EVALUATION OF CHEMICAL COMPOSITION AND *IN SACCO* RUMINAL DEGRADATION CHARACTERISTICS OF LEAVES AND FRUITS OF CONDENSED TANNIN RICH TREE SPECIES

MSc. THESIS

By

BELACHEW ZERFU

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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Production

By

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APPROVAL SHEET

Jimma University College of Agriculture and Veterinary Medicine
Graduate Studies

As thesis research advisor, we hereby certify that we have read and evaluated this thesis prepared, under our guidance by Belachew Zerfu, entitled **'Evaluation of Chemical Composition and *In Sacco* Ruminal Degradation Characteristics of Leaves and Fruits of Condensed Tannin Rich Tree Species'** and recommend that it be submitted as fulfilling the thesis requirement.

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DEDICATION

I dedicate this thesis to my family and to all people that gave me a positive inspiration to go on with my studies.

STATEMENT OF THE AUTHORS

I declare that this thesis is my work and that all sources of material used for this thesis have been appropriately acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the awards of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author, Belachew Zerfu, was born on September 29, 1988 G.C at Qimbibit *Wereda* of North Shewa zone, Oromia, Ethiopia. The author attended his elementary, secondary and preparatory schools between 1995 and 2007 G.C in the same place in Sheno elementary then, later Sheno secondary and preparatory schools. After successful completion of his high school education in 2007/2008, he joined Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) and graduated with a Bachelor of Science (B.Sc) degree in Animal Sciences, on July, 2010.

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LIST OF ABBREVIATIONS

AIBP	Agro-Industrial By-Products
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
BFT	Birds foot Trefoil
BW	Body Weight
CRs	Crop Residues
CT	Condensed Tannin
DMD	Dry Matter Disappearance
ED	Effective degradability
FAO	Food and Agriculture Organization
GGCSWE	Gilgel Ghibe Catchments of South Western Ethiopia
HARC	Holeta Agricultural Research Center
HF	Holstein Friesian
HT	Hydrolysable Tannin
IAEA	International Atomic Energy Agency
ILRI	International Livestock Research Institute
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
MPTS	Multipurpose Tree Species
NRC	National Research Council
OMD	Organic Matter Disappearance
SAS	Statistical Analysis System
TLU	Tropical Livestock Units

Evaluation of chemical composition and *in sacco* ruminal degradation characteristics of leaves and fruits of condensed tannin rich tree species

By: Belachew Zerfu

Major advisor Yisehak Kechero(Ass.Prof) and Co-advisor Taye Tolemaria(PhD)

ABSTRACT

The objectives of this study were to determine the chemical composition, in sacco rumen dry matter and organic matter degradability of leaves and fruits of indigenous tannin rich multipurpose tree species (MPTS) and also to assess the relationship between chemical composition and in sacco ruminal degradability parameters. The MPTs studied were Ekebergia capenesis, Ficus sycomorus, Maesa lanceolata and Rhus glutinosa. The leaves and fruits of the MPTS were collected from the Omo-Nada woreda of Jimma zone, southwestern Ethiopia during East African Autumn season. Chemical composition measured were dry matter (DM), crude protein (CP), crude ash (CA), ether extract (EE), crude fiber (CF), neutral detergent fiber (NDF), non-fiber carbohydrates (NFC) and condensed tannin (CT). In situ rumen degradability was measured with of three rumen fistulated Holstein Friesian-Boran cross steers in times at 0, 6, 12, 24, 48, 72 and 96 h. Ruminal in sacco OM degradabilities were estimated from residues in nylon bags. The DM and OM degradability data were fitted to the exponential equation $Y = a + b(1 - e^{-ct})$*. The values for each chemical constituents was ranged from 92.43 to 96.84% DM, 5.43 to 11.49 % CA, 7.97 to 17.06 % CP, 1.57 to 31% EE, 12.20 to 27.5% CF, 5.84 to 39.30 %NFC, and 7.2 to 16.72% CT. For DM degradation, the highest and lowest values of soluble fraction (a) of leaves were recorded in M. lanceolata (14.55% DM) and E.capensis (-16.20% DM), respectively (P<0.001). The highest (0.12%/h)in E.capensis leave and lowest (0.01%/h) for R.glutinosa leave were the values of degradation rate(c). However in OM degradation kinetics, the 'a' value was ranged from -1.02% in R.glutinosa to 10.69% in E.capensis leaves where the variation was significant for the plant species (P<0.001); on the other hand, the highest and lowest 'a' value was recorded for fruits of R. glutinosa (31.84%) and E.capensis (14.22%) (P<0.001). The insoluble but degradable fraction (b) was 83.35% in R. glutinosa and 45.21% in E.capensis leaves (P<0.001); On the contrary, the highest and lowest values of potential degradability (PD) was recorded for F.sycomorus (89.89%) and 55.90% for E.capensis leaves (P<0.001). On the other hand, the highest and lowest effective degradability(ED) value was obtained in R.glutinosa (63.97%) and E. capensis leaves (P<0.001). The degradation rate constants (c) varied widely between MPTS with similar rates for E.capensis and F.sycomorus leaves. In general, it was observed that variation of plant parts lead to highly significant differences in DM and OM degradability and the degradable parameters. DM and OM degradation were highly correlated with time taken for the incubation, CP, NFC and CT concentration. The edible parts of MPTS recorded more than 60% DM and OM degradability at 24 h, which implied that they were all highly degradable in the rumen. Their incorporation into ruminant feeding systems as dry season forage supplements is therefore highly recommended.*

Key words: *Chemical composition; in sacco rumen degradation; fruit; leaves; multipurpose trees; condensed tannin*

1. INTRODUCTION

Inadequate feed supply is a major constraint of ruminant livestock production in sub-Saharan African countries (Arigbede *et al*., 2011). Dry season is always a critical period when most feed resources especially grasses and herbaceous forages dry out (Kanani *et al*., 2006). Crop by-products, available during dry season, have a low nutritive value (Salem *et al*., 2006). This obviously adds to the poor performance of ruminant livestock. Improvement of the performance of ruminants in Sub-Saharan Africa (Solomon *et al*., 2004; Babayemi *et al*., 2004b; Mekoya *et al*., 2008) call for, use methods of extending the availability and quality of local feedstuffs. One potential way for increasing the quality and availability of feeds is the use of various multipurpose trees and shrubs (MPTS) (Devendra, 1989; Kaitho *et al.,* 1998: Woldemeskel *et al.,* 2001).

Leaves, twigs, stems, pods, fruits and seeds of MPTS have been used as cheap and affordable supplements for ruminant animals in herds of resource poor farmers in several regions of the World (Salem *et al*., 2006). These morphological fractions of MPTS has been used to supplement straws to alleviate protein deficiency in fibrous feeds, reduce rumen acidosis and other health-related problems, and improve intake and productivity of animals (Owens *et al*., 1998; Mekoya *et al*., 2008).

A variety of MPTS are growing in the Gilgel Ghibe catchments of Southwestern Ethiopia (GGCSWE) (Yisehak *et al*., 2010), mainly due to the suitability of the environment and the need to use them as fire wood, local construction, mulch, and shade for cash crops like coffee and spices. They replenish soil fertility, serve as of human and veterinary medicine, and also serve as environmental conservation. Currently small-holder farmers of sub-Saharan African countries in general(Aremu and Onadeko, 2008) and South West Ethiopia in particular (Yisehak and Belay, 2011; Yisehak *et al*., 2012) are increasingly relying on various potential browse plants that can provide a green feed throughout the year which may be particularly useful as feed supplements to the typical low-quality diets.

Among MPTS growing in the GGCSWE*, Ekebergia capensis, Ficus sycomorus, Maesa lanceolata,* and *Rhus glutinosa* are widely abundant, evergreen throughout the year, and have a good biomass yield and multiple uses and highly preferred by farmers (Yisehak *et al*., 2010).

Most browse species have an advantage of maintaining their greenness and nutritive value throughout the dry season when grasses dry up and deteriorate both in quality and quantity. Browse is generally richer in protein and minerals (Le Houeron, 1980; Kadzere, 1995; Alonso-Diaz *et al*., 2010) and thus has the potential to be an inexpensive, locally produced protein supplement that plays an important role in the nutrition of grazing animals (Meuret *et al*., 1990; Salem *et al.*, 2006). Unfortunately, their content of nutrient activating factor like condensed tannins (CT) varies widely and unpredictably (Babayemi *et al*., 2004b). The use of edible parts of tree and shrub leaves by herbivores is restricted by defending or deterring mechanisms related to high CT content (Provenza *et al*., 1995). High levels of CTs in leaves restrict the nutrient utilization and decrease voluntary food intake, nutrient digestibility and nitrogen (N) retention (Kumar and Vaithiyanathan, 1990; Silanikove *et al*., 1996). Their effect on animals ranges from beneficial to toxicity and death (Makkar *et al*., 2003).

The CT content of plants is affected by plant species (Ozturk *et al*.,2006), and stage of growth, and may vary with plant part (leaf, stem, inflorescence, seed), season of growth and other specific environmental factors such as temperature, rainfall, cutting and defoliation by grazing herbivores including insects (Makkar and Singh,1991b). The chemical composition and digestibility of forages are also influenced by plant species, plant morphological fractions, environmental factors and stage of maturity (Papachristou and Papanastasis, 1994).

The performance of herbivores when grazing depends on forage digestibility and intake (Ramirez *et al*., 2000; Decruyenaere *et al*., 2009; Fraser *et al*., 2009). Moreover, forage intake is related to fibre digestibility because intake is reduced when fibre is increased in the digestive tract (Mertens, 1993). Rate of digestion provides an important measure of forage quality because intake of forages having rapid rates of digestion is greater than that for forages with slower rates of digestion but similar total digestibility (Holechek *et al*., 1982). Since the rumen is the primary site of digestion of forages, it is important to monitor their degradation kinetics. This can be achieved by using *in sacco* technique which is quicker and cheaper than whole animal studies.

The *in sacco* nylon bag technique, in which feed samples in nylon bags are suspended in the rumen, is widely used to estimate the rate and extent of degradation and digestion of feed in the rumen (Marinucci *et al*., 1992; NRC, 2001). The methodology used to generate degradability values has a major influence on degradability values published (Michalet-Doreau and Cerneau, 1991). Standardization of the method is related to a large number of factors causing variation, e.*g.* the bag (sample dry matter, bag surface area to sample weight ratio and cloth pore size), sample preparation (particle size of sample), pre-incubation treatment, washing procedure, diet of fistulated animals, correcting for microbial contamination of residues, etc. (Nocek, 1988; Vanzant *et al*., 1998).

