

**Tropical and
Subtropical
Agroecosystems**

ENSILING CHARACTERISTICS AND FEEDING VALUE OF SILAGE MADE FROM BROWSE TREE LEGUME-MAIZE MIXTURES

[CARACTERÍSTICAS Y VALOR NUTRITIVO DE ENSILAJE DE MEZCLA DE ÁRBOLES FORRAJERO-MAÍZ]

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SUMMARY

Male wether Sabi sheep (50 ± 2 kg body weight) were used in a nitrogen (N) balance trial to evaluate the feeding value of browse tree legume-maize mixed silages. Treatment diets as follows: a) 2 kg of *Acacia boliviana*-maize (ABM) mixed silage b) 2 kg of *Leucaena leucocephala*-maize (LLM) mixed silage and c) 1.5 kg sheep dairy concentrate (SDC). The chemical composition, before and after ensiling, and fermentation characteristics of maize silage, ABM and LLM mixed silages was also determined. The CP (CP) content of ABM was higher (P<0.05) than LLM and maize silage before and after ensiling. Ensiling decreased CP and neutral detergent fibre (NDF) of the three silages, while the modified acid detergent fibre (MADF) increased. The MADF of the mixed silages was similar but higher (P<0.05) than the maize silage. Maize silage had the highest lactic acid and the lowest acetic acid concentration. Silages had similar isobutyric, n-butyric, isovaleric acid and n-valeric acid concentrations. Maize silage had a lower pH. The ammonia-nitrogen content was highest in ABM and lowest in maize silage. The dry (DM) and organic matter (OM) intakes were similar in SDC and LLM and lower (P<0.05) in the ABM diet. Apparent digestibility of DM and OM was similar in all silages, while NDF, acid detergent fibre (ADF) and N digestibility was lower (P<0.05) in ABM. N intake, N balance and microbial protein yield were similar for SDC and LLM and lower (P<0.05) in ABM. Ensiling maize with tree forage legumes maintains good silage quality. ABM silage at 50:50 (w/w) between *A. boliviana* and maize was not suitable for ruminant feeding.

Key words: *Acacia boliviana*, *Leucaena leucocephala*, silage, maize, nitrogen balance, apparent digestibility, pH, ammonia-nitrogen.

RESUMEN

Machos ovinos Sabi (50 ± 2 kg peso vivo) fueron empleados en una prueba de balance de nitrógeno (N) para evaluar el valor nutricio de ensilajes de árbol forrajero-maíz. Los tratamientos fueron: a) 2 kg ensilaje *Acacia boliviana*-maíz (ABM), b) 2 kg ensilaje *Leucaena leucocephala*-maíz (LLM) y, c) 1.5 kg concentrado comercial para ovino (SDC). La composición química antes y después del ensilaje, así como las características de fermentación del ensilaje de maíz, ABM y LLM fueron evaluadas. El contenido de proteína cruda (PC) de ABM fue mayor (P<0.05) antes y después del ensilaje. El ensilaje redujo la PC y fibra detergente neutro (NDF) e incrementó la fibra ácido detergente (MADF). MADF en los ensilajes mixtos fue similar pero mayor (P<0.05) que en el ensilaje de maíz. El ensilaje de maíz tuvo el mayor contenido de ácido láctico y menor ácido acético. Los ácidos isobutírico, butírico, isovalérico y valérico fueron similares en los tres ensilajes. El ensilaje de maíz tuvo el menor pH. El contenido de N-amoniaco fue mayor en ABM. Los consumos de material seco (MS) y materia orgánica (MO) fueron similares en SDC y LLM y menores (P<0.05) en ABM. La digestibilidad aparente de MS y MO fue similar, mientras que la digestibilidad de NDF, ADF y N fue menor (P<0.05) en ABM. El consumo y balance de N, así como la producción de proteína microbiana fueron similares para SDC y LLM y menores (P<0.05) en ABM. Se concluye que el ensilaje de maíz con leguminosas forrajeras resulta de buena calidad. El ensilaje ABM 50:50 de *A. boliviana* y maíz no resulta adecuado.

Palabras clave: *Acacia boliviana*, *Leucaena leucocephala*, ensilaje, maíz, balance de N, digestibilidad aparente, pH, N-amoniaco.

