Nutritive value of selected and non-selected (untreated or thermo-ammoniated) fractions of maize residues

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The nutritive value of maize residues, presented in three forms to growing Simmentaler steers (250 ± 31 kg), was evaluated by means of a growth and digestion study. The three forms of maize residues evaluated were: (i) selected material which implied free choice selection of approximately 33% of the residues presented (Treatment 1), (ii) material remaining after selection, which was milled (Treatment 2) and (iii) material remaining after selection which was thermo-ammoniated and milled (Treatment 3). Residues were supplemented with crude protein (CP) and phosphorus. Steers selected material with an *in vitro dry* matter digestibility (IVDMD) of 67,9 and 71,2%, leaving non-selected remains with an IVDMD of 51,8 and 51,5% during growth and digestion trials, respectively. The IVDMD values for ammoniated remains during growth and digestion trials were 59,7 and 59,2% respectively. These IVDMD values were determined for maize residue fractions without supplementation. Steers fed in Treatment 1 showed a mean mass increase of 0,65 ± 0,19 kg/d compared to 0,37 ± 0,10 kg/d ($P < 0,05$) for steers in Treatment 2. Mean dry matter (DM) intake for steers in Treatments 1 and 2 was 2,67 and 2,08% of body mass, respectively. Steers fed on ammoniated remains plus oilcake as protein supplement (Treatment 3) showed a mean mass increase of 0,67 ± 0,21 kg/d, which was higher ($P < 0,05$) than that of steers in Treatment 2. DM intake was 2,06% of body mass. Apparent DM digestibility for selected residues plus a CP supplement (Treatment 1) was 69,2 ± 3,0%.

Die voedingswaarde van mielie-oesreste wat in drie vorme aan groeiende Simmentaler-ossies (250 ± 31 kg) gevoer is, is deur middel van 'n groei- en verteringstudie ge-evalueer. Die drie vorme van mielie-oesreste was: (i) geselekteerde materiaal wat die vrye seleksie van ongeveer 33% van die reste wat aangebied was, behels het (Behandeling 1), (ii) nie-geselekteerde materiaal wat oorgebly het na seleksie, in gemaalde vorm (Behandeling 2), en (iii) nie-geselekteerde materiaal wat oorgebly het na seleksie, termies ge-ammonifiseerd en gemaal (Behandeling 3). Die reste is met ruproteïen en fosfor aangevul. Ossies in Behandeling 1 het restemateriaal met 'n droëmateriaal *in vitro* verteerbaarheid (DMIVV) van 67,9 en 71,2% geselekteer en nie-geselekteerde oorskietmateriaal met 'n DMIVV van 51,8 en 51,5% agtergelaat tydens die groei- en verteringstudies, onderskeidelik. Die DMIVV van die ge-ammonifiseerde oorskietmateriaal was 59,7 en 59,2% tydens groei- en verteringsfases respektiewelik. Die DMIVV waardes was slegs dié van die reste-fraksies sonder aanvulling. Ossies in Behandeling 1 het 'n gemiddelde massatoename van 0,65 ± 0,19 kg/d getoon in vergelyking met 0,37 ± 0,10 kg/d ($P < 0,05$) vir ossies in Behandeling 2. Die gemiddelde droëmateriaal(DM)-inname vir ossies van Behandelings 1 en 2 was respektiewelik 2,67 en 2,08%. Ossies wat op ge-ammonifiseerde oorskietreste met oliekoek as proteïenaanvulling (Behandeling 3) gevoer is, het 'n gemiddelde massatoename van 0,67 ± 0,21 kg/d getoon, wat hoër ($P < 0,05$) was as dié van ossies in Behandeling 2. Die DM-inname was 2,06%. Die skynbare DM-verteerbaarheid van geselekteerde reste, aangevul met ruproteïen (Behandeling 1), was 69,2 ± 3,0%.

Keywords: Ammoniation, chemical composition, digestibility, maize residues, nutritive value, selection.

The *in vitro* dry matter digestibility (IVDMD) of the various parts of the ripe maize plant is highly variable (Leask & Daynard, 1973; Henning & Steyn, 1984; Snyman, 1985; Schoonraad *et al.*, 1987). Mean values for IVDMD of the stems, cobs, plant leaves and husks of ripe frosted maize plants, sampled from 22 different locations in the Highveld Region, were found to be 49, 53, 55 and 66%, respectively (Snyman, 1985). These values suggest that leaves and husks, which together comprised 45% of the total plant residue, may have a higher available energy content and, therefore, a higher nutritive value than the rest of the plant residue. These parts were shown to be preferrentially selected in a grazing system (Lamm & Ward, 1981), as they would be when fed in cribs. The nutritive value of maize residues being harvested under South African conditions and utilized on a selective basis from cribs, as well as of the non-selected remains, has not been evaluated previously.

