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 isonitrogenous 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 ($P \leqslant 0.05$) 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 ($P \leqslant 0.05$) 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.

Die chemiese samestelling en droëmateriaal *in vitro* verteerbaarheid van 'n aantal voergewasse, naamlik lusern (*Medicago sativa*), Italiaanse raaigras (*Lolium multiflorum*), korog (*Triticale hexaploide*), hawer (*Avena sativa*), lang swenkgras (*Festuca arundinacea*), babala (*Pennisetum typhoides*), voersorghum (*Sorghum bicolor sudanense*), oulandsgras (*Eragrostis curvula*), Smutsvinger (*Digitaria eriantha*) en mielie(*Zea mays*)-oesreste is met 'n Neotec model 51A naby-infrarooirefleksiespektrofotometer voorspel. Die r^2 waardes (waar r die enkelvoudige korrelasiekoëffisiënt is) tussen laboratorium-gemete en naby-infrarooirefleksiespektroskopie (NIRS)-voorspelde waardes vir die ruproteïen (RP), droëmateriaal *in vitro* verteerbaarheid (DMIVV), suurbestande vesel (SBV) en neutraalbestande vesel (NBV) vir die verskillende voersoorte het respektiewelik tussen 0.92—0.96, 0.65—0.97, 0.75—0.95 en 0.34—0.87 gevarieer. Die standaardfout vir die NIRS-voorspelling van die verskillende chemiese komponente en DMIVV het gevarieer met 0.57—1.78% vir RP, 1.37—3.82% vir DMIVV, 1.11—2.17% vir SBV en 1.90— 4.47% vir NBV.

Keywords: Chemical composition, forage, *in virto* dry matter digestibility, near infrared reflectance spectroscopy.

Optimal feeding is essential for economical animal production. The most suitable ration for reaching a specific producion goal can be formulated only if the exact nutrient quality of the various diet components is known. The forage component may vary greatly in chemical composition and nutritive value, depending on factors such as the kind and amount of fertilizer used, climate, growth stage, etc. (Murray, 1986). Although of great value, the estimation of forage nutrient quality from published tables (NRC, 1988; Allen, 1989; Preston, 1989) is inaccurate and may lead to over- or underfeeding with respect to production needs. Laboratory analysis, on the other hand, is laborious and time consuming so that results often emerge late at the farmer with only retrospective value as management aid. Near infrared reflectance spectroscopy (NIRS), however, is a technique with great potential for a rapid and accurate evaluation of forage nutrient quality (Norris *et al.*, 1976; Shenk *et al.*, 1976). A paucity of NIRS calibrations with respect to the nutrient quality of subtropical forages worldwide, however, exists, while only few calibrations have been developed for South African grown forages in general (Eckard *et al.*, 1988; Stoltz, 1990; Snyman & Joubert, 1992). For most reliable and accurate NIRS prediction of forage nutrient quality, samples used for calibration should be representative of those which are going to be tested. In this investigation, NIRS calibrations were developed for assessing the nutrient qualities of a number of temperate and subtropical forages grown for ruminant feeding in the Highveld.

Forage samples used for NIRS calibration/validation were: lucerne, Italian rye grass, triticale, oats, tall fescue, babala, forage sorghum, weeping lovegrass, Smuts finger and maize residues. Forages were grown on the experimental farm at Potchefstroom and sampled by hand cutting approximately 3--5 cm above the ground. Samples were taken at various growth stages since the early vegetative to seed stage during 1987 and 1988. The samples were de-activated against enzymatic and microbial degradation by previous heating in a microwave oven (3 min at maximum irradiation) within 15 min after sampling, followed by drying in a force draught oven at 65°C for 48 h. Maize residues were sampled on different farms located in the Highveld Region during the period 1980—1986 and hamermilled through a 6-mm sieve. The dry samples of all forages were ground through a smooth surface 1-mm stainless steel sieve in a Fritsch laboratory cutting mill (pulverisette 15). Nutrient quality of each forage sample was laboratory analysed for crude protein (CP), *in vitro* dry matter digestibility (IVDMD), acid detergent fibre (ADF) and neutral detergent fibre (NDF) as referred to by Snyman (1991). For NIRS prediction of the chemical composition and IVDMD, a Neotec model 51A near infrared reflectance spectrophotometer containing a tilting filter system which allows reading at 768 selectable wavelength points and interfaced with an IBM personal computer, was used. The system was issued with software for NIRS calibration/validation and sample reading developed by Shenk & Westerhaus (1984). Reflectance data were expressed as log $(1/R)$ (R = reflectance). Samples of the different forages were randomly divided into a calibration sample set (Table 1) for equation development and a prediction sample set (Table 2) for equation validation. Calibration of the instrument was performed by obtaining the NIR spectra for samples in the calibration sample set. Wavelengths at which log $(1/R)$ fluctuated most with changing values of specific forage qualities (CP, IVDMD, ADF, NDF) were identified by the calibration program by means of multiple linear regression. The wavelengths were incorporated into a prediction equation for each forage quality. The equations were validated by simple linear regression of the laboratory determined vs. the NIRS predicted values of the prediction sample set. Optimum statistics for calibration included a low

