The chemical composition and *in vitro* dry matter digestibility of untreated and ammoniated crop residues

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Abstract

The chemical composition and *in vitro* dry matter digestibility (IVDMD) of untreated and ammoniated crop residues, sampled at various sites in the North West Province of South Africa, were investigated. The mean IVDMD of maize residues obtained by means of a whole plant maize harvester was found to be relatively high (IVDMD = 55.6±7.0%) while the crude protein (CP) (46±10 g/kg dry matter (DM)) and phosphorus (P) (1.2±0.5 g/kg DM) concentrations were below the maintenance requirement for dry gestating beef cows. The neutral detergent fibre (NDF) concentration was 837±39 g/kg DM. Maize residues obtained by means of a cob harvester tended to be of a somewhat higher nutritional quality (IVDMD = 58.3±7.7%; CP = 64±19 g/kg DM; NDF = 817±42 g/kg DM; P = 1.2±0.6 g/kg DM). Grain-sorghum residues, like maize residues, were low in CP (61±11 g/kg DM) and P (1.9±0.5 g/kg DM) concentration, but also had a low IVDMD (37.7±9.3%). Ammoniation (35 g ammonia/kg DM, 320 g moisture/kg DM) increased the IVDMD (17.6 and 18.1 percentage units) and CP concentration (89 and 93 g/kg DM) and decreased the NDF concentration (207 and 148 g/kg DM) of maize- and grain- sorghum residues, respectively. The IVDMD (71.5±6.2%) and NDF concentration (380±73 g/kg DM) of sunflower-cob residues reflected a high-energy value while the CP (93±26 g/kg DM) and P (2.2±0.7 g/kg DM) concentration met the needs for dry gestating beef cows. Ammoniation increased the CP concentration (186±21 g/kg DM), but had no effect on the IVDMD and NDF concentration of sunflower-cob residues.

Keywords: Maize residues, grain-sorghum residues, sunflower-cob residues, ammoniation, chemical composition, *in vitro* dry matter digestibility
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Introduction

Crop residues in the summer rainfall area of South Africa fulfill a strategic role in the fodder flow program of ruminants. Livestock farmers, particularly in the eastern part of this region, rely heavily on crop residues during winter when roughage is scarce and the nutritive value of natural veld has declined to a very low level. Analyses of veld grass samples from this region in winter showed a mean *in vitro* dry matter digestibility (IVDMD) of 33.9±7.4% (Snyman, L.D., unpublished results).

Residues from the harvesting of maize, grain-sorghum and sunflower-cobs are the most abundant crop residues in this summer-rainfall area. However, insufficient information regarding their nutritive value results in inefficient utilization and thus sub-optimal animal production. Data on the nutritive value of specifically dry frosted grain-sorghum and sunflower-cob residues, the forms most abundantly available to cattle, are scarce. The nutritive value of maize residues produced when a cob harvester has been used is also unknown. This form of maize residues, as well as whole plant maize residues, is of great value when fed in milled form during times of feed scarcity. Furthermore, scientific data regarding improvement of the feeding value of these crop residues by means of ammoniation (Sundstol & Owen, 1984) seem to be scarce.

Although information from abroad is available on the effect of ammoniation on the nutritive value of low quality roughages, it cannot necessarily be applied to crop residues produced and harvested under quite different conditions in South Africa. Therefore, the nutritive value of maize-, grain-sorghum- and sunflower-cob residues, and the improvement of their feeding value by means of ammoniation were investigated in terms of chemical composition and IVDMD.

Materials and Methods

Maize- (n = 44), grain-sorghum- (n = 12) and sunflower-cob residues (n = 20) were sampled on various sites in the North West Province of South Africa. Harvesting took place after the plants had ripened and frosted to death. Twenty-three of the maize residue samples were obtained after cob-harvesting (harvesting the cobs [ears] and some of the upper parts of the plant, mostly leaves) while the rest of the samples (21) were obtained after harvesting the whole plant. Grain-sorghum residues (whole plant) and sunflower-cob residues were sampled by hand.