It was shown (Henning & Steyn, 1984) that treatment with sodium hydroxide improved IVDMD of cobs and stems more than that of husks and plant leaves, which suggested that the less preferable fraction should react more favourably to chemical treatment. This contention is supported by a statement of Owen & Kategile (1984) that chemical treatment of cobs and stems only should be a better economical proposition than treatment of entire maize residues. An improvement of 85% in digestible energy intake when whole maize residues were ammoniated and milled (Morris & Mowat, 1980), indicated that a large improvement could be expected from the ammoniation and milling of the less preferable or non-selected fraction. This may be of great significance during droughts and other circumstances of feed shortages when stored maize residues is the only source of roughage available. The nutritive value of such treated remains, however, is currently unknown.

The purpose of this investigation was to evaluate the nutritive value of (i) selected maize plant residues, (ii) milled non-selected remains, and (iii) non-selected remains ammoniated and milled.

Thirty-three 12-month-old Simmentaler steers, with a mean body mass of 250 ± 31 kg, were stratified according to body mass and allocated to three treatments (11 steers per treatment). This was done at the end of the winter. During the five months preceeding the trial, steers grazed on winter veld at close to maintenance level. Steers in Treatment 1 were fed maize plant residues obtained from ripe, frosted maize plants (DM = 93%), harvested *c.* 100 mm above the ground by a combine harvester (Slattery). Grain yield was *c.* 4 t/ha. The total amount needed was harvested within a few days and baled. Residues were supplied unmilled as obtained from the harvester in quantities of approximately three times the daily voluntary intake. This was done to assure free selection of *c.* one third of the plant residues. The non-selected remains were removed each morning from the cribs. One half was hammermilled through a 12-mm screen and fed on an *ad libitum* basis to the second group of steers (Treatment 2). The other half was thermo-ammoniated (3% NH_3 with no re-circulation, 85°C, 20 h), hammermilled (12-mm screen) and similarly fed to the third group of steers (Treatment 3). Selection of specific plant parts in the last two treatments was eliminated by the milling process. Steers in each treatment were fed as a group in a kraal. and all residues were supplied in cribs. In the pre-experimental period, all steers were fed on Treatment 1 in order to collect sufficient non-selected residues for Treatments 2 and 3, including a certain amount of reserve material. Steers were then weighed after being withheld from food and water overnight and allocated to the three treatments as described above. The steers were then adapted to the different diets for four weeks, whereafter all three treatments were started simultaneously. Non-selected remains which became available during the experiment were suitably treated and included in Treatments 2 and 3. Treatments 1 and 2 each lasted for 70 days and Treatment 3 for two periods of 28 days each.

Crude protein (CP) supplements were provided during the growth trial to ensure CP concentrations of *c.* 12%. Treatments 1 and 2 were supplemented with a high protein concentrate (HPC) (35% non-protein nitrogen, 6,25% urea, 3,6% phosphorus) containing 60% CP. Treatment 3 was supplemented with natural protein in the form of soybean oilcake during the first 28-day period only. CP supplementation for Treatment 1 was achieved by feeding the HPC mixed with salt (sodiumchloride, feeding grade). By doing this, intake of the required amount of HPC (0,96 kg/steer/d) was spread over a 12—24 h period. For Treatments 2 and 3 (first 28 days) the required amounts of protein supplements (0,67 and 0,50 kg/steer/d respectively) were mixed with the milled residues. Residues were replenished each morning to such an extent that no accumulation of feed in the cribs took place but that feed was still available at all times. Treatment 3 additionally received a salt-dicalciumphosphate lick and Treatment 2 a salt lick only. Phosphorus was supplied by the HPC supplement in the cases of Diets 1 and 2.

Body mass was determined fortnightly after the steers had been withheld from food and water overnight. The growth study was followed by a digestion and nitrogen balance study over 10 days for Treatments 1 and 3. The study was performed with the same animals and was carried out in metabolism crates. A period of three days was allowed for adaptation under the new circumstances. Protein supplementation for Treatment 1 was the same as that for the growth trial, except that it was supplied on an individual basis. Treatment 3 received a salt–dicalciumphosphate lick (1:1) but no protein supplement. This was done in order to determine the CP digestibility of ammoniated residues *per se*.

