The chemical composition and nutritive value of leaves of indigenous fodder trees

By

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Declaration

I **declare** that this thesis is my own work, has been submitted for the degree M. Ins. Agrar Animal Production to the Faculty of Natural and Agricultural Sciences Department Animal and Wildlife Sciences University of Pretoria.

This work has not been submitted for any examination or at any other University

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Signature: _____

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ABSTRACT

The nutritional value of indigenous fodder plants has been reported to be high and constant throughout seasons as compared to grasses. The aim of this study was to evaluate the nutritional value of three tree species of the *Combretum* family, *C. apiculatum, C. molle, C. zeyheri,* and two other plant species, *Colophospermum mopane* and *Pelthophorum africanum.* This would be achieved through the determination of chemical composition (ash, dry matter (DM), organic matter (OM), CP, acid detergent fibre (ADF), acid detergent lignin (ADL), acid detergent indigestible nitrogen (ADIN), condensed tannins (CT) and ether extract (EE)), rumen degradability and *in vitro* digestibility of the leaves of these species were determined.

The foliage of the tree species were collected in and north of Pretoria. After rinsing a portion of each species' samples, they were freeze-dried, prepared for analyses and stored as fresh samples pending analyses. The *in situ* analysis was done as blanket analysis over all the seasonal samples of each plant species excluding *Mopane.* This was done because the leaf materials collected were not enough to conduct a complete trial for each seasonal collection. Therefore sites were not considered for statistical analyses hence species were compared across seasons only. All the plant species exhibited a wider range of the chemical fractions.

Their ash concentrations ranged from 30.3 g/kg DM for *C. zeyheri* to 85.8 g/kg DM for *C. molle*, NDF 270.3 g/kg DM for *C. apiculatum* to 410.1 g/kg DM for *P africanum*, ADF 208.1 g/kg DM *P. africanum* to 375.2 g/kg DM for *C. molle*. Their CP ranged from 62.9 g/kg DM for *C. molle* to 172 g/kg DM for *Mopane*, CT 65.6 mg sorghum tannin equivalent (STE)/g DM for *C. zeyheri* to 660.3 mg STE/g DM for *Mopane*, ADIN ranged from 1.2 g/kg DM for *C. apiculatum* to 3.3 g/kg DM in *C. mopane.*

The range of some mineral concentrations of all the plants was not as wide as the other fractions. The concentrations of Ca ranged from 7.9 g/kg DM for *Mopane* to 16 g/kg DM for *C. molle*, K 1.2 g/kg DM *Mopane* to 7.8 g/kg DM for *C. molle*, Mg 1.4 g/kg DM for *C. molle* to 3.8 g/kg DM for *C. apiculatum*. The concentrations of Cu ranged from 7.8 mg/kg DM for *C. molle* to 66 mg/kg DM for *C apiculatum*, Fe 169

mg/kg DM for *Mopane* to 435 mg/kg DM for *C. zeyheri*. The *in vitro* dry matter digestibility (IVDOM) ranged from 52.6 % for *Mopane* and *C. zeyheri* to 64.1% for *C. apiculatum*. The *in situ* degradability fractions for the Combretum species ranged as follows: soluble fraction was 4.02% for *C. apiculatum* to 25.4% for *C. zeyheri*; degradable fraction was 34% for *C. zeyheri* to 44% for *C. apiculatum* and the extent of nitrogen (N) degradation was 47% for *C. apiculatum* to 60% for *C. zeyheri.*

The concentrations of the chemical fractions of all the plants did not show a particular seasonal trend. However significant and insignificant variations were observed. The CP concentrations were almost constant implying a better N supply to animals throughout the seasons. The CT concentrations were not high enough to adversely affect the digestibility of protein. The *Combretum* species showed reasonable N degradability *in situ, C. zeyheri* the most degradable. The plant's digestibility values were within the range of browse plants. These results cannot be conclusive on the eventual nutritional value of these plants to the animals. Further studies would be necessary to quantify the availability of the chemical fractions and the foliage's palatability to the animals.

CHAPTER 1

1. INTRODUCTION AND LITERATURE REVIEW

1.1. Trees and bushes as feed sources

Reduced animal production is often experienced in tropical and subtropical regions because of varying and/or the poor quality of the natural forage during different seasons of the year (Bosma et al., 1996; Odenyo, et al., 1999). This has led, in these regions, to an interest in the use of the abundant foliage from indigenous trees and shrubs as a potentially sustainable source of food for grazing ruminants (Degen et al., 1997). The foliage of trees and shrubs found in arid, semiarid and tropical regions may be used as protein and energy supplements when animals are subjected to low quality roughage during the dry season and when pasture is less available (Bhattacharya, 1989, Reed et al., 1990).

During periods of forage scarcity animals prefer plant species that provide more dry matter (DM) (Owen-Smith & Cooper, 1983). Certain species, although abundantly available, were constantly rejected despite apparent high nutrient levels (Sauer, 1983). Several studies focussed on a number of plant species constantly browsed by various animals, both livestock and game. Table 1.1 shows some South African fodder trees of the *Acacia, Combretum* families and other species that have been studied by researchers such as Groenewald & Joubert (1967), Owen-Smith & Cooper (1983) and Sauer (1983).

Many recent studies have evaluated a vast array of fodder plants for their potential in ruminant nutrition (Rittner & Reed, 1992; Woodward & Reed, 1995; Makkar et al., 1995; Jackson et al., 1996; Bosma & Bicaba, 1997; Balogun et al., 1998; Ramirez & Lara, 1998; Larbi et al., 1998; Apori et al., 1998; Sawe et al., 1998; Thorne et al., 1999; Molina et al., 1999; Nherera et al., 1999; Shayo & Uden, 1999; Odenyo et al., 1999; Palmer & Jones, 2000; Jones & Palmer, 2000; Ramirez et al., 2001). The plants studied, includes multipurpose trees, forage legumes, shrubs and forbs that form part of the diets of herbivores such as domesticated animals and game. Over the years other plants, such as *Leucaena leucocephala* have been evaluated and found to exhibit a high nutritive potential for ruminant feeding. They, however, contain components deleterious to livestock production and their health (Lowry, 1987; Allison, 1991; Craig, 1995).

Table 1.1.
Fodder tree species of southern Africa evaluated for nutritive value

Acacia species	*Combretum* species	Other species	Shrubs and forbs
A. albida [a]	*C. apiculatum* [a b c]	*Burkea africana* [b]	*Aloes* [b]
A. ataxacantha [c]	*C. erythrophyllum* [c]	*Cissus loncerifolia* [b]	*Euphorbias* [b]
A. caffra [c]	*C. hereroense* [c b]	*Dombeya rotundifolius* [b]	*Euclea undulata* [b]
A. erubescens [c]	*C. imberbe* [c]	*Grewia monticola* [b]	*E. natalensis* [b]
A. exuvialis [c]	*C. molle* [c]	*Grewia flava* [a]	*E. divinorum* [b]
A. galpinii [a]	*C. zeyheri* [c]	*Grewia occidentalis* [a]	*Maytenus heterophylla* [b]
A. gerrardii [c]	---	*Leucosphaera bainesii* [a]	*Strychnos pungens* [b]
A. giraffae [a]	---	*Colophospermum Mopane* [a]	---
A. karroo [c]	---	*Pelthophorum africanum* [b]	---
A. nigrescens [c b]	---	*Pentzia incana* [a]	---
A. nilotica c	---	*Pterocarpus rotundifolius* [b]	---
A. robusta [c]	---	*Rhus lancea* [a]	---
A. tortilis [c b]	---	*Salix capensis* [a]	---
A. senegal [c]	---	*Salsola aphylla* [a]	---
A. sieberiana [a]	---	*Ziziphus mucronata* [a]	---

Groenewald & Joubert (1967) [a]
Owen-Smith & Cooper (1983) [b]
Sauer (1983) [c]

1.2. Browse availability and abundance

The amount of feed material available from shrubs and fodder trees is enormous in developing countries (Ramirez, 1998). However, only a few of these sources has been incorporated into ruminant feeding systems. The value of these plants in animal nutrition is associated with features such as abundance, accessibility, protein content and quality in terms of energy, minerals and vitamins (Kibria et al., 1994; Ramirez, 1996). These forages are important for animal production owing to their potentially good nutritive value and deep root system which takes up minerals and access ground water during water-scarce periods (Kamatali et al., 1992). In Africa, tree fodder has been used for livestock feeding since time immemorial. Woody browse is most sought after during the early growing stage when their new shoots are softest and when forbs are least available (Owen-Smith & Cooper, 1983). In general, the abundance of fodder, availability of the nutrients and the carrying capacity of most indigenous browse plants have not been investigated extensively.

1.3. Animal species utilizing these forages

A large number of livestock in many parts of the world depends on indigenous browse as principal feed source. However, most of these plants do not meet their nutrient requirements (McDowell et al., 1993). Free ranging small ruminants (goats and sheep) spend between 20-70% of their time browsing indigenous plants (Dicko, 1983; Janke, 1984; Sissoko & Debrah, 1989). Many researchers have related their investigations of nutritional value of fodder plants to both domestic and some wild animals, such as kudu and giraffe (Sauer, 1983; Owen-Smith & Cooper, 1983), grey duiker and other wild ruminants (Odenyo et al., 1999). Most recent studies have also put more emphasis on the nutritive value of fodder plants for browsing small stock, i.e. goats and sheep (Woodward & Reed 1995).

1.4. Potential contribution

1.4.1. Potential to complement or supplement grasses

Fodder trees contain higher crude protein (CP) concentrations (120-300 g/kg DM) than grasses (30-100 g/kg DM) (Gupta & Pradhan, 1975; McDonald & Ternouth, 1979; Bamualin, 1981; Minson, 1990; Rittner & Reed, 1992). The chemical composition of some of the South African species are presented in Table 1.2. Fodder trees tended to remain green longer into the dry season when feed resources are scarce than the grasses which become lignified and of a poor quality (Ahn et al., 1989; Devendra, 1990). The chemical composition of browse plants tended to vary less throughout seasons than tropical grasses (Bamualin, 1981). Le Houerou (1980) reported adequate protein and phosphorus (P) concentrations for the maintenance of livestock in a wide range of browse plants during the dry season. Species such as those of the *Acacia* and *Combretum* families have been identified as vital food sources for game, the giraffe in particular (Dagg, 1959; Hall-Martin, 1974; Kok & Opperman, 1980; Sauer, 1982; 1983).

Table 1.2
The chemical composition (g/kg DM) of leaves of some indigenous fodder trees of southern Africa

Plants	Crude Protein	Crude Fibre	Ash	Calcium/Phosphorus
Acacia albida [a]	12.5	228	65	4; 1.5
A. erubescens [c]	194	185	05	--
A. galpinii [a]	116	240	35	--
A. giraffae [a]	116	266	75	1.4; 1.5
A. karroo [c]	173	159	04	--
A. nigrescens [c]	130	200	05	--
A. nilotica c	129	137	11	--
A. robusta [c]	143	248	04	--
A. senegal [c]	286	162	04	--
Combretum imberbe [c]	125	276	10	--
C. erythrophyllum [c]	133	206	14	--
C. hereroense [c]	107	217	11	--
C. apiculatum	115 [a c]	335 [a], 221 [c]	58 [a], 09 [c]	18; 1.5 [a]
C. molle [c]	108	230	10	--
C. zeyheri [c]	143	210	10	--
Colophospermum Mopane [a]	125	232	75	20; 1.6

Groenewald & Joubert (1967) [a]
Owen-Smith & Cooper (1983) [b]
Sauer (1983) [c]

Balogun et al. (1998) analyzed tropical browse plants, e.g. *C. apiculatum*. Its CP concentration (124 g/kg) was almost similar to those in Table 1.2. The neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) concentrations and the *in situ* digestibility of *C. apiculatum* were 32.4, 21.4, 2.6 and 62.3 % respectively (Balogun et al., 1998). Several researchers reported a wide range of NDF (20 – 69%), ADF (9.5 – 68%), ADL (1.5 –19%) and CP (10 – 30%) concentrations for the foliage of multipurpose and tropical browse plants, including legumes (Makkar & Sighn, 1991; Kamatali et al., 1992; Woodward & Reed, 1995; Apori et al., 1998; Balogun et al., 1998; Larbi et al., 1998). A study of different oak species indicated that younger leaves tended to contain higher concentrations of CP, tannins and lower levels of NDF, ADF and ADL than older leaves (Makkar & Sighn, 1991).

From all these studies, it was concluded that the potential of browse plants to be used as supplements or as sole diets for herbivores could not be established merely from their chemical compositions. Some indigenous fodder species that vary widely in digestibility and intake by ruminants may differ only slightly in chemical composition (Minson & McLeod, 1970; Mertens & Loften, 1980). This implies that other forage characteristics also impart differences in intake and digestibility, e.g. physical structure, the leaf texture and its surface area (Smith et al., 1971).

Rittner (1992), Diagayete (1981) and Larbi et al. (1998) screened browse tree species for nutritive value. These studies have shown that some of the plant species that contained high CP concentrations were less suitable than others to be used as protein supplements to overcome the N deficiency in agricultural by-products or residues (Mertens & Ely, 1979). Certain plant species were rarely browsed despite being common and abundantly available, e.g. *Pelthophorum africanum* (Owen-Smith & Cooper, 1983). This could be attributed to natural occurring anti-nutritional factors, which may reduce their palatability, thus lowering their value as supplements to crop residues, and exclude them as fodder.