Important characteristics of digestion in the rumen with regard to forages are: effective degradability, rate of digestion and the amount of digestible fibre (Singh *et al*., 1989; Larbi *et al*., 1997). Rumen degradation is thus regarded as a major descriptor of forage quality (Orskov and McDonald, 1979). It is useful in ranking trees and shrubs in terms of nutritive value (Larbi *et al*., 1994) and for comparing the digestive capabilities of forages (;Singh *et al*., 1989).

However, limited information is available on the combined effects of the factors (species, and plant parts) on chemical composition and *in sacco* ruminal degradation characteristics of the tannin rich tree plants. Therefore, the present research was initiated to investigate the following specific objectives:

(1) To evaluate the effect of browse species and plant parts on the chemical composition and *in sacco* ruminal degradation characteristics of dry matter and organic matter and
(2) To assess the relationship between some chemical composition and *in sacco* ruminal degradability parameters.

2. LITERATURE REVIEW

2.1 Feed Resources in Ethiopia

According to Alemayehu (2003), the major livestock feed resources of Ethiopia includes natural grazing and browse, crop residues, agro-industrial by-products, and cultivated pasture and forage-crop species.

2.1.1 Natural pastures

Natural pastures include annual and perennial species of grasses, forbs and trees. Many researchers and development workers agreed that natural pasture comprises the largest feed resource in Ethiopia but estimates of the contribution of this feed resource vary greatly. Alemayehu (1998a) estimated that 80-85% of all feed comes from natural pasture while some estimates indicate the natural pasture provides 88-90 percent. This is because the quantity and quality of native pasture varies with altitude, rainfall, soil and cropping intensity. Currently, with the rapid increase of human population and increasing demand for food, grazing lands are steadily shrinking being converted to arable lands, and are restricted to areas that have little value or farming potential such as hill tops, swampy areas, roadsides and other marginal land (Ibrahim, 1999). This is particularly evident in the mixed farming highlands and mid altitudes. Communal grazing is normal and managed as a common property resource (Behnke and Schoones, 1993; Wolmer, 1997). Due to land scarcity and crop-dominated farming (Alemayehu, 2002) there has been limited spontaneous introduction of improved pasture and forages. During the Fourth Livestock Development Project, different strategies and species for pasture and forage development were selected.

2.1.2 Crop residues

Crop residues (CRs) are roughages that become available as livestock feeds after crops have been harvested. They are distinct from agricultural by-products (such as brans, oil cakes, etc), which are generated when crops are processed. Residues can usually be grouped along crop types-cereals, grain legumes, roots and tubers, and so on (World Bank, 1989; Nordblom and Shomo, 1995). Apart from being a source of animal feed, residues are sources of building, roofing and fencing materials. They are used also as fuel and as fertilizers or as surface mulch in cropland (Van Raay and De Leeuw, 1970, 1974). Their value as feed depends on the demand from livestock owners, which varies with the overall supply and demand situation for feeds. This, in turn, depends on the density of livestock, usually expressed in tropical livestock units per square kilo meter (TLU km^{-2}) and the supply of other feed resources, in particular, forage and browse from natural vegetation (De Leeuw and Rey, 1995). The supply of CRs is a function of the proportion of land used for cropping and the amount of edible feed yields per unit of land.

2.1.3 Agro-Industrial by-products

Agro-industrial by-products (AIBP) are derived from the processing of a particular crop or animal product usually by an agricultural firm. The AIBP widely used as livestock feed in Ethiopia are materials like molasses, bagasse, oilseed cakes and maize milling by-products, and brewer's wastes. Unfortunately, there is no factory in Ethiopia producing animal by- products (e.g. meat and bone meal, bone meal, and fish meals) (Berhanu *et al*., 2009).

2.1.4 Multipurpose tree species

Multipurpose tree species (MPTS) are trees that provide multiple benefits and serve multiple purposes. MPTS serve purposes like: soil erosion control , shade and shelter, and soil fertility improvement and provide beneficial products like: fodder and cattle feed , food , fuel wood , green manure ,manure (oil cakes) , timber , pulp, tannin, gum , raw material for dyes, medicines, pesticides, posts and poles. They can be grown on farm bunds, along boundaries and in degraded areas of the farm. Generally MPTS are hardy and grow well without special care in suitable agro-climatic conditions (Mekoya, 2008).

2.1.4.1 Chemical composition of multipurpose trees

The chemical composition of the MPTS shows substantial variation across species and seasons. The DM content is higher during the dry than rainy seasons and (Asiegbu and Anugwa, 1988; Anele *et al*., 2008) and elsewhere (Topps, 1992; Ly *et al*., 2001). Greater DM content observed during the dry season might be as a result of reduced photosynthetic activity due probably to the lower moisture levels in the soil during this period relative to the rainy season. Contrary to this, greater CP content recorded during the rainy season might be due to re-growth of new flush of leaves during this period and their lower CP content during the dry season may be largely due to the moisture stress experienced by the trees during this period. The CP content across seasons for all MPTS investigated was adequate to support meat and milk production of ruminant animals (Lamers and Khamzina, 2010). They may therefore serve as ready source of year-round cheap protein supplements for herds of resource-poor farmers in Sub-Saharan Africa and thereby help to improve the quality of feed and at the same time reduce the cost of production.

Reports from literature confirmed that ruminant animals are able to handle browse plants with tannin content below 100 mg/g DM (Gasmi-Boubaker *et al*., 2005) although, the tolerance level may vary between animal species (Onwuka, 1992). Apart from seeds, trypsin inhibitors and phytic acid have not been reported at levels that could pose nutritional dangers to ruminant animals in most tropical browse species, thus, their analysis before feeding may become optional for farmers in Sub-Saharan Africa.

2.1.4.2. Multipurpose tree species in ruminant feeding systems

Differences in chemical composition and *in sacco* dry matter degradation characteristics have practical implications for MPTS-based agro-forestry technologies and ruminant feeding systems. Because of their high CP content and potential extent of DM and OM degradation as compared to majority of grass species, they can be a source of rapidly degradable nutrients for microbial protein synthesis in the rumen (Lamers and Khamzina, 2010). Incorporation of MPTS foliage with animal feed could increase the CP content to above 10% of DM, even at low levels of supplementation. With depleted grazing resources in the dry season, the grazing period could be drastically reduced and level of foliage intake increased to 50%. This practice can increase the

CP content of diet to 14% or above during the dry season and at the same time reduce the cost of feeding and amount of energy normally expended on trekking in search for grazing resources(Patra, 2010).

2.2. Methods for Estimating Rumen Degradation of Feeds

Currently, numerous methods involving different procedures are available for estimating degradation of feeds like, the in vivo methods involve markers and the *in sacco* method requires animals that are surgically modified with rumen cannulae. The in vitro methods require the use of rumen fluid, which is obtained from fistulated animals, to estimate either digestibility (Tilley and Terry, 1963) or gas production (Krishnamoorthy *et al*., 2005, Menke *et al*., 1979). But the emphasis is on the *in sacco* method to estimate feed degradation.

2.2.1. *In* sacco method to estimate feed degradation

The *in sacco* technique was first suggested by (Quin *et al*., 1938) and it has since been used by others to estimate utilisation of either forages (Van Keuren and Heinemann, 1962) or concentrates and high-protein feeds (Mehrez and Orskov, 1977).

Interest in the technique has intensified since Mehrez and Orskov, (1977) critically assessed the factors causing variability in DM and N degradability. They concluded that as long as the bags were large enough to allow free movement of substrate within, the technique could be extremely useful as a rapid guide to determine nutrient disappearance, particularly the rate and extent of nutrient disappearance from the rumen. All modern systems of feeding ruminants (ARC, 1993, NRC, 1996, ARC, 1984) require an estimation of the amount of feed protein escaping ruminal degradation. This estimation is obtained by the in sacco technique, which is probably the best-known simple and reliable method to assess the degradability of DM and protein in the rumen (ARC, 1993, NRC, 1996, Thomas, 2004, Mehrez and Orskov, 1977, ARC, 1984).

The *in sacco* method requires the use of fistulated animals, which limits its routine use by the commercial laboratories. However, it is widely applied by researchers since it requires fewer measurements, is relatively less labor intensive and so is cheaper as compared with the in vivo method. The *in sacco* method involves the sealing of feed samples within nylon, polyester or Dacron bags, which are then suspended in the rumen of sheep or cattle for varying periods of time, followed by determination of the DM and protein in the washed residues. The technique allows the test feed to be incubated in the ruminal environment (i.e. pH, temperature and CO2), but unlike the normal situation the feed is not subjected to mastication and rumination. Despite its widespread use, the technique has inherent limitations that must be taken into account, particularly if comparisons of degradation among different laboratories are to be made. The sources of variations in the use of the *in sacco* method among different laboratories in terms of bag size, sample size, particle size and time (h) of incubation used by different authors. The assumption that the N leaving the bag during washing in water, at 0h of incubation, is completely degraded may not be true (Chaudhry andWebster, 2001, Mahadevan *et al*., 1980). Extensive loss of feed material at 0h incubation times will lead to an overestimation of degradability. Although (Chaudhry, 2007, De Smet *et al*., 1995, Djouvinov *et al*., 1998, Kristensen *et al*., 1982, Noziere and Michalet, 1996) present information in relation to degradable crude protein values only, it is assumed that similar variations in practice will also cause variations in DM and organic matter degradability values.

Beside microbial contamination within the bag, there are numerous other sources of errors that affect the *in sacco* DM and N disappearance from feeds. The importance of sample weight in a given bag size has been emphasized by (Bullis *et al*., 1967) who observed reduced DM digestibility with increased weight in the bag. Van Keuren and Heineman, (1962), showed that sample weight influenced DM digestibility, at least when short incubation times were used; the difference tended to disappear with longer periods of incubation. Also, oven drying of silage samples at high temperatures was found to reduce N degradability and solubility (Lopez *et al*., 1995) of the sample.

Additionally, Noziere and Michalet-Doreau, (2000), reported that grinding and pre-wetting underestimates degradation rates due to the increased microbial colonisation. Machine washing of residues overestimates solubles and particulate losses but it is less subjective than hand washing (Cockburn *et al*., 1993).

Huntington and Givens, (1995), reported that bag pore size less than 15mm can reduce degradation by restricting microbial colonization and diversity and trapping fermentation gases. However, bag pore size of more than 40 mm can cause losses of soluble and undegradable particles. Furthermore, the animal effects and bag incubation sequence also contribute to the variation in results among laboratories (Nocek, 1988). The disappearance of DM is also affected by the diet fed to the host animal (Caton *et al*., 1988). While these effects make it difficult to compare feeds for degradation across studies, DM or protein degradation of a feed is not entirely a function of the feed, but also affected by the ruminal conditions, so variation across studies is expected. The pH inside the nylon bag has been shown to be lower than that outside the bags, especially when small pore-sized bags were used (Marinucci *et al*., 1986). The microbial population inside the bags also differed, both in composition and concentration, from that of the outside of the bag. For example, both protozoa and bacterial populations were found to be lower inside the bags (Meyer and Mackie, 1986). This could be due to the limited micro-environment that existed within the bag involving a single ingredient of smaller size with limited exposure to rumen microbes perhaps due to the bag size and its pores.

