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Nutritive value of Acacia tree foliages growing in the Limpopo Province of South Africa

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Abstract

Acacia trees form the third largest woody plant family in southern Africa and are an important ecological component of the bushveld vegetation that is prevalent in the Limpopo Province of South Africa. The purpose of the study was to determine types and amounts of tannins and also to evaluate the nutritive value of tree foliages, *Acacia karroo, Acacia nilotica, Acacia tortilis, Acacia galpinii, Acacia sieberiana, Acacia hebeclada* and *Acacia rhemniana*, grown in the Limpopo Province and also to determine types and amounts of tannins occurring in them. Young leaves with petioles from seven tree foliages were collected from five different trees per species at the University of the North (now University of Limpopo) in April 2003, in a completely randomized design. Packed volume ranged from 1.50 mL/g for *A. karroo* to 3.00 mL/g for *A. hebeclada* whilst water retention ranged from 3.71 g/g for *A. galpinii* to 4.98 g/g for *A. sieberiana.* These results suggest that all the tree leaves have a high intake potential. All the Acacia species had crude protein levels above 100 g/kg dry matter (DM), ranging from 103 g/kg DM for *A. rhemniana* to 183 g/kg DM for *A. sieberiana.* Crude protein levels of this magnitude in a diet are adequate to support the maintenance requirements of cattle, sheep and goats at low to medium production levels. The Acacias contained medium to high levels of neutral and acid detergent fibres with ranges of 488 to 622 and 415 to 545 g/kg DM, respectively. *In vitro* DM and organic matter degradabilities varied from 345 to 534 and 254 to 474 g/kg DM, respectively. *Acacia hebeclada, A. sieberiana* and *A. galpinii* contained traces of total phenolics whilst *A. tortilis* contained approximately 90 g/kg DM of total phenolics and *A. karroo, A. nilotica* and *A. rhemniana* contained intermediate concentrations. Extract condensed tannin (CT) content ranged from 1.1 g/kg in *A. hebeclada* to 80.7 g/kg in *A. karroo.* At level above 50 g/kg, CT tends to negatively affect intake and digestibility in ruminants. Consequently, reduced intakes of *A. galpinii, A. karroo* and *A. tortilis* could be expected because they contained CT values above 50 g/kg. Only *A. nilotica* showed a sharp curve in the potassium iodate test, reflecting its considerable content of hydrolysable tannins (HT). All the other species had flat curves reflecting low levels of HT in them. The results showed that all the species except for *A. galpinii, A. karroo* and *A. tortilis* are of good nutritive value and have a potential for integration into livestock feeding systems in the Limpopo Province.

Keywords: Foliage, tannins, nutritive value, Acacia, packed volume, water retention
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Introduction

Inadequate amounts and low feed quality result in reduced livestock productivity in tropical countries. In the Limpopo Province of South Africa ruminant livestock productivity is very low especially during the dry season, when there is a shortage of protein. Acacia trees form the third largest woody plant family in southern Africa and are an important ecological component of the bushveld vegetation that is prevalent in the Limpopo Province. Because of their widespread distribution in the province, they offer a potentially suitable source of supplemental protein for ruminant livestock which would improve their intake and digestibility of native pasture. This should result in improved animal performance (Norton, 1994; Abdulrazak *et al*., 1996). Their use has been limited by the scarcity of information relating the amount and types of tannins they contain which would affect animal performance. The toxic or anti-nutritional effects tend to occur in times of stress when a very large proportion of the diet is tanniniferous. With a better understanding of their tannin properties and proper management, they could become invaluable sources of protein for strategic supplementation. The main objective of this study was to determine the nutritive value of Acacia tree foliages based on physical properties, chemical composition including tannin content and *in vitro* digestibility.

Materials and Methods

The experiment was conducted at the University of the North (now called University of Limpopo) in April 2002. Young leaves with petioles from the foliages of *Acacia karroo*, *Acacia nilotica*, *Acacia tortilis*, *Acacia galpinii*, *Acacia sieberiana*, *Acacia hebeclada* and *Acacia Rhemniana* were collected from five different trees per species. The experimental design was a completely randomised design. After collection, the young leaves were left to dry at room temperature in a well-ventilated laboratory until a constant dry weight was reached, and then stored in brown paper bags pending grinding. Dry herbage was ground to pass through a 1 mm screen for analysis of dry matter (DM), organic matter (OM), nitrogen (N) and detergent fibres. Samples for polyphenolic analysis were further ground to pass through a 0.2 mm screen.