Apart form anti-nutritive factors, lignification of fibre also reduces intake due to a slow rate of disappearance from the digestive tract (Mertens & Ely, 1979). Irrespective of their high protein concentration that can potentially correct N deficiency of herbaceous vegetation (Le Houerou, 1978), some of the browse trees have most of their CP in the form of NDF-CP (Shayo & Uden, 1999). This form (NDF-CP) indicates low availability. Therefore, its utilization by the animal would be lower than expected.

1.4.2. Chopping, winter and drought feeding

Some fodder trees that are often browsed by livestock in the tropics and sub-tropics are casually chopped or lopped and fed to animals (Skerman, 1977; Le Houerou, 1980). These are often the sole source of protein and energy for ruminants and are converted via this route into high-quality food for human consumption (Woodward & Reed, 1989). A case study in Nepal has shown the usage of foliage from on-farm fodder trees by farmers (Thapa et al., 1997). They "cut and carry" the foliage to feed animals or store them for latter use. The foliage is evaluated in terms of leaf texture, maturity,

bitterness, fodder toxicity and season and management regimes applied to the fodder trees. These attributes aid the farmers to know the exact leaf development stage for chopping. This is their means of preserving the foliage to ensure continuous availability of good quality fodder.

Apart from these attributes, quality fodder has to meet certain conditions, e.g. they should satisfy appetite; have no effect on milk production and milk odour, animal health and palatability and have the potential to improve animal growth rate; and the selection of different fodder by different animal species (Thapa et al., 1997). In essence the farmers of Nepal have a unique method as a yardstick of evaluating fodder to know when to chop the foliage either for preservation or use as fresh forage. Forages from indigenous plant species have been and are still utilized by animals in both the developed and developing countries. However, documented cases of chopping, preserving these forages and feeding them in winter are scarce.

1.5. Limitations and problems

The availability of nutrients from the browse plants depends on other factors like plant defense mechanisms such as secondary phenolic compounds, etc. These can eventually lower the forage's nutritive value through the reduction of its digestibility, palatability and eventually intake by the animal (Shayo & Uden, 1999). The defense mechanisms are the major limitations or problems associated with fodder plants for animal feeding. The mechanisms range from strong odours that can reduce feed intake (Barry et al., 1986), physical structures and nonlignin secondary plant compounds (SPC) of various classes. The latter is shown in Table 1.2.

Most nonlignin defense compounds are of a molecular weight, lower than lignin and are metabolically active. Physical mechanisms include thorns, spines, leaf hairs and silica-loaded tissues (Cheeke, 1995). Heavy browsing pressure results in increased thorns on spiny trees and shrubs, e.g. in *Acacia* species (Cooper & Owen-Smith, 1985). Increased herbivory results in increased chemicals such as alkaloids, that have substantial biochemical inputs (Harborne, 1993). The SPC are classified into two groups: toxic and non-toxic. The toxic compounds are present in plants at low concentrations (< 20 g/kg DM) and have negative physiological effects when absorbed, such as neurological

problems, reproductive failure, goitre and inevitably death in severe cases (Reed et al., 2000). They include alkaloids, cyanogenic glycosides, toxic amino acids, saponins, isoflavonoids, etc.

Table 1.3.

Defense compounds in forage plants[†]

Classes	Compounds	Occurrence	Biological effects
Phenylpropanoids	Lignin	All woody structures	Limit cell wall digestion
	Proanthocyanidins/ Condensed Tannins	Many plants	Limit digestion of protein & Carbohydrates
	Isoflavones	Legumes	Estrogenic, antifungal
Gallate esters	Hydrolyzable tannins	Oak trees, many plants	Limit protein digestion, toxic
Terpenoids	Terpenes	Conifers	Toxic
	Saponins	Legumes etc.	Toxic, bloat
Waxes	Cutin	Surface protection	Reduce digestion
Lectins	Proteins	Widely distributed	Protease inhibitors
Silica	Opal	Grasses, sedges	Inhibit digestion, sharp edges (decrease intake)

[†] Van Soest, 1994

The non-toxic compounds inherently limit the nutritive value of forages by lowering their digestibility and palatability (Van Soest, 1982). Higher concentrations (> 20 g/kg DM) of these compounds are required for negative effects and the primary site of activity is in the digestive tract or through sensory organs associated with feeding behaviour (Reed et al., 2000). They include lignin, tannins (condensed, CT and hydrolyzable), cutins, biogenic silica, volatile terpenoids, etc. The compounds that have a structural role in plants lower the extent of microbial degradability in cell wall polysaccharides behaviour (Reed et al., 2000). Although all the chemical defense mechanisms have adverse effects to animal nutrition, CT in browse plants has been explored extensively.

1.5.1. Non-toxic Secondary Plant Compound

1.5.1.1. Condensed tannins

Many fodder trees contains proanthocyanidins (PA) or CT (Feeny & Bostock, 1968; Barry & Duncan, 1986; Reed, 1986; Mueller-Harvey et al., 1987; Reed, 1995). Condensed tannins lowers feed intake through reducing palatability (Cooper & Owen-Smith, 1985; Woodward & Reed, 1995), digestibility of proteins (Diagayete, 1981; Kumar & Vaithiyanathan, 1990) and DM digestibility (Van Soest et al., 1966; Barry & Manely, 1984; Reed & Soller, 1987; Robbins et al., 1987a; 1987b; Khaazal et al., 1994). The primary site of activity is in the digestive tract or through sensory organs associated with feeding behaviour (Reed et al., 2000).

The insoluble proanthocyanidins are strongly bonded to fibre. Therefore, they affect the rate and extent of ruminal degradation (Haslam, 1979). Condensed tannins reduce CP degradability in the rumen by precipitating and interacting with dietary true proteins (Lowry et al., 1996). They form protein-tannin complexes (Haslam, 1979; Swain, 1979; Reed & Soller, 1987; Robinson et al., 1987; Hagerman, 1989), inactivate digestive enzymes e.g. pepsin (Nastis & Malechek, 1988) and inhibit microbial enzymes (Waage et al., 1984; Nastis & Malechek, 1988).

Most of the complexes become indigestible (Zucker, 1983; Nastis & Malechek, 1988) and can be insoluble in neutral detergent solution (Reed et al., 1990). The complexes that are formed before the fermentation process become part of the NDF-CP of the feed. The proteins in this form are, therefore, rendered unavailable for rumen microorganisms and the host animal (Reed et al., 1990). Condensed tannins also form complexes with fibre and carbohydrates, thereby reducing the degradation of the plant cell wall (Wong, 1973; McLeod, 1974; Nelson et al., 1975; Mould & Robbin, 1981 & 1982; Akin et al., 1988) and total nutrient-absorption capabilities (McLeod, 1974).

A study was conducted on leaves of leguminous browse as supplements for ruminants (Nsahlai et al., 1995). The leaves contained a moderate to high concentration of tannins and fibre bound N (NDFN), which in some cases constituted a high proportion (270-580 g/kg) of total N (Tanner et al., 1990), and was not digested. The concentration of that component increased along the digestive tract (Reed et al., 1990; Tanner et al.,

1990). This was attributed to the formation of protein-tannin complexes (Butler & Bailey, 1973; Barry, 1989) that might limit microbial activity for fibre digestion (Tanner et al., 1990).

Ebong (1989), however, observed that fibre digestion in goats fed tanniferous browse was not impaired. This was a result of a proline-rich protein in saliva secreted by goats, which has a higher affinity for tannin than for dietary protein (D'Mello, 1992). Condensed tannins may have beneficial effects. They are capable of binding proteins reversibly such that the dietary true protein would escape degradation in the rumen to be released in the intestines (Nsahlai et al., 1995). However, reduction of hemicellulose fermentation and other fermentation functions and non-degradable protein are not a guarantee for efficient intestinal absorption (Barry et al., 1986).

Silanikove et al. (1997) suggested that the use of fodders containing low concentrations of tannins can protect dietary protein and provide additional N to the animal. Higher concentrations may overprotect the protein which eventually are excreted through the faeces, thus yielding a low N retention in the animal. Tannin containing forages have a reputation for being bloat free.

Recent studies have shown that some microorganisms in the rumen are capable of tolerating or/and detoxifying some anti-nutritional factors that are found in feeds. They may proliferate following a prior exposure to these compounds (Kumar, 1992; Odenyo et al., 1997). Odenyo et al. (1999) has shown that some animal species, e.g. Gunther's dick-dick and impala fermented tannin-rich leaves efficiently. They further suggested that some browsers are more likely to harbor tannin-tolerant or tannin-degrading microorganisms. The negative effects of higher tannin concentrations may be counteracted also by the use of polyethylene glycol (Jones & Palmer, 2000, Palmer & Jones, 2000).

It is hypothesized that soluble phenolics do not inhibit digestion, but are absorbed and reduce intake through their toxicity. They, however, are more important in defending plant parts against ruminants (Robinson et al., 1987). The highest concentrations of tannins were monitored in freeze-dried leaf samples than those dried at room temperature (Du Toit & Wolfson, 1996). This is because in the freeze-drying process, samples do not thaw and the aqueous phase is absent, polymerition and complexing is minimized. This

suggests that tannins in freeze-dried material are more available for extraction than those of oven-dried material (Du Toit & Wolfson, 1996).

1.5.1.2. Lignin

The lignin fraction increases as plants mature, consequently reducing the nutritive value of forages. This phenomenon is even a major setback with grasses as they mature quickly. Excessive lignification of woody plant leaves physically binds or encapsulates the nutrients. Lignin reduces the palatability and digestibility of browse, especially for small ruminants such as goats and sheep. Lignin also reduces the N balance of the animals by increasing endogenous and microbial N loss in faeces (Woodward & Reed, 1995).

1.5.2. Toxic compounds in plants

Plants exhibit a wide range of toxic compounds, which affect animals in various ways. Toxins may result in the death of the animal (Barry & Duncan, 1986). Animal species differ in their susceptibility to plant toxins, i.e. browsers are less susceptible to some toxins than grazers (Cheeke, 1995). Among other toxins, mimosine, pyrrolizidine alkaloids, oxalates and saponins are some of those produced by plant and are important in animal diets.

1.5.2.1. Saponins

Saponins occur in numerous forage plants (Cheeke, 1995). Saponins of important implications in ruminants nutrition are those in pasture grasses, i.e. alfalfa and minor grains (Cheeke, 1995). The disorders resulting from these compounds include a dermatitic condition, photosensitization and reproductive failure (Cheeke, 1995). They have several negative effects that include poor growth, ruminal bloat, enzyme inhibition, reduced feed intake and palatability, reduced nutrient absorption, antifungal activity that effects rumen microbiology and rumen metabolism and ammonia binding properties.

Saponins have detergent properties, thereby forming a stable foam in the rumen (Cheeke, 1995) and reduce volatile fatty acid (VFA) and microbial protein synthesis (Lu

et al., 1987) by rumen bacteria. They reduce the number of rumen protozoa, a phenomenon referred to as defaunation (Yang & Vagra, 1993). Defaunation yields an increased number of bacteria and fungi, thus increasing rumen microbial efficiency and improving protein utilization (Yang & Vagra, 1993).

This could imply that saponin rich plants could be used as additives for the tropical diets of low-protein high-energy (Preston & Leng, 1987). However, their implication on the photosensitization syndrome (Cheeke, 1995) could exclude the probability of their use. They also bind to the intestinal mucosal cells, although this mechanism prevents their absorption and, therefore, toxicity (Gee & Johnson, 1988). They increase the permeability of these cells, thereby inhibiting active nutrients transport and facilitate the uptake of substances to which the gut would normally be impermeable (Johnson et al., 1986).

1.5.2.2. Mimosine

It is a nonprotein amino acid found in tropical leguminous shrubs of the *Leucaena* species, *Leucaena leucocephala* in particular (Craig, 1995). It affects goats, sheep poultry, pigs, horses and cattle (Lowry, 1987). After ingestion, mimosine in the particular species is rapidly metabolized by rumen microbes into a toxic molecule, 3-hydroxy-4-(1H)-pyridone (3,4DHP) which is considered the primary moiety to these animal species (Jones, 1985). The toxic effects are less severe in ruminants while they may be lethal to non-ruminants (Lowry, 1987). Ruminants in some countries are affected by the 3,4DHP (Lowry & Jones 1984) while the same species in other geographical locations are not (Dominguez-Bello & Stewat, 1990).

The transfer of ruminal fluid from resistant ruminants to those that are susceptible prevents the toxicity (Jones, 1985; Hammond et al., 1989a; b). Ruminal bacteria that degrade the 3,4DHP to nontoxic metabolites (McSweeney et al., 1993a; b) have been isolated from sheep, cattle and goats (Allison et al., 1990; Allison, 1991). However, the ruminal microbes spread naturally to untreated animals and appeared to colonize in the rumen (Quirk et al., 1988; Hammond et al., 1989b).

1.5.2.3. Pyrrolizidine alkaloids

These are found in many plants throughout the world. Plants of most importance in terms of toxicity are of the genera of *Crotalaria, Senicio, Amsinckia, Heliotropium* and *Echium* (Craig, 1995). Cattle are more susceptible while sheep are resistant (Craig, 1995), possibly due to ruminal microbia and hepatic metabolism (Dick et al., 1963).

1.5.2.4. Oxalates

These are found in many plants (Craig, 1995), affecting ruminants and non-ruminants including human beings (Allison & Reedy, 1984). However, some individuals within species possess oxalate-degrading bacteria (Craig, 1995). Plant oxalates form Ca oxalates in the digestive tract, thereby interfering with Ca absorption (Craig, 1995). The formation of calcium oxalate crystals in acute toxicity causes the loss of circulating ionized Ca, or the extensive deposits of these crystals could cause kidney and gastrointestinal damage (Craig, 1995). Adapted animals tolerate levels that are lethal to non-adapted animals (Dawson et al., 1980a).