Table 1 Mean, *SD* and range values for the different nutrient qualities of forage species in the calibration sample set

	Nutrient quality															
	CP (g/100 g DM)				IVDMD (g/100 g DM)				ADF (g/100 g DM)				NDF (g/100 g DM)			
Forage specie	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range
Lucerne	80	24.6	5.2	11.9—38.2	78	70.1	5.7	52.2—81.5	78	30.6	6.5	17.1—46.3	79	47.7	6.8	32.7—78.7
Italian rye grass	64	24.5	6.5	9.5—39.4	63	76.4	5.5	56.5—84.6	65	27.4	6.5	15.6—41.4	64	52.0	7.6	35.3—65.9
Triticale + oats + tall fescue	35	24.2	3.9	12.0—31.5	35	78.4	3.7	64.0—85.0	35	26.3	3.9	20.0—38.0	36	45.9	6.8	37.9—69.6
Babala + forage sorghum	92	13.8	4.3	7.2—27.6	93	60.3	9.3	31.8—72.6	92	39.4	4.9	31.4—54.6	78	68.1	3.6	60.2—76.7
Weeping lovegrass	80	11.5	2.9	6.2—19.6	79	53.2	6.3	38.4—71.6	82	42.4	2.7	32.4—47.1	81	84.0	2.9	70.3—92.9
Smuts finger	38	12.2	4.4	4.2—20.5	39	56.5	13.4	35.0—73.2	27	42.6	6.8	32.1—56.4	27	75.8	4.3	67.0—82.4
Maize residues	101	5.9	2.2	2.4—12.9	102	58.3	6.6	40.4—73.8	69	45.1	3.8	36.5—55.7	69	78.4	4.0	68.4—89.6

Table 2 Mean, *SD* and range values for the different nutrient qualities of forage species in the prediction sample set

	Nutrient quality															
	CP (g/100 g DM)				IVDMD (g/100 g DM)				ADF (g/100 g DM)				NDF (g/100 g DM)			
Forage specie	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range	*n*	Mean	*SD*	Range
Lucerne	38	23.3	5.3	13.7—34.5	35	69.2	6.6	51.4—79.9	36	31.9	7.2	21.3—56.6	36	48.5	7.1	35.1—67.5
Italian rye grass	33	23.3	7.2	7.8—39.4	32	76.5	6.4	59.2—84.9	31	28.6	6.5	16.5—41.4	30	52.5	7.6	35.3—64.2
Triticale + oats + tall fescue	18	23.8	4.6	14.2—29.4	15	79.2	3.7	70.7—83.0	16	25.6	4.1	21.0—33.3	18	43.3	5.4	36.2—54.2
Babala + forage sorghum	92	13.8	4.4	7.5—24.6	93	60.8	9.2	34.0—74.0	92	39.7	4.9	32.3—52.6	52	68.7	3.3	62.4—76.6
Weeping lovegrass	39	11.6	3.1	6.3—20.1	35	52.6	7.3	39.4—70.2	40	42.6	2.6	36.8—47.7	41	83.9	2.6	75.0—88.2
Smuts finger	20	11.8	4.8	5.1—21.7	19	57.1	12.6	36.0—72.5	13	43.1	6.7	34.0—54.7	13	76.0	4.6	70.1—84.4
Maize residues	97	5.6	2.0	2.0—9.8	96	58.0	6.5	40.0—69.1	66	45.7	3.9	37.2—58.6	68	79.0	4.4	61.9—87.2

Table 3 NIRS calibration statistics and wavelength properties related to equation development for the different nutrient qualities of forage species

	Nutrient quality											
	CP			IVDMD			ADF			NDF		
Forage specie	R^2	SEC[b] (%)	Wavelengths (nm)	R^2	SEC (%)	Wavelengths (nm)	R^2	SEC (%)	Wavelengths (nm)	R^2	SEC (%)	Wavelengths (nm)
Lucerne	0.94	1.32	2220 2360	0.93	1.57	2220 2320 2360 1760	0.91	2.00	2320 2360 1675	0.85	2.62	2360 2220 1676
Italian rye grass	0.93	1.72	2360 2220	0.88	1.87	1760 2360 1636 2100 2360	0.94	1.61	2220 2360 2360	0.78	3.58	2360 2220 1760 2320
Triticale + oats + tall fescue	0.90	1.24	1760 2220	0.83	1.52	1760 1760 2320 2320	0.84	1.54	2100 1760 2360	0.36	5.43	2220 2320 2360 1760
Babala + forage sorghum[a]	0.92	1.24	2220 1658 1760	0.95	2.17	1760 2320 1672 1760	0.91	1.45	2360 1760 2320 1675	0.62	2.24	1760 2100 2360
Weeping lovegrass	0.95	0.66	2320 2220	0.89	2.08	1676 1760 2220 2320 2100	0.73	1.41	2320 1760 2360	0.41	2.20	2100 2360
Smuts finger	0.97	0.79	2220 2220	0.97	2.19	1760 2320 1661 2220	0.94	1.69	1623 2360	0.76	2.12	2360 1678
Maize residues	0.91	0.66	2220 2220	0.74	3.40	1760 2360 2100 1760	0.77	1.85	1760 2360	0.82	1.69	2360 2360 2220 2360