Packed volume and water retention were determined using the methods described by Seoane *et al*. (1981). Forage samples were analysed for N concentration, using the Kjeldahl procedure (AOAC, 1984), and neutral (NDF) and acid detergent fibre (ADF) levels using the method of Van Soest (1983) as modified by Van Soest *et al*. (1991). *In vitro* enzymatic degradability was determined by the method described by Aufrere & Michalet-Doreau (1988). Total phenolics were determined using Folin–Ciocalteau methods and expressed as tannic acid equivalent (g/kg DM) (Waterman & Mole, 1994). Condensed tannin (CT) was determined using the Butanol–HCl method and expressed as leucocyanidin equivalent (g/kg DM) (Porter *et al*., 1986) and hydrolysable tannin (HT) levels were determined using the potassium iodate method (Willis & Allen, 1998). Radial diffusion was determined using the method described by Hagerman (1987).

Analyses of variance were used to test for effect of species on chemical composition, physical characteristics and *in vitro* enzymatic degradability, using the general linear model procedure of the statistical analysis systems (SAS, 1998), for completely randomized design. If significant P values occurred, separation of means was done using the probability of difference (pdiff) facility of SAS. Correlation was used to measure the degree of association between variables.

Results

There were significant species effects ($P < 0.05$) on packed volume and water retention (Table 1). The difference on packed volume between the species with the highest *vs.* the lowest concentration (*A. hebeclada vs. A. karroo)* was 100% and in water retention *ca.* 34.2%, (*A. sieberiana vs. A. galpinii*) (Table 1).

Table 1 Mean packed volume (mL/g) and water retention (g/g) of seven Acacia species grown in the Limpopo Province

Species	Packed volume (mL/g)	Water retention (g/g)
A. karroo	1.50^{d}	3.76^{cd}
A. nilotica	2.87^{a}	3.84^{bcd}
A. tortilis	2.75^{ab}	3.89^{bcd}
A. galpinii	2.50^{bc}	3.71^{d}
A. sieberiana	2.87^{a}	4.98^{a}
A. hebeclada	3.00^{a}	4.31^{b}
A. rhemniana	2.37^{c}	4.21^{bc}
s.e.	0.082	0.146

$^{a, b, c, d}$ Column means with common superscripts do not differ ($P > 0.05$); n = 5 per species

Crude protein (CP) levels differed by *ca.* 44% between the species with the highest (*A. sieberiana*) and that with the lowest (*A. rhemniana*) concentration (Table 2). *Acacia tortilis* had the highest neutral and acid detergent fibre levels, which were 21.5% higher than that in *A. rhemniana*, the species with lowest NDF, and 25.3% more than in *A. karroo*, the species with the lowest ADF (Table 2).

Table 2 Mean dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) in seven Acacia species (n = 5)

Species	DM (g/kg)	OM (g/kg DM)	CP (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)
A. karroo	945.4^{f}	897.0^{b}	108.0^{d}	504.6^{cd}	406.9^{e}
A. nilotica	951.6^{d}	882.6^{cd}	151.7^{c}	572.0^{b}	472.2^{b}
A. tortilis	947.7^{e}	864.6^{e}	150.2^{c}	621.7^{a}	544.9^{a}
A. galpinii	944.5^{g}	886.7^{bc}	149.6^{c}	509.0^{c}	454.7^{bc}
A. sieberiana	970.2^{b}	887.8^{bc}	183.2^{a}	561.3^{b}	414.9^{de}
A. hebeclada	971.8^{a}	915.1^{a}	164.9^{b}	570.1^{b}	428.8^{cde}
A. rhemniana	957.4^{c}	874.0^{de}	102.7^{e}	487.9^{d}	441.6^{bcd}
Standard error	0.017	0.373	0.123	0.627	0.988

$^{a, b, c, d, e, f}$ Column means with common superscripts do not differ (P > 0.05)

There were significant species differences in the *in vitro* enzymatic degradability of the DM and OM of the foliage (Table 3). *Acacia sieberiana* had the highest DM and OM degradabilities which were *ca.* 54.7 and 86. 3%, respectively, higher than that of *A. tortilis* (Table 3).