Analysis of digesta from nylon bags incubated in vitro showed that some nutrients escaped the nylon bags before being digested (Spencer *et al*., 1988). The microbial attachment to feeds incubated *in sacco* is frequently not measured, though several studies have shown high levels of contamination of incubated feed with rumen microbes (Huntington and Givens, 1995). All these sources of errors increase variability of predictions of degradability among laboratories. In spite of being widely used and standardised, the application of this methodology needs to address two points: first, the fraction assumed to be completely degraded, and the DM and N disappearance during this step could simply be due to DM or N washed out of the bag; second, the microbial contamination of feeds within the bags. The first point would overestimate degradation and the second point would underestimate it (Madsen and Hvelplund, 1994).

The significance of these two factors would be important depending on the type of feed being analysed. However, the *in sacco* method is still the reference method in most countries; the reason is probably that the degradability is measured in the rumen and, therefore, from a biological point of view it is more reliable than those of the in vitro methods (Hvelplund and Weisbjerg, 1998).

2.2.2. *In sacco* dry matter and organic matter degradation of multipurpose trees

The MPTS recorded more than 60% DM and OM degradability at 24 h which implied that they are extensively degraded in the rumen. Variation in DM and OM degradability is directly related to the proportion of structural and non-structural protein and carbohydrate fractions which in turn affects their solubility and bioavailability (Whetton *et al*., 1997). Inter-species variations in OM and DM degradabilities could result in differential intakes of the MPTS when given as sole diets to animals (Papachristou and Papanastasis, 1994).

2.3. Condensed Tannins

Condensed tannins (CT) are secondary plant compounds found in some plant species. These plant products are polymers of flavan-3-ol (catechin) or flavan-3, 4-diol (proanthocyandins) units linked by C-C bonds (Waghorn *et al*., 1997; McMahon *et al*., 2000). The CT are typically found in plant cell vacuoles (Min *et al*., 2003), but location can vary among plant species. The CT can be found in cell walls, stems, bark, leaves, flowers, and seeds (McMahon *et al*., 2000). In the *japonicas* variety of birdsfoot trefoil (BFT), CT were not found in leaf tissue (as in other BFT cultivars), but were observed in stems and flowers by Morris *et al*. (1993). Conversely, CT are found throughout sainfoin (*Onobrychis viciifolia* Scop.), with the highest concentration of CT being found in the leaves (Lees *et al*., 1993). CT concentration of plants can also be influenced by maturity, temperature, and soil fertility as well as grazing (McMahon *et al*., 2000). Tannin concentration in BFT was reported to increase with increasing plant maturity and was higher in regrowth than in spring growth in West Virginia (Cassida *et al*., 2000).

The structure of CT can vary greatly. Monomers can be linked by C-4 and C-8 or C-4 and C-6 interflavan bonds, which alter the shape of the compound (Haslam, 1989; Barry and McNabb, 1999). The number of polymer units, and therefore the molecular weight (MW) can also vary among CT. These differences can dramatically alter the structure of CT, which can subsequently modify the nutritional effect of CT from different plant sources (McMahon *et al*., 2000).

Condensed tannins form complexes with many compounds, including protein and carbohydrates (Barry and McNabb, 1999). Feeding forages with high concentrations of CT (10% DM or greater) has been shown to reduce feed intake, N utilization, and carbohydrate digestion (Waghorn *et al*., 1997; Barry and McNabb, 1999). Condensed tannins from plant species such as BFT and sainfoin can bind protein by hydrogen bonding at near neutral pH (pH 6.0 to 7.0) in the rumen to form CT-protein complexes, and then dissociate and release bound protein at pH less than 3.5 in the abomasum (Barry *et al*., 2001). This, in turn, decreases protein degradation and NH_3-N production in the rumen, which results in improved N utilization and reduces N waste excretion by the animal. This reduction in soluble protein digestion in the rumen also prevents frothy bloat, making forages containing CT safe to graze (Kendall, 1966).

2.3.1. Effect of tannins on the utilization of browse

Most browse species contain large amounts (up to 50% of the dry matter) of tannins (Leinmuller *et al*., 1991; Cabiddu *et al*., 1998). Tannins are complex phenolic compounds that contain sufficient hydroxyl and carboxyl groups to precipitate proteins and to bind carbohydrates under conditions that prevail in the digestive tract of mammals and birds. The negative effects of tannins on palatability and digestibility in ruminants are multiple (Kumar and Vaithiyanathan, 1990). They include: (i) reduction in protein availability due to binding of food proteins and inactivation of enzymes in the digestive tract, (ii) astringency caused by the interaction of tannins with salivary protein and oral mucosa, and (iii) gut irritation and systemic toxicity. All of the aversive effects can reduce forage palatability. In general, there is an inverse relationship between tannin concentration in browse sources and voluntary feed intake by herbivores (Kumar and Vaithiyanathan, 1990).

Condensed tannin contents above 3% may act as a feeding deterrent (Provenza, 1995), influence feed degradation in the rumen (Silanikove et al., 1996a) and the digestibility of the whole diet (MacNaughton, 1987; Silanikove *et al*., 1997). Hence, when tannin-rich leaves are offered as a sole feed to sheep and goats they may not provide for adequate absorbed nutrients for maintenance despite their relatively high-protein and low-fibre contents (Silanikove *et al*., 1994, 1996a). They may also reduce animal productivity in terms of weight gain, milk yield and wool growth (Kumar and Vaithiyanathan, 1990). Silanikove *et al*. (1996a) reported that tannin levels of approximately 20% of DM drastically reduced leaf intake of *Pistacia lentiscus* and goats fed such a diet were in marked negative nitrogen balance, and lost weight very rapidly(100g/day).

Tannins can suppress intake by reducing digestibility or by causing illness. Tannins may bind to cell walls and cell solubles (Kumar and Vaithiyanathan, 1990; Reed, 1995) and in the process reduce the digestion of protein and yield of energy-rich byproducts of microbial fermentation such as volatile fatty acids (Makkar *et al*., 1995). This in turn may adversely affect preference of the feed containing the tannins (Villalba and Provenza, 1996, 1999). Tannins may also produce adverse postingestive effects that cannot be accounted for by digestion inhibition alone, primarily because they cause such rapid (within a few to 60 min) and dramatic decreases in food intake (Silanikove *et al*., 1997b; Landau *et al*., 2000). Silanikove *et al*. (1997b) in goats and Landau *et al*. (2000) in heifers have shown that feeding ruminants diets rich in condensed tannins was associated with lowered feed intake and shorter duration of eating bouts, mainly of the first eating bout, immediately after distribution of the diet. The data of Silanikove *et al*. (1997b) and Landau *et al*. (2000) suggest that: i) negative effects of condensed tannins derive from astringency and short-term post-ingestive malaise; ii) the increased number of eating bouts and their wider partition throughout the day are means to preserve the ruminal environment.

2.3.2. Effect of tannins on animal production

Tannin content is highest when the shrub is rapidly growing and tannin poisoning can occur when young or inexperienced livestock consume immature buds in the spring. Tannin content can also increase following summer rains. Research reported by Gomes, (1990) at the University of Arizona for turbinella oak concluded that condensed tannins are highest in the winter with immature leaves and that soluble tannins are highest in immature leaves in the summer through early fall.

Tannins, because of their protein-binding properties, are known to be strongly astringent. This astringency appears to be a major cause of reduced feed intake in mammalian herbivores. There is some controversy, however, over whether reduced food intake is a result of the nature of tannins. Singleton (1981) considers it to be unfair to consider the effects of tannins on feed intake as considers it to be unfair to consider the effects of tannins on feed intake as consumption itself. On the other hand, Provenza *et al*. (1990) suggest that mammals may reject tannin-containing plants because they cause internal malaise. Severe growth depression can be a result of reduced feed intake, as has been shown to appear in rats and chicks when fed tannin containing diets (Fahey and Jung, 1989). When tannins complex with proteins in an animal's gut, they are believed to be responsible not only for growth depression, but also for low protein digestibility and increased faecal nitrogen concentrations (Salunkhe *et al*., 1990). Thus, once they have been consumed, their adverse effects seem to be related to their binding of dietary protein. There is evidence that enzymatic protein as well as endogenous proteins comprise a considerable portion of excreted nitrogen when animals are fed tannins (Allredge, 1994). When endogenous proteins are lost in this manner, the animal may incur a deficiency in one or more essential amino acids.

The ability of tannins to form strong complexes with proteins is the most important aspect of their anti-nutritional effects. Tannins bind with at least four groups of proteins in the ruminant: dietary proteins, salivary proteins, endogenous enzymes and gut microbes including microbial enzymes (Hagerman and Butler, 1981). The effects on such as inhibition of feed intake and digestion by ruminants are usually ascribed to their ability to bind to proteins. The strength of the tannin-protein complexes depends on characteristics of both the tannin and protein (Haslam, 1989). HTs and CTs differ in their nutritional significance and toxic effects, but both precipitate proteins (Reed, 1995). While CTs are not readily degraded in the gut, hydrolysable tannins undergo microbial and acid hydrolysis with the release of simpler phenolics. These are absorbed and can cause toxicity. While CTs reduce forage quality, the HTs cause poisoning in animals if sufficient quantities are consumed. McSweeney *et al*. (1988) found that although sheep were sensitive to the toxicity of hydrolysable tannins present in the browse tree *Terminalia oblongata*, the digestion of N, organic matter and cell wall constituents remained unaffected. In contrast, CTs have detrimental nutritional effects such as reducing feed intake, reducing feed digestibility and increasing faecal nitrogen excretion (Reed and Soller, 1987). On the other hand, CTs can be of benefit in the prevention of bloat (Jones *et al*., 1973), in the protection of feed protein against degradation in the rumen (Barry *et al*., 1986) and by increasing N retention (Robbins *et al*., 1987) under some conditions.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The chemical composition study including tannin components was carried out in animal nutrition laboratory of Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) campus which is located in Jimma city, south western Ethiopia. This city is situated at 7°40′N and 36°50′E latitude and longitude, respectively (http://en.wikipedia.org/wiki/Jimma).

The *in sacco* rumen degradation study was carried out in Holeta Agricultural Research Center (HARC) animal nutrition laboratory. HARC is located in the West Shewa zone of the Oromia National Regional State, Ethiopia. It has a latitude and longitude of 9° 3′ 0″ N, and 38° 30′ 0″ E, respectively. The centre is located at an average altitude of 2391 meters above sea level (http://en.wikipedia.org/wiki/Holeta_Genet).