[a] R^2 and SEC values for the water soluble carbohydrate content were respectively 0.89 and 1.05 ($n = 75$).

[b] Standard error of calibration.

Table 4 NIRS prediction statistics for the different nutrient qualities of forage species

	Nutrient quality															
	CP				IVDMD				ADF				NDF			
Forage specie	r^2	SEP(C)[b] (%)	Slope	Bias	r^2	SEP(C) (%)	Slope	Bias	r^2	SEP(C) (%)	Slope	Bias	r^2	SEP(C) (%)	Slope	Bias
Lucerne	0.94	1.30	1.01	−0.19	0.91	1.97	1.04	−0.08	0.95	1.66	0.97	0.61	0.87	2.61	0.95	0.08
Italian rye grass	0.94	1.78	0.98	−0.32	0.93	1.73	0.91	−0.37	0.94	1.54	1.00	0.01	0.79	3.92	0.94	−0.39
Triticale + oats + tall fescue	0.92	1.36	0.93	0.53	0.90	1.37	1.26	0.37	0.92	1.22	0.90	−0.64	0.50	4.47	0.63	−3.39
Babala + forage sorghum[a]	0.93	1.20	0.99	0.04	0.95	2.04	1.01	0.31	0.90	1.57	1.01	0.05	0.61	2.17	0.75	0.61
Weeping lovegrass	0.95	0.67	0.99	0.16	0.90	2.39	1.08	0.05	0.81	1.11	0.96	0.10	0.34	2.10	0.87	−0.01
Smuts finger	0.96	1.00	1.00	−0.04	0.97	2.44	1.03	0.12	0.91	2.17	0.95	−0.07	0.85	1.90	1.15	−0.20
Maize residues	0.92	0.57	0.93	0.13	0.65	3.82	0.67	−0.07	0.75	1.95	0.85	0.31	0.78	2.08	0.89	−0.16

[a] R^2, SEP, slope and bias values for the water soluble carbohydrate content were respectively 0.92, 0.98, 0.95, and −0.09 ($n = 38$).

[b] Standard error of prediction, corrected for bias.

standard error (SEC) and a large R^2 value. Optimum statistics for validation included a low standard error of prediction (SEP), a large r^2, a bias value close to zero and a slope value close to 1.0. The calculation of all statistics was performed by the NIRS calibration/validation program (Shenk & Westerhaus, 1984).

The mean, standard deviation (*SD*) and range values for the different nutrient qualities of forages in the calibration and prediction sample sets respectively, are given in Tables 1 and 2. The data indicate that values in the calibration sample set compared well with corresponding values in the prediction sample set. The data also indicate that the nutrient quality values for most forages were largely representative of those that could be expected in practice. Calibration statistics and wavelength properties for equation development are shown in Table 3. Prediction statistics to validate the developed equations are shown in Table 4. The calibration statistics as shown in Table 3 indicate useful calibrations for nutrient qualities of most of the forages. The R^2 and SEC values for the NDF of most forages, however, compared relatively poor with those of the other nutrient qualities. Two wavelength terms were needed for best equation development of CP while mostly more than two were needed for IVDMD, ADF and NDF. This agrees with results of Shenk *et al.* (1979) and Holechek *et al.* (1982). The prediction statistics in Table 4 indicate reliable prediction of nutrient quality for most forages. The r^2 values were generally high (>0.9) while SEP values were relatively low. This is supported by slope values close to 1 and bias values close to zero in most cases. The exceptions, however, were the poor prediction statistics for the NDF content of most forages and the IVDMD of maize residues. The usefulness of applying NIRS in these cases will largely depend on the accuracy that is required. The results in Table 4 furthermore indicate reliable predictions for certain combinations of forages.

In conclusion it can be said that useful NIRS calibrations were developed with respect to the chemical composition and IVDMD of a number of forages most used for ruminant feeding in the Highveld. This will allow quick and reliable prediction of forage nutrient quality, enabling monitoring of the nutrient quality of dietary forage components on a continuous basis.

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