerne (*Medicago sativa*), Italian rye grass (*Lolium multiflorum*), triticale (*Triticale hexaploide*), oats (*Avena sativa*), tall fescue (*Festuca arundinacea*), babala (*Pennisetum typhoides*), forage sorghum (*Sorghum bicolor sudanense*), weeping lovegrass (*Eragrostis curvula*), Smuts finger (*Digitaria eriantha*) and maize (*Zea mays*) residues, were predicted by a Neotec model 51A near infrared reflectance spectrophotometer. The r^2 values (where r is the simple coefficient of correlation) between laboratory determined and near infrared reflectance spectroscopy (NIRS) predicted values for the different forages ranged between 0.92—0.96 for crude protein (CP), 0.65—0.97 for *in vitro* dry matter digestibility (IVDMD), 0.75—80.95 for acid detergent fibre (ADF) and between 0.34—0.87 for neutral detergent fibre (NDF). Standard errors for NIRS prediction of the chemical components and IVDMD of the different forages ranged between 0.57—1.78% for CP, 1.37—3.82% for IVDMD, 1.11—2.17% for ADF and 1.90—4.47% for NDF.