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FEED POTENTIAL OF *ACACIA KARROO* LEAF MEAL FOR COMMUNAL GOAT PRODUCTION IN SOUTHERN AFRICA: A REVIEW

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ABSTRACT

Indigenous goats are widely spread in most countries of southern Africa and they are nutritionally, economically and socially important to rural households. However, their productivity is constrained by shortage of good quality feed, especially during the long dry season. *Acacia karroo* is an important leguminous tree in communal rangelands of southern Africa and is able to thrive in severe and dry conditions. The leaves, fruits and pods are highly palatable and excellent fodder for goats. It is regarded as a multipurpose tree with great potential for increasing goat productivity and can be considered as a cheap source of protein in communal goat production. Despite its importance in goat nutrition, the species contains phenolic compounds, especially condensed tannins. Recent studies have shown that though tannins have some harmful effects, they have also been shown to be beneficial, for sustainable goat production when given in small amounts. However, very little attempt has been devised to enhance the feeding strategies that reduce the negative effects caused by tanniniferous feeds. The objective of this paper was to review information on the significance of *A. karroo* in communal goat production in Southern Africa. Possible future areas of research are also highlighted.

Keywords: browse, condensed tannins, fodder, rangeland, ruminant.

INTRODUCTION

Nutritional constraint is a major problem facing the small scale goat producers in the communal areas of Southern Africa as vast majority of goats in these areas are kept under extensive system of management. This problem is more pronounced during the dry seasons due to erratic rainfall patterns. The quality and quantity of available fodder decline during this period and, goats utilize feedstuff from poor natural pastures which is low in protein. Poor nutrition results in low productivity and body weight loss. Browse plants are constituents of rangeland systems that act as shade, windbreakers, nitrogen fixers, soil stabilizers etc. The use of browse trees as fodder for ruminant is increasingly becoming important in many parts of the tropics (Njidda, 2010). Tree fodders maintain higher protein and mineral contents during growth than grasses, which decline rapidly in quality with progress to maturity (Shelton, 2004).

The introduction of non-native legume species into the natural rangeland community in the early 80's and 90's such as *Stylosanthesguianensis* (Graham stylo), *S. hippocampoides* (Oxley fine-stem stylo), *S. scabra* (Shrubby stylo), *Macroptilium atropurpureum* (Siratro), *Neonotonia wightii* (Glycine), *Chamaecrista rotundifolia* (cv. Archer), *Lotononis bainesii* (Belt lotononis) etc. has been unsuccessful due to the scarcity and high cost of agronomic inputs, difficulties associated with their establishment and their competition for land with food crops (Mapiye *et al*., 2011). These exotic herbaceous species also pose a threat to the local forage legume genetic resources (Clatworthy, 1991). This, therefore, suggest the importance of exploiting the potentials of the indigenous legume species on smallholder and communal rangelands.

Acacia genus is widely distributed throughout the arid and semi-arid regions of Sub-Saharan Africa, and *Acacia karroo* is the most widespread among the acacias in Southern Africa (Barnes *et al.,* 1996). This browse specie is abundant in most communal rangelands; the foliage is ever green and is preferred by goats. In time past, *A. karroo* was considered as an encroacher of the natural rangeland and researchers have focussed their attention on eradicating this browse tree (Nyamukanza and Scogings, 2008). However, there has been a paradigm shift from an invader of the natural rangeland to a livestock feed, particularly for goats. Adoption of this resource browse tree as a protein supplement during the dry season amongst the smallholder and communal farmers in Southern Africa is limited due to poor understanding of the browse. Hence, this paper describes the feed potential of *Acacia karroo* for goats on communal rangelands.