Samples of the maize residues (before supplementation) of the different treatments were collected weekly during the growth trial. During the digestion trial, samples of the maize residues, faeces and urine were taken daily from each steer after total mass and volume of faeces and urine respectively, had been determined. Samples from each steer were pooled and mixed at the end of the digestion period. Faeces were dried at 105°C while urine was preserved with sulphuric acid and stored at 5°C. The following chemical analyses were performed on the forage samples: nitrogen (Clare & Stevenson, 1964), acid detergent insoluble nitrogen (ADF-N) (Goering *et al.*, 1972), phosphorus (Basson, 1974), acid detergent fibre (ADF) (Van Soest, 1963), neutral detergent fibre (NDF) (Van Soest & Wine, 1967) and IVDMD (Tilley & Terry, 1963 as adapted by Engels & Van der Merwe, 1967). Nitrogen was also determined on samples of faeces, urine and the HPC–60 lick.

Table 1 Chemical composition and IVDMD of the different maize residue fractions (without supplementation) during the growth and digestibility trials

Measurement (Mean ± *SD*)	Maize residue fractions			
	Presented	Selected[a]	Remains	Ammoniated remains[b]
IVDMD (g / 100 g DM)				
Growth trial	57,1 ± 0,0	67,9	51,8 ± 1,6	59,7 ± 2,0
Digestion trial	58,6 ± 1,4	71,2	51,5 ± 1,4	59,2 ± 0,8
Crude protein (g / 100 g DM)				
Growth trial	3,8 ± 0,3	3,2	4,1 ± 0,3	10,8 ± 1,6
Digestion trial	3,9 ± 0,5	2,0	5,0 ± 0,4	9,1 ± 0,2
ADF-N (g / 100 g N)	26,9	–	25,2	32,5
Phosphorus (g / 100 g DM)				
Digestion trial	0,08 ± 0,01	0,08	0,08 ± 0,02	0,08 ± 0,01
ADF (g / 100 g DM)				
Digestion trial	50,1 ± 1,3	50,2	50,0 ± 1,1	51,9 ± 0,8
NDF (g / 100 g DM)				
Digestion trial	84,9 ± 0,6	88,8	82,7 ± 0,9	81,0 ± 0,8

[a] Values calculated.

[b] Mean IVDMD values during periods 0—28 days, 28—56 days and 56—70 days of the growth trial were 57,6, 60,8 and 61,2% respectively. Mean CP values during periods 0—28 days, 28—56 days and 56—70 days of the growth trial were 10,8, 11,8 and 9,4% respectively.

Treatments were statistically compared in a completely randomized design, using Anova. Standard deviations (*SD*) were calculated for the mean values.

The chemical composition and IVDMD of the different fractions (without supplementation) of maize residues during both growth and digestion trials are shown in Table 1. Steers selected plant material that was higher in IVDMD than that presented. As a result, the non-selected remains contained a lower IVDMD than the material presented. Crude protein concentration of selected material, however, was lower than that of the material offered, leaving behind remains with a higher CP concentration. Mean values for ADF-N, phosphorus and ADF contents of selected material and non-selected remains seemed to be the same as those presented. The NDF content was higher for selected material. These results suggest that steers selected for plant material containing not only the higher IVDMD but also the higher cell wall content. According to visual observations, consumed forage consisted mainly of husks and plant leaves, which normally make up 36—45% of total plant residues (Leask & Daynard, 1973; Henning & Steyn, 1984; Snyman, 1985; Schoonraad *et al.*, 1987). The relatively high IVDMD and NDF content of husks, as given by these workers, partly explain the present results. Thermo-ammoniation of the non-selected remains (Table 1) increased IVDMD and CP content. The increase in CP content, however, included a corresponding increase in ADF-N content which predicts a lower percentage of available nitrogen (Goering *et al.*, 1972).

The mass changes and DM intake of steers subjected to the different treatments are shown in Table 2. Steers in Treatment 1 showed a higher mass increase when compared to steers in Treatment 2. Steers in Treatment 1 also showed a higher mean DM intake when compared with those in Treatment 2. These results suggest that the nutritive value of Treatment 1 was higher than those of the other treatments, which is in agreement with the higher IVDMD found for selected residues. It can be predicted from these and IVDMD results that selected residues also will have a higher nutritive value than the maize residues presented (unselected).

The results in Table 2 indicate a higher mass increase for steers in Treatment 3, supplemented with oilcake during the first 28 days, than for steers in Treatment 2 over this same period. When steers in Treatment 3 were fed ammoniated residues without soybean oilcake supplementation during the succeeding 28 days, their mass increase did not differ from that of steers in Treatment 2 fed during the corresponding period. These results show a positive response when thermo-ammoniated residues with an IVDMD of 58% and a CP content of 10,8% were supplemented with soybean oilcake. A mass decrease was measured for steers fed on ammoniated residues (Treatment 3) without protein (oilcake) supplementation during days 56—70. This could not be explained to the DM intake and IVDMD, which remained almost the same. It, however, may be connected to the lower CP concentration (8,5%) found for the last batch of ammoniated residues fed during the latter half of the 63—70 day period.