The various samples were hammer milled through a 6 mm sieve. Representative samples were taken for chemical analysis and for ammoniation. Ammoniation was performed by mixing 50 g residue material with 6.6 ml ammonia solution (25%) added to 15 ml water. This resulted in a mixture containing 35 g ammonia/kg dry matter (DM) and 320 g moisture/kg DM. The mixture was sealed in a fruit jar and kept at room temperature (20 ºC). The jars were opened six months later and the contents dried at 105 ºC for 24 h. Untreated and ammoniated samples were milled through a 1 mm sieve and analyzed for phosphorus (P), crude protein (CP), IVDMD and neutral detergent fibre (NDF) according to methods previously referred to (Snyman, 1991). The DM content was determined by drying at 105 °C for 24 h.

Data were analyzed using the statistical program, GenStat (1993). The Student's t-test was used to test whether the paired differences between untreated and ammoniated plant residues were significantly different from zero.

Results and Discussion

The chemical composition and IVDMD of the various crop residues and the effect of ammoniation are shown in Table 1. Whole plant maize residues had a mean CP concentration of 46 g/kg DM and a mean IVDMD of 55.6%. It is expected that this IVDMD, which is in agreement with a previous finding (Snyman, 1985), will provide in the maintenance energy need of ruminants if supplemented with nitrogen (Snyman, 1991). This value is high when compared with *in vitro* organic matter digestibility values reported for wheat straw (38.9%), oats straw (39.5%) and barley straw (32.9%) (Brand *et al*., 1989). The mean NDF concentration (837 g/kg DM) was high, indicating a high cell wall content that may limit DM intake (Van Soest, 1965). The data in Table 1, furthermore, show that maize residues obtained by means of a cob harvester tended to have a higher nutritional quality than whole plant maize residues (CP = 64 g/kg DM, IVDMD = 58.3%, NDF = 817 g/kg DM). This might be ascribed to an increased ratio in the cob harvested residues of plant- and cob leaves (husks), having a more favourable chemical composition and IVDMD to other plant parts (Henning & Steyn, 1984; Snyman, 1985; Schoonraad *et al*., 1987). Both the CP and P concentrations of maize residues were below the maintenance requirement of dry gestating beef cows (NRC, 1984). The large variation of the IVDMD among individual samples is of practical significance and has to be taken into account when utilizing maize residues.

Grain-sorghum residues, like residues from small grain crops (Brand *et al*., 1989), had a low IVDMD (37.7%) and a high NDF concentration (750 g/kg DM). The IVDMD of frosted grain-sorghum residues was previously found to be appreciably lower (*c*. 10 percentage units) than the IVDMD of green unfrosted grain-sorghum residues (Snyman & Joubert, 1995). Grain-sorghum residues also had a sub-maintenance level of CP (61 g/kg DM), while the P concentration (1.9 g/kg DM) was found to be close to the maintenance level for dry gestating beef cows (NRC, 1984).

The high mean IVDMD (71.5%) of sunflower-cob residues was superior to the IVDMD of good quality maize silage (Snyman *et al*., 1990). The mean CP (93 g/kg DM) and P (2.2 g/kg DM) concentrations of sunflower-cob residues were also relatively high and seemed to meet the requirements set for dry gestating beef cows (NRC, 1984). The mean NDF concentration (380 g/kg DM) was low, predicting a high DM intake (Van Soest, 1965). Sunflower-cob residues seem to be a forage with a high energy value that might be suitable for use in production diets.

Table 1 Mean (± s.d.) values for some chemical constituents and IVDMD of untreated and ammoniated crop residues