INTRODUCTION

In the tropics, particularly the semi-arid tropical regions, where the major constraint to livestock production is the shortage of fodder during the dry season, conservation through ensilage of forage produced during the rainy season is likely to be the practice adopted by most small holder livestock owners, particularly those in dairy or beef production. However, tropical grasses and legumes are not natural ensilage material, largely because at cutting, they have a low content of water soluble carbohydrates, which are essential to successful ensilage (McDonald *et al.*, 1991; Havilah and Kaiser, 1992; de Figueredo and Marais, 1994). This results in them having a higher buffering capacity and the protein being susceptible to proteolysis (Woolford, 1984; McDonald *et al.*, 1991). Thus, limited attempts have been reported on grass-forage tree mixture silage (Cárdenas *et al.*, 2003). However, the levels of fermentable carbohydrates can be improved through various treatments including mixing legumes with cereal crops.

In the high rainfall subtropical areas of Zimbabwe and South Africa maize is the preferred cereal crop for silage, producing high yields (14.7 tonnes dry matter (DM) per hectare) and high energy (10.2 MJ/kg DM) (Titterton, 1997). Maize can also be easily ensiled. However, its major shortcoming is its low CP (CP content, which ranges from 70 g/kg DM to 80 g/kg DM (McDonald *et al.*, 1987; Church, 1991; Topps and Oliver, 1993). The protein content of the maize silage can be increased by adding a protein rich legume. The CP content increased from 77 g/kg DM in pure maize silage to a range of 93 g/kg DM to 153 g/kg DM with a legume incorporated (Titterton and Maasdorp, 1997). Maasdorp and Titterton (1999) successfully ensiled, on a fresh mass ratio of 50:50 (w/w), the leaf material of four forage tree legumes with maize with improvement of CP content to 140 g/kg DM, 155 g/kg DM, 172 g/kg DM and 187 g/kg DM in maize/*Calliandra calothyrsus*, maize/*Gliricidia sepium*, maize/*Leucaena leucocephala* and maize/*Acacia boliviana* silages respectively. Titterton and Maasdorp (1997) found that the fermentation quality was acceptable (pH of the range 3.7 to 4.5; ammonia (NH₃): nitrogen (N) ratio of less than 1: 2) when sole crops of maize and legumes were mixed at harvesting 50:50 by volume for ensilage.

This study further evaluated two tree forage legumes *L. leucocephala* and *A. boliviana* which had the higher CP content when ensiled with maize in the study carried out by Maasdorp and Titterton (1999). The fermentation characteristics of the maize-legume silages were examined and the mixed silages were also fed to sheep in a nitrogen balance trial.

MATERIALS AND METHODS

Forage production and silage preparation and sampling

Long season white maize (SC 709) was grown on 0.3 hectares at the University of Zimbabwe Farm Teaching and Research Unit, at a density of 60 000 plants per hectare. Compound D (8 %N; 6 %P; 6 %K; 6.5 %S) was applied as a basal fertilizer dressing at the rate of 350 kg per hectare, while ammonium nitrate was applied as top dressing fertilizer at the rate of 250 kg per hectare. Hand weeding was done twice during the growing period. *L. leucocephala* cv. Cunningham and *A. boliviana* (CPI 40175), were also harvested from the same farm, after a whole season's growth. The *L. leucocephala* and *A. boliviana* forage contained a significant fraction of flowers and brown pods at the time they were harvested and ensiled. The browse legume trees were established on red clay loam soils.

Maize and browse legumes (*L. leucocephala* and *A. boliviana*) were harvested in the morning. Whole maize plant was harvested at the medium dough stage with a forage chopper, while browse were harvested by hand cutting the branches followed by stripping off all leaves, flowers and pods under the shade. To achieve a 50:50 (w/w) ratio of maize and browse, 500 g of each browse legume and 500 g of chopped maize were put into thin polythene bags (38 x 86 cm) after mixing thoroughly. Chopped maize (1 kg) was also ensiled on its own into similar bags. After filling the bags, they were compressed by hand pressing. The open end of each bag was rolled up to seal the bag and tied with a string to prevent air from entering into the bag (silo). About 550 bags each of maize and browse legume-maize mixture were stored in a room on a concrete floor. For each fresh forage type and silage type 20 bags were sampled (400 g each) in duplicate, soon after packing and 60 days after ensiling respectively. These 40 samples were mixed and sub-sampled (2 sub-samples each) and stored at 4 °C. The samples were used to determine chemical composition of the silage types before and after ensiling as well as the fermentation characteristics.