1.5.2.5 Other toxins

Table 1.4 Other plant toxins

Toxin	Effects
Phytochemicals	Inhibit digestive processes (Cheeke & Palo, 1995)
Cyanogenic glycosides	Releases cyanides which lead to the cessation of ATP production, inhibit terminal respiratory enzyme cytochome oxidase, in severe cases, rapid death is inevitable (Cheeke & Palo, 1995).
Fluoracetate	In South African and Australian poisonous plants inhibit aconitase therefore the Kreb's cycle (Cheeke & Palo, 1995)
Tritepenes and phenolics	Cause high Na excretion in nonruminants (Iason & Palo, 1991)
Pyrrolizidine alkaloids	Causes elevated liver Cu, lower Zn concentration (Swick et al., 1982) and markedly reduced liver and blood vitamin A levels (Huan et al., 1992)
Toxins and phenolics in browse plants may alter mineral and vitamin metabolism (Cheeke & Palo, 1995).	

1.6 Factors affecting minerals in plants

The nature, form and availability of plant minerals for animal nutrition depend on a range of factors. The mineral status of the plant is influenced primarily by the mineral status of the soil (McDowell, 1985). It is also influenced by the stage of maturiy of the plant, climate (sunlight, rainfall) both directly and indirectly (Underwood & Suttle, 1999) and genetic differences among plant species (Underwood, 1981).

1.6.1 Minerals availability

Interactions between minerals are a major cause of variation in the availability and thus influence the nutritive value and potential toxicity of a particular source (Underwood & Suttle, 1999). The availability of Ca and P varies according to their chemical combination or physical association with other compounds in the feeds (McDowell & Valle, 2000). The concentration of Ca in lucerne has been reported to be poorly available although higher (18 g/kg DM) than that required for ruminants (8.21 g/kg DM). This may be due to the large amounts of oxalates in this feed (Ward et al., 1979). Phytic acid suppresses intestinal absorption of Ca, P and other minerals in non-ruminants (McDowell & Valle, 2000).

1.6.2 Genus, species effect

Plants growing in the same location often exhibit different concentration of certain minerals. This has been observed in selenium (Se) accumulator plants growing on seleniferous soils, and in saltbush that contained more than double the concentration of sodium (Na) and chlorine (Cl) than the other plants in the same area (Underwood, 1981). Legumes contain higher concentration of Ca, potassium (K), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe) and cobalt (Co) than grasses, while the latter contained higher manganese (Mn) and molybdenum (Mo) concentrations than the former, growing on the same soil (Underwood & Suttle, 1999).

1.6.3 Soil

The soil mineral content and chemical form, soil pH and degree of water logging influence the availability of some minerals which affect the mineral concentrations in the plant source (Underwood & Suttle, 1999). A change of pH from 5.4 to 6.4 reduced the herbage concentration of Co (Mitchell, 1957). The concentrations of Zn and Cu in herbage tend to decrease with the increase in soil pH (Mitchell, 1957). Deficiencies of some minerals, i.e. Se, P, Co and Na, in grazing animals stem from the fact that the soil contains adequate levels for plant growth, yet low for animal requirements (Underwood, 1981).

1.6.4 Climate and seasons

The tendency for forage concentration of Cu to increase and Se to decrease with increasing altitude (Jumba et al., 1996) is probably a reflection of rainfall. White et al. (1981) found a negative correlation between rainfall and the Se concentration of the forages. Heavy rainfall results in water logging which increases the availability of some soil minerals to plants, notably Co and Mo. Soluble minerals in forages such as K and P are susceptible to leaching in wet weather, unlike Cu, Zn and Mn that are bound in the plant tissue (White et al., 1981). Changes in the leaf to stem ratio during winter decrease plant mineral concentration (White et al., 1981). The concentrations of P, K and Mg in forages are higher during the wet than in the dry season (Kiatoko et al., 1982).

1.6.5 Stage of growth

Generally, the concentrations of minerals such as P, Mg, K, Zn, Co, Mn, Cu and Fe in forages tend to decline markedly with advancing maturity (Underwood, 1981; McPherson, 2000). There is a rapid uptake of minerals during the early growth and a gradual dilution as the plant matures (Berger, 1977). The distribution of P between leaf and stems is relatively uniform although the concentration declines as the plant matures, particularly during the dry season. Evidence suggests that a uniform high proportion of P in dry and fresh forages is absorbable (Ternouth, 1989; Ternouth & Coates, 1997). The shedding of seeds is normally responsible for losses of many plant minerals (Underwood, 1981; Underwood & Suttle, 1999).

1.7. Evaluating the nutritional status of fodder

Over the years fodder has been evaluated using different techniques. The *in vitro* (Tilley & Terry, 1963; Alexander & McGowan, 1969; Lindgren, 1979; Mbwile & Uden 1991) digestibility and *in situ* degradation technique (Øskov et al., 1980; Lindberg, 1970) proved to be reliable when used in conjunction with the chemical composition analysis. The *in vitro* and *in situ* techniques are fairly simple and efficient for screening browse quality (Siaw et al., 1993; Nsahlai et al., 1994) and has an advantage of giving a very rapid estimate of nutrient digestion in the rumen.

1.7.1. The *in situ* technique

This technique has been used to estimate ruminal digestion of DM and carbohydrates, but has been used most frequently to estimate microbial protein degradation (Aerts et al., 1977; Stern et al., 1997; Ørskov et al., 1980). Basically, it has been used to characterize the ruminal digestibility of a feed (Robbin et al., 1986; Nocek, 1988). Denhurst et al. (1995) suggested that the *in situ* technique might not be as precise with forages as it is with concentrates or protein supplements, because of the high proportion of water-soluble material that can leave the bag unfermented. However, in some cases the rate of degradation of the soluble fractions could be slower than that of the insoluble fractions (Ørskov et al., 1980).

They also concluded that the use of this technique on feeds with a low ADF content (< 250 g/kg) is rather limited. It assumes that all protein is completely soluble and instantaneously degraded in the rumen. All protein that disappears at zero time is assumed to be soluble. However, part of this fraction leaves the bag because of small particle size relative to porosity of the bag material (Mahadevan et al., 1979; Wallace & Kopency, 1983). Moreover, some feed particles are lost during washing of the bag, especially if done by a machine rather than by hand washing.

The *in situ* has been criticized mainly because it focussed on protein solubility in various solvents rather than degradability characteristics and lacks biological basis (Nocek, 1988). Although the *in situ* technique leads to an underestimation of cell wall ruminal degradation, it appears to be valid to estimate differences in ruminal degradation of and between feeds (Noziere & Michalet-Doreau, 1996). It provides an advantage

compared to laboratory methods as it involves the digestive processes occurring within the rumen of a live animal. Thus, it closely correlated with digestion *in vivo* (Wanapat et al., 1986). The data obtained from the rumen degradability studies provide information on both the degradable and undegradable fraction of the feeds and also the rate of degradation (Ibrahim et al., 1995).

1.7.2. The *in vitro* technique

The *in vitro* methods, such as the gas production technique, are more reliable in detecting inhibitory compounds in feeds where their effects on the activity of the rumen microbes are readily evident (Khazaal et al., 1994). However, they cannot simulate adaptation or they are not sensitive to factors that might affect the host animal directly or indirectly as a result of microbial fermentation (Stern et al., 1997). It is easier to detect anti-nutritional compounds with the *in vitro* technique, since it is a closed system with a limited supply of rumen liquor.

The effects of these anti-nutritional factors on the rumen microbes become prominent (Apori et al., 1998). The *in vitro* digestible organic matter (IVDOM) range of tropical browse plants is 36 to 69% (Minford & Minson, 1968). In developing countries, the *in vitro* digestibility estimates are commonly used as an index of feeding value because of the difficulties associated with conducting feeding trials (Ibrahim et al., 1995). Lower *in vitro* digestibility with low ADF samples can be related to a drop in pH of the inoculum rather than losses of the soluble substrates from the dacron bags (Stern et al., 1997).

1.8. Hypothesis and objective

The nutritive value of the foliage of fodder trees has been reported to be high and constant throughout seasons, as compared to that of grasses. In fact, it has been suggested that their CP concentrations are high enough for these plant materials to be used as a nitrogen (N) supplement to grasses in animal diets. It can, therefore, be hypothesized that the foliage from trees in southern Africa would contain a constant supply and be rich in nutrients such as CP, minerals etc. consequently have a high nutritive value for ruminants utilizing them. However, information on the nutritive value is limited in the case of many indigenous tree species of southern Africa. The

aim of this study was to evaluate the nutritive value of the foliage of three species of the *Combretum* family, *C. apiculatum, C. molle,* and *C. zeyheri, Colophospermum mopane* and *Pelthophorum africanum;* all of them are well described in the appendix. The objective would be achieved through the determination of the chemical composition, rumen degradability and *in vitro* digestibility of the foliage of these tree species. Among the *Combretum* species given in Table 1.1 and 1.2, only the three were evaluated, as they were the only ones available at the collections cites.

CHAPTER 2

INTRODUCTION

Foliage of three *Combretum* species: *C. apiculatum*, *C. zeyheri* and *C. molle* as well as *Colophospermum mopane* and *Pelthophorum africanum* was collected from the collection sites chosen. They were prepared for chemical analyses and the determination of digestibility through the *in vitro* digestion technique and rumen degradability using the *in situ* technique.

2.1 MATERIALS AND METHODS

2.1.1. Collection sites

The foliage of the tree species was collected in and north of Pretoria at: Hatfield Experimental Farm in Pretoria, La Montagne in Pretoria, Tswaing Crater Museum near Pretoria, Hammanskraal / Petronella between Warmbaths and Pretoria, Warmbaths, Delftzyl Agricultural Research Station near Marble Hall, Selati, a game farm near Gravelotte in the Northern Province and at Hazyview in Mpumalanga.

2.1.2. Sample Collection

The foliage samples were collected throughout the four seasons of the year, designated as winter, spring, summer and autumn respectively. Leaves were picked randomly by hand from different tree specimens at a site and pooled. A sample of approximately 500 g dry matter was put in a brown paper bag and taken to the laboratory for preparation.

2.1.3. Sample preparation

As soon as possible after collection the sample was divided into two portions. One was rinsed in distilled water, the other half not. This was done to establish the degree of dust contamination and its effect on mineral concentration. Both portions were freeze-dried. Thereafter, all the stems were removed and the leaves were milled. Each portion had a sample coarsely milled through a 4 mm screen for the *in situ* digestibility determination and another finely milled through a 1 mm screen for the *in vitro*

digestibility studies and chemical analyses. The coarse samples were stored in plastic bags while the fine samples were stored in capped bottles. All samples were saved in dark cabinets, pending analyses.

2.2. Chemical analyses

2.2.1. Dry matter content

The DM content was determined as recommended by the AOAC (1990). A gram of plant leaf material was weighed into a porcelain crucible then placed in an oven at 100 ^{0}C overnight. Thereafter, the crucibles were put into a desiccator that contained silica gel for 30 minutes to cool before being weighed. The DM was calculated as follows:

$$\% \text{ DM} = \{A / B\} \times 100$$

Where: A = dry mass

B = wet sample mass

2.2.2. The ash content

After the DM determination the crucibles were placed in a cold furnace. Temperature was set at 600 ^{0}C for a minimum of four hours. Afterwards, the furnace was allowed to cool down to at least 250 ^{0}C. The crucibles were then placed in a desiccator for 30 minutes and weighed.

The ash content of samples was calculated as follows:

$$\% \text{ ASH} = \{A / B\} \times 100$$

Where: A = ash mass

B = wet sample mass

The ash content was corrected for DM and reported as g/kg DM.

2.2.3. Organic matter (OM)

The OM content, which would be used for the *in vitro* digestibility calculations, was calculated as follows: OM = DM (g/kg) - Ash (g/kg)

The OM content was reported in g/kg DM.

2.2.4. Nitrogen and crude protein

The N concentration of leaf samples was determined by the macro kjeldhal method (AOAC, 1990) using a block digester and distilling with a Tector kjeltec system model 1002. The N and CP were calculated as follows:

% N = {sample titration – blank titration (factor) / sample mass (g)} x 100

% N was corrected for DM and reported as g N/kg DM.

% CP = % N x 6.25

2.2.5 Neutral detergent fibre

The NDF concentration was determined according to Robertson & Van Soest (1981) using the tector fibertec system. One gram of a sample was weighed in a filter crucible and placed on the hot extraction unit of the system. A neutral detergent solution (NDS) was added into the crucible and allowed to boil for 1 h. Then the solution was removed by washing out with hot distilled water. The residues in the crucibles were dried at 100 ^{0}C overnight, cooled in a desiccator for 30 min. After weighing, they were placed in a muffle furnace to be ashed at 600 ^{0}C for 3 h. The furnace was allowed to cool to at least 250 ^{0}C then the crucibles cooled in a desiccator for 30 min and weighed. Percentage NDF was calculated as follows:

$$\% \text{ NDF} = [W_1 - W_2 / W_3] \times 100$$

Where: W1 = Dry mass of sample after NDS extraction (g)

W2 = Mass of ash (g)

W3 = Sample mass (g)

% NDF was corrected for DM and reported in g/kg DM.

2.2.6. Acid detergent fibre

The ADF was determined according to the method of Goering & Van Soest (1970) using a tecator fibretec system as outlined in the Application Note AN 03/78, exactly like NDF except that the acid detergent solution (ADS) (Van Soest 1963) was used.

Percentage ADF was calculated as follows:

$$\% \text{ ADF} = [W1 - W2 / W1] \times 100$$

Where W1 = Dry mass of sample after ADS extraction (g)

W2 = Mass of ash (g)

W3 = Sample mass (g)

% ADF was corrected for DM and reported in g/kg DM.