Chemical constituent	Treatment	Whole plant maize residues (n = 21)	Cob harvester maize residues (n = 23)	Grain-sorghum residues (n = 12)	Sunflower-cob residues (n = 20)
Crude protein (g/kg DM)	Untreated	46±10[a]	64±19[a]	61±11[a]	93±26[a]
	Ammoniated	131±18[b]	158±26[b]	154±18[b]	186±21[b]
In vitro DM digestibility (g/100 g DM)	Untreated	55.6±7.0[a]	58.3±7.7[a]	37.7±9.3[a]	71.5±6.2[a]
	Ammoniated	73.2±5.3[b]	75.9±5.2[b]	55.8±8.5[b]	73.0±6.5[a]
Neutral detergent fibre (g/kg DM)	Untreated	837±39[a]	817±42[a]	750±48[a]	380±73[a]
	Ammoniated	642±29[b]	599±46[b]	602±32[b]	384±46[a]
Phosphorus (g/kg DM)	Untreated	1.2±0.5[a]	1.2±0.6[a]	1.9±0.5[a]	2.2±0.7[a]
	Ammoniated	1.0±0.4[a]	1.4±0.7[a]	2.0±0.5[a]	2.0±0.5[a]

[a,b]Mean (± s.d.) values in the same column for a specific chemical constituent having different alphabetical superscripts differ ($P < 0.05$)

The mean CP concentration of the ammoniated crop residues was approximately 90 g/kg DM higher ($P < 0.05$) than the corresponding untreated residues. These values met the CP needs of growing calves (NRC, 1984). However, the quality of CP may still be a limiting factor (Seed *et al*., 1985; Snyman *et al*., 1993). The mean IVDMD values of ammoniated maize- and grain-sorghum residues was 17 - 18 percentage units higher ($P < 0.05$) than the corresponding values of the untreated residues. The increase in IVDMD is in accordance with a concomitant decrease ($P < 0.05$) in the NDF concentration of 206 g/kg DM (mean value for whole plant and cop harvester maize residues) and 148 g/kg DM for ammoniated maize- and grain-sorghum residues, respectively. The IVDMD of ammoniated sunflower-cob residues, however, did not differ ($P < 0.05$) from that of the untreated residues. In agreement with this, the NDF concentration of sunflower-cob residues also did not change with ammoniation.

Seed *et al*. (1985) reported a similar increase in the CP concentration of ammoniated maize residues, but a smaller response for the IVDMD. This might be ascribed to differences in conditions of ammoniation such as time, temperature, etc. (Sundstol & Coxworth, 1984). The sealed containers used in this study might have favoured conditions for the reactions to take place by preventing ammonia losses.

The response in the IVDMD (% units increase) of maize residues to ammoniation is related in Fig. 1 to the corresponding IVDMD values before treatment (grouped into a 10 percentage range unit for values between 35 and 45 and five percentage range units for values between 45 and 70). The figure indicates a decrease in response with increasing IVDMD values, suggesting that ammoniation of maize residues with a high IVDMD will not be as effective as for maize residues with a low IVDMD. This is in agreement with results reported in other studies (Sundstol & Coxworth, 1984).

The response in the IVDMD (% units increase) of grain-sorghum residues due to ammoniation is related in Fig. 2 to the corresponding initial IVDMD values before treatment (grouped into 10 percentage range units). The same tendency found for maize residues, namely a decrease in ammoniation response with increasing initial IVDMD values, was also found for grain-sorghum residues.