Nitrogen balance trial

Three male wether Sabi sheep of mean body weight 50 ± 2 kg were used in a nitrogen balance trial. Each animal was placed in a metabolism crate that allowed separate total faecal and urine collection. The experiment was conducted in a 3 x 3 Latin square cross over design of 12 days per period. Each experimental period consisted of a seven-day dietary adjustment phase followed by a five-day collection phase.

Three treatment diets were fed as follows: a) 2 kg of *A. boliviana*-maize (ABM) mixed silage b) 2 kg of *L. leucocephala*-maize (LLM) mixed silage and c) 1.5 kg sheep dairy concentrate (SDC). The sheep dairy concentrate contained 166g per kg CP, and 13 MJ ME/kg DM. A basal diet of 2 kg maize silage was offered to each animal at 08:00 hours followed by one of the treatment diets at 14:00 hours. The CP contents of ABM, LLM and maize silage fed were 148, 132 and 69 g/kg DM with the corresponding energy contents of 10, 9 and 10 MJ ME/kg DM respectively. Fresh water was available at all times from nipple drinkers.

Measurements and collections

During the collection period the amount of faeces excreted daily was recorded and a 100g sample stored. Total urine produced daily was collected in plastic buckets with 25 ml of 10 % (v/v) sulphuric acid as a preservative. A 10% aliquot was removed each day and stored at 4°C. A second sample of urine, 10 % of the daily output, was collected daily from each animal and diluted five times with distilled water and stored frozen for use in the analysis of total purine derivatives. Daily samples of individual animal's feed refusals, faeces and urine were pooled over the five day collection period, thoroughly mixed and sub-samples taken.

Chemical analysis

Samples were dried at 60 °C for 48 hours to determine DM while ash content was determined by igniting the samples in a muffle furnace at 600 °C for 4 hours. CP and ammonia-nitrogen were determined using the Kjeldahl method according to standard procedures (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Goering and Van Soest (1970), while the modified acid detergent fibre (MADF) was determined using methods in MAFF (1986). Metabolisable energy (ME) was determined by the method of Linn and Martin (1991). The pH of the silages was determined using an Orion digital pH meter 611 on the aqueous extract of silage. Volatile fatty acids were determined by Pye Unicam GCV gas liquid chromatography. Condensed tannins were determined using butanol-HCl method according to Porter et al. (1986). Urinary allantoin was analyzed by the method described by Borchers (1977). Allantoin excretion was used to calculate microbial protein yield according to Chen and Gomes (1992).

Statistical analysis

The chemical composition and fermentation characteristics of herbage before and after ensiling were analyzed using a one-way analysis of variance in a completely randomized design using the General

Linear Model procedure of the SAS Institute (1994). The model used was:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} was the chemical composition or fermentation characteristics of herbage, μ the overall mean, T_i the treatment effect and e_{ij} residual error.

The DM intake (DMI), OM intake, apparent dietary digestibility, nitrogen balance and microbial protein yield (MPY) were subjected to analysis of variance for Latin square cross over design using the General Linear Model procedure of the SAS Institute (1994). The model used was:

$$Y_{ijkl} = \mu + T_i + A_j + P_k + e_{ijkl}$$

Where:

Y_{ijkl} was the observed variable, μ the overall mean, T_i the treatment effect, A_j the animal effect, P_k the period effect and e_{ijkl} the residual error.

Multiple comparisons of means were done using the Tukey's studentized range test of SAS (1994).

RESULTS

Silage chemical composition

The chemical composition of maize silage, ABM and LLM before and after ensiling are given in Table 1. The CP content of ABM was higher ($P < 0.05$) than maize and LLM before and after ensiling. Ensiling decreased the CP and NDF of the three silages, while the MADF increased. The MADF of the mixed silages was similar but higher ($P < 0.05$) than the maize silage before and after ensiling. The condensed tannin content of the mixed silages was different ($P > 0.05$).