2.2.7. Acid detergent lignin (ADL)

The ADL was determined according to the method of Goering & Van Soest (1970). Samples were prepared according to the ADF procedure, yet not ashed. The crucibles with the ADF residues were transferred into 50 ml beakers. The residues were subsequently extracted with a 72% sulphuric acid for 3 h with stirring every 30 min. The residues, after filtration and washing out of the acid with hot distilled water were dried overnight, cooled in a desiccator and weighed (W_1). The residues in the crucibles were then ashed in a muffle furnace at 550 ^{0}C for 3 h. The crucibles were cooled in a desiccator for 30 minutes and weighed (W_2). Percentage ADL was calculated as follows:

$$\% \text{ ADL:} \quad [W_1 - W_2 / W_3] \times 100$$

Where: W_3 = sample mass (g)

%ADL was corrected for DM and reported in g/kg DM.

2.2.8. Acid detergent insoluble nitrogen (ADIN)

The ADIN in the sample was extracted using the same procedure as in ADF except that the sample mass was higher, 2 g. Therefore, 150 ml of acid detergent solution was used to yield a larger residue enough for N determination. The samples were dried at 60 ^{0}C overnight, to reserve the residual N. The N concentration of the residues was

determined and calculated similarly as N determination in 2.2.4. The ADIN was calculated as follows:

% ADIN = % N in residue.

It was corrected for DM and presented in g/kg DM.

2.2.9. Ether extract (EE)

Total fat was determined according to the EE method (ADSIR, 1988), Soxtec System, Soxtec HT6 Model. A 5 g of a freeze-dried sample that was milled through a 1 mm screen was weighed onto a filter paper then placed into a thimble which was then placed on an extraction unit. Petroleum ether of 60 ^{0}C – 80 ^{0}C was used for extraction. The extracts were collected into extraction cups for 2 h of boiling. The cups with the EE were then dried in a 100 ^{0}C oven for 30 min, put in a desiccator then weighed. The EE or total fat was calculated as follows:

$$\%EE = (A / B) \times 100$$

Where:

A = mass of residue in grams

B = mass of original sample in grams

%EE was corrected for DM and reported in g/kg DM.

2.2.10. Condensed tannin concentration

The concentration of CT in the leaf samples was estimated using the Acid Butanol Essay for Proanthocyanidins (Porter et al., 1986), modified by Hagerman (1995). The CT concentrations were expressed as relative to Sorghum Tannin Extract (STE). The assay was conducted by Mr Dawood Hattas, Range and Forage Institute, University of Western Cape, Bellville, RSA.

2.2.11. Minerals

The concentrations of the following minerals were determined in all the samples: Ca, P, K, Na, Mg, selenium (Se), manganese (Mn), cobalt (Co), copper (Cu), zinc (Zn) and iron (Fe). Samples were digested through a wet digestion. A gram of a sample, in duplicates, was digested in a block digester at 230 ^{0}C. The concentrations of Ca and Mg

were determined using the Perkin Elmer 2380 Atomic Absorption Spectrophotometer pp Ay II. The minerals, K, Mg, Co and Mn were determined on the Varian Atomic Absorption Spectrophotometer 50. The concentration of P was determined using a Technicon Auto Analyzer II and the concentration determined from calibration curve. Selenium was digested on a block digester with a temperature-timed programmer. It was determined on the same spectrophotometer that was used for Ca and Mg except that a continuous flow vapour hydride generator was attached. An internal laboratory standard sample with known concentrations of all the minerals analyzed, was included in every digestion. The standard was always kept in the refrigerator. The wavelength and slit setting used for each mineral is shown in Table 2.1.

The macro minerals, Ca, P, K, Mg and Na were reported in g/kg DM while the trace minerals Zn, Fe, Co, Mg and Mn were reported in mg/kg DM. The concentration of Se was in ng/g DM. They were calculated as follows:

Macro minerals: % = {ng/kg x D / M} / 1000

Trace minerals: % = {ng/kg x D/ M}/ 1000

Where: D = dilution factor, M = sample mass

Se: = ng/g {1000 / % DM)

ng/kg = reading from the atomic absorption machine

Table 2.1

Wavelength and slit settings of the minerals analyzed

Minerals	Wave Length (nm)	Slit Setting
Ca	422.7	0.7
P	440.0	--
K	766.5	2.0 emission
Mg	285.2	0.7
Na	589.0	0.2 emission
Se	196.0	--
Mn	279.5	0.2
Co	240.7	0.2
Cu	324.7	0.7

2.3 The digestibility and degradability techniques

2.3.1 The *in vitro* digestibility of organic matter (IVDOM)

The two-staged *in vitro* technique, as described by Tilley & Terry (1963) and modified by Engels & Van der Merwe (1967) was used to determine IVDOM. A 0.2 g freeze-dried sample milled to pass a 1 mm screen was incubated in a test tube with rumen fluid collected from mature whether sheep fitted with rumen cannulae fed on a diet of 100% lucerne (*ad lib*), urea solution, McDougall's artificial saliva and carbon dioxide for 48 hours at 39 ^{0}C in a water bath. Samples were shaken continuously. After this period the tubes were centrifuges at 1000 RPM for 15 min.

The initial solution was decanted, a 20 ml solution of HCl and pepsin was added. This solution was made of a 4 g of pepsin and a liter of 0.1 M HCl. The tubes were further incubated for another 48 h. After the incubation the samples were centrifuged and decanted as in the first stage then dried overnight at 100 ^{0}C in an oven. They were, afterwards, cooled in a desiccator for 30 min then weighed. The tubes with the residues were ashed in a muffle furnace at 550 ^{0}C for 3 hrs, cooled and weighed. A *Panicum maximum* sample with an IVDOM of 70 – 75 % was used as a reference. The % IVDOM was calculated as follows:

D = 100 - {Undigested residue (OM) / sample mass (g)} x 100

Where: D = digestibility of OM (%IVDOM)

The sample mass of the incubated sample and the undigested residue is expressed in terms of OM content.

2.3.2. The rumen degradability trial (*in situ* digestion)

The rumen degradability of DM and N of the samples was determined according to the technique standardized by the AFRC (1992).

2.3.2.1. Samples and nylon bags preparation

Freeze-dried samples were milled through a 4 mm screen and fine particles removed through a 45 µ sieve. Synthetic polyester fibre bags of 53 µm pore size and approximately 26% open area and 10 X 21cm dimension were used. Bags were dried for 2 h at 60 ^{0}C and their mass was recorded for the calculations.

2.3.2.2 Animals preparation

Three mature whether sheep fitted with rumen cannulae were used. They were fed a diet of 100% lucerne (*ad lib*). They were adapted to the lucerne for a period of two weeks before the trial commenced.

2.3.2.3. Incubation

Approximately 5 g of a sample, in triplicates, were weighed out and put into bags. A DM determination was done on a separate sample. The bags with samples were securely tied with fish lines onto metal rings. The rings with bags were securely tied by nylon twines, which will be held outside the cannulae. Samples were incubated for 0, 4, 8, 16, 24 and 48 h using a sequential withdrawal method. On removal the bags were immediately hand washed under running water until the rinse water was clean, and finally with distilled water.

The zero time disappearance was obtained by applying the same wash procedure on to the unincubated bags. *Pannicum maximum* was used as a standard and it was included in every incubation period. Post washing, the bags were dried in a 60 ^{0}C oven for 48 h or until reaching a constant weight. Bags plus residues were placed in a desiccator for 30 min then weighed. The residues in bags were further analyzed for N (as in 2.3.4).

2.3.2.4. Parameters

The following variables were calculated: percentage disappearance DM and N (DMD and ND)

%DMD = {(A-C)/A} x 100

%ND = {(B-D)/A} x 100

Where: A = Wt of DM, B = Wt of N

C = Residual DM, D = Residual N

The DMD and ND data were fitted into the nonlinear model:

$$p = a + b\,(1 - e^{-ct})$$

Suggested by Ørskov & McDonald (1979), where p = the amount of protein and DM degraded at time t, a = the rapidly soluble fraction, b = insoluble but fermentable fraction

in time, c = degradation rate constant of the b fraction and PD = the extent of degradation (a + b). The effective degradability p was estimated from the a, b and c fractions by introducing the fractional outflow rate k (0.2, 0.5 and 0.8) into the equation:

$$p = a + (bc/c+k)$$

2.4 Statistical analysis

The chemical composition and *in vitro* digestion data of each species was subjected to the analysis of variance with the GLM procedure (SAS, 1994) and the collection sites were not considered. Variables were seasons and wash and non-wash. The level of significance was tested with the Fischer Test (Samuels, 1989). The least square means and standard errors were also calculated. The Pearson correlation coefficients between variables of the same data mentioned above, within plant species was determined with the CORR model (SAS, 1994). The *in situ* degradation data was subjected to the iterative least squares method using the nonlinear procedure, NLIN (SAS, 1994) to estimate the nonlinear variables a, b and c.

CHAPTER 3

3. RESULTS

3.1. Chemical composition

The results of the chemical composition of all the tree species are presented in Table 3.1 to 3.4. The number (*n*) of observations in Tables 3.1 and 3.2 are also applicable to minerals and the *in vitro* analysis for all the plant species and the seasons. The samples for *C. mopane* were collected, as from spring to autumn, hence winter values are not available for all the analysis.

The ash content ranged from 30.3 g/kg DM in *C. zeyheri* to 85.8 g/kg DM in *C. molle* while the OM concentration ranged from 918 g/kg DM in *C. molle* to 963.2 g/kg DM in *C. zeyheri*, with no significant seasonal variation among all the species. The CP concentrations ranged from 62.9 g/kg DM in *C. molle* to 172.3 g/kg DM in *C. mopane,* while the winter concentration was lower, 107 g/kg DM ($P< 0.05$), than the other seasons only for *C. apiculatum*. The fibre bound N (ADIN) ranged from 1.2 g/kg DM for *C. apiculatum* to 3.3 g/kg DM in *C. mopane* with no significant seasonal variation in any of the species.

The NDF concentrations ranged from 270.3 g/kg DM in *C. apiculatum* to 410.1 g/kg DM in *P. africanum.* The only variation ($P< 0.05$) between seasons was evident in *C. zeyheri*, where the summer concentrations were lower, 297 g/kg DM, than the other seasons. The ADF ranged from 208.1 g/kg DM in *P. africanum* to 375.2 g/kg DM in *C. molle*. The ADF concentrations varied ($P< 0.05$) between seasons for *C. apiculatum* (spring concentrations were lower at 211 g/kg DM, $P< 0.05$), *C. zeyheri* (summer concentrations were lower at 230 g/kg DM, $P< 0.05$) and *C. mopane* (summer concentrations were higher at 322 g/kg DM, $P< 0.05$).

The CT concentrations ranged from 65.6 mg STE/g DM in *C. zeyheri* to 660.3 mg STE/g DM in *C. mopane.* A seasonal variation ($P< 0.05$) was shown by *C. apiculatum,* where the winter and autumn concentrations, 505 and 515.3 mg STE/g DM respectively, were higher than those of spring and summer at 286 and 305 mg STE/g DM respectively.

C. Zeyheri showed a different CT trend, where the autumn concentrations (104 mg STE/g DM) were lower than those of summer (196 mg STE/g DM), while winter and

spring showed zero concentrations. The ADL concentration ranged from 45.6 g/kg DM in *C. apiculatum* to 172.6 g/kg DM in *C. mopane* and a seasonal variation ($P< 0.05$) was shown only by *C. apiculatum* where the summer concentrations, 80 g/kg DM, were higher. The washing of the samples, for all the plant species of all the chemical analysis between seasons showed insignificant variation.

Table 3.1
The chemical composition of the foliage (LSM and SE values) are reported in g/kg DM except for tannins, mg STE/g

Season	*N*	Ash	OM	CP	NDF	ADF	ADIN	ADL	EE	CT
C. apiculatum										
Winter	8	51± 3	945 ± 3	107 ± 7	321 ± 14	261 ± 6^{a}	1.8 ± 0.4	55 ± 3^{a}	54 ± 3^{a}	505 ± 37^{a}
Autumn	8	55 ± 2	941 ± 2	119 ± 6^{b}	326 ± 11	251 ± 5^{a}	1.5 ± 0.2	52 ± 2^{a}	40 ± 2^{b}	515 ± 27^{a}
Spring	8	53 ± 3	940 ± 4	118 ± 24^{b}	319 ± 18	211 ± 8^{b}	1.4 ± 0.5	43 ± 4^{a}	37 ± 4^{b}	286 ± 48^{b}
Summer	8	54 ± 8	940 ± 10	118 ± 24^{b}	332 ± 45	253 ± 20^{a}	2 ± 1	80 ± 10^{b}	45 ± 9^{ab}	305 ± 120^{b}
Mean		53.3	943.6	107.4	322.7	242.3	6.7	54.6	42.6	414.4
Minimum		48.0	930	92.6	270.3	222.5	5.5	45.6	32.7	224.6
Maximum		64.3	951.9	125.2	357.9	263.8	8.2	85.5	59.1	498.8
C. zeyheri										
Winter	7	40 ± 4	956 ± 3	109 ± 11	353 ± 14^{a}	312 ± 8^{a}	1.5 ± 0.5	61 ± 5	41 ± 3^{a}	0.00
Autumn	8	41 ± 3	952 ± 2	120 ± 7	372 ± 10^{a}	306 ± 6^{a}	1.7 ± 0.4	66 ± 4	26 ± 2^{b}	104 ± 36^{a}
Spring	7	38 ± 5	958 ± 4	125 ± 15	318 ± 19^{a}	292 ± 12^{a}	1.9 ± 0.7	51 ± 7	17 ± 5^{b}	0.00
Summer	8	40 ± 6	956 ± 5	77 ± 17	297 ± 22^{b}	230 ± 14^{b}	1.2 ± 0.9	60 ± 8	35 ± 6^{a}	196± 84^{b}
Mean		39.8	955.4	107.3	326.3	289.3	1.5	65.4	32.3	99.1
Minimum		30.3	947.6	82.2	288.7	270.9	0.9	48.3	23.9	65.6
Maximum		46.6	963.2	137.8	376.9	319.8	2.1	75.4	41.4	204.1
C. molle										
Winter	2	71 ± 6	922 ± 6	85 ± 10	382 ±16	356 ±19	2 ± 0.5	79 ± 9	45 ± 8	334 ±149
Autumn	4	54 ± 6	940 ± 7	102 ± 10	398 ± 16	347 ±19	1.9 ± 0.5	75 ± 9	29 ± 8	312 ±149
Spring	2	73 ± 7	921 ± 8	99 ± 11	409 ± 19	364 ± 22	2.1 ± 0.6	64 ± 10	19 ± 10	317 ±175
Summer	4	85 ±12	909 ±14	69 ± 20	358 ± 34	352 ± 39	2 ± 0.98	76 ± 19	39 ± 8	354 ± 129
Mean		69.7	925.1	91.8	390.8	353.8	2	74	32.3	247.1
Minimum		62.7	918	62..9	374.3	332.2	1.2	63.3	23.9	78.8
Maximum		85.8	945.5	103.9	407.7	375.2	3.2	84	45.4	409.7

Superscripts ^{a,b} within columns of each species denote a significant difference at $P < 0.05$
LSM, least square means; SE, standard error; STE, sorghum tannin equivalent.