Description of *Acacia karroo:* *Acacia karroo* Hayne is synonymous with karroo thorn or sweet thorn, belonging to the family called Fabaceae (International Legume Database and Information Service, 2010). It is known to be one of the fastest growing acacias in Southern Africa, and produces high-density wood between 800-890 kg/m^3

(Barnes *et al.*, 1996). Historically, this woody plant is named after the Karoo region of the Cape Province of South Africa, where it is common, and often the only tree found (Barnes *et al.*, 1996). It is referred to as sweet thorn due to the sweet aroma of the flowers, and the species can be found in sweetveld due to its nutritious vegetation. Ross (1979) presented the modified botanical description of *A. karroo* leaves as being typically glabrous but occasionally densely pubescent. More detailed reviews on the botanical description of *A. karroo* have been described by Ross (1979), Barnes *et al*. (1996) and Palgrave (1996). *Acacia karroo* contains thorns which are long (2-5cm), straight and whitish with brown tips and paired at the nodes (Teague, 1989). The presence of thorns obstructs efficient browsing by goats. The tree is habitually evergreen under auspicious conditions (Pooley, 1998) and can tolerate severe and frequent defoliations, suggesting its potential as a protein supplement for goats during periods of drought. The plant has a long tap root which enables it to use water and nutrients from deep within the soil profile (van Wyk *et al.*, 2000) and can grow on acidic infertile soils with large temperature variations (Barnes *et al.*, 1996). Information regarding the root morphology of *A. karroo* is scanty. *Acacia karroo* varies in height from a shrub to a tree, generally between 1 and 15 m tall, but can grow up to 25 m tall (Archibald and Bond, 2003). *Acacia karroo* was historically known as a noxious weed and tends to be an invasive species in poorly managed rangelands (Du Toit, 1966). It is the second on the Alert List for Environmental Weeds and has been targeted for eradication (CRC Weed Management, 2003). It can invade rangelands and open grasslands, and reduce agricultural productivity by suppressing the growth of grasses, preventing stock movement and restricting watering (CRC Weed Management, 2003). Several methods have been devised by researchers to eradicate encroaching *Acacia karroo* with little or no success (Strang, 1974; Trollope, 1974). It has been suggested that browsing animals like goats are best suited in the defoliation studies of *Acacia karroo* (Teague, 1988a). It is, therefore, important to report and synthesise available information on its nutritive value.

Nutritive value of *Acacia karroo* leaf meal: The feeding value of forages 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 (Adesogan *et al.*, 2006). Feeds of high nutritive value promote high levels of production. Performance of ruminants is greatly influenced by the amount of nutrients consumed. Tropical forages such as hay, straw and stover are low in nitrogen (N), which is the critical element in the dry season (Lazzarini *et al*., 2013). The crude protein (CP) content of these forages (20-50 g CP/kg DM) does not meet the minimum CP requirement of 80 g CP/kg DM needed for optimal rumen microbial function (Norton, 2003). It has been reported that *A. karroo* is two to three times richer in CP than grasses and cereal grains (Chepape *et al*., 2011).

The use of *Acacia karroo* as dry season protein supplements has been extensively reported in literature (Mapiye *et al*., 2011; Marume *et al*., 2012; Ngambu *et al*., 2013). *Acacia karroo* leaves contain high levels of CP and minerals (Tables 1 and 2) (Halimani, 2002; Ngwa *et al*., 2002). The CP values for *Acacia karroo* are within the optimal range of 120 - 230 g/kg DM required for body weight gain, maintenance and production requirements in growing goats (Meissner, 1997; Negesse *et al*., 2001). *Acacia karroo* leaves, also, have moderate levels of detergent fibres which are indication of high feeding values (Mokoboki *et al*., 2005; Mapiye *et al*., 2011).

The variation in the nutrient composition of *A. karroo* leaves observed in Tables 1 and 2 can be ascribed to differences in populations, soils, climate, season, stage of growth, browsing pressure, assay methods and presence of secondary plant metabolites, respectively (Aganga *et al.*, 2000; Mapiye *et al.*, 2011). The inclusion of *A. karroo* leaf meal in the diet of goats could benefit the smallholder farmers in the communal areas of Southern Africa during the critical fodder scarcity. However, recommendations on the use of *A. karroo* leaf meal are complicated owing to the presence of the anti-nutritional factors in the plant. The knowledge of these secondary plant metabolites is essential to achieve an optimal use of these resources as fodder for goats.