Silage fermentation characteristics

The fermentation characteristics of maize silage, ABM and LLM are given in Table 2. Maize silage had the highest lactic acid concentration, although it was not significantly different ($P > 0.05$) from ABM, and the lowest acetic acid concentration. The three silages had similar isobutyric, n-butyric, isovaleric acid and n-valeric acid concentrations. Maize silage had a lower pH than that of the mixed silages. The ammonia-nitrogen content was highest in ABM and lowest in maize silage.

Table 1. Chemical composition (g/kg DM) of maize silage, *Acacia boliviana* – maize (ABM) and *Leucaena leucocephala*- maize (LLM) mixed silages before and after ensiling

Constituent	Before ensiling			After ensiling			SED
	MS	ABM	LLM	MS	ABM	LLM	
CP	76 ^a	156 ^b	141 ^c	69 ^d	148 ^e	132 ^f	2.42
MADF	280 ^a	285 ^a	288 ^a	311 ^b	337 ^c	348 ^c	4.42
NDF	516 ^a	521 ^a	523 ^a	499 ^b	491 ^b	477 ^c	4.01
ADF	363 ^a	361 ^a	369 ^a	350 ^a	346 ^a	353 ^a	8.41
Ash	60 ^a	62 ^a	62 ^a	58 ^a	56 ^a	57 ^a	2.29
ME (MJ/kg DM)	11 ^a	10 ^a	10 ^a	10 ^a	10 ^a	9 ^a	0.08
CT (g/kg DM)	nd	nd	nd	Nd	12 ^b	14 ^a	0.07

^{a,b,c,d,e,f}Means with different superscripts in a row differ significantly at $P < 0.05$, SED = standard error of the differences, nd = not determined, ME = metabolisable energy, CT = condensed tannins, MS = maize silage, ABM = *Acacia boliviana* – maize, LLM = *Leucaena leucocephala*- maize, DM = dry matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, MADF = modified acid detergent fibre.

Table 2. Fermentation characteristics of maize silage (MS), *A. boliviana*-maize (ABM) and *L. leucocephala*-maize (LLM) mixed silages.

Constituent (g/kg DM)	MS	ABM	LLM	SED
Lactic acid	63.21 ^a	44.23 ^{ab}	27.96 ^b	7.66
Acetic acid	18.16 ^a	41.44 ^b	46.21 ^b	0.75
Propionic acid	1.08 ^a	1.41 ^a	2.16 ^a	0.24
Isobutyric acid	2.75 ^a	4.28 ^a	5.80 ^a	0.38
n-butyric acid	1.03 ^a	1.87 ^a	2.32 ^a	0.25
Isovaleric acid	0.25 ^a	0.37 ^a	0.41 ^a	0.12
n-valeric acid	0.48 ^a	1.19 ^a	0.80 ^a	0.097
pH	3.71 ^a	4.19 ^b	4.66 ^b	0.059
NH ₃ -N (g/kg total nitrogen)	32.31 ^a	71.95 ^b	64.99 ^c	0.31

^{a,b,c}Means with different superscripts in a row differ significantly at $P < 0.05$, SED = standard error of the differences, MS = maize silage, ABM = *Acacia boliviana*-maize, LLM = *Leucaena leucocephala*-maize, NH₃-N = ammonia-nitrogen

Nitrogen balance trial

The intake, apparent digestibility, nitrogen balance and microbial protein yield of sheep fed three treatment diets of SDC, ABM and LLM is given in Table 3. The dry and organic matter intakes were similar in SDC and LLM and lower ($P < 0.05$) in the ABM diet. Apparent digestibility of DM and organic matter was similar in all the three treatment diets, while NDF, ADF and N digestibility was lower ($P < 0.05$) in ABM. The nitrogen intake, nitrogen balance and microbial protein yield was similar for SDC and LLM and lower ($P < 0.05$) in ABM.