Table 3.2
The chemical composition of the foliage (LSM and SE values) are reported in g/kg DM except for tannins, mg STE/g

Season	*n*	Ash	OM	CP	NDF	ADF	ADIN	ADL	EE	CT
C. mopane										
Autumn	3	53 ± 2	943 ± 2	154 ± 11	361 ± 21	299 ± 24[a]	3.3 ± 0.2	136 ± 18	43 ± 8	660 ± 8
Winter	---	---	---	---	---	---	---	---	---	---
Spring	3	55 ± 2	941 ± 2	169 ± 11	373 ± 21	302 ± 24[a]	3.02 ± 0.2	134 ± 18	41 ± 8	643 ± 8
Summer	4	42 ± 2	955 ± 3	99 ± 13	399 ± 26	322 ± 27[b]	3.1 ± 0.3	168 ± 22	44 ± 9	659 ± 10
Mean		50.8	945	148.5	380.8	305.3	3	132.3	40.8	599.1
Minimum		42	944.3	99.3	373	304	2.05	122.3	38.3	487.3
Maximum		55.3	956	172.3	399	325.1	4.3	172.6	44.9	660.3
P. africanum										
Autumn	8	49 ± 3	945 ± 3	126 ± 4	406 ± 7[b]	231 ± 6	---	---	---	---
Winter	7	49.6 ± 3	946 ± 3	116 ± 5	347 ± 9[a]	229 ± 7	---	---	---	---
Spring	8	44 ± 3	952 ± 4	132 ± 6	393 ± 11[b]	219 ± 9	---	---	---	---
Summer	8	46.4 ± 9	949 ± 9	129 ± 15	383 ± 28[b]	225 ± 23	---	---	---	---
Mean		47.3	948.2	109.2	387.3	225.9	---	---	---	---
Minimum		41.4	937.8	97.6	364.0	208.1	---	---	---	---
Maximum		56.6	954.3	123.4	410.1	249.6	---	---	---	---

Superscripts [a-b] within columns of each species denote a significant difference at $P < 0.05$
LSM, least square means; SE, standard error; STE, sorghum tannin equivalent.

3.1.1. Minerals

3.1.1.1. Macro elements

The Ca concentrations of the *Combretum* species and *C. mopane* ranged from 7.9 g/kg DM for *C. mopane* to 16 g/kg DM in *C. molle.* A seasonal variation ($P< 0.05$) was shown only by *C. mopane* where spring concentrations were higher than those of the other seasons. The P concentrations ranged from 0.81 g/kg DM in *C. mopane* to 2.1 g/kg DM in *C. mopane* with seasonal variations ($P< 0.05$) in all the species. Thus the concentrations in one or two of the seasons varied from the others. The K concentrations ranged from 1.2 g/kg DM to 7.8 g/kg DM in *C. mopane* with no significant seasonal variations within all the species. The concentration of Mg ranged from 1.4 g/kg DM in *C. molle* to 3.8 g/kg DM in *C. apiculatum.* A seasonal variation, spring concentrations higher at 2.8 g/kg DM ($P< 0.05$) than other seasons, was shown only by *C. mopane.*

The concentrations of Na ranged from 0.03 g/kg DM in *C. molle* to 0.05 g/kg DM in *C. mopane* with no significant seasonal variations for all the species. The Na results could be almost similar for all the species possibly due to the minute concentrations in the samples, which were almost undetectable by the atomic absorption.

3.1.1.2. Micro elements

The Cu concentrations ranged from 7.8 mg/kg DM for *C. molle* to 66 mg/kg DM for *C apiculatum.* This element's significant seasonal variations were evident in *C apiculatum* (winter concentrations were higher than those of the other seasons) and *C. molle* (the spring concentrations, 9.2 mg/kg DM, were higher than those of the other seasons).

The Zn concentrations ranged from 8.5 mg/kg DM for *C. molle* to 65 mg/kg DM for *C. zeyheri* with no significant seasonal variations for any of the plant species. The Co concentrations ranged from 0.049 mg/kg DM in *C. zeyheri* to 0.69 mg/kg DM in *C. molle* with a significant seasonal variation ($P < 0.05$) for *C. zeyheri* and *C. mopane.*

The Se concentrations ranged from 46 ng/g DM in *C. apiculatum* to 159 ng/g DM in *C. molle* with significant seasonal variations ($P < 0.05$) only in *C. mopane* (the autumn concentrations, 149 ng/g DM, were higher than those of the other seasons).

The concentrations of Fe ranged from 169 mg/kg DM for *Mopane* to 435 mg/kg DM for *C. zeyheri* with no significant seasonal variations in any of the plant species. The Mn concentrations ranged from 29 mg/kg DM in *C. apiculatum* to 169 mg/kg DM in *C. apiculatum*. Its significant seasonal variation ($P<0.05$) was evident in all the plants except for *C. zeyheri*.

Table 3.3
The macro minerals concentration of the foliage (LSM and SE values) are reported in g/kg DM, micro-minerals in mg/kg DM except for Se, in ng/g DM

Plant Species /Season	Macro Minerals					Micro Minerals					
	Ca	P	K	Mg	Na	Cu	Co	Se	Zn	Mn	Fe
C. apiculatum											
Autumn	8.9 ±2	1.4±0.1 [b]	6.6 ±0.9	3.8±0.3	0.04±0.003	39 ±17	0.16 ±0.05	68 ±16	18 ±3	169 ±40 *	377 ±31
Winter	9.1 ±1	0.88 ±0.1[a]	5.7 ±0.5	3.0±0.2	0.04±0.002	66 ±11 [a]	0.18 ±0.03	82 ±10	23 ±2	48 ±25 *	391 ±20
Spring	9.5 ±1	1.1 ±0.1 [a]	6.8 ±0.04	3.0 ±0.1	0.04±0.002	27 ±7.6 [b]	0.13 ±0.02	68 ±7.1	22 ±1	92 ±18 *	389 ±11
Summer	11 ±3	0.95 ±0.3 [a]	5.7 ±1.6	2.8 ±0.5	0.04±0.007	12 ±34	0.15 ±0.10	46 ±32	13 ±5	29 ±81 *	399±63
C. zeyheri											
Autumn	11 ±3	0.95 ± 0.3 [a]	5.7 ±1.6	2.8 ±0.5	0.04±0.007	10.1 ±5	0.1 ±0.1[a]	120 ±66	65 ±25	163 ± 58[a]	435 ±75
Winter	11 ±1	0.92 ± 0.1[a]	6.7 ±0.5	2.1 ±0.2	0.04±0.003	11 ±1.2	0.11±0.03[b]	112 ±23	41 ±9	91 ± 20[a]	299 ±41
Spring	10 ±1	1.1 [a] ± 0.1	6.9 ±0.4	2.3 ±0.2	0.04±0.002	14 ±1	0.1 ±0.02[b]	149 ±17	44 ±6	29 ± 15[b]	223 ±31
Summer	12 ±2	1.5 ± 0.2[b]	7.1 ±0.8	2.1 ±0.3	0.04±0.004	15 ±1.7	0.1±0.04[b]	74 ±32	23 ±12	58 ± 29[a]	195 ±58

Superscripts [a−b] within rows denote a significant seasonal variation at $P < 0.05$
LSM, least square means; SE, standard error

Table 3.4
The macro minerals concentration of the foliage (LSM and SE values) are reported in g/kg DM, micro-minerals in mg/kg DM except for Se, in ng/g DM

Plant Species/ Seasons	Macro minerals					Micro minerals					
	Ca	P	K	Mg	Na	Cu	Co	Se	Zn	Mn	Fe
C. molle											
Winter	16 ± 4	0.8±0.2[a]	6.9 ± 1	3.2 ± 0.1	0.04±0.002	7.9 ± 0.4[a]	0.18 ± 0.1[a]	159 ± 35	37 ± 13	51 ± 29	311 ± 50
Autumn	8.4 ± 5	1.1±0.4	6.9 ± 1	1.4 ± 10	0.03±0.004	7.8 ± 1	0.17 ± 0.1[b]	107 ± 74	38 ± 19	59 ± 59	275± 71
Spring	10 ± 3	1.5±0.2[b]	6.4 ± 1	3.2 ± 0.1	0.04±0.002	9.2 ± 0.4[b]	0.16 ± 0.1[a]	79 ± 35	39 ± 14	111 ± 29	235 ± 71
Summer	9.4 ± 4	1.7±0.3[b]	6.5 ± 1	1.4 ± 0.1	0.04±0.003	9.1 ± 1	0.69 ± 0.1[b]	92 ± 49	17 ± 19	134 ± 40	234 ± 71
C. mopane											
Autumn	7.9 ± 2[b]	0.81±02[b]	7.8 ± 1	1.7 ± 1[b]	0.04±0.004	12 ± 2.4	0.25 ± 0.2	149 ± 35[b]	27 ± 3	112 ± 39[a]	207 ± 13
Winter	---	---	---	---	---	---	---	---	---	---	---
Spring	11 ± 2[a]	1.4±0.2[b]	1.2 ± 1	2.8 ± 0.2[a]	0.04±0.004	11 ± 1.7	0.12 ± 0.1	76 ± 25[a]	15 ± 3	102 ± 28[a]	169 ± 12
Summer	9.1 ± 2[b]	2.1±1[a]	6.8 ± 1	1.9 ± 0.3[b]	0.04±0.004	15 ± 2	0.36 ± 0.1	57 ± 31[a]	20± 3	166 ± 34[b]	176 ± 11

Superscripts [a – b] within rows denote a significant seasonal variation at $P < 0.05$
LSM, least square means; SE, standard error

3.1.1.3 Minerals correlation

The correlation coefficients of the minerals within plant species are presented in Table 3.5 and Table 3.6. A high correlation (P< 0.01) within species was observed between Ca, Mg and K, Na (r = 0.47), P and Mn (r = 0.50), Cu and Co (r = 0.66) in *C. apiculatum*; K and Co (r = -0.49), Ca, K and Zn , Se (r = -0.59), Mg, Na (r = 0.62) and P and Cu (r = 0.72) in *C. zeyheri*; Ca and Se (r = 0.86), Mg and Co (r = -0.95) in *C. molle* and in *C. mopane* it was Se and Mn (r = 0.95); P and Cu (r = 0.99). High correlation coefficients (P< 0.01) between some minerals over the tree species prevailed and they are shown in Table 3.7.