Table 3 Mean *in vitro* enzymatic dry matter (DMD) and organic matter degradability (OMD) of seven Acacia species grown in the Limpopo Province

Species	DMD (g/kg DM)	OMD (g/kg DM)
A. karroo	460.9^{b}	428.9^{b}
A. nilotica	363.9^{e}	325.3^{e}
A. tortilis	345.4^{f}	254.4^{f}
A. galpinii	383.7^{d}	350.9^{d}
A. sieberiana	534.2^{a}	473.9^{a}
A. hebeclada	426.2^{c}	396.4^{c}
A. rhemniana	353.9^{ef}	315.3^{e}
Standard error	3.28	3.67

Column means with common superscripts do not differ (P > 0.05)

There were significant species differences in total phenolics, simple phenolics, extracted CT and total CT concentrations in NDF and ADF solutions and radial diffusion (Table 4). All Acacia species except *A. tortilis* had low levels of both total phenolics and simple phenolics (Table 4). Extracted CT differed by *ca.* 98.6% between the species with the highest (*A. karroo*) and lowest (*A. hebeclada*) concentrations (Table 4). *Acacia karroo* had the highest proanthocyanidin concentrations in both ADF and NDF solutions compared to *A. sieberiana* (Table 4). *Acacia tortilis* had the highest radial diffusion measurement and *A. hebeclada* had the lowest (Table 4).

All samples produced relatively flat curves in the potassium iodate test (Figure 1). *Acacia nilotica* had a distinct peak after 21 min whilst *A. tortilis* and *A. karroo* had curves with several peaks, the first appearing after 6 min. *Acacia rhemniana*, *A. galpinii*, *A. hebeclada* and *A. sieberiana* developed no peaks at all and generally showed no reaction to the potassium iodate.

Table 4 Mean concentration of total phenolics, simple phenolics, extracted condensed tannin (ECT), condensed tannin in neutral detergent fibre (CTNDF), condensed tannin in acid detergent fibre (CTADF), and measurement of radial diffusion assay in seven Acacia species

Species	Total phenolics (g/kg DM)	Simple phenolics (g/kg DM)	ECT (g/kg DM)	CTNDF (g/kg DM)	CTADF (g/kg DM)	Radial diffusion (cm^2/g)
A. karroo	31.3 [c]	8.9 [d]	80.7 [a]	38.9 [a]	24.1 [a]	233.3 [b]
A. nilotica	25.4 [d]	7.5 [e]	44.3 [c]	25.9 [c]	18.3 [b]	113.3 [c]
A. tortilis	89.7 [a]	13.9 [c]	5.0 [f]	19.8 [d]	16.3 [c]	267.5 [b]
A. galpinii	23.4 [d]	23.1 [a]	57.1 [b]	31.9 [b]	16.4 [c]	321.7 [a]
A. sieberiana	12.5 [e]	7.6 [e]	10.4 [e]	4.4 [f]	3.3 [f]	100.8 [c]
A. hebeclada	11.2 [e]	7.6 [e]	1.1 [g]	4.5 [f]	3.5 [f]	55.0 [d]
A. rhemniana	39.6 [c]	16.1 [b]	25.6 [d]	11.4 [e]	8.3 [e]	250.0 [b]
Standard error	0.101	0.40	1.02	0.54	0.30	13.09

[a, b, c, d, e, f] Column means with common superscripts do not differ ($P > 0.05$)