3.2. Description of the Browse Species

The browse species were selected based on their abundance in the area, preference and accessibility to browsing livestock as well as additional uses other than livestock feed (Yisehak *et al*., 2010). The browse species included in the study were *Ekebergia capensis, Ficus sycomorus, Maesa lanceolata,* and *Rhus glutinosa*, which are non legume trees. These species are commonly consumed by ruminants and equines. They are available to animals throughout the year (Yisehak *et al*., 2010).

3.3. Sampling, Drying and Storage of Plant Materials

Plant parts/morphological fractions of the tannin-rich browse species were collected from Waktola *kebele* of Omo Nada *woreda,* Jimma zone, Southwestern Oromia, Ethiopia during autumn season. Omo Nada *woreda* (http://en.wikipedia.org/wiki/Kersa_Jimma zone) was selected based on previous study (Yisehak *et al*., 2010). Fresh leaves and fruits were harvested from *Ekebergia capensis, Ficus sycomorus, Maesa lanceolata* and *Rhus glutinosa*, then placed in plastic bags and they were transported to JUCAVM, animal nutrition laboratory. Four individual plants per species were sampled and analyzed individually in order to have some measure for the intra-species variation and to perform statistical analyses in factorial procedure. After arrival in 35 minutes, the plant parts were placed in a new yellow paper bags, measured (fresh weight), and placed in oven at 55°C for 72 hours (checked for a constant dry weight). The dried samples were ground to pass through 1 mm sieve size of a Wiley mill for chemical analysis and 2 mm sieve for rumen *in sacco* degradation measurement and placed in air-tight plastic sample containers and stored in the nutrition laboratory at room temperature until analysis.

3.4. Chemical Analysis

Browse species were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash according to AOAC, (2005), whereas Neutral detergent fiber (NDF) was determined by the method of Van Soest *et al*. (1991), while Non-Fiber Carbohydrates (NFC) were calculated as 100-CP-NDF-ash-ether extract according to NRC, (2001). Chemical extraction of foliages for tannin components' analysis was done following the procedures of FAO/IAEA, (2002). Total condensed tannin was determined according to (Polshettiwar *et al*., 2007). Extraction of tannins was done in 70 per cent aqueous acetone, i.e. 700 ml acetone + 300 ml distilled water. For each sample four replicates were analyzed and the absorbances of the tannin extracts were measured at 550 nm (Makkar, 1995).

3.5. *In Sacco* Degradability Measurements

Ruminal *in sacco* degradation of DM and OM was determined according to (Orskov and McDonald, 1979). Dried forage samples (AOAC, 2005) milled to pass through a 2 mm sieve screen was weighted (3g /bag) into 4.5 cm × 18 cm nylon bags (pore size 40 µm). The bags were manually pushed deep into the liquid phase of the ventral sac of the rumen and incubated for 6, 12, 24, 48, 72 and 96 hours in the rumen of three male Boran X Holstein-Friesian steers. Two bags were incubated for each sample in each bull for each incubation time. Upon removal from the rumen, bags were washed in running tap water while rubbing gently between thumb and fingers until the water became clear. Zero time disappearances (washing losses) were obtained by washing un-incubated bags in a similar fashion. Bags were dried in an oven at 60^{o}c for 48 hours and weighed to determine the dry weight of the incubation residues.

In experiment the animals were allocated to a maintenance ration composed of natural pasture hay offered adlibtum as a basal ration and 2 Kg of a concentrate diet formulated from wheat bran, noug seed cake and salt in the ratio of 55: 43: 2. The animals were housed in individual pens and provided ad libitum water.

Dry matter disappearance (DMD) was estimated as follows:

$$DMD = \frac{((BW+S_1)-(BW+RW))}{(S_1 x DM)} x 100$$

Where, BW = bag weight; RW = residue weight; S_1 = sample weight; DM = dry matter content of the original sample

Degradability (Y) of DM was calculated using the equation of Orskov and McDonald, (1979):

$$Y = a + b (1 - e^{-ct})$$

Where "a" is the soluble fraction, "b" is the insoluble but potentially degradable fraction, "c" is the degradation rate constant of the "b" fraction, "t" is the degradation time 0, 6, 12, 24, 48, 72 and 96 hrs and the nonlinear parameters *a*, *b* and *c* were estimated using non-linear procedures of statistical analysis system (SAS, 2010).

The potential degradability was determined by the equation,

$$PD = a + b$$

The effective degradabilities (ED) for dry matter and organic matter were estimated according to ARC, (1980).

$$ED = a + bc/k + c,$$

Where k is rumen outflow rate, assumed to be 0.03/h

3.6. Statistical Analysis

A two ways analysis of variance was performed according to 4 x 2 factorial arrangements using general linear model procedure of statistical analysis system (SAS, 2010 version 9.3). Duncan's multiple range test procedure was used for mean separation. Mean differences were considered significant at $P \leq 0.05$. A spearman's correlation analysis was used to establish the relationship between some chemical composition parameters and *in sacco* ruminal DM and OM disappearances.

The DM and OM disappearances and the degradation characteristics such *a, b*, *PD*, *c, ED,* were estimated for each plant species and plant parts using nonlinear regression procedures of SAS. The model used was:-

$$Y_{ij} = \mu + s_i + p_j + (sp)_{ij} + \varepsilon_{ij}$$

Where, Y_{ij}=observation, μ = population mean, S_i=i^{th} species effect (i = 1 to 4), p_j = j^{th} plant part effect (j = 1 to 2), $(sp)_{ij}$ is interaction effect b/n ps and pp; and ε_{ij} is the residual error.

4. RESULTS AND DISCUSSION

4.1. The Effect of Plant Species and Forage Parts on Chemical Composition

The least square means for the chemical compositions of forage parts (leaves and fruits) of the studied plant species separately compared for the each plant species is presented in appendix Table 1. The dry matter (DM) contents varied from 92.66% in *Ficus sycomorus* leaf to 96.84% and 96.86% in *Rhus glutinosa* and *Ekebergia capensis* leaves, respectively (P<0.001). The crude ash (CA) content obtained in the present study for the leaf of plants fell within the range of 7.15 to 11.49 % in *Measa lanceolata* and *Ficus sycomorus* leaves, respectively. Highly significant difference was observed for CA values in the leaves of the plant species (P<0.001). The CP contents varied among the species and ranged from 9.76% in *Ekebergia capensis* leaf to 17.06 % in *Maesa lanceolata* leaf (P<0.001). The highest content of ether extract (EE) was recorded in the leaves of the three tree species such as *Maesa lanceolata* (5.17%), *Rhus glutinosa* (4.710%) and *Ekebergia capensis*(5.06%) while the lowest EE content was obtained in *Ficus sycomorus* leaf (1.57%)(P<0.001). The neutral detergent fiber (NDF) content was ranged from 37.96% in *Ekebergia capensis* to 61.33% in *Maesa lanceolata* and 61.01% in *Ficus sycomorus* leaves, respectively (P<0.001). On the other hand, the highest and lowest contents of non-fiber carbohydrates (NFC) was estimated for *Ekebergia capenis* (39.30%) and *Ficus sycomorus* (13.51%) and *Maesa lanceolata* (8.71%), respectively (P<0.001).

Similar to chemical composition of leaves of the plants species studied, there were also significant variations in the chemical composition of fruits of the tree species for the majority of chemical composition parameters (P<0.001) (appendix Table 1). The chemical contents ranged from: 7.97 to 12.10% CP, 5.97 to 31% EE, 35.90 to 68.90 NDF, 5.84 to 17.28% NFE and 7.20 to 10.17% CT.

The least square mean differences for the chemical composition parameters that compared between leaves and fruits are presented in Table 1. The highest CA continent was determined in the leaves of *F. sycomorus* whereas the lowest total cash values were recorded for fruits of *E. capensis* (5.43%) and *R. glutinosa*(5.57%)(P<0.001). Similarly, the highest CP contents were recorded in leaves as compared to fruits (P<0.001). On the other hand, extremely the highest EE content was determined for fruits of *E. capensis* as compared to the rest of plant parts; EE content in the fruits tends to be higher except in the *R. glutinosa* fruit(P<0.001). Similar to EE content of fruits the highest NDF content was also recorded in the fruits of the plants as compared to leaves (P<0.001). Unlike the contents of EE, CF and NDF contents of the fruits, the nitrogen free carbohydrate content was found to be the highest for leaves of the *E. capensis* (P<0.001). Furthermore, CT of leaves and fruits was comparable and attained the level that affects utilization of feedstuffs by livestock species. The largest ash content was obtained in the leaves of *F.sycomorus* as compared to ash values of leaves and fruits of the studied plant species (P<0.001). The leaves had relatively highest CP value as compared to fruits where as the EE values in fruits tends to be larger in fruits(P<0.001). On the contrary, the larger NDF content was recorded in fruits as compared leaves; the possible reason could be attributed to lack of amylase, an enzyme that catalyses the breakdown of starch into sugars enzyme digests starch during NDF analysis. Starch content decreases in the leaves during fruit development (Gerhard and Luddersl, 1997; Proietti *et al*., 2000). The highest CT content was recorded in the leaves as compared to fruits indicating a low CT content in fruits than browse leaves.

The Crude ash (CA) content of the leaves and fruits in the present study, the mineral level in a feed and large amount of silica was approximately ranged between 5 and 12%. CA contents of browse trees ranged from 8-12% (Bogdan, 1977). Carlos *et al*., 2005) also found 7.9 to 12.6% CA for leaves of some tree fodders.

In general, all the tree leaves and fruits had a high CP content (more than 7%) which indicates their high nutritive value in terms of CP, since the browses are intended to be used as protein supplements for low quality tropical pastures and crop by-products. Norton, (1994) reported that feeds with less than 6% CP levels are unlikely to provide the minimum ammonia levels required for maximum microbial growth in the rumen. Therefore, the entire browse species evaluated in this study would be a good protein supplements provided that they were adequately degraded and non-toxic to the rumen microbes and host animal. The preference of differences in the CP content across the plants is inconsistent with the reports of (Guerin, 1987; Mekoya *et al*., 2008), Kind *et al*., 2009; Ngodigha and Anyanwu, 2009) and Arigbede *et al*., 2011). In the present study, the CP content of the browse species was higher than the minimum level of 7–8% CP in DM required for optimum rumen function and feed intake in ruminant livestock (McDonald *et al*., 2002; Norton, 2003; Van Soest, 1994).