Table 3.5

The coefficients (r) of determination between mineral concentrations within plant species

	Ca	P	K	Mg	Na	Cu	Zn	Fe	Co	Se
C. apiculatum										
P	0.13									
K	0.08	0.08								
Mg	.47*	0.29	0.40†							
Na	0.25	0.41	0.47*	0.26						
Cu	0.28	-0.03	-0.06	0.09	0.12					
Zn	-0.15	0.09	0.16	-0.15	0.14	0.16				
Fe	0.05	0.16	-0.16	-0.12	0.28	0.06	0.33†			
Co	-0.06	0.05	0.14	-0.18	0.26	0.66*	0.44*	0.16		
Se	0.42†	0.25	-0.17	0.16	0.22	0.38	0.22	0.17	0.37†	
Mn	0.28	0.50*	0.25	0.24	0.62	-0.15	-0.33	0.06	-0.28	-0.04
C. zeyheri										
P	0.12									
K	-0.59*	0.16								
Mg	0.04	0.02	-0.13							
Na	-0.23	0.16	0.22	0.62						
Cu	-0.31	.72*	0.37	0.12	0.27					
Zn	-0.11	-0.30	-0.33	0.27	0.14	-0.30				
Fe	-0.23	-0.19	0.07	0.14	0.26	-0.3	0.10			
Co	0.05	-0.22	-0.49*	-0.02	0.12	-0.38	0.19	0.47†		
Se	-0.08	-0.17	-0.04	-0.09	-0.03	-0.15†	0.59*	0.05	0.06	
Mn	0.001	.05	-0.13	-0.21	-0.41	0.02	0.03	0.13	0.17	-0.12

Symbols † = P<0.05; * = P<0.01

Table 3.6
The coefficients (r) of determination between mineral concentrations within plant species

Miner.	Ca	P	K	Mg	Na	Cu	Zn	Fe	Co	Se
C. molle										
P	-0.32									
K	0.68†	-0.43								
Mg	0.39	-0.1	0.05							
Na	0.12	0.26	-0.29	0.58						
Cu	-0.38	0.09	0.01	-0.38	-0.31					
Zn	0.41	0.34	0.03	0.45	0.39	-0.26				
Fe	0.21	-0.25	-0.19	0.17	-0.22	-0.38	0.04			
Co	-0.45	0.12	-0.02	-0.95*	-0.62	0.25	-0.66	-0.14		
Se	0.86*	-0.25	0.64	0.27	0.12	-0.36	0.40	0.26	-0.29	
Mn	-0.42	0.75	-0.34	-0.44	-0.11	0.32	0.06	-0.04	0.34	-0.26
Mopane										
P	0.03									
K	0.10	-0.72								
Mg	-0.08	0.55	-0.41							
Na	-0.74	-0.11	0.06	-0.09						
Cu	-0.03	0.99*	-0.69	0.48	-0.06					
Zn	-0.87†	-0.31	0.24	-0.27	0.90	-0.24				
Fe	-0.59	-0.59	0.35	0.11	0.22	-0.59	0.48			
Co	0.75	0.64	-0.23	0.32	-0.54	0.59	-0.78	-0.82		
Se	-0.37	0.88†	0.72	-0.24	0.35	-0.87	0.55	0.84	-0.76	
Mn	-0.71	-0.55	0.08	-0.48	0.49	-0.49	0.73	0.64	-0.95*	0.58

Symbols † = P<0.05; * = P<0.01

Table 3.7
The coefficients of determination (r) of the mineral concentrations over the plant species

Min	Ca	P	K	Mg	Na	Cu	Zn	Fe	Co	Se
P	0.03									
K	-0.02	0.15								
Mg	0.16	-0.06	0.00							
Na	-0.02	0.27	0.34	0.09						
Cu	-0.02	-0.06	-0.09	0.29	-0.05					
Zn	0.12	-0.04	-0.09	-0.06	0.16	-0.18				
Fe	-0.15	-0.24	-0.17	0.39	-0.08	0.31	-0.14			
Co	-0.07	-0.02	-0.12	-0.17	-0.05	0.21	-0.11	0.16		
Se	0.31	-0.17	0.07	-0.17	0.14	-0.09	0.58	-0.14	-0.01	
Mn	0.01	.31	0.05	0.06	0.18	-0.05	-0.12	0.11	0.07	-0.16

3.2. Digestibility

3.2.1. The IVDOM

The results of the IVDOM analyses are presented in Table 3.8. The IVDOM percentages of the *Combretum* species and *C. mopane* ranged from 52.6% for *C. mopane* and *C. zeyheri* to 64.1% for *C. apiculatum* with no significant variations between seasons and the wash. This analysis was not done on the samples of *P. africanum*.

Table 3.8
The in vitro digestibility of organic matter of the various species in percentages

Species	Winter	Spring	Summer	Autumn	Mean
C. apiculatum	58.4 ±1.9	60.2 ±0.5	64.1 ±2.6	62.7 ±6.4	60.4
C. zeyheri	54.1 ±1.3	56.8 ±0.9	55.2 ±1.8	56.8 ±12	55.9
C. molle	56.9 ±2.2	55.7 ±2.2	55.5 ±2.5	54.1± 4.5	55.9
C. mopane	---	54.3 ±0.5	52.6 ±0.5	53.4 ±0.6	53.4

LSM, least square means; SE, standard error

3.2.2 Correlation between chemical composition and IVDOM

The correlation coefficients of the chemical composition and IVDOM within plant species are presented in Table 3.9 and the correlation coefficients over the plant species are shown in Table 3.10. The correlations within plant species were observed between CT and ADL ($r = 0.87$, $P<0.01$) in *C. molle*. The lowest negative correlations were between ADL and NDF ($r = -0.02$) in *C. mopane* while the highest was between ADFN and ADF ($r = -0.95$, $P< 0.01$) in *C. mopane*.

Table 3.9
The coefficients (r) of determination between chemical fractions and *in vitro* digestible organic matter within plant species

Parameter	NDF	ADF	ADIN	ADL	CP	CT
C. apiculatum						
ADF	0.28					
ADIN	-0.08	-0.20				
ADL	0.08	0.23	0.39			
CP	-0.04	-0.60*	0.35	-0.17		
CT	0.37†	0.49*	-0.08*	0.39*	-0.52	
IVDOM	-0.13	-0.33†	-0.14	-0.23	0.19	-0.18*
C. zeyheri						
ADF	0.29					
ADIN	-0.30	0.34				
ADL	0.55*	0.09	-0.23			
CP	0.36†	0.15	-0.18	0.21		
CT	0.24	0.04	0.21	0.40	-0.18	
IVDOM	0.16	-0.04	-0.04	-0.14	-0.08	0.01
C. molle						
ADF	0.51					
ADIN	-0.24	-0.41				
ADL	-0.76†	-0.64†	0.49			
CP	0.67*	0.60	-0.65*	-0.69†		
CT	-0.83	-0.83*	0.32	0.87*	-0.48	
IVDOM	0.48	0.53	-0.62†	-0.65†	0.48	-0.53
C. mopane						
ADF	0.56					
ADIN	-0.29	-0.95†				
ADL	-0.02	0.75	-0.84†			
CP	-0.77	-0.84†	0.67	-0.48		
CT	0.13	0.85	0.07	0.12	-0.26	
IVDOM	-0.31	-0.10	0.06	0.09	0.17	0.28

Symbols † = P<0.05; * = P<0.01

The IVDOM, within the plants, significantly correlated with ADF (r = -0.33, P< 0.05) and CT (r = -0.18, P< 0.05) for *C. apiculatum*; ADFN (r = -0.62, P< 0.05) and ADL (r = 0.65, P< 0.05) for *C. molle*. Its significant correlation over the plants was with ADF (r = -0.38, P< 0.01) and ADL (r = -0.37). The IVDOM, generally, correlated negative and insignificant with most of the chemical composition fractions, within and over the plants.

It is with *C. apiculatum* where CT, within plants, had a highly significant correlation (P< 0.01) with the other fractions (ADF, ADFN, ADL and IVDOM) while the same significant correlation, over the plant species was observed except with IVDOM.

Table 3.10
The coefficients of determination (r) of the chemical composition and *in vitro* digestibility of organic matter over the plant species

Parameter	NDF	ADF	ADIN	ADL	CP	CT
ADF	0.55*					
ADIN	-0.09	-0.07				
ADL	0.36*	0.33*	0.49*			
CP	-0.02	-0.31*	0.23†	0.05		
CT	-0.05	-0.34*	0.06*	0.34*	-0.02	
IVDOM	-0.19	-0.38*	-0.12	-0.37*	0.14	0.08

Symbols † = P<0.05; * = P<0.01

3.3 Rumen degradability

3.3 .1 The *in situ* degradability trial

The *in situ* trial was done on a few selected samples of the *Combretum* species. These were the species that provided enough foliage samples for this trial though not in all the seasons. Therefore, the available samples of each species were pooled. The analysis excluded the seasonal variations within species. The degradation parameters of DM and N (a, soluble fraction; b, degradable fraction; c, rate of degradation and PD, the extent of degradation) were recorded for these species and they are shown in Table 3.11. These parameters have also been presented graphically and are shown in Figures 3.1 and 3.2.

The N soluble fraction was lowest for *C. apiculatum* (4.02%), while *C. zeyheri* had the highest (25.4%). The N degradable fraction was lowest for *C. zeyheri* (34%) while *C. apiculatum* had the highest (44%). The highest extent of degradation for N was that of *C. zeyheri* (60%) followed by *C. molle* (51%) while the lowest was that of *C. apiculatum* (47%). The DM and N degradability at fractional outflow rates per hour are also presentedinTable3.11.

Table 3.11
Degradability estimates of dry matter and nitrogen determined through NLIN, $n = 42$

Species	The degradability							
	R^2	a	b	c	PD	$0.02^{¥}$	$0.05^{¥}$	$0.08^{¥}$
Dry Matter								
C. apiculatum ^{n1}	0.94	34.85	58.92	0.045	93.77	0.758	0.629	0.568
C. zeyheri ^{n2}	0.91	35.43	47.18	0.056	82.61	0.705	0.604	0.549
C. molle ^{n3}	0.91	33.08	45.21	0.073	78.29	0.687	0.599	0.547
Nitrogen								
C. apiculatum ^{n1}	0.98	4.04	43.57	0.072	47.14	0.378	0.294	0.245
C. zeyheri ^{n2}	0.95	25.39	34.95	0.042	60.34	0.491	0.414	0.375
C. molle ^{n3}	0.96	10.73	39.85	0.056	50.58	0.401	0.318	0.272

Superscript $^{¥}$ = the degradability at fractional outflow rates (k) 0.02, 0.05, 0.08.
Superscript $^{n1} = n - 20$; $^{n2} = n - 12$; $^{n3} = n - 10$
a - rapidly soluble fraction; b - insoluble but fermentable fraction in time
c - degradation rate constant of the b fraction; PD - extent of degradation (a + b).

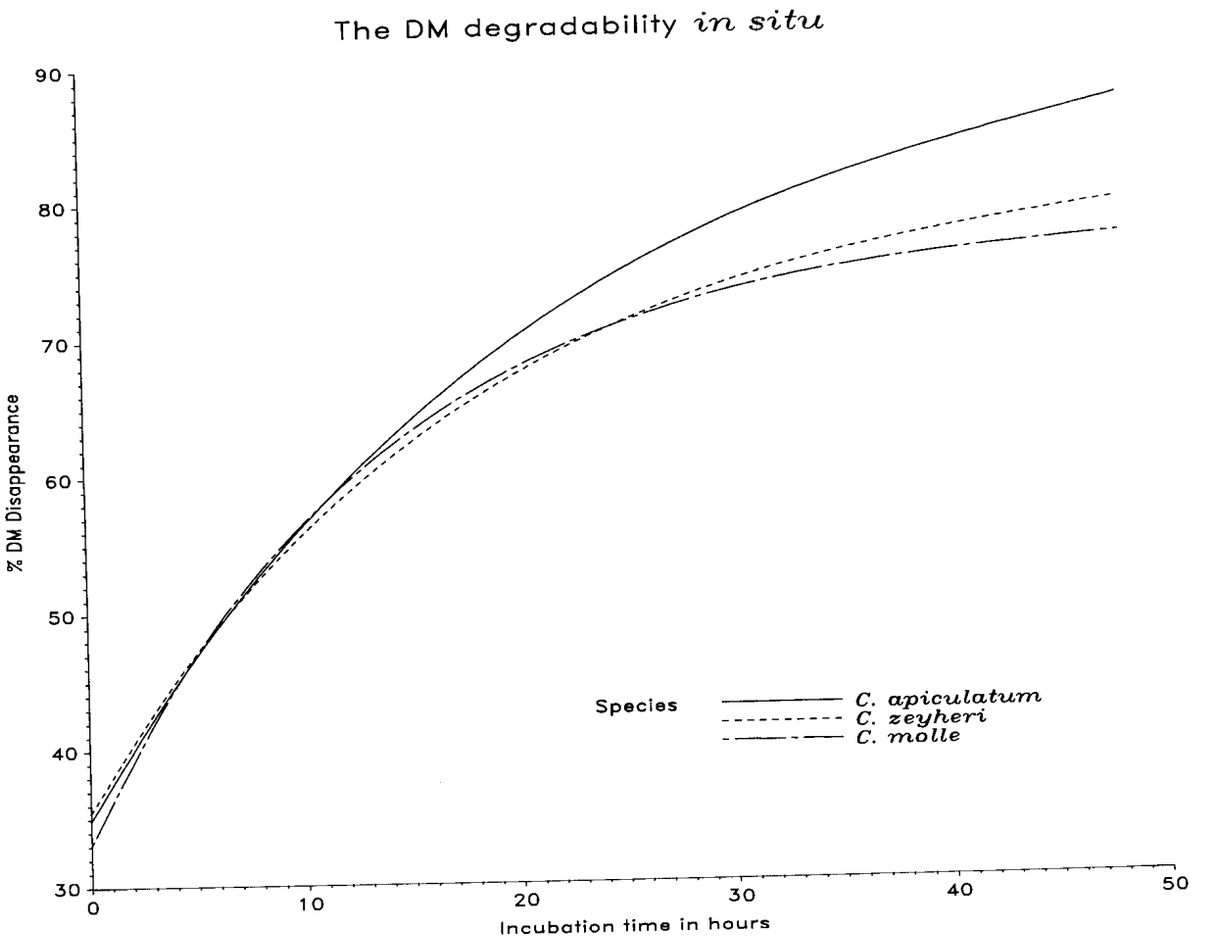

Figure 3.1 The DM rumen degradability of forage for three *Combretum* species over time in hours