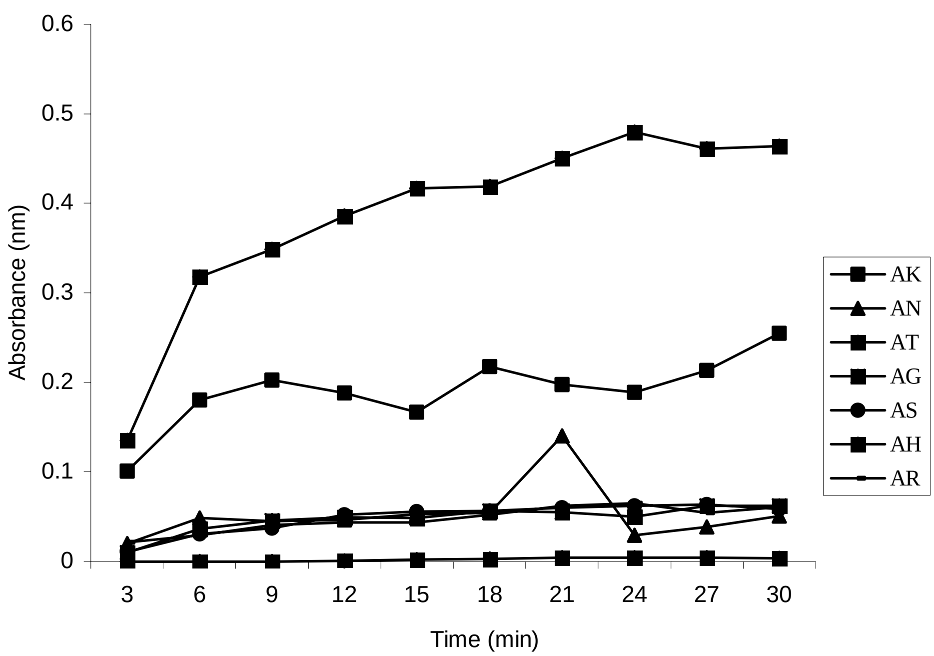

Figure 1 Profiles of hydrolysable tannins in *Acacia karroo* (AK), *Acacia nilotica* (AN), *Acacia tortilis* (AT), *Acacia galpinii* (AG), *Acacia sieberiana* (AS), *Acacia hebeclada* (AH) and *Acacia rhemniana* (AR)

Dry matter degradability was strongly negatively correlated ($P < 0.05$) to total phenolics and CTs in ADF (Table 5). Radial diffusion was strongly positively correlated to simple phenolics and weakly positively correlated to both total phenolics and CT in the NDF solution (Table 5). Condensed tannins were strongly positively correlated to both CTs in NDF and ADF whilst the CTs in NDF and ADF were both strongly correlated to one another (Table 5).

Table 5 Pair-wise correlation coefficients for chemical and degradation parameters of Acacia species

Parameters	DMD	TOTP	SP	RD	NDFCT	ADFCT	CT
DMD	-						
TOTP	-0.71*	-					
SP	NS	NS	-				
RD	NS	0.53*	0.81*	-			
NDFCT	NS	NS	NS	0.53*	-		
ADFCT	-0.59*	NS	NS	NS	0.96*	-	
CT	NS	NS	NS	Ns	0.89*	0.78*	-

DMD – *in vitro* enzymatic dry matter degradability; TOTP – total phenolics; SP – simple phenolics; RD – radial diffusion; NDFCT – condensed tannins in neutral detergent fibre; ADFCT – condensed tannins in acid detergent fibre; CT – condensed tannins; NS – non–significant; * = $P < 0.05$

Discussion

The nutritive value of forages for livestock feeding depends on the balance between the nutritive components of the plants, the digestibility of such nutrients, the metabolism of absorbed nutrients and the quantity of nutrients ingested by the animal (Seoane *et al*., 1981). In order to decrease the cost and time involved in *in vivo* forage evaluation, laboratory procedures have been developed. Chemical and physical analyses contribute to determine the nutritive value and have been suggested as alternative ways to determine quality of feedstuffs (Van Soest, 1983).

Physical analyses such as packed volume and water retention influence the bulk effects of feeds. It has been postulated that in legume species, a packed volume of less than 2.98 mL/g and a water retention of less than 6.45 g/g would be associated with a high voluntary intake by ruminants (Seoane *et al*., 1981). The packed volumes ranging from 1.50 to 3.00 mL/g and water retention of between 3.71 and 4.98 g/g recorded in the present study suggested that the potential voluntary intakes by ruminants of the foliage of all the Acacia species studied should be high.

The CP concentration in feedstuffs is often the constituent with the most pronounced effect on the performance of animals on veld. The CP concentrations of the tree legumes in our study, 102.68 – 183.18 g/kg DM, were lower than values of 137.5 – 212.5 g/kg DM reported for West African browse (Rittner & Reed, 1992). However, the levels in the present study were above the minimum requirements for maintenance of between 70 and 80 g CP/kg DM for ruminants (Meissner, 1997). All species except *A. karroo* and A. *rhemniana* contained more than 130 to 140 g CP/kg DM, which is required for high producing animals (Meissner, 1997). Low levels of the detergent fibres are associated with high voluntary DM intakes in ruminants consuming all forage diets. From our study, NDF levels varied between 438.4 and 621.7 g/kg DM among the different species. Wide variations in NDF levels in browse have been observed in other studies (Reed *et al*., 1990; Tanner *et al*., 1990; Kaitho *et al*., 1997; Larbi *et al*., 1998; Maasdorp *et al*., 1999; Hove *et al*., 2001). The higher NDF levels recorded in our study could be due to the inclusion of petioles in the foliage of all species tested.