DISCUSSION

Silage chemical composition

The CP content of maize silage (69 g/kg DM) obtained from this study was below the range of 90 g/kg DM to 140 g/kg DM reported by McDonald *et al.* (1987) but was similar to the values reported by Topps and Oliver

(1993) and Titterton and Maasdorp (1997) of 77 g/kg DM and 75 g/kg DM, respectively. The variations could be attributed to differences in maize varieties as well as the stage at which the crop was harvested. The CP content of ABM (148 g/kg DM) and LLM (132 g/kg DM) were above the proposed minimum required for growth (113 g/kg DM) in ruminant animals (ARC, 1984).

The NDF content of the silages ranged from 477 g/kg DM to 499 g/kg DM and was lower than the acceptable levels of 600 g/kg DM to 650 g/kg DM, while the ADF content ranged from 346 g/kg DM to 353 g/kg DM and was within the maximum acceptable and desirable levels of 350 g/kg DM and 380 g/kg DM (Mahanna, 1994). The ash contents of between 56 g/kg DM to 58 g/kg DM were below the range of 80 g/kg DM to 100 g/kg DM reported by Topps and Oliver (1993). The ME content of maize silage (10 MJ/kg DM) obtained from this study was similar to that reported by Titterton and Maasdorp (1997). The ME content of all silages was above the minimum

acceptable level of 8 MJ/kg DM required for maintenance (Ekern and Vik-Mo, 1979). The levels of condensed tannins for the mixed browse legume-maize mixed silages of 12 g/kg DM and 14 g/kg DM were less than the range of 20-40 g/kg DM (Waghorn, 1990).

Silage fermentation characteristics

Ensiling resulted in reduced NDF content in the silages as reported by Keady et al. (1996). This could be attributed to the hydrolysis of hemicellulose to monosaccharides that provide additional sugars for lactic acid production during fermentation (Muck, 1989). Ensiling had no effect on silage ADF as reported by Synman et al. (1987). This could be attributed to the fact that ADF does not provide sugars for lactic acid production during fermentation. The absence of a significant effect of ensiling on ash content is contrary to findings in other studies (Keady and Murphy, 1997; Keady et al., 1996) and could be attributed to no loss of silage effluent in the bags used in this study as opposed to loss in silage effluent in bunkers normally used during fermentation. An increase in MADF content during ensiling is similar to the finding of Keady and O'Kiely (1996) and could be attributed to hydrolysis of the soluble fraction of the fibre contents during fermentation. A decrease in CP content during ensiling is contrary to that reported by

Keady and Murphy (1998). This reduction in CP could be attributed to the degradation of protein during ensiling which resulted in higher non-protein nitrogen in the silage than in the herbage before ensiling (Whittenbury et al., 1967).

All the silage types were well preserved as indicated by low pH (<5), low ammonia N (<9 % total N) and low concentration of butyric acid (<5.5 g/kg DM). The low pH together with elevated levels of lactic acid showed that the herbage contained sufficient amounts of soluble carbohydrates to effectively preserve the silage. An increase in silage pH following mixing maize with browse legumes observed in this study was in agreement with that reported by Titterton and Maasdoorp (1997). This can be attributed to the high buffering capacity and low DM content of the legumes, which favours the production of other organic acids other than lactic acid (Woolford, 1984; McDonald et al., 1991). Maize silage had the lowest ammonia N concentration as compared to the mixed browse legumes. This could be attributed to the fact that maize contained low CP content that resulted in low ammonia N production. High concentration of ammonia N indicates excessive protein degradation during fermentation, which is undesirable, as it indicates poor preservation of the material (Haigh, 1987).

Table 3. Intake, apparent digestibility, nitrogen balance and microbial protein yield of sheep fed sheep dairy concentrate (SDC), *Acacia boliviana*-maize (ABM) and *Leucaena leucocephala*-maize (LLM) mixed silages.