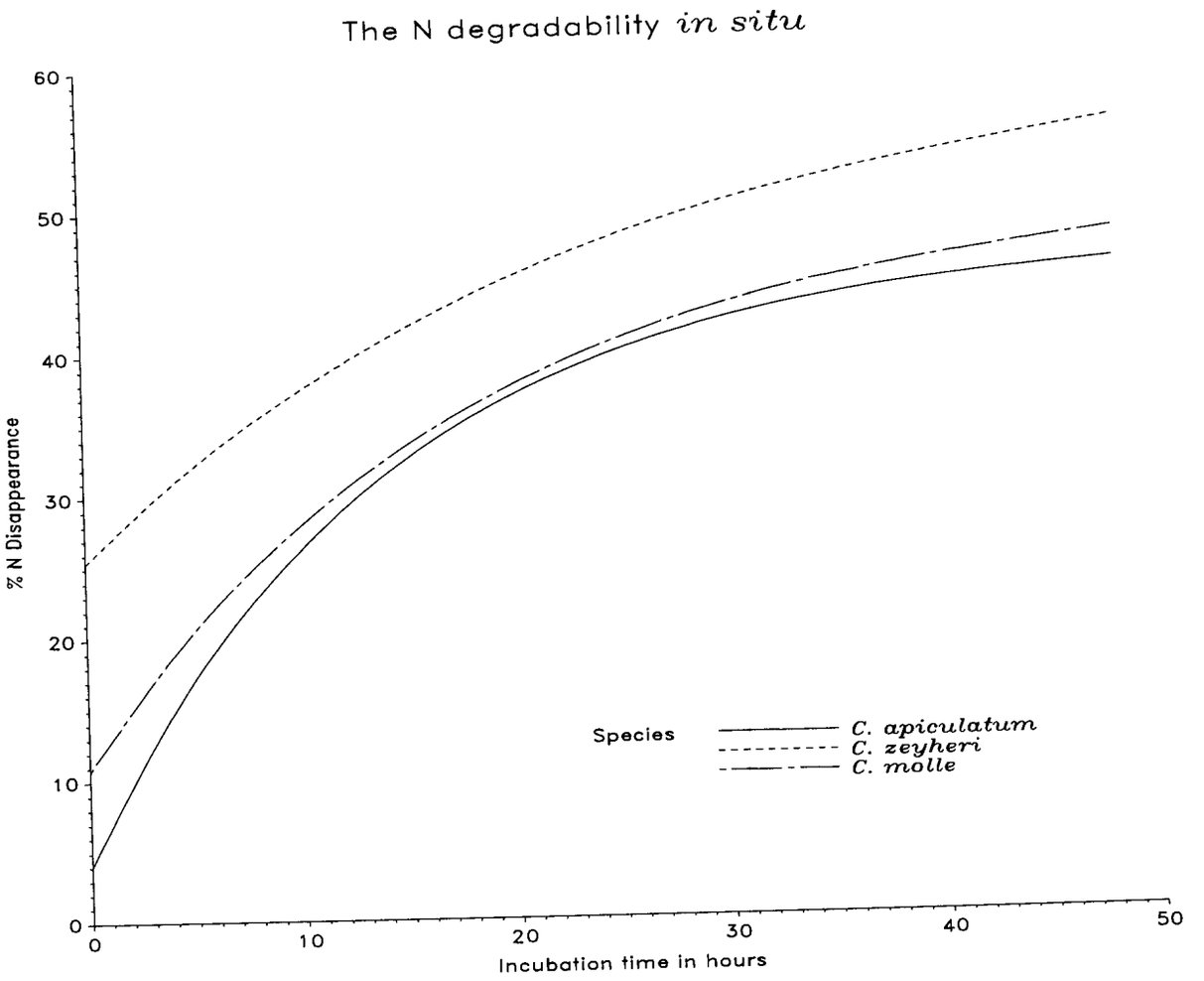

Figure 3.2 The N rumen degradability of leaf samples of forage of three *Combretum* species

CHAPTER 4

4. DISCUSSION

4.1. Introduction

A common weakness of the experimental design in the chemical composition analyses, *in vitro* digestibility and *in situ* degradability trial was the uneven number of samples of the same species from a collection site. Some of the plant species were found only at few sites, while some did not have enough leaf material at the time of collection. This fact necessitated the limiting of statistical comparisons of parameters for the same species from different sites. Therefore, samples of the same species from different sites were considered as treatments or replicates. The chemical composition was determined for all the plant species, although *P. africanum* was subjected to a few fraction analyses. The IVDOM was done for all the plants, except for *P. africanum,* while *in situ* degradability was determined only for the *Combretum* species.

4.2. Chemical composition

The ash content of the *Combretum* species was lower than those reported by Sauer (1983). However, the ash content of *C apiculatum* was similar to those reported by Groenewald & Joubert (1967, while Mopane contained less. The ash content of all the plant species investigated showed no significant differences between seasons and wash or no wash. The results of the washing of samples could imply that the dust on the leaves was, if there were any, not enough to can possibly influence the concentrations of both the ash and the minerals thereof than was expected.

The CP concentrations of *C. apiculatum* differed significantly between seasons and are in agreement with Groenewald & Joubert (1967), Sauer (1983) and Balogun et al. (1998). The CP concentrations of *C. molle* were lower than those reported by Sauer (1983), while those of *Mopane* were higher than those reported by Groenewald & Joubert (1967). The CP concentration of all the species fell within the general range of protein concentrations of 12 – 30% in browse plant species (Gupta & Pradhan, 1975; McDonald & Ternouth, 1979; Bamualin, 1981; Minson, 1990; Rittner & Reed, 1992). The mean values suggested that *Mopane* leaves contained higher CP concentrations than those of

the *Combretum* species. The latter fell within a relatively narrow range of concentrations. The *Combretum* species showed relatively constant CP concentrations over the four seasons with a mean value of 101 g/kg DM. The highest was 120 g/kg DM for *C. zeyheri* during spring and the lowest was 69 g/kg DM for *C. molle* during summer.

The *Mopane* also showed relatively constant CP concentrations over the seasons with a higher mean value of 148 g/kg DM. The plant species especially the *Combretum* did not show a similar seasonal trend of CP concentrations and the variation was insignificant for all the species. This confirms the report by Bamualin (1981) that the chemical compositions of browse trees tends to vary less throughout seasons than tropical grasses. This could imply a better CP supply to animals throughout the year. These plants' CP levels suggest that they can form part of animal diets or complement grasses to provide adequate dietary N to the animal.

The ADF concentrations of the foliage in all the tree species, except *C. molle*, were higher in winter than in summer. The fibre, in ADF and NDF, was higher in *C. molle* and *Mopane* compared to the other species in the study. However, the concentrations of both these fractions were similar to concentrations of similar species reported by Balogun et al. (1998). The ADIN of the plants varied insignificantly between seasons. *Mopane* exhibited a higher fibre bound N (ADIN) than the *Combretums*.

The ADL concentration of *C. apiculatum* was higher than that reported by Balogun et al. (1998), yet the lowest of the *Combretum* species study and the only that varied between seasons. *Mopane* exhibited higher ADL concentrations than the *Combretum* species. The higher ADL could imply less availability of some chemical fractions or that the foliage would need longer period to be digested in the rumen. The higher ADIN could suggest lower solubility or availability of N for that particular tree species.

Several studies on multi-purpose trees reported a wide seasonal variation in CP, NDF and ADF concentrations (Carew et al., 1980; Onwuka et al, 1989; Rittner & Reed, 1992). Although it cannot be explained, this present study found seasonal variations to fluctuate much less than in the reported studies irrespective of separation of site effects during statistical analyses.

4.2.1 Condensed Tannins

The species *C. apiculatum* and *C. zeyheri* were the only plants that showed a s seasonal variation ($P<0.05$) in CT concentration, where the winter and autumn concentrations were higher for *C. apiculatum* while those of summer were higher for *C. zeyheri*. Although the CT seasonal concentrations of *Mopane* were insignificantly different, those of winter and spring were higher. The seasonal trend shown *by C. apiculatum, C. molle* and *Mopane* could be attributed to the fact that mature leaves contain higher levels of CT than younger leaves (Makkar & Sign, 1991), as these were the seasons where leaves are already matured. The seasonal trend for *C. zeyheri*, where winter and spring concentrations were zero is very strange. Human or mechanical error could be a possible conceivable explanation.

The CT concentrations of the plants in this study ranges from 65.6 to 498.8 mg STE/ g DM for the *Combretum* species and a seasonal range of 487 to 660 mg STE / g DM for *Mopane* with a mean value of 599 mg STE / g DM. The CT concentrations of *C. apiculatum* were lower than those reported by Balogun et al. (1998). Generally all these plants are within the same CT range as other tropical forage plants (Makkar & Sign, 1991; Jackson et al., 1996; Apori et al, 1998; Balogun et al., 1998; Shayo & Uden 1999).

Although condensed tannins are non-toxic secondary phenolic compounds, they lower the digestibility and palatability of plants at high concentrations, >20 g/kg DM, (McDowell & Valle, 2000). *Mopane* showed the highest CT concentration, as was expected, though not sufficient to affect the digestibility of the foliage. At lower concentrations, CT is associated with better CP digestion and metabolism in ruminants particularly in protecting them against legume bloat (Reed, 1995; Waghorn et al., 1998). When CP intake is high, lower levels of CT have a positive effect on N retention and increase the flow of essential amino acids to the duodenum (Thomson et al., 1971; Harrison et al., 1973; Egan & Ulyatt, 1980; John & Lancashire, 1981; Barry & Manley, 1984; Beever & Siddons, 1985; Waghorn et al., 1988). Higher levels of soluble phenolics are associated with higher levels of NDIN (Shayo & Uden, 1999).

4.2.2. Minerals

The macro and trace minerals of this study were almost at the same range as those analyzed in some Kenyan *Acacia* species (Sawe et al., 1998). The concentration of some macro mineral in some tree species in this study depicted a trend of only one season significantly varying from the others. Cases where this trend was observed were Ca, Mg, Se for *Mopane;* Cu for *C. apiculatum* and *C. molle;* Co for *C. zeyheri* and *C. molle.* All the trees except *C. molle* had Mn that varied significantly between seasons.

4.2.2.1 Macro minerals

The macro mineral concentrations of all the plant species, within seasons, can meet the requirements of ruminants except for P, which was comparatively low. The P concentrations of all the plants showed a seasonal variation ($P< 0.05$) and even the highest concentration of all the plants (2.1 g/kg DM), during summer for *Mopane* was lower than the critical level (2.5 g/kg DM) for ruminant requirements (McDowell, 1992; 1997).

This could imply that these forages would not provide the P levels required by ruminants. The P levels of these species also suggest that animals of P deficient regions consuming the foliage thereof as sole diets could suffer P deficiency. Therefore, if better performance by livestock utilizing foliage from these trees as sole diets is to be achieved, P supplementation should be a major consideration for additional feeding. The P concentrations of all the plants in this study are in agreement with the report that the concentrations of Ca and P in tropical forages are higher in the wet season than in the dry seasons (Valasquez, 1979; Faria et al., 1981; McDowell & Valle, 2000), while Ca only for *Mopane* agrees.

The K and Mg concentrations meet the requirements of ruminants. The seasonal concentrations of the two minerals, for all the tree species were almost constant with an insignificant variation. All the macro minerals analyzed are within the range of the concentrations in tree leaves studied in Kenya by Sawe et al. (1998). The Na concentration among all the plants was lower than the critical level required for ruminants (see Table 4.1.). They are in agreement with McDowell's (1985) report that Na is generally low in tropical forages.

Table 4.1

Mineral requirements and the critical requirement levels for ruminants in g/kg DM

Minerals	Requirement†	Critical levels×
Ca	1.8 - 8.21	3
Mg	1 - 2	2
P	1.8 - 4.8	2.5
K	6 - 8	6 – 8
Na	0.6 - 1.8	0.6

† Requirements (DM) and × critical levels based on Ruminant National Research and Agricultural Research Councils for various ruminant species (McDowell, 1992; 1997)

4.2.2.2. Trace elements

The concentrations of Cu, Zn, Mn and Co of all the plants meet the mineral requirements of ruminants (Table 4.2.). The *C. apiculatum* Cu concentrations, though highest for all the species, were different ($P < 0.05$) between seasons and higher in summer than in winter. The other species showed an insignificant seasonal variation of Cu concentrations and were within the same range. This could imply consistent seasonal supply to animals.

The Se concentrations were higher in winter for *C. molle* and *Mopane* while all the seasonal concentrations of *C. molle* were the highest of all the species. The concentrations of Se for all the plants in this study were lower than the requirements for herbivores.

Manganese in forages is usually present in excess of requirements for ruminants (Minson, 1990). The Mn concentrations of the plants in this study confirmed this report, showing a range of 29 mg/kg DM to 169 mg/kg DM. The Fe winter concentrations were higher for all the plants. They were also very high, for all the plants, compared to the desirable required concentration for ruminants as reflected in Table 4.2. According to Beeson (1950) the Co concentration in forages ranged from <0.01 to 1.26 mg/kg DM, due

mainly to variations in soil Co. The plants in this study fell within this range. Forage legumes generally contain higher concentrations of Co than grasses (Andrews, 1966). Fleming & Murphy (1968) reported that Co is contained in the leaves of plants. Although no definitive trend could be asserted, Co concentration in forages tended to be high during spring and autumn (Voss & MacPherson, 1977). The Co concentrations of the trees in this study were lowest particularly in spring. However, were higher than the desirable requirements for ruminants except for those of *C. zeyheri*.

The winter Co concentration of *C. zeyheri* was within the desirable concentration while those of the other seasons were at a deficient level according to ruminant requirements (MacPherson, 2000). The summer concentrations were higher for *Mopane* and *C. molle* than the other seasons of the same plants. The summer concentration of *Mopane* was the highest of all the plants and seasons while all the seasons of *C. zeyheri* were the lowest of all the plants.