Dry-matter intake, apparent DM digestibility and nitrogen balance of steers fed in Treatment 1 and Treatment 3 (without protein supplementation) are shown in Table 3. The apparent DM digestibility of the diet fed in Treatment 1 was 69,2%, which compared well with IVDMD values of 67,9 and 71,2% found for maize residues selected during the growth and digestion trials, respectively. This clearly indicates that steers selected material with a higher digestibility. A positive

Table 2 Mass changes and DM intake by steers fed on [1]Treatments 1, 2 and 3 during the growth trial

Measurement (Mean ± *SD*)	Maize residue treatments: [2]Treatment 1 (Selected + HPC)	[3]Treatment 2 (Remains + HPC)	[4]Treatment 3 (Ammoniated remains) + oilcake	[4]Treatment 3 (Ammoniated remains) − oilcake	[5]LSD ($P < 0,05$)
Mass increase (kg/d)					
0—28 days	0,65 ± 0,29[a]	0,37 ± 0,13[b]	0,67 ± 0,21[a]		0,153
28—56 days	0,61 ± 0,19[a]	0,45 ± 0,11[b]		0,33 ± 0,12[b]	0,153
56—70 days				−0,41 ± 0,37	
0—70 days	0,65 ± 0,19[a]	0,37 ± 0,10[b]			0,155
DM intake (% of body mass)					
0—28 days	2,81	1,77	2,06		
28—56 days	2,62	2,26		2,14	
56—70 days				2,18	
0—70 days	2,67	2,08			

[1] Crude protein contents for Treatments 1 and 2 were 11,4 and 11,6%, respectively. Crude protein content for Treatment 3 with oilcake (0—28 days) was 13,8% and without oilcake 11,8% (28—56 days) and 9,4% (56—70 days).
[2] Mean DM intake for selected residues and HPC were 5,71 and 0,96 kg/steer/d, respectively.
[3] Mean DM intake for non-selected remains and HPC were 4,31 and 0,67 kg/steer/d, respectively.
[4] Mean DM intake for ammoniated remains and oilcake were 4,18 and 0,50 kg/steer/d, respectively.
[5] Values with common superscripts in the same row did not differ significantly ($P < 0,05$).

Table 3 DM intake, apparent DM digestibility and nitrogen retention by steers fed on selected maize residues and ammoniated remains

Measurement (Mean ± *SD*)	Maize residue treatments: Treatment 1 (Selected + HPC)	Treatment 3 (Ammoniated remains[1])
DM intake (% of body mass)	2,25 ± 0,08	1,87 ± 0,18
Faeces excreted (kg DM/d)	2,04 ± 0,23	2,45 ± 0,20
Apparent DM digestibility (%)	69,2 ± 3,0	53,2 ± 1,4
Nitrogen intake	117,0 ± 7,2	75,8 ± 7,5
Nitrogen excretion:		
Faeces (g/d)	33,2 ± 3,2	43,9 ± 3,1
Urine (g/d)	33,8 ± 17,5	32,8 ± 14,6
(% of nitrogen absorbed)	52,7	102,3
Apparent nitrogen digestibility (%)	71,6 ± 2,9	41,9 ± 3,6
Nitrogen retention (g/d)	50,0 ± 19,8	−1,9 ± 16,0
(% of nitrogen absorbed)	59,6	—

[1] Without oilcake supplementation.

nitrogen retention of 50,0 g/d was calculated from the data obtained from steers in Treatment 1. This was largely due to an apparent nitrogen digestibility of 71,6% and a retention of the nitrogen absorbed from the gastrointestinal tract of 59,6%.

The apparent DM digestibility of the diet fed in Treatment 3 was found to be 53,2%, six percentage units lower than the IVDMD of ammoniated residues. Apparent nitrogen digestibility was only 41,9%, while the nitrogen retention was negative. Although IVDMD was the same, CP content (9,1%) of ammoniated residues was lower than that used during the growth trial (10,8%). These figures may be related to the mass loss during the last period (days 56—70) of the growth trial. More research, using a suitable control, would be required to confirm these figures. These results, however, are supported by the increased ADF-N content measured for ammoniated remains (Table 1) and for low-quality forages (Brown *et al.*, 1987).

The results of this investigation showed that a higher nutritive value was obtained when maize residues were selectively utilized. The remains, after the selection of maize residues with an initial IVDMD of 57%, contained sufficient nutrients, with the exception of crude protein and phosphorus, to provide at least maintenance needs of yearling steers. Thermo-ammoniation of the non-selected fraction (remains) increased IVDMD and CP content. When supplemented with soybean oilcake, a growth rate similar to that recorded on selected material was found.

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