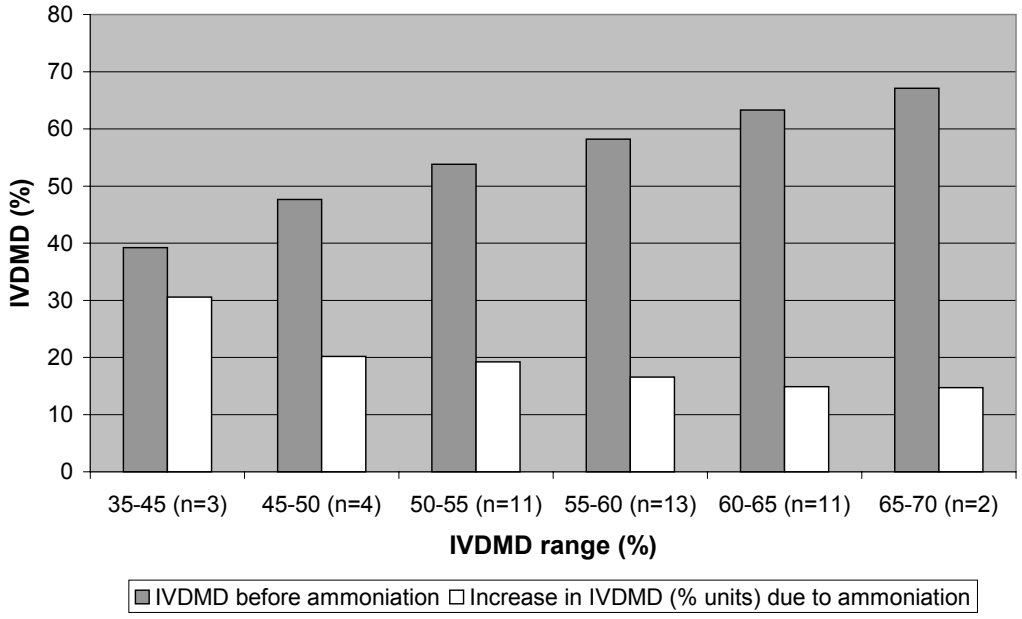

Figure 1 Relationship between the initial *in vitro* dry matter digestibility (IVDMD) of maize residues and the increase in IVDMD due to ammoniation

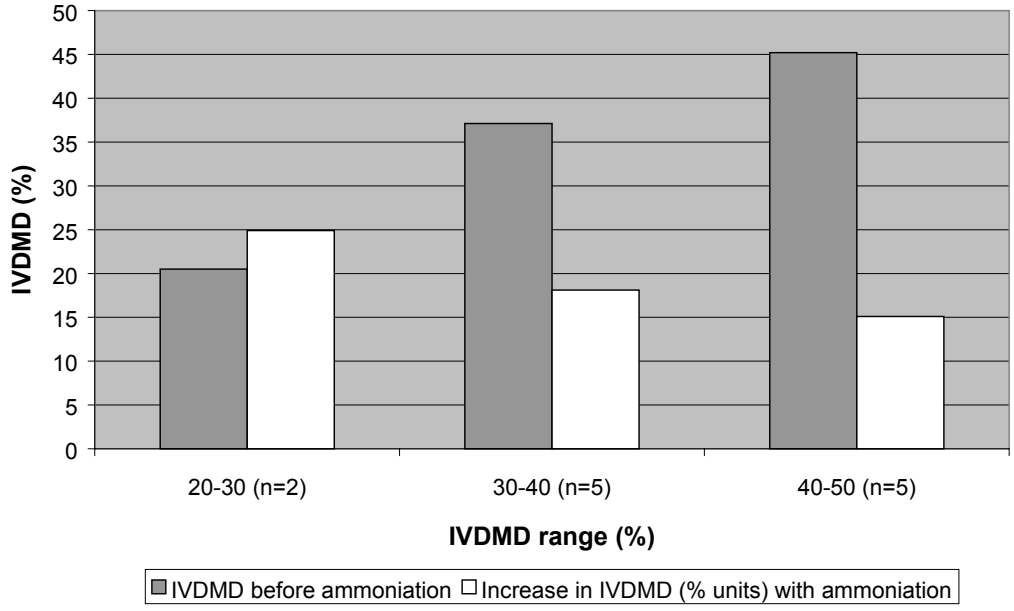

Figure 2 Relationship between the initial *in vitro* dry matter digestibility (IVDMD) of grain-sorghum residues and the increase in IVDMD due to ammoniation

Conclusion

The results of this investigation indicate sub-maintenance levels for the CP and P concentrations of maize- and grain-sorghum residues, while the concentrations of these nutrients in sunflower-cob residues meet the maintenance requirements for dry gestating beef cows. The mean IVDMD of maize residues predicts that it may supply in at least the maintenance energy needs of ruminants, while the mean IVDMD of grain-sorghum residues points to a sub-maintenance energy level. The high IVDMD and low NDF value of sunflower-cob residues, suggest that it could be used in diets intended for production. The nutritional quality of both grain-sorghum- and maize residues was markedly improved by means of ammoniation to produce forages with maintenance and production potential, respectively. The ammoniation response at the various IVDMD values may help in predicting the economical justification for ammoniation.

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