Anti-nutritional factors and adverse effects of *A. karroo* leaves on animal production: Condensed tannins (CTs), also known as proanthocyanidins, are phenolic plant secondary compounds that are found in plants, leaves, bark, fruit, wood and roots (Hassanpour *et al*., 2011). Condensed tannins are the most common type of tannins found in forage legumes, trees and shrubs such as *Lotus corniculatus* and in several Acacia species (Min *et al.*, 2003). They are more copious in the parts of the plants which are more likely to be consumed by herbivores (Alvarez del Pino *et al*., 2001). There have been several notions regarding the basis for CTs synthesis which include protection against herbivory, plant defence against pathogens, nitrogen conservation, etc. (Waghorn, 2008).

The presence of CTs in *Acacia karroo* has been documented by several authors (Mokoboki *et al*., 2005; Ngambu *et al.*, 2012; Gxasheka *et al*., 2015). *Acacia karroo* contains high levels of extracted CTs ranging from 55 - 110 g/kg DM (Dube *et al*., 2001; Mokoboki *et al*., 2005). Consumption of tannin rich plant materials can be beneficial or detrimental to ruminants depending on how much is ingested among other factors (Hagerman and Butler 1991; Makkar, 2003; Waghorn, 2008).

However, information on the inclusion level at which its effects on production and goat performance move from being beneficial to detrimental are inconclusive.

Condensed tannins in *Acacia karroo* have been implicated in increasing faecal N and negative N retention in goats (Dube and Ndlovu, 1995; Mapiye *et al*., 2011). The negative nitrogen balance is as a result of complexation between tannins and endogenous proteins (Silanikove *et al.,* 1996; Barbehenn and Constabel, 2011). Faecal excretion of N is a clear proof that CTs reduce the digestibility of feed (Frutos *et al.,* 2004). However, further research is needed to ascertain this observation. Browsing animals secrete proline-rich proteins (PRPs) which are considered to be the first line of defence against dietary tannins (Mueller-Harvey 2006; Lamy *et al.,* 2011). The effects of proline-rich salivary protein as a first line of defence against CTs also merit further studies. Generally, there is dearth of information on the adverse effects of CTs in *A. karroo* on goat production.

Strategies to overcome detrimental effects of tannins: Several detanninification methods (by inactivation or removal of tannins) have been postulated by several authors, which include but not limited to: the use of alkalis (e.g. sodium hydroxide (0.05M), sodium carbonate (0.1M), urea, ammonia: Makkar, 2003; Vitti *et al.,* 2005), oxidising agents (e.g. potassium permanganate (0.03M), potassium dichromate (0.02M), ferrous sulphate (0.015M), hydrogen peroxide: Deshpande *et al*., 1986; Makkar and Singh, 1992c; Makkar and Becker, 1996b), extraction with organic solvents (e.g. acetone, methanol, ethanol: Makkar and Singh, 1992c), use of tannin binding compounds such as polyvinylpyrrolidone (PVP) and polyethylene glycol (PEG) (Getachew *et al.,* 1998; Barry *et al*., 2001; Makkar, 2003). Although, chemical treatments of CTs have been extensively reported, adoption of these methods by the smallholder farmers in the communal areas seems impracticable since it requires expertise, competence and capital.

There is need to develop simple, cost-effective and practicable detanninification techniques that can be easily adopted by the impoverished smallholder farmers for increased animal performance in Southern Africa. Such approaches include: wetting the feed with good and cheap source of alkali (e.g. wood ash and charcoal: Frutos *et al.,* 2004; Ben Salem *et al.,* 2005), chopping the leaves and storage, which has been found practicable by farmers (Makkar, 2003). Drying or wilting is also an inexpensive option and can irreversibly bind the CTs to protein in the forage (Waghorn, 2008).