	SDC	ABM	LLM	SED
Intake (g/d)				
Dry matter	785 ^a	585 ^b	759 ^a	39.5
Organic matter	724 ^a	562 ^b	699 ^a	40.2
Apparent digestibility (g/kg)				
Dry matter	575 ^a	535 ^a	565 ^a	16.5
Organic matter	575 ^a	532 ^a	567 ^a	22.3
Neutral detergent fibre	534 ^a	375 ^b	506 ^a	32.7
Acid detergent fibre	519 ^a	312 ^b	497 ^a	27.6
Nitrogen	604 ^a	407 ^b	585 ^a	18.5
Nitrogen intake (g/day)	18.8 ^a	12.7 ^b	17.6 ^a	0.65
Nitrogen excreted (g/day)				
Faecal nitrogen	4.2 ^b	8.5 ^a	5.0 ^b	0.54
Urinary nitrogen	9.0 ^a	4.9 ^b	8.4 ^a	0.77
Total nitrogen excreted	13.2 ^a	13.4 ^a	13.4 ^a	0.81
Nitrogen balance (g/day)	5.6 ^a	-0.7 ^b	4.2 ^a	0.90
Microbial protein yield (MN/kg DOMR)	12.7 ^a	8.5 ^b	11.2 ^a	0.04

^{a,b,c}Means with different superscripts in a row differ ($P < 0.05$), SED = standard error of the differences, MN = microbial nitrogen, DOMR = organic matter apparently digested in the rumen

Nitrogen balance trial

Both DM and organic matter intake was higher in LLM than in ABM. The low ABM intake can be attributed to the lower apparent digestibility due to the higher soluble polyphenolics and proanthocyanidins in *A. boliviana* as compared to *L. leucocephala* (Maasdorp, Muchenje and Titterton, 1999). Cattle fed the two forages consumed all the *L. leucocephala* but refused seven percent of the *A. boliviana* (Maasdorp *et al.* 1999).

The observed low digestibility of the fibre components (NDF and ADF) and nitrogen in the ABM diet was in agreement with that reported by Reed *et al.* (1985) and can be attributed to the presence of tannins in the silage. Protein and NDF degradability has been found to be negatively correlated with polyphenolics and proanthocyanidins content of browse (Rittner and Reed, 1992). Dzowela, Hove, Topps and Mafongoya (1995) reported a depressing effect of tannins in *A. boliviana* on DM degradation, while Norton (1994) showed that *L. leucocephala* had moderate protein degradability despite having substantial tannin content.

The high urinary nitrogen obtained from sheep given LLM silage implied that the condensed tannins-protein complexes formed in the rumen dissociated in the abomasums and intestines making the nitrogen available for digestion, absorption and metabolism, while the high faecal nitrogen obtained from ABM diet indicated that the condensed tannin-protein complexes formed in the rumen were stronger and passed undigested through the lower tract and were completely lost in faeces (Perez-Maldonado and Norton, 1996). Similar observations have been made by other researchers (Nastis and Malechek, 1981; Richards *et al.*, 1994; Reed, 1995). The negative nitrogen balance obtained from sheep given ABM silage indicates that protein requirements for maintenance were not met (NRC, 1985).

Reported yields of microbial nitrogen (MN) range from 14 to 49 g of MN /kg of organic matter apparently digested in the rumen (ARC, 1984). The low microbial protein yield obtained from this study could be attributed to low energy content of silage organic matter (Masama *et al.*, 1997), but is within the range previously found (Sebata *et al.*, 2005). In addition, silages have been shown to increase ruminal protozoa population whose activities reduce the efficiency of total microbial protein synthesis (Hanna Research Institute, 1982).

CONCLUSION

This study showed that ensiling maize with tree forage legumes maintains good silage quality. ABM silage intake was lower than LLM silage, following a similar

trend in which *A. boliviana* is less palatable than *L. leucocephala* foliage. This suggests that forage tree legumes exhibit similar attributes when ensiled and when feed without ensiling. There is need for further research on the effect of ensiling on polyphenolic and proanthocyanidin activities in browse species.