Table 1. Comparison of the least square means for chemical compositions (%) of leaves and fruits of the plant species

		Chemical composition, mean (%)							
Plant species	PP	DM	CA	CP	EE	NDF	CF	NFC	CT
E. capensis		96.84[a]	7.91[d]	9.76[d]	5.06[de]	37.96[d]	19.10[bc]	39.30[a]	8.00[b]
F.sycomorus	Leaf	92.66[d]	11.49[a]	12.42[bc]	1.57[f]	61.01[b]	15.40[cd]	13.51[bc]	8.49[b]
M. lanceolata		95.10[b]	7.15[e]	17.06[a]	5.17[de]	61.33[b]	21.45[bc]	8.71[cd]	13.65[a]
R. glutinosa		96.86[a]	9.29[c]	16.04[ab]	4.70[e]	49.31[c]	12.20[d]	20.66[b]	16.72[a]
E. capensis		94.11[c]	5.43[f]	11.07[c]	31.00[a]	35.9[d]	20.25[bc]	17.28[b]	7.27[b]
F. sycomorus	Fruit	95.56[b]	9.70[b]	10.81[c]	5.97[c]	66.71[ab]	27.5[a]	9.07[cd]	8.17[b]
M.lanceolata		96.5[a]	7.45[e]	7.97[c]	8.20[b]	62.00[b]	22.20[ab]	14.38[bc]	7.20[b]
R. glutinosa		92.43[d]	5.57[f]	11.21[c]	5.33[d]	68.9[a]	22.30[ab]	5.84[d]	8.59[b]
	SE	0.31	0.35	0.72	1.57	2.29	1.00	1.92	0.55
	P	***	***	***	***	***	***	***	*

PP, Plant part; DM, dry matter; CA, crude ash; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; CF, crude fiber; NFC, non-fibre carbohydrates; CT, condensed tannin; [a, b, c, d, e, f] *Least square means with the different letters within the column are significantly different (P <0.05); *P<0.05; ***P<0.001.*

The CP values obtained from the leaves and fruits in the present study were, however, lower than those CP valued reported for some leguminous browse species in south-west Nigeria (Larbi *et al*., 1998) and also lower than the CP values obtained for *Acacia* species (Abdulrazak *et al*., 2000).These variations could be due to plant variety, agro climatic conditions, or even maturity stages at harvesting (Makkar and Becker, 1997; Bamikole *et al*., 2004). The chemical composition of tree leaves vary with the maturity of leaves and also with localities (Mandal, 1997). Thus, the chemical composition of the leaves of plant species analyzed here provides a good source to be used as the nutrient source of ruminant animal feed. The level of CP was, however, comparable with the reported CP of browsed species in tropical West Africa (Le- Houerou, 1980).

The entire browse species in this study had CP level within the acceptable range (7 - 14%) for production and reproduction performance of ruminants (NRC, 1981). The results of the present study also agrees with (Getachew *et al*., 2000) in that the browse forages are better used as protein supplement than poor quality roughages such as hay, straws and stovers whose CP content is lower than 7%CP (Skerman and Riveros,1990). Voluntary feed intake rapidly falls if CP content of forage is below 6.2% (Nasrullah *et al*., 2003). It is well reported that feeds containing less than 7% CP cannot provide the minimum ammonia levels required by rumen microorganisms to support optimum activity, the leaves and fruits of the present study can be potential supplement for low CP feeds except their CT content. Further, rumen fermentation is affected if the CP level in diet is less than 10% (Alam and Djajanigra, 1994), however, CP level in these trees is higher than this level except *M. lanceolata* fruit. Differences in CP contents between leaves of different trees are probably due to differences in protein accumulation in them during growth. Even though the CP contents of the plant parts attains the minimum protein level for optimum rumen function, their CP concentration was relatively lower than those of protein supplementary legume browses such as *Leucaena leucocephala*: 27.2%; *Sesbania sesban*: 27.6% (Mupangwa *et al*., 2003; Thandei *et al*., 2001; Giang *et al*., 2004); *Albizia gummifera*: 29.6% (Yisehak *et al*., 2010).

The NDF content of the plants, except *E.capenesis* leaf (47.72%), *M.lanceolata* fruit (56.67%) and *R.glutinosa* leaf (49.50%), was found more than 60%. Optimum NDF content of a ration should be in the range of 27-30% (Jolly and Wallace, 2007). The threshold level of NDF in tropical plants beyond which feed intake of ruminants affected is 60% (Meissner *et al*., 1991) suggesting that some of the diets included in this study marginally have above 60% NDF in DM. Tree forages with a low NDF content (20–35%) are usually of high digestibility (Norton, 1994; Bakshi and Wadhwa, 2007) that the low level of fiber can facilitate the colonization of the plant parts included in the present study by the rumen microbial population, which in turn might induce even higher fermentation rate, therefore improving its digestibility(Van Soest, 1994). The results of present studies were inconsistent with (Schmidek *et al*., 2000) and (Cheema *et al*., 2011) who reported 26.2 to 39.3% NDF for multipurpose trees and shrub species. The NDF values of the plants of the present study was also comparable with the NDF values reported for some browse species in Nigeria (Larbi *et al*., 1998) and shrub species from a mountain area in northern Spain (Frutos *et al*., 2000) with just little variations. High contents of cell wall are typical of tropical forages (Van Soest, 1982) which have serious implication on the digestibility of forages. NDF actually determines the rate of digestion because it is inversely related to digestibility (McDonald *et al*., 1995; Gillespie, 1998).

The EE content in leaves of the plants except in *F.sycomorus* (avg. 1.57%) exceeded 5%. The EE content (avg. < 5% in DM) is an indication of low energy level for the animal. Odedire and Babayemi (2008) reported that feedstuffs contained more than 5% considered higher energy level for an animal. Therefore the present study could achieve the above requirement. However, the EE content of *E. capenesis* fruits was above the acceptable range for the animals (avg. 28.10%). Total diets that do not contain EE more than 10 %(Preston, 1995). The higher value of ether extracts in some of the tested samples is an indication of higher energy level for the animal (Babayemi and Bamikole, 2006; Odedire and Babayemi, 2008) and this is a major form of energy storage in plants which is being utilized by the animals for body maintenance and production. The crude fat content of all the tree fruits and leaves evaluated were higher than the levels reported in pasture grass (0.6-1.3 per cent), and fodder maize (4.4 per cent) (Schlink and Burt, 1993).

The CT content in all the plants was above 5% that is why these plants considered as tannin rich plants. Tannin concentrations higher than 5% adversely affect forage intake and digestibility (Perevolotsky *et al.*, 1993; Silanikove *et al*., 1996). Tannins have ability to bind and inhibit the digestive enzyme activities (Kumar and Singh, 1984) and affect the microbial and enzyme activities (Makkar *et al*., 1989), whereas, lower concentration of tannins can improve nutrition for ruminants by reducing protein degradation in the rumen and increasing the flow of amino acids to the intestine (Mc Nabb *et al*., 1996). Concentration of tannins less than 4% in the ration is beneficial by promoting bypass protein and bloat suppression in ruminant animals (Aganga and Tshwenyane, 2003). Compared with tropical, mature grasses, browse appears to be richer in protein and minerals (Le Houerou, 1980; Devendra, 1995). In most situations, its practical use is as a supplement to enhance the intake and utilization of other fibrous crop residues like cereal straws and hays, and thus meet the maintenance and variable levels of production requirements.

4.2. The Effect of Plant Species and Plant Parts on *In Sacco* Ruminal Dry Matter Disappearances

Interspecies variation for DM disappearances from leaves and fruits of tannin rich trees for different incubation hours are presented in appendix Table 2. The highest DM disappearance at zero hour incubation was recorded in leaves of *E.capensis* (29.43%) whereas the DM disappearance value was lowest for *F.sycomorus* leaves (6.32%) (P<0.001). This might be attributed to processing or distribution in particle size of the ground materials. The reports of Welch, (1986); Singh *et al*., (1989) and Khan *et al*., (2009) confirmed that DM disappearance at zero hour is mainly due to mechanical action rather than microbial fermentation. At 6 hours of post incubation, the highest DM disappearances were recorded for the leaves of *E. capensis* (32.12%) and *M. lanceolata* (32.60%) where as the lowest DM disappearances were determined for *F. sycomorus*(15.82%) and *R. glutinosa* (16.87%) leaves (P<0.001). Yet at 6 hour incubation, the *E. capensis* fruits had the highest DM disappearances as compared to rest of the plants (P<0.001). Across all the incubation hours, the leaves of *E. capensis* had the highest DM disappearances; comparably, *M. lanceolata* leaves had also the highest DM disappearances in 6, 24 and 72 hours incubation in contrast to the rest of plants (P<0.001). In comparison, the highest DM disappearance value was only recorded for *E. capensis* fruit (P<0.001).

The least square mean differences for the DM disappearance that compared between leaves and fruits are presented in Table 2. At zero-hour incubation both the highest and lowest DM disappearance or bag wash loss was recorded in *E.capensis fruit* (39.28%) and leaves of *F.sycomorus* (6.32%), respectively (P<0.001). *E.capensis* leaves and fruits acquire the largest share in DM disappearances in almost all incubations hours as compared to DM disappearances in edible parts of the rest plants (P<0.001). In general species variation was significant for DM disappearances across the incubation hours. A possible reason to this effect might be species difference in since plant and their edible fractions has inconsistent values of chemical constituents used for rumen microbes. Arigbede *et al*. (2011) reported similar findings that an effect of species variation is significant for variations in DM disappearances of various multipurpose tree species.

Table 2. Least square means for *in sacco* ruminal dry matter disappearances compared for leaves and fruits of the plant species

		Incubation time (h), mean (%)						
Plant species	PP	0	6	12	24	48	72	96
E. capensis		29.43^{b}	32.12^{b}	59.47^{a}	73.11^{a}	82.49^{a}	81.79^{a}	83.38^{a}
F. sycomorus	Leaf	6.32^{g}	15.82^{d}	26.09^{c}	22.53^{d}	61.07^{b}	59.52^{b}	69.89^{c}
M. lanceolata		23.69^{c}	32.60^{b}	35.59^{b}	64.99^{ab}	65.72^{b}	81.46^{a}	77.53^{b}
R. glutinosa		19.28^{de}	16.87^{d}	17.99^{d}	23.72^{d}	38.20^{c}	47.07^{c}	47.64^{d}
E. capensis		39.28^{a}	43.34^{a}	60.01^{a}	62.02^{b}	78.95^{a}	75.94^{a}	84.85^{a}
F. sycomorus		20.81^{d}	23.29^{c}	34.20^{b}	43.17^{c}	58.90^{b}	62.34^{b}	69.89^{c}
M. lanceolata	Fruit	10.32^{f}	15.14^{d}	19.03^{d}	28.64^{d}	40.11^{c}	54.15^{bc}	46.08^{d}
R. glutinosa		17.60^{e}	17.91b^{cd}	20.30^{cd}	22.16^{d}	26.46^{d}	34.16^{d}	21.65^{e}
	SE	2.04	1.55	2.47	3.14	2.99	2.51	3.06
	P	***	***	***	***	***	***	***

*PP, plant parts; $^{a, b, c, d,e,f,g}$ Least square means in a column with different superscripts are significantly different (P<0.05); ***P<0.001; SE, Standard error of means*

The other possible reason might be associated with the NFC content, the major energy source for rumen microbes, in content in the leaves and fruits of *E. capensis* were found to be superior. The range of NFC content showed that the trees under evaluation can be easily degraded or fermented because NFC is an estimate of the carbohydrate pool that differ in digestibility from CF and NDF. It has also been reported that NFC has a positive relationship with ammonia nitrogen (NH3-N) utilization in the rumen (Tylutki *et al*., 2008). As nitrogen utilization by rumen microflora is related to the amount of fermentable energy, the adequate NFC contents especially in *E. capensis* could enable efficient microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Cabrita *et al*., 2006). DM disappearance values were highest at terminal incubation hours across plant species. Many authors (Orskov *et al*., 1988; Kabuga and Darko, 1993; Tesema and Baars, 2003; Lanyasunya *et al*., 2006; Vranic *et al*, 2009 and Lebopa *et al*., 2011) confirmed the increasing trends of that ruminal degradation of DM as advances in incubation hours. The other possible reason could be tannin content of the feed materials. Although the tannin content of the leaves and fruits are attained the level that affects nutrient utilization, CT content in leaves and fruits of *E.capensis* was one of the lowest CT values among the plant parts. Tannins are complex polyphenolic compounds with an ability to precipitate proteins and to form complexes with carbohydrates thereby, reducing the digestibility (Kumar and Vaithiyanathan, 1990; Makkar, 2003; Ferreira, 2004**;** Mezzomo *et al*., 2011).