The potential of oven, freeze and sun-air drying in alleviating the adverse effects of dietary CTs have been fully appraised by Mapiye *et al.* (2011). However, depending on the temperatures used, drying causes losses in water-soluble carbohydrates due to respiration and possibly decomposition (Ahn *et al.,* 1989; Deinum and Maasen, 1994) and maillard reaction (Schnickels *et al.,* 1976). It has been reported that oven-drying resulted in increases in the fibre components and lignin, thereby decreasing *in vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) (Nastis and Malechek, 1988; Papachristou and Nastis, 1994; Dzowela *et al.,* 1995). Sun-air drying on the other hand, exposes the leaf material to ultra-violet radiation, which reacts with forage constituents to increase acid detergent fibre (ADF) and neutral detergent fibre (NDF), thus reducing digestibility (Dzowela *et al.,* 1995). According to Dzowela *et al.* (1995), freeze-drying gives the results that are closest to the ideal because the enzyme activity is low and ice crystals may not disrupt membranes and cell walls (Deinum and Maasen, 1994). This method requires ultra-modern equipment, expertise and electricity (Stewart *et al*., 2000) which are not at the disposal of the resource poor goat producers in the communal areas. Sun-air and oven-drying should be avoided and a simple air-drying under a thatched shade is recommended (Brown *et al*., 2016).

EVALUATION OF *ACACIA KARROO* LEAF MEAL IN GOAT PRODUCTION

Goat production in the communal areas of Southern Africa: Goats are generally owned by smallholder farmers in the communal areas (Lebbie and Ramsay, 1999). They represent the principal economic output, contributing a large proportion of income to the resource-poor farmers (Ben Salem and Smith, 2008). The contribution of goats to the nutritional and economic status of the rural dwellers is well recognized (Peacock 2005, 2008; Rumosa Gwaze *et al.*, 2009; Iniguez, 2011) (Table 3). Reports from a number of development projects in the last 20 years indicate the significant role of indigenous goats in poverty alleviation and household food security (Morand-Fehr, 2005; ICG, 2010).

Despite the important role that indigenous goats play in the livelihood of the rural poor farmers, not much has been done in terms of improving their productivity (Peacock, 1996). One of the main constraints to increasing goat production in the communal areas is limited forage availability, particularly during the dry season (Alemu *et al*., 2014). Inadequate feeding of goats is a major limiting factor facing the small-scale goat producers in the communal areas of Southern Africa as vast majority of goats in these areas are kept under extensive system of management (Rumosa Gwaze, 2009). This problem is more pronounced during the dry season due to erratic rainfall patterns. The quality and quantity of available fodder decline during this period, and goats utilize feedstuff from low quality natural pasture which is low in protein (Tolera *et al*., 2000). Poor nutrition results in low productivity and body weight loss (Aw-Hassan, 2010). Provision of appropriate and inexpensive supplementary feedstuffs such as *Acacia karroo* is important to enhance the productivity of goats under smallholder systems.

Growth performance and carcass characteristics: It has been documented that protein sources may affect carcass characteristics and meat composition (Khalid *et al.,* 2012). Ngambu *et al.* (2013) observed that goats supplemented with *A. karroo* leaves had higher growth rates and lowered meat pH than non-supplemented groups. Similarly, Ngambu *et al.* (2012) observed significant effects of *A. karroo* supplementation on meat tenderness and juiciness. Nyamukanza and Scogings (2008) reported higher average daily gain (ADG) of goats fed *A. karroo* compared to those on the control diet. Significant higher contents of α- linolenic acid and more desirable *n*- 6/*n*-3 polyunsaturated fatty acids (PUFA) have been reported in beef from steers' supplemented with *A. karroo* leaf-meal (Mapiye *et al*., 2011). The importance of tannins in ruminant nutrition is rooted in their effect on protein digestion. It has been observed that tannins can reduce the amount of protein that is degraded in the rumen and increase the protein flow for digestion in the small intestine (Mueller-Harvey, 2006). This tannin-protein interaction leads to increased protein metabolism into the muscle, leading to higher slaughter weights and heavier carcasses (Gleghorn *et al.*, 2004). The mechanisms by which *A. karroo* browse reduces ruminal protein digestion and improves its utilisation need further investigation.