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REFERENCES

- AOAC (Association of Official Analytical Chemists). 1990. Official Methods of Analysis. 15th Edition. 2200 Wilson Boulevard, Arlington. Virginia 22201, USA.
- ARC (Agricultural Research Council). 1984. The Nutrient Requirements of Livestock. Commonwealth Agricultural Bureaux, Slough, England.
- Borchers, R. 1977. Allantoin determination. *Analytical Biochemistry*. 79: 612-613.
- Cárdenas Medina, J.V., Sandoval Castro, C.A., Solorio Sánchez, F.J. 2003. Composición química de ensilajes mixtos de gramíneas y especies arbóreas de Yucatán, México. *Técnica Pecuaria en México* 41: 283-294
- Chen, X.B. and Gomes, M.J., 1992. Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives. An overview of the technical details. International Feed Resource Unit, Rowett Research Institute, Aberdeen, Occasional Publication. 2-20.
- Church, D.C. 1991. *Livestock Feeds and Feeding*. 3rd Edition. Prentice-Hall. Incl. New Jersey, USA. 80-94.
- de Figuerido, M. and Marais, J.P. 1994. The effect of bacterial inoculants on Kikuyu silage quality. *Journal of Agricultural Science*. Cambridge. 122: 53-60.
- Dzowela, B.H., Hove, L., Topps, J.H. and Mafongoya, P.L. 1995. Nutritional and anti-nutritional characters and rumen degradability of DM and nitrogen for some multipurpose tree species with potential for agroforestry in

- Zimbabwe. Animal Feed Science Technology 55:207-214
- Ekern, A. and Vik-Mo, I. 1979. Conserved forage as feeds for dairy cows. In: Broster, W.H., Swan, H. (Eds). Feeding strategy for the high yielding cow. Grenada Publications, London.
- Goering, H.K. and Van Soest, P.J. 1970. Forage fibre analysis. Agricultural Handbook, No. 379. United States Department of Agriculture.
- Haigh, P.M. 1987. The effect of dry matter content and silage additives on the fermentation of grass on commercial farms. Grass Forage Science. 42:1-8.
- Hanna Research Institute. 1982. Report for studies relating to the production and utilization of milk. Bell and Bain Ltd, Glasgow. Pp. 27-34.
- Havilah, E.J. and Kaiser, A.G. 1992. Sorghums for silage: a review. Proceeding of the 2nd Australian Sorghum Conference. February 4th-6th, Gatton. 338-54.
- Keady, T.W.J. and Murphy, J.J. 1998. The effects of ensiling and supplementation with sucrose and fish meal on forage intake and milk production of lactating dairy cows. Animal Science. 66: 9-20.
- Keady, T.W.J. and Murphy, J.J. 1997. The effects of treating low dry matter herbage with a bacterial inoculant or formic acid on the intake and performance of lactating dairy cattle. Animal Science. 64: 25-36.
- Keady, T.W.J. and O'Kiely, P., 1996. An evaluation of the effects of nitrogen fertilization of grassland on silage fermentation, in-silo losses, effluent production and aerobic stability. Grass Forage Science. 51: 350-362.
- Keady, T.W.J., Murphy, J.J. and Harrington, D. 1996. The effects of ensiling on dry matter intake and milk production by lactating dairy cattle given forage as a sole feed. Grass Forage Science. 51: 131-141.
- Linn, J.G. and Martin, N.P. 1991. Forage quality analyses and interpretation. Veterinary Clinics North America Food Animal Practice. 7: 509-523.
- Maasdorp, B.V., Muchenje, V. and Titterton, M. 1999. Palatability and effect on dairy cow milk yield of dried fodder from the forage trees *Acacia boliviana*, *Calliandra calothyrsus* and *Leucaena leucocephala*. Animal Feed Science and Technology. 77:49-59
- Maasdorp, B.V. and Titterton, M. 1999. The use of planted trees for fodder. In Smith T. (Ed.) Proceeding of Workshop on Livestock Production Research in the Semi-Arid Tropics, held by Department for International Development. (DFID) Matopos, Zimbabwe. Feb. 1999.
- Mahanna, W. 1994. Proper management ensures high quality silage grains. Feedstuff 10: 12.
- Masama, E., Topps, J.H., Ngongoni, N.T. and Maasdorp, B., 1997. Effects of supplementation with foliage from tree legumes *Acacia angustissima*, *Cajanas cajan*, *Calliandra calothyrsus* and *Leucaena leucocephala* on intake, digestibility and nitrogen metabolism of sheep given maize stover *ad. lib.* Animal Feed Science Technology. 69: 233-240.
- McDonald, P., Henderson, A. R. and Hermon, S. J. E. 1991. The biochemistry of silage. A Wiley-Interscience Publication. New York.
- McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. 1987. Animal Nutrition. 4th Edition. Longman Group, UK Ltd. 1-7.
- MAFF, 1986. The Analysis of Agricultural Materials. HMSO, London, UK.
- Muck, R.E. 1989. Initial bacterial numbers on Lucerne prior to ensiling. Grass Forage Science. 44: 19-25.
- Nastis, A. S. and Malechek, J.C. 1981. Digestion and utilization of nutrients in oak browse by goats. Journal of Animal Science. 53: 283-290.
- NRC (National Research Council). 1985. Nutrient Requirements for domestic animals. Nutrient requirements for sheep. 6th Edition. Washington DC. NRC, National Academy Press.
- Norton, B.W. 1994. The nutritive value of tree legumes. In: Gutteridge, R.C., Shelton, H.M. (Eds), Forage tree legumes in tropical Agriculture. CAB International, Wallingford, pp. 177-191.
- Perez-Maldonado, R.A. and Norton, B.W. 1996. The effects of condensed tannins in *Desmodium*