Except in fruits and leafs of E.capensis and leaves of M. *lanceolata,* the DM disappearance of the plants is lower than the values recorded for most of the legume and non-legume multipurpose trees reported by Ramana *et al.* (2000). This difference might be associated to differences in plant species. The higher NDF and CT contents in the plant species might also attribute to lower DM disappearances.

4.3. *In Sacco* Dry Matter Degradability Characteristics of the Leaves and Fruits of the Plant Species

The *in sacco* DM degradability characteristics of leaves and fruits of the studied plants are presented in appendix Table 3. The highest and lowest soluble fraction (b) of leaves was recorded in *M. lanceolata* (14.55%) and *E.capensis* (-16.20%), respectively (P<0.001). This could be related to the loss of finer particles from the bags in this treatment, rather than a higher solubility. Yet in the fruit, the highest value of soluble fraction (35.51%) was obtained for *E.capensis*. Except in fruits of *M. lanceolata* (*14.55%)* and *F. sycomorus* (15.49%), the values of soluble fraction (a) in the present study were lower that the 'a' values estimated for 20 multipurpose trees and shrub species (both legumes and non legumes) studied in Nigeria by Ngodigha and Anyanwu, (2009). The possible reason could be linked to variation in plant species. However, the least square means obtained for slowly degradable fraction (b) in the leaves of *E.capensis* was found to be the superior (98.37%) where as the least value was recorded for *R.glutinosa* leaves (P<0.001). This could be associated with the concentration of CTs; the highest CT concentration in *R.glutinosa* leaves has had the least DM disappearance of the potentially degradable fraction. CTs depress DM degradability (Gonzalez *et al*., 2002; Ozkan and Sahin, 2006; Gupta *et al*., 2011). In general, *E. capensis* leaves had the highest values for slowly degradable fraction, effective degradability and rate of degradation(c) as compared to values recorded for other plants(P<0.001). Unlike in leaves, *E.capensis* fruit had significantly the highest a soluble fraction (a), potential degradability (b) and effective degradability (ED) values as compared to the '*a', PD* and *ED* values in the fruits of other plants(P<0.001). This might be due higher content NFC and as well as EE content in *E.capensis* leaves and fruits. Higher level of soluble fraction is known to result in a more efficient fermentation in the rumen (Beever *et al*., 1978).The differences in soluble fraction could be attributed to the proportion of soluble carbohydrates to structural carbohydrates (Ngodigha and Oji, 2009). According to Van Soest ,(1982), the soluble carbohydrates ferment faster than structural carbohydrates.

Table 3. Comparison of the least square means for in sacco ruminal drymatter degradability characteristects of leaves and fruits of the plant species

		Degradability parameters				
Plant species	PP	a	b	PD	ED	c
E.capenesis	Leaf	-16.2[h]	98.37[a]	82.17[c]	61.83[b]	0.12[a]
F. sycomorus		7.37[f]	77.82[b]	85.19[a]	35.78[e]	0.02[e]
M. lanceolata		14.5[c]	64.91[c]	79.47[d]	53.76[c]	0.05[b]
R.glutinosa		11.23[e]	52.76[e]	63.99[f]	27.86[g]	0.01[f]
E. capenesis	Fruit	35.51[a]	47.11[f]	82.62[b]	63.18[a]	0.04[c]
F. sycomorus		15.49[b]	56.15[d]	71.64[e]	43.28[d]	0.03[d]
M. lanceolata		5.78[g]	46.59[g]	52.36[g]	29.22[f]	0.03[d]
R. glutinosa		13.92[d]	13.69[h]	27.61[h]	22.57[h]	0.05[b]
SE		2.63	4.69	3.99	3.11	0.006
P		***	***	***	***	***

*PP, plant part; a, soluble fraction; b, slowly degradable fraction; (%/hour);PD, potential degradability; ED, effective degradability; c, rate of degradation; [a, b, c,d,e,f,g,h] Least square means within the same column with different superscripts are significantly different (P<0.05); SE, Standard error of the mean; ***P<0.001*

The *in sacco* DM degaradability characteristics of fruits and leaves of various multipurpose tree species (MPTS) compared and the results were presented in Table 3. Although the species variation was significant for degardability parametres, the effect of plant parts for the same species was also found to be significant for the degradability parametres(P<0.001).The difference among the MPTS in degradation characteristics may be partly related to variations in chemical composition (Nashlai *et al*., 1994), the relationship of cell wall polysaccharides and their effect on rumen microbial attachment and colonization of digesta particles (Cheng *et al*., 1984). The high ED recorded for *E. capensis* may relate to its low cell contents (NDF). This confirmed earlier reports that *in situ* nylon bag method could be used to rank MPTS for quality in initial screening studies. Based on ED values in this study, MPTS could be ranked as high (> 450 g kg^{-1} DM), medium (400-450 g kg^{-1} DM) and low (< 400 g kg^{-1} DM) quality groups. *E. capensis* (leaf and fruit), *M. lanceolata* (fruit), were among the high quality group; *F. sycomorus* fruit was in the medium quality group, while both *R. glutinosa* leaf and fruit and *M.lanceolata* fruit belonged to the low quality group. The highest (0.12%/h) and lowest (0.01%/h) values of passage rate were recorded for *E.capensis* leaves and *R.glutinosa* leaves as compared to the ‘c’ values in fruits of the plant species, respectively (P<0.001).

4.4. The Effect of Plant Species and plant parts on *in sacco* ruminal Organic Matter Disappearances

The 0- hour disappearance of OM was largest for leaves and fruits of *E.capensis* as compared to the rest of plants (P<0.001) (appendix Table 4). Similarly, at 6 h incubation the highest OM disappearance was recorded for leaves and fruits of *E.capensis*, as well as leaves *M.lanceolata.* Throughout the incubation hours the leaves and fruits of *E.capensis* has taken the highest OM disappearance values followed by leaves of *M.lanceolata* as compared to OM disappearance values of plant parts in the rest of plant species(P<0.001).

The high washing loss (0 h disappearance) of MPTS evaluated in this study is an indication of the presence of soluble or ruminally degradable nutrients that may be rapidly utilized in the rumen. The MPTS recorded more than 60% OM degradability at 24 h which implied that they were extensively degraded in the rumen. As compared to 0h OM disappearances of leaves and fruits, the highest value (39.28%) was recorded in the *E.capensis* fruit (P<0.001, Table 4). Yet, *in sacco*, throughout the incubation hours other than 0 h, even though the OM disappearance values were one of the highest values among plants and their edible fractions, statistically significant variation was not recorded between leaves and fruits of *E.capensis* (P>0.001). Variation in protein degradability is directly related to the proportion of structural and non-structural protein and carbohydrate fractions which in turn affects their solubility and bioavailability (Whetton *et al*., 1997). The lowest OM degradability values for leaves and fruits (< 60%) of the plant species except *E.capensis* leaves and fruits, as well as *M.lanceolata* leaves might be associated to the presence of secondary metabolites. Several studies have documented effects of secondary metabolites especially tannins (Reed, 1995; Ammar *et al*., 2004; Gasmi-Boubaker *et al*., 2005) on OM degradability; However, it can be concluded that tannins at levels reported in this study could not affect OM degradability in *E.capensis* leaves and fruits and leaves of *M.lanceolata,* even if CT content reached the values that complicates feed digestion.

Although, changes in the tannin content of individual species may affect rumen nitrogen and OM degradability (Barry and Forss, 1983), it is perhaps not valid to compare the effect of tannin content on such parameters between species as there is no existing accurate method for estimation of ``active" tannins. The other possible reason might be associated with higher NDF contents; ruminant livestock require fiber for normal rumen function but fiber also limits feed intake and digestibility (Albrecht and Broderick, 1990).