Table 1. Comparative analysis of the nutritive value of *Acacia karroo* leaves.

Nutritive value	Composition (%)	Sources
Dry matter	94.5	Mokoboki *et al*. 2005
	89.7	Mapiye *et al*. 2011
	91.9	Marume *et al*. 2012; Ngambu *et al*. 2013
	97.0	Brown *et al*. 2016
Organic matter	89.7	Mokoboki *et al*. 2005
	92.1	Brown *et al*. 2016
Crude protein	12.2	Kahiya *et al*. 2003
	10.8	Mokoboki *et al*. 2005
	12.6	Aganga *et al*. 2000; Brown *et al*. 2016
	14.8	Mapiye *et al*. 2009; Mapiye *et al*. 2011
	23.2	Marume *et al*. 2012; Ngambu *et al*. 2012, 2013
Ether extract	2.0	Mapiye *et al*. 2009, 2011
	3.6	Marume *et al*. 2012; Ngambu *et al*. 2013
	2.4	Brown *et al*. 2016
NDF	50.4	Mokoboki *et al*. 2005
	50.2	Mapiye *et al*. 2011; Ngambu *et al*. 2012; Marume *et al*. 2012; Ngambu *et al*. 2013
	38.0	Brown *et al*. 2016
ADF	28.6	Dube, 1999
	40.6	Mokoboki *et al*. 2005
	28.9	Mapiye *et al*. 2009, 2010; Marume *et al*. 2012; Ngambu *et al*. 2012; 2013
	29.0	Mapiye *et al*. 2011;
	32.4	Brown *et al*. 2016
CT	2.2	Aganga *et al*. 2000
	2.1	Marume *et al.* 2012; Ngambu *et al.* 2012, Ngambu *et al*. 2013
	7.4	Mapiye *et al.* 2009; 2011.
	2.0	Brown *et al.* 2016
TP	0.5	Marume *et al*. 2012; Ngambu *et al*. 2012; 2013;
	0.4	Mokoboki *et al*. 2011
	1.9	Brown *et al.* 2016

Control of internal parasites: The use of anthelmintic medicine in controlling parasitic nematodes of the gastro-intestinal (GI) tract poses serious threat to meat consumers due to its residual effect in meat and its products. The rapid development of resistance to anthelmintic constitutes another challenge, even though large proportion of the smallholders' farmers cannot afford to buy these medicines due to financial constraints. Some recent results indicate that tannin rich plants might present a promising option to reduce nematode infections in small ruminants (Githiori *et al.*, 2006; Hoste *et al.*, 2006). Marume *et al.* (2012) observed reduction in faecal larval counts and *Haemonchus contortus* worm counts in goats that consumed *A. karroo* leaves. Kahiya *et al.* (2003) fed mixed diets containing either 40% *A. karroo* or *A. nilotica* leaves and observed that goats that consumed *A. karroo* had reduced faecal egg counts as compared to goats on *A. nilotica* diet. The lack of anthelmintic effect on goats fed *A. nilotica* containing diet could be due to low concentration of CTs in the diet. Similarly, Paolini *et al.* (2003b) reported that CTs consumption was associated with a significant reduction of *Trichostrongylus colubriformis* and *Teladorsagia circumcincta* in goats.