- intortum* and *Calliandra calothyrsus* on protein and carbohydrate digestion in sheep and goats. *British Journal of Nutrition*. 76: 515-533.
- Porter, L.J., Hrstich, L.W. and Chan, B.C. 1986. The conversion of proanthocyanidins and prodelphinidins to cyanidins and delphinin. *Phytochemistry*. 25: 223-230.
- Reed, J.D. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. *Journal of Animal Science*. 73 (5): 1516-1528.
- Reed, J.D., Horvath, P.J., Allen, M.S. and Van Soest, P.J. 1985. Gravimetric determination of soluble phenolics including tannins from leaves by precipitation with trivalent ytterbium. *Journal of Science and Food Agriculture*. 36: 255-261.
- Richards, D.E., Brown, W.F., Ruegsegger, G. and Bates, D.E. 1994. Replacement value of tree legumes for concentrates in forage-based diets. II. Replacement value of *Leucaena leucocephala* and *Gliricidia sepium* for lactating goats. *Animal Feed Science and Technology*. 46: 52-65.
- Rittner, U. and Reed, J.D. 1992. Phenolics and in vitro degradability of protein and fibre in West African browse. *Journal of Science and Food Agriculture*. 58:21-28
- SAS (Statistical Analysis Systems) Institute inc., 1994. SAS Guide for personal computers. Cary, North Carolina, USA.
- Sebata, A., Ngongoni, N.T., Mupangwa, J.F., Nyakudya, I.W., Imbaryarwo-Chikosi, V.E. and Dube, J.S. 2005. Effects of supplementing native pasture hay with puncture vine (*Tribulus terrestris*) on the intake, weight change, nitrogen balance and excretion of purine derivatives of sheep. *Tropical and Subtropical Agroecosystems*. 5:123-128.
- Snyman, L.D., Irma, C. and Ross, A. G. 1987. Ensiling characteristics and feeding value of silage made from cattle waste and maize residues. *South African Journal of Animal Science*. 17: 49-53.
- Titterton, M. 1997. The feasibility of using forage sorghum in drought years for silage in Zimbabwe. In (Kirk R (Ed). *Proceedings of the Annual General Meeting on Forage production for dairying in Zimbabwe*, Grasslands Society of Zimbabwe. August, 1997.
- Titterton, M. and Maasdorp, B.V. 1997. Nutritional improvement of maize silage for dairying: Mixed crops silages from sole and intercropped legumes and a long season variety of maize. 2. Ensilage. *Animal Feed Science and Technology*. 69: 263-270.
- Topps, J.H. and Oliver, J. 1993. *Animal foods of Central Africa*. Zimbabwe Agricultural Journal Technical Handbook No. 2:135.
- Waghorn, G.C. 1990. Effect of condensed tannin on protein digestion and nutritive value of fresh herbage. *Proceeding of the Australian Society of Animal Production*. 18: 412-415.
- Whittenbury, R., McDonald, P. and Bryan-Jones, D.G. 1967. A short review of some biochemical and microbiological aspects of ensilage. *Journal of Science and Food Agriculture*. 18: 441-444.
- Woolford, M.K. 1984. *The Silage Fermentation*. Marcel Dekker, New York.

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