Plant secondary compounds play a more significant role in tropical animal production than in temperate climate because tropical plants tend to have higher levels of these compounds. Simple phenolics have minimal impact on ruminant nutrition compared to tannins (Reed, 1995). *Acacia tortilis* had the highest total phenolics content, which can have a toxic effect on ruminants. It is, however, more important from a nutritional perspective to consider tannins in terms of CT and HT tannins (Mueller-Harvey, 2001). Condensed tannins are polymers of flavonol units most frequently linked at C4 - C8 or C4 – C6. They interfere with intake and digestion of the feeds in which they occur (Dube *et al*., 2001) at high levels, but at very low levels most have beneficial effects (Foo *et al*., 1996). The ideal CT concentration for ruminant animal nutrition has been suggested to be in the range 20 to 40 g/kg DM, based on the butanol-HCl method (Barry & Duncan, 1984). *Acacia galpinii* and *A. karroo* contained high levels of extracted CTs (80.7 and 57.1 g/kg DM) compared to the range considered nutritionally safe (Barry & Manley, 1986; Reed, 1995). All species from our study had low concentration of CT in ADF and NDF. Thus, they can be considered to be nutritionally safe. The study showed that more CTs exist in bound form in NDF compared to ADF and that NDF represents not only hemicellulose, cellulose, lignin and silica fractions but also proanthocyanidins in the leaves of tree species. Moreover, the presence of CT at high concentrations in the fibre fractions may affect their digestion kinetic parameters and confound the relationship between kinetic measurements and fibre composition (Makkar & Singh, 1991).

Hydrolysable tannins are esters of a sugar, usually glucose and a phenolic acid such as gallic acid in gallotannins and hexahydrodiphenic acid in ellagitannin. The HTs are known to be toxic to ruminants (Dollahite *et al*., 1962; Holliman, 1985; Shi, 1988). Recent studies showed that HTs may have inhibitory effects on various enzymes (Yoshida *et al*., 2000). All the tree legume species from our study except *A. nilotica* had low levels of HTs mainly due to gallotannins which have a lower sensitivity to potassium iodate and hence lower absorbance than ellagitannins (Willis & Allen, 1998). *Acacia nilotica* contained a higher level of HTs, mostly, according to Mueller-Harvey *et al*. (1987), as the phenolics, catechin gallates.

Methods that determine the ability of tannins to precipitate proteins are better tools for nutritional studies than colorimetric methods (Mueller-Harvey, 2001). The radial diffusion assay (Hagerman, 1987) is a protein precipitation method that depends on the formation of tannin complexes with bovine serum albumin embedded in an agar and allowed to diffuse through the agar.

In vitro digestibility is the disappearance of DM after 48 h incubation with rumen microorganisms. The DM degradability value obtained in the current study for *A. sieberiana* was within the range of 500 to 560 g/kg DM, which was reported by Mullen (1999) as adequate to meet the energy requirements for non-productive ruminants and at low levels of production. The other species showed medium to low *in vitro* enzymatic degradability. This suggested that the tannin content and fibre content of the Acacia species negatively affected the nutritive value of the forages. The measured DM degradability was negatively correlated to both total phenolics and CTs in ADF solution, whilst there was a positive correlation between different types of tannins assays. This is because trees and shrubs containing high levels of tannin tend to have a low DM degradability and therefore a low voluntary intake by ruminants.

These results suggested that the nutrient composition of Acacia species from the Limpopo Province was above the minimum requirements for ruminants. The practical implication is that smallholder farming systems could benefit from a feed resource that includes harvesting of Acacia species and utilizing them during the dry seasons when there is a shortage of protein.

Conclusion

The *in vitro* degradability of the tree foliages from the Acacia species used in the experiment ranged from low to medium, despite their high intake potential based on packed volume and water retention, high protein and low detergent fibre levels. The low nutritive value was attributed to a combination of type and amount of tannins present in foliage. It is proposed that there is a need for differentiation of tannins in terms of chemical structure, since chemical analyses could not adequately explain the observed differences in nutritive value.

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