Table 4. Comparison of least square means of leaves and fruits of the tannin rich plants for *in sacco* organic matter disappearances

		Incubation time (h), mean (%)						
Plant species	PP	0	6	12	24	48	72	96
E. capensis	Leaf	29.43^{b}	37.55^{ab}	61.05^{a}	73.28^{a}	82.48^{a}	81.79^{a}	83.38^{a}
F.sycomorus		6.32^{g}	22.63^{cd}	26.45^{c}	23.57^{c}	62.64^{c}	61.05^{b}	69.89^{b}
M.lanceolata		23.69^{c}	31.21^{bc}	36.05^{b}	65.91^{a}	72.30^{b}	81.69^{a}	77.60^{a}
R.glutinosa		19.28^{de}	17.44^{d}	20.63^{c}	26.26^{c}	42.02^{e}	47.27^{d}	48.98^{c}
E. capensis	Fruit	39.28^{a}	43.34^{a}	60.68^{a}	64.81^{a}	81.34^{a}	80.29^{a}	84.99^{a}
F.sycomorus		20.81^{d}	21.27^{d}	34.96^{b}	45.43^{b}	53.40^{d}	64.88^{b}	69.36^{b}
M.lanceolata		10.32^{f}	14.85^{b}	19.03^{c}	29.73^{c}	47.86^{de}	54.61^{c}	45.63^{c}
R.glutinosa		17.60^{e}	17.91^{d}	20.30^{c}	24.39^{c}	27.73^{f}	38.25^{e}	31.09^{d}
	SE	2.04	1.73	2.49	3.06	2.83	2. 37	2.82
	P	***	***	***	***	***	***	***

*PP, plant part; [a, b, c,d,e,f,g] Least square means within the same column with different superscripts are significantly different (P<0.05); ***P<0.001; SE, Standard error of the mean*

4.5. Effect of Species and Plant Parts on *In Sacco* Organic Matter Degradability

Table 5 shows the nonlinear parameter estimates and effective degradability values of OM of the leaves and fruits of the studied plants. The soluble fraction (a) ranged from -1.02% in *R.glutinosa* to 10.69% in *E.capensis* leaves where the variation was significant for the plant species (P<0.001). On the other hand, the highest and lowest 'a' value was recorded for fruits of *R. glutinosa* (31.84%) and *E.capensis* (14.22%) (P<0.001). The insoluble but degradable fraction (b) was 83.35% in *R. glutinosa* and 45.21% in *E.capensis* leaves (P<0.001); On the contrary, the highest and lowest values of potential degradability (PD) was recorded for *F.sycomorus* (89.89%) and 55.90% *for E.capensis*(P<0.001) respectively. Similarly, the highest and lowest effective degradability(ED) was obtained in *R.glutinosa* (63.97%) and *E. capensis* leaves

(P<0.001). The degradation rate constants (c) varied widely between MPTS with similar rates for *E.capensis* and *F.sycomorus*. The highest washing losses, soluble or rapidly degradable OM fraction at time 0h was highest for *R.glutinosa* fruit whereas it was the least value (-1.02%) in the leaf of the same plant(P<0.001)(Table 5). This might be associated to differences in the solubility of leaves and fruits of the same plant. Yet, in leaves and fruits, the value recorded for the insoluble but potentially fermentable OM fraction that degrades with time was highest in *R.glutinosa* (83.35%) leaves and lowest in *E.capensis* fruit (45.21%) (P<0.001). Conversely, the among the plant species, the highest PD (89.89%) and lowest (35.60%) was determined for *F. sycomorus* leaves and *E.capensis* fruit (P<0.001). Similar to the rapidly soluble fraction 'a', effective degradability (ED) was found to be largest in fruits as compared to leaves of the plants (P<0.001). In general, it was observed that variation of plant parts lead to highly significant differences in OM degradability characteristics of the plant species.

The observed differences in OM degradation characteristics of the studied plant species may be partly due to the differences in their chemical composition which is influenced by the species, foliage parts of the trees. The range of values for the readily soluble 'a', potentially degradable fractions 'b', the rate 'c' and extent of OM degradation in this study agreed with the reports of (Larbi *et al*., 1998; El Hassan *et al*., 2000; Hervas *et al*.,2000) which also confirmed significant differences in OM degradation characteristics of several tropical browse trees. Degradation constants as measured by the *in sacco* nylon bag technique are strongly related to digestible DM intake (Kibon and Orskov, 1993). Thus, interspecies variations in OM degradability could result in differential intakes of the plants when given as sole diets to animals. The 'a' for leaves of the plants are lower that previous reports for various MPTS in Nigeria (Ngodigha and Anyanwu, 2009; Arigbede *et al*., 2011), 12 species in Kenya (Ondiek *et al*., 2010). These differences might be attributed to differences in plant species location and contents of secondary plant components especially condensed tannin; higher CT content is obtained in the present study.

Table 5. Comparison of least square means for *in sacco* ruminal degradability characteristics of organic matter of leaves and fruits of the plant specie

Plant species	PP	Degradability parameters				
		a	b	PD	ED	C
E. capenesis		10.69[e]	45.21[g]	55.90[f]	29.61[g]	0.02[e]
F. sycomorus		12.63[d]	77.27[b]	89.89[a]	38.11[e]	0.02[e]
M. lanceolata	Leaf	8.11[f]	71.98[c]	80.09[d]	54.55[c]	0.05[b]
R. glutinosa		-1.02[h]	83.35[a]	82.33[c]	63.97[b]	0.11[a]
E.capenesis		14.22[c]	21.38[h]	35.60[h]	24.58[h]	0.03[d]
F. sycomorus	Fruit	15.26[b]	56.40[d]	71.66[e]	42.84[d]	0.03[d]
M. lanceolata		2.06[g]	50.28[f]	52.34[g]	30.59[f]	0.04[c]
R.glutinosa		31.84[a]	52.02[e]	83.86[b]	64.65[a]	0.05[b]
SE		2.03	4.04	3.82	3.15	0.006
P		***	***	***	***	***

*PP, plant part; 'a', soluble fraction; b, slowly degradable fraction; PD, potential degradability; ED, effective degradability; c, rate of degradation; [a, b, c,d,e,f,g,h] Means within the same column with different superscripts are significantly different (P<0.05); ***P<0.001; SE, standard error of the mean.*

4.6. The Correlation between Chemical Composition and *In Sacco* Ruminal Degradation of Dry matter and Organic Matter

The spearman's correlation coefficient (r) between chemical composition and *in sacco* rumenal degradability of DM and OM are presented in Table 6. The statistical correlation between CT and DM and OM disappearances in all incubation hours was negative and highly significant ($P<0.001$) (Table 6). This is an indication of the negative influences of CTs on DM and OM disappearances the MPTS. Condensed tannins are known to reduce digestible matter by binding essential nutrients in the digestive tracts of livestock (Hagerman and Butler, 1981; Provenza *et al*., 1990; Allredge, 1994; Reed, 1995; Getachew *et al*., 2000; Makkar, 2003). The poor non-significant correlation was observed between CP and *in sacco* degradability of DM and OM, might be associated with the condensed tannin content in the MPTS that in turn affects degradability by protecting feed proteins from microbial utilization. Moreover, the correlation between DM and OM disappearances and NDF or CF was negative; however, the strong and significant correlation was observed for DMD at ($r = 0.755$) and OMD ($r = 0.786$) at 96 h ($P<0.05$). The digestibility of plant material in the rumen is related to the proportion and lignification of cell walls (Van Soest, 1994). NDF actually determines the rate of digestion because it is inversely related to digestibility (McDonald *et al*., 2002). Except in leaves and fruits of *E. capensis* and *R. glutinosa* leaves the NDF contents of the plant species are more 60 % in DM and degradability was associated with higher NDF contents. Ruminant livestock require fibre for normal rumen function but fibre also limits feed intake and digestibility (Albrecht and Broderick, 1990).

6. The spearman's rho correlation coefficient between chemical composition and *in sacco* dry matter and organic matter disappearances for some incubation hours

	DMD_{12}	DMD_{24}	DMD_{48}	DMD_{72}	DMD_{96}	OMD_{12}	OMD_{24}	OMD_{48}	OMD_{72}	OMD_{96}	DM	Ash	CP	EE	NDF	CF	NFC	CT
DMD_{12}	1.00	0.74*	0.89**	0.86**	0.90**	0.91**	0.71*	0.88**	0.86**	0.88**	-0.21	-0.33	0.12	0.29	-0.48	0.07	0.12	-0.36**
DMD_{24}		1.00	0.83*	0.93**	0.80*	0.81*	0.98**	0.83*	0.93**	0.76*	0.43	-0.19	0.21	0.21	-0.50	-0.02	0.41	-0.31**
DMD_{48}			1.00	0.95**	0.95**	0.91**	0.74*	1.00**	0.95**	0.95**	0.10	-0.07	0.14	0.02	-0.69	-0.26	0.43	-0.38**
DMD_{72}				1.00	0.90**	0.90**	0.86**	0.95**	1.00**	0.88**	0.19	-0.05	0.12	0.05	-0.52	-0.10	0.31	-0.29**
DMD_{96}					1.00	0.95**	0.79*	0.95**	0.90**	0.99**	0.08	-0.13	0.01	0.08	-0.76*	-0.29	0.42	-0.25**
OMD_{12}						1.00	0.76*	0.91**	0.91**	0.93**	0.10	-0.10	0.02	-0.02	-0.64	-0.21	0.36	-0.12**
OMD_{24}							1.00	0.74*	0.86**	0.67	0.41	-0.33	-0.24	0.31	-0.41	0.10	0.33	-0.29**
OMD_{48}								1.00	0.95**	0.95**	0.10	-0.07	0.14	0.02	-0.69	-0.26	0.43	-0.38**
OMD_{72}									1.00	0.88**	0.19	-0.05	0.12	0.05	-0.52	-0.10	0.31	-0.29**
OMD_{96}										1.00	0.05	-0.12	0.05	0.024	-0.79*	-0.36	0.43	-0.24
DM											1.00	0.31	0.24	-0.14	-0.33	-0.33	0.71*	-0.02
Ash												1.00	0.02	-0.64	0.07	-0.29	0.17	0.19
CP													1.000	-0.52	-0.05	-0.38	-0.33	0.88**
EE														1.00	0.14	0.67	-0.14	-0.64
NDF															1.00	0.76*	-0.81*	0.17
CF																1.00	-0.67	-0.29
NFC																	1.00	-0.31
CT																		1.00

*DMD_{12}, dry matter disappearance at 12 h; DMD_{24}, dry matter disappearance at 24 h; DMD_{48}, dry matter disappearance at 48 h; DMD_{72}, dry matter disappearance at 72 h; DMD_{96}, dry matter disappearance at 96 h; OMD_{12}, organic matter disappearance at 12 h; OMD_{24}, organic matter disappearance at 24 h; OMD_{48}, organic matter disappearance at 48 h; OMD_{72}, organic matter disappearance at 72 h; OMD_{96}, organic matter disappearance at 96 h ;DM, dry matter; CA, crude ash; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; CF, crude fiber; NFC, non-fibre carbohydrates; CT, condensed tannin; *P<0.05; **P<0.0*

5. SUMMARY AND CONCLUSION

The present study covered chemical composition, *in sacco* rumen dry matter and organic matter degradability of leaves and fruits of indigenous tannin rich multipurpose tree species (MPTS) and also assessed the relationship between chemical composition and *in sacco* ruminal degradability parameters

The chemical composition of the multipurpose tree species has wide-ranging variation both in plant species and edible plant parts. The leaves of the plants were rich in crude ash, crude protein, non-fiber carbohydrates and condensed tannin when comparing with the fruits. In contrast, fruits had the highest ether extract, neutral detergent fiber and crude fiber comparing with the leaves of the plants.

The present study shows that all the MPTs are potential sources for use as protein banks to supplement grasses or crop residues in dry seasons. However, the nutrient activating factor (condensed tannin) in the edible parts of studied plants were greater than the thresh hold value that affects nutrient utilization and bioavailability in grazing livestock species. yet, the presence of CT at higher levels in some species may be a major constraint to their utilization by the livestock.