Several arguments exist regarding the mechanism by which CTs counteract effects of parasitic GI nematodes in ruminants (Min *et al.*, 2003; Frutos *et al*., 2004; Waghorn 2008; Hoste *et al.* 2009; Marume *et al*., 2010). Direct effect on the parasites and indirect effect on the host animal have been hypothesized. The mechanism of action deserves further research. The use of *A. karroo* for helminthic control can be used as a feasible alternative to commercially manufactured anthelmintic or as part of an integrated system to reduce future occurrences of anthelmintic resistance to commercial medicines. *Acacia karroo*, thus, presents an inexpensive, risk-free and eco-friendly approach to controlling worm population among the indigenous goats in the communal areas of Southern Africa.

Reduction in methane emission: Global warming is an increasing concern throughout the world today. The most important greenhouse gases are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) (Beauchemin *et al*., 2011). Domestic ruminants account for about 15% of the total CH_4 emissions due to anaerobic fermentation of feeds (Moss *et al.*, 2000), and this represents a loss of 2-15% of the gross energy intake (Holter and Young, 1992). The use of chemicals (e.g., several halogenated CH_4 analogues such as chloroform, bromochloromethane (McAllister and New bold (2008) and statins (Miller and Wolin, 2001) have been exploited in reducing the production of CH_4. However, these substances are inefficient as their effect is ephemeral and toxic to the host animal. There is evidence in literature that plant secondary metabolites such as CTs are able to suppress methanogens (Waghorn, 2008; Hess *et al.*, 2003a, 2006; Goel and Makkar, 2012). However, the mechanism of action of CTs on methanogens is not clear. Direct and indirect inhibitions of methanogen in the rumen have been suggested (Dschaak*et al.*, 2011; Williams *et al.*, 2011). There is dearth of information on strategic use of *A. karroo* in reducing CH_4 emission in goats.

Table 2. Mineral profiles of *Acacia karroo* leaves.

Nutritive value	**Composition (%)**	**Sources**
Ca	1.73	Aganga *et al*. 2000
	37.7	Mapiye *et al.* 2009; 2010
	2.3	Marume *et al*. 2012
	1.64	Brown *et al*. 2016
P	0.13	Aganga *et al*. 2000
	0.8	Mapiye *et al.* 2009; 2010
	0.08	Marume *et al*. 2012
	0.14	Brown *et al.* 2016
Mg	0.32	Aganga *et al*. 2000
	3.9	Mapiye *et al*. 2009; 2010
	0.34	Brown *et al*. 2016
K	0.97	Aganga *et al*. 2000
	18.7	Mapiye *et al*. 2009; 2010
	0.34	Brown *et al*. 2016
Na	0.01	Aganga *et al.* 2000
	1.7	Mapiye *et al.* 2009; 2010
	0.05	Brown *et al*. 2016

Table 3. Ranges of products and socio-economic services from goats (Peacock, 1996).

List of Products	List of services
Meat (raw, cooked, blood, soup)	Cash income
Milk (fresh, sour, yoghurt, butter, cheese)	Security
Skins (clothes, water/grain containers, tents, thongs, etc.)	Gifts
Hair (cashmere, mohair, coarse hair tents, wigs, fish lures)	Loans
Horns	Religious rituals
Bones	Judicial role
Manure (crops, fish)	Pleasure
	Pack transport
	Draught power
	Medicine
	Control of bush encroachment
	Guiding sheep

Conclusions: Shortage of good quality feed, especially during the long dry season in tropical and subtropical areas has increased the need to provide supplementary feed to sustain livestock production, particularly goats. Tree fodders, such as *Acacia karroo*, are adapted to harsh environmental conditions and remain green long into the dry season. The leaves are rich in most principal nutrients, such as proteins and minerals, and tend to be more digestible than tropical grasses and crop residues. Incorporating *Acacia karroo* leaves in the diets of goats fed low quality roughages could lead to better performance. Emphasis should therefore focus on formulating feeding strategies that enhances the positive effects rather than researching on ways to eradicate encroaching *A. karroo* on natural rangeland. There should be synergy between the pasture scientists, animal nutritionist and plant chemist to maximize the potential of this resourceful browse tree.

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