The Mn concentration was higher in autumn for *C. zeyheri* and in summer for the other plant species compared to the other seasons. These concentrations were, in some seasons, i.e. the summer of *C. apiculatum*, six times higher than the desirable level required for ruminants. Problems arising from excess intake of Mn are more likely than those from deficiency (Jumba et al., 1996), i.e. high Mn concentration (+400 mg/kg DM) reduced growth rate of ruminants (Grace, 1973).

The concentration of Mn for forages ranged markedly from 1 to 2670 mg/kg DM (MacPherson, 2000). The absorption of Mn by domestic livestock appears to be poor and is adversely affected by high concentrations of Ca, P and Fe (MacPherson, 2000). However, excess P appears to be a greater inhibitor of dietary Mn than Ca (Wedekind & Baker, 1990a, b). The Ca and especially P of the plants in this study are at lower levels to affect the absorption of Mn, but Fe was far above the requirements for ruminants.

McDowell & Conrad (1990) reported that about 60% of Latin American forage samples were deficient in Co and Mn while 50% were below the requirements for ruminants (Strikauska et al., 1994). Forage species vary widely in the range and quantity of trace-minerals they provide and this in turn is affected by other factors (MacPherson, 2000).

Table 4.2.

Threshold concentration of trace minerals (mg/kg DM) in forages for ruminants (MacPherson, 2000)

Mineral	Desirable	Marginal	Deficient
Cu	>6	>6	<6
Se	>0.10	0.05 – 0.03	< 0.03
Co	>0.11	0.10 – 0.05	< 0.07
Mn	25	--	--
Zn	50	40	25
Fe	30	--	--

4.2.2.3 Correlation between minerals

Correlation of minerals over the plants that were very high and also highly significant were between Ca & Se, P & Mn, K & Na, Mg & Fe and Zn & Se. The negative correlation between the minerals was very low and insignificant. There was no definitive trend of correlation between certain minerals over and within the plants.

4.3. The *in vitro* digestibility of OM

The *Combretum* species showed a superior IVDOM to *Mopane*. The *C. apiculatum* was the highest with a mean of 60%. *Mopane* showed a mean of 53% while the other *Combretums* shared a mean of 56%. The IVDOM range of the plants in this study (53 to 64%) fall within the range of tropical browse plants of 36 to 69% (Minford & Minson, 1968) and those of Shayo & Uden (1999).

4.3.1 Correlation between chemical composition and IVDOM

The IVDOM negatively correlated with the NDF, ADIN, ADF and ADL. It was highly significant between the latter two. Its correlation with CP and CT was very low and insignificant. The CP showed a high and significant correlation with ADF while its correlation with CT was very low and insignificant. The CT's negative correlation with

ADF and ADL was high and significant. Although its correlation with ADIN was very low, it was highly significant. This high significance could be related to the increase of fibre bound N, along the digestive tract of animals that consumed leaves of moderate to high tannin content foliage (Reed et al., 1990; Tanner et al, 1990).

Lignin and fibre at higher concentration reduces the digestibility of OM (Khaazal et al., 1994). The insoluble proanthocyanidins are strongly bonded to fibre. Therefore, they affect the rate and extent of ruminal degradation (Haslam, 1979). Condensed tannins form complexes with fibre and carbohydrates, thereby reducing the degradation of the plant cell wall (Mould & Robbin, 1981 & 1982; Akin, et al., 1988) and total nutrient-absorption capabilities (McLeod, 1974). Excessive lignification of plant leaves physically binds or encapsulates the nutrients (Short & Reagor, 1970), rendering them unavailable to digestion to rumen microbia.

4.4 The *in situ* degradability

The superior N degradation characteristic of *C. zeyheri* over the other plants is distinctly depicted in Figure 3.1b. Although degradable fraction and degradation rate of *C. apiculatum* was the highest of all the other plants, its rapidly soluble fraction and extent of degradation were the lowest. However, its DM degradation characteristics are the highest. All the degradation estimates of the species in this study were within the range of various forage plants evaluated by Kamatali et al. (1992).

The rate of feed degradation increases with particle fineness as more surface area tends to be exposed (Dulphy et al., 1999). This could explain the DM disappearance at zero hours (>30 %) for all the plants. The leaves of the *Combretum* species were very brittle when dry and consequently would break into very fine material. Thus, fine particles were present even after sieving of the leaf material.

The drying process may influence the nature and content of various feed constituents. In comparison to freeze-drying, oven drying decreases the soluble content of N and the *in situ* N degradability (Lopez et al., 1995; Dulphy et al., 1999). However, the N degradability of freeze-dried samples tended to increase after grinding (Dulphy et al., 1999).

The *in situ* technique is unlikely to show the negative effects of phenolic compounds on the rumen microbial fermentation (Apori et al., 1998). This is as a result of the dilution effect of the rumen content. The limitations of the technique include low repeatability and lack of reproducibility (Noziere & Michalet-Doreau, 2000). Although the *is situ* technique leads to an underestimation of cell wall ruminal degradation, it appears to be valid to estimate differences in ruminal degradation in and between feeds (Noziere Michalet-Doreau, 1996). It provides an advantage compared to laboratory methods because it involves the digestive processes occurring within the rumen of a live animal. Thus, it is closely correlated with digestion *in vivo* (Wanapat et al., 1986).

4.4.1 Correlation between *in situ*, IVDOM and chemical fractions.

The correlation coefficients were determined between minerals; chemical composition and IVDOM. However, the *in situ* data could not be correlated with the IVDOM and chemical composition as a result of insufficient foliage material that was available for the *in situ* study.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

This study has focused on the screening of the chemical composition, digestibility and the *in situ* degradability of *C. apiculatum, C. zeyeheri, C. molle, P. africanum* and *C. mopane.* However, it goes without saying that the utilization of the forage material of browse plants by animals transcends their chemical composition and *in vitro* digestibility. Although Sauer (1983) significantly correlated the relative acceptance of some *Combretum* species and the *Acacias* to the CP and P concentrations during the wet seasons, certain species were consistently rejected despite their adequate nutrients level.

The utilization of species such as *C. apiculatum, C. zeyheri* and *C. imberbe* was correlated with the seasonal changes of CP and crude fibre (Sauer, 1983). The acceptance of some plant species depended on other characteristics of their leaves. The species *C. imberbe*, for instance, is utilized by giraffes during the dry season when feed sources become scarce, presumably because of its aromatic smell and not that it can provide for their energy requirements (Sauer, 1983).

Some plants become alternative feed sources with seasons i.e. kudus were observed to shift their preference in favour of those plant species that offered highest eating rates when feed availability became limiting, especially during the dry seasons (Owen-Smith & Cooper, 1983). When the dry season advanced, unarmed plant such as the *Combretum* species were relatively more browsed than *Acacias* (thorny species) and other prickly species

The concentrations of the chemical composition of the plants in this study, except for some minerals, indicated levels that are adequate for ruminant feeding requirements. Their seasonal variation were insignificant for most of the fractions especially proteins, implying a consistent supply throughout the seasons. The P levels suggest that the foliage of these plants is deficient in this mineral. Thus, P supplementation will be critical for animals utilizing foliage from these plants, particularly lactating cows. The condensed tannin levels are within the range measured in some other tropical plants and the concentrations suggested that this compound might not adversely affect digestibility,

particularly of N. However the extent at which these plants' CT can affect digestibility should still be quantified.

The plant leaves showed an acceptable level of digestibility *in vitro* and degradability *in situ*. These results could be used together with intake studies to further predict their value as feeds for animals. I recommend the use of the near infrared spectroscopy if the analysis of a large number of samples for plant material is involved, as this technique could ensure accuracy of reports. Moreover, it will reduce the costs and time spent on wet chemistry. The chemical component information does not give an indication of the available fraction. Therefore, it is crucial that feed intake studies are conducted to establish the availability fractions, *in vivo*, of the various chemical components.

This could provide meaningful information on the effective utilization of these plants' foliage in the animal body. Further studies should be conducted on the palatability, acceptance and utilization of the *Combretum* species, especially for goats as they are reported to be superior in utilizing tanniferous fodder (McCammon-Feldman et al., 1981).

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APPENDIX

PLANTS DESCRIPTION

i. *Combretum apiculatum* spp *apiculatum*

Its national Number: 532. Common names: Red bush willow, Umbondwe omyama (Zulu), Xikukutso (Tsonga), Mohwelere (N.Sotho). *Combretum* is derived from Latin for a climbing plant and the specific name (*apiculatum*) refers to the small point or tip, at the apex of the leaves. It is a slow growing plant, which is drought resistant but not frost resistant. As a fodder plant for domestic stock as well as game, its leaves are eaten either when they have fallen or are about to fall. The seeds are said to be poisonous, causing prolonged hiccupping.

Leaves: A sticky-shiny leaf with curved apices, usually 2-3 opposite. Oval narrowed to both ends or rarely of oblonged and rounded at the apex. The withered leaves are retained and dropped slowly over a long period. **Bark:** Grayish bark flaking in small thin scales. The tree is about 4 - 6 m high with a twisted trunk. Young twigs are usually hairless and compressed while the branches are reddish brown. **The fruit**: A four winged small fruit that turns russet brown at maturity. **Soil type:** Found on sandy, often reddish, granite soils usually on rocky hill slopes where it is often dominant. It requires rainfall of 15-20 mm in a year and it is not frost resistant.

ii. *Colophospermum mopane*

Its national number, 198. The plant was initially known as *Copaifera mopane*. *Colophospermum* is Greek for "seed inhabiting the light". The leaves provide important fodder for cattle and game. If they are acclimatized to it, cattle readily browse the leaves on the tree as well as dry ones on the ground. Elephants relish the green shoots and antelope eat the dry leaves on the ground. The leaves and the pods have a high feeding value despite the aromatic resin. Neither milk nor the meat get tainted by turpentine. Trees are usually 6-11 m high but under favourable condition they grow up to 18-22 m. The tree is a host of Mopane worms, *Gonimbrasia belvia*, relished by the natives as a protein rich source.

Leaves: Two leaflets arranged like a butterfly's wings, yellowish green, leathery shiny with a smell of turpentine when crushed. Leaflets are triangular, attached at one of the points with adjacent margins. **Bark:** Flattened, oval to kidney-shaped, pendulous from a short stalk on a narrow end. It is yellowish brown not opening to release the seed. Trunk is 25-46 cm in diameter,

up to 1 m in large trees. Covered with a dark gray to greenish brown rough, deeply fissured, fibrous bark.

Soil type: In the former Transvaal, it usually avoids sandy flats. It indicates areas of high temperature, low rainfall and shallow, poorly drained often-alkaline soils. The largest trees thrive in rich deep alluvial soil. In Namibia, it is widespread on sandy soils.

iii. *Combretum molle*

Its national number 537, it is also known as *C. gueinzii*. Common names: Velvet bush willow, Baster rooibos. It is a small to medium sized spreading tree up to 10 m in height. Occur on open woodland over a wide range of attitudes. **Leaves:** opposite, narrowly elliptic and broadly oval to almost circular with dense grey velvety hairs on both surfaces. Have a tapering apex.

Fruit: a four winged, yellowish green flushed with red pod that dries to golden reddish brown. Some of the pods or old fruit remain on the tree into the subsequent flowering season. **Bark:** gray brown to almost black, rough inclined to be flaky.

iv. *Combretum zeyheri*

Its national number 546, common names: Raasblaar (Afrikaans), Umbondwe omhlope (Zulu), Mafambara-borile (Tsonga), Mokabi (N.Sotho). Species *zeyheri* was named after K. L. P Zeyheri, a German plant collector who found the plant at Magaliesberg in 1841. It is called raasblaar because the dry withered leaves make a characteristic rustling noise in the wind. A spreading deciduous tree, small to medium sized up to 10 m tall that occurs at medium to low altitudes in open woodland, rocky hillsides and sometimes along rivers.

Leaves: elliptic to oblong smooth, 3-whorled leaves, clustered towards the ends of the branches. They are hairy when young becoming glabrous, leathery oblong-oval to ovulate and rounded at the apex. They loose the hairiness at maturity. They are dark green normally yellow green.

Fruit: a four winged very large, probably the largest of this genus, up to 6 X 6 cm. They are pale green when fresh to a pale brown when dry and remain on the tree until the leaves have fallen. **Bark:** brownish gray to gray, smooth to finely fissured and flaking in small pieces. Very slender, round, often-reddish branchlets which falls off sometimes. **Soil Type:** it is an

indicator of sour bush-veld that carries poor grasses that are usually not palatable to stock and game. It is often found on rocky hillsides and sometimes along riverbanks.

v. *Pelthophorum africanum*

National number: 215, common names: Weeping Wattle, Huilboom (Afrikaans), Umsehle (Zulu), Musese (Venda), Ndzedze (Tsonga). The generic name is from Greek for carrying a small shield. A small to medium sized deciduous tree with a spreading crown, 5 to 10 m high and frequently branched from near the ground. Animals do not favour it. It occurs in bushveld or open woodland in medium to low altitudes in dry areas with little frost.

Leaves: alternate, compound, 2- pinnate with 4-7 pairs of pinnae each bearing 10-12 oblong leaflets, feathering leaflets, that are dull green above and pale green below with a rounded apex and asymmetric base.

Fruit: the fruit is a flattened pod that is tapering to apex and base with a wing like margin. Young pods are almost leathery, rusty hairy or grayish brown and ripening to dark brown. Hangs in dense clusters and are indehiscent.

Bark: It is light to dark brown, rough and longitudinally fissured. Eve Palmer (19..) refered to the tree as "rainy tree of Africa" because water drips from the branches wetting the ground below. This is as a result of a small insect, *Ptychus grossus,* which obtains its nourishment by piercing the bark and suckling the sap at a greater spread and eject almost pure water equally fast. **Soil type:** it usually grow in grayish or red sandy soil often among rocks.