Dry matter and OM degradation were highly correlated with time taken for the incubation. *In sacco* degradability trial showed presence of both ruminally degradable and undegradable dietary nutrients. Rumen degradation characteristics could be used to characterize and detect variation in forage quality of the browse. Depending on their DM disappearance potentials both leaf and fruit of *E. capensis* were > *M. Lanceolata* > *F. sycomorus* > *R. glutinosa* at 96hr of incubation. While for OM disappearance leaves of *E. capensis* and *M. lanceolata* > *F. sycomorus* > *R. glutinosa* leaves but for the fruits, *E.capensis* > *F.sycomorus*>*M.lanceolata*>*R.glutinosa*. So it is possible to conclude leaves and fruits of *E. capensis* are superior in DM and OM disappearances of the other plant species. The lowest DM and OM were resulted in both leaf and fruit of *R. glutinosa* plant at the end of 96h incubation time. In general, the DM and OM disappearances of plant parts were negatively correlated to concentrations of condensed tannins.

Among the plant species, the highest PD (89.89%) and lowest (35.60%) was determined for *F. sycomorus* leaves and *E.capensis* fruit (P<0.001). Similar to the rapidly soluble fraction 'a', effective degradability (ED) was found to be largest in fruits as compared to leaves of the plants (P<0.001). In general, it was observed that variation of plant parts lead to highly significant differences in OM degradability characteristics of the plant species.

Based on the above summary and conclusion the following recommendations are forwarded:

- The chemical composition can indicate nutrient potentials of a given feedstuff but depending on the simple chemical composition parameters like in the present study it is difficult to recommend a given plant is better than the other, thus the concise recommendation should be based on the complete chemical, allelochemical and/or phytochemical parameters before including this plant species in to total mixed rations are necessary.

- Since the present works only reveal the chemical composition and *in sacco* degradation of plant parts in one season that can again not clearly show the seasonal influences on the chemical composition and *in sacco* degradation of edible fractions of plant species; thus combining the effects of seasons and plant parts should call for further study.

- To see the clear effect of CTs on feed degradability, the CP and NDF degradability should be done because tannin bind both protein and carbohydrates.

- Further studies should again focus on the bioavailability of nutrients using CT rich MPTS in different classes and breeds of livestock species.

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7. APPENDICES

7.1. Appendix. Chemical Composition and *In Sacco* degradability Tables

Appendix Table 1. The least square means for chemical compositions (%) of plant species

		Chemical composition, mean							
Plant species	PP	DM	CA	CP	EE	NDF	CF	NFC	CT
E. capensis		96.84^{a}	7.91^{c}	9.76^{d}	5.06^{a}	37.96^{c}	19.10^{ab}	39.30^{a}	8.00
F. sycomorus		92.66^{c}	11.49^{a}	12.42^{c}	1.57^{b}	61.01^{a}	15.40b^{c}	13.51^{bc}	8.49
M. lanceolata	leaf	95.10^{b}	7.15^{d}	17.06^{a}	5.17^{a}	61.33^{a}	21.45^{a}	8.71^{c}	13.65
R. glutinosa		96.86^{a}	9.29^{b}	16.04^{b}	4.70^{a}	49.31^{b}	12.20^{c}	20.66^{b}	16.72
	SE	0.06	0.17	0.27	0.16	2.46	1.49	2.41	1.66
	P	***	***	***	***	***	**	**	NS
E. capensis		94.11^{c}	5.43^{d}	11.07	31.00^{a}	35.90^{d}	20.25	17.28^{a}	7.27
F. sycomorus	fruit	95.56^{b}	9.70^{a}	10.81	5.97^{c}	66.71^{b}	27.5	9.07^{bc}	8.17
M. lanceolata		96.5^{a}	7.45^{b}	7.97	8.20^{b}	62.00^{c}	22.20	14.38^{b}	7.20
R. glutinosa		92.43^{d}	5.57^{c}	11.21	5.33^{d}	68.9^{a}	22.30	5.84^{c}	8.59
	SE	0.30	0.30	2.04	0.18	1.26	2.41	2.39	0.86
	P	***	***	NS	***	***	NS	*	NS

PP, plant part; DM, dry matter; CA, crude ash; CP, crude protein; EE, ether extract ,NDF, neutral detergent fiber; CF, crude fiber; NFC, non-fibre carbohydrates; CT, condensed tannin; $^{a,\ b,\ c,d}$ *Least square means with the different letters within the column are significantly different (P <0.05); *P<0.05; ***P<0.001; NS, non-significant(P>0.05).*

Appendix Table 2. The Least square means of *in sacco* ruminal dry matter disappearance (%) of the plant species

		Incubation time (h), mean (%)						
Plant species	PP	0	6	12	24	48	72	96
E. capensis		29.43^{a}	32.12^{a}	59.47^{a}	73.11^{a}	82.49^{a}	81.79^{a}	83.38^{a}
F. sycomorus	Leaf	6.32^{d}	15.82^{b}	26.09^{c}	22.53^{b}	61.07^{b}	59.52^{b}	69.89^{c}
M. lanceolata		23.69^{b}	32.60^{a}	35.59^{b}	64.99^{a}	65.72^{b}	81.46^{a}	77.53^{b}
R. glutinosa		19.28^{c}	16.87^{b}	17.99^{c}	23.72^{b}	38.20^{c}	47.07^{c}	47.64^{d}
	SE	0.68	1.88	3.13	3.87	4.71	2.79	1.47
	P	***	***	***	***	***	***	***
E. capensis		39.28^{a}	43.34^{a}	60.01^{a}	62.02^{a}	78.95^{a}	75.94^{a}	84.85^{a}
F. sycomorus	Fruit	20.81^{b}	23.29^{b}	34.20^{b}	43.17^{b}	58.90^{b}	62.34^{b}	69.89^{b}
M. lanceolata		10.32^{d}	15.14^{c}	19.03^{c}	28.64^{c}	40.11^{c}	54.04^{c}	46.08^{c}
R. glutinosa		17.60^{c}	17.91b^{c}	20.30^{c}	22.16^{c}	26.46^{d}	34.16^{d}	21.65^{d}
	SE	0.45	2.12	1.49	3.37	2.44	2.79	1.57
	P	***	***	***	***	***	***	***

PP, plant spcies; $^{a,\ b,\ c,\ d}$ *,Least square means within the same column with different superscripts are significantly different (P<0.05); SE , Standard error of the mean; ***P<0.001.*

Appendix Table 3. *In sacco* dry matter degradability characteristics for the leaves and fruits of the plant species

Plant species	Degradability parameters (leaf)					Degradability parameters (fruit)				
	a	b	PD	ED	c	A	b	PD	ED	C
E. capenesis	-16.2[d]	98.37[a]	82.17[b]	61.83[a]	0.12[a]	35.51[a]	47.11[b]	82.62[a]	63.18[a]	0.04[b]
F. sycomorus	7.37[c]	77.82[b]	85.19[a]	35.78[c]	0.02[c]	15.49[b]	56.15[a]	71.64[b]	43.28[b]	0.03[c]
M. lanceolata	14.55[a]	64.91[c]	79.47[c]	53.76[b]	0.05[b]	5.78[d]	46.59[c]	52.36[c]	29.22[c]	0.03[c]
R.glutinosa	11.23[b]	52.76[d]	63.99[d]	27.86[d]	0.01[d]	13.92[c]	13.69[d]	27.61[d]	22.57[d]	0.05[a]
SE	0.17	0.03	0.12	0.05	0.001	0.007	0.01	0.01	0.01	0.004
P	***	***	***	***	***	***	***	***	***	***

*a, soluble fraction; b, slowly degradable fraction;PD, potential degradability; ED, effective degradability; c, rate of degradation; [a, b, c,d] Least square means within the same column with different superscripts are significantly different (P<0.05); SE, Standard error of the mean; ***P<0.001*

Appendix Table 4. Least square means for *in sacco* ruminal organic matter disappearance (%) of leaf and fruit of tannin rich trees

Plant species	PP	Incubation time (h), mean (%)						
		0	6	12	24	48	72	96
E. capensis		29.43[a]	37.55[a]	61.05[a]	73.28[a]	82.48[a]	81.79[a]	83.38[a]
F. sycomorus	Leaf	6.32[d]	22.63[c]	26.45[c]	23.57[b]	62.64[b]	61.05[b]	69.89[c]
M. lanceolata		23.70[b]	31.21[ab]	36.05[b]	65.91[a]	72.30[ab]	81.69[a]	77.60[b]
R.glutinosa		19.28[c]	17.44[c]	20.63[c]	26.26[b]	42.02[c]	47.27[c]	48.98[d]
	SE	0.68	3.49	3.03	3.54	3.46	2.36	1.43
	P	***	***	***	***	***	***	***
E. capensis		39.28[a]	43.34[a]	60.68[a]	64.81[a]	81.34[a]	80.29[a]	84.99[a]
F.sycomorus	Fruit	20.81[b]	21.27[b]	34.96[b]	45.43[b]	53.40[b]	64.88[b]	69.36[b]
M.lanceolata		10.32[d]	14.85[b]	19.03[c]	29.73[c]	47.86[b]	54.61[c]	45.63[c]
R.glutinosa		17.60[c]	17.91[b]	20.30[c]	24.39[c]	27.73[c]	38.25[d]	31.09[d]
	SE	0.45	2.44	1.60	2.91	2.31	1.73	3.50
	P	***	***	***	***	***	***	***

*PP, plant part; [a, b, c,d] Least square means within the same column with different superscripts are significantly different (P<0.05); ***p<0.001; SE, Standard error of the mean*

Appendix Table 5. *In sacco* organic matter degradability characteristics of leaves and fruits of selected browses species

Plant species	Degradability parameters (*leaf*)					Degradability parameters (*fruit*)				
	a	b	PD	ED	c	a	b	PD	ED	C
E. capenesis	10.69[b]	45.21[d]	55.90[d]	29.61[d]	0.02[c]	14.22[c]	21.38[d]	35.60[d]	24.58[d]	0.03[c]
F. sycomorus	12.63[a]	77.27[b]	89.89[a]	38.11[c]	0.02[c]	15.26[b]	56.40[a]	71.66[b]	42.84[b]	0.03[c]
M. lanceolata	8.11[c]	71.98[c]	80.09[c]	54.55[b]	0.05[b]	2.06[d]	50.28[c]	52.34[c]	30.59[c]	0.04[b]
R. glutinosa	-1.02[d]	83.35[a]	82.33[b]	63.97[a]	0.11[a]	31.84[a]	52.02[b]	83.86[a]	64.65[a]	0.05[a]
SE	0.02	0.009	0.08	0.04	0.002	0.01	0.06	0.05	0.007	0.001
P	***	***	***	***	***		***	***	***	***

a ,soluble fraction; b,slowly degradable fraction;PD, potential degradability; ED, effective degradability; c, rate of degradation; [a, b, c, d]Least square m*eans within the same column with different superscripts are significantly different (P<0.05); ***p<0.001; SE, Standard error of the mean*