# COMPARISON OF POLYETHYLENE GLYCOL AND WOOD ASH EXTRACT ON FEEDING VALUE AND ECONOMIC EFFICIENCY OF SELECTED HIGH-TANNIN FEED SOURCES IN GROWING LAMBS

**MSc THESIS**

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# Comparison of Polyethylene Glycol and Wood Ash Extract on Feeding Value and Economic Efficiency of Selected High-Tannin Feed Sources in Growing Lambs

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# DEDICATION

This piece of work is dedicated to my beloved mother Martha Genjebo and my Uncle Desalegn Genjebo for their dedicated partnership in the success of my life.

# STATEMENT OF THE AUTHOR

I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principle of scholarship in the preparation, data collection, data analysis and compilation of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation.

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# BIOGRAPHICAL SKETCH

The author, Workineh Tadesse, was born from his father Tadesse and from his mother Martha Genjabo on May 18, 1989 near Hossana town, at Doyogene town, (SNNPR), Ethiopia. He attended his Elementary School at Doyogene from 1993 to 2000 and High School education (Grade 9-10) at Hossana Yekatit 25/67 secondary school from 2001 to 2002 and his preparatory school at Wachemo preparatory school between 2003 and 2004 at Hossana town of Hadiya Zone in SNNPR.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| ADF | Acid Detergent Fiber |
| ADFICP | Acid Detergent Fiber Insoluble Crude Protein |
| ANFS | Ant-Nutritive Factors |
| ANOVA | Analysis of Variance |
| AOAC | Association of Official Analytical Chemists |
| BDL | Below Determinant Limit |
| BW | Body Weight |
| CCM | Commercial Concentrate Mixture |
| CSA | Central Statistical Agency |
| CT | Condensed Tannin |
| DMIDM | Dry Matter Intake Dry Matter |
| EARODMI | Ethiopian Agricultural Research Organization Dry Matter Intake |
| EATAEARO | Ethiopian Agriculture Transformation Agency Ethiopian Agricultural Research Organization |
| FAOEATA | Food and Agriculture Organization of The United Nations Ethiopian Agriculture Transformation Agency |
| FAOSTATFAO | Food and Agricultural Organization Statistics Food and Agriculture Organization of The United Nations |
| FAOSTAT | Food and Agricultural Organization Statistics |

**LIST OF ABBREVIATIONS (*Continued*)**

| | |
|---|---|
| EE | Ether Extraction |
| FE | Fecal Energy |
| GE | Gross Energy |
| GLM | General Linear Model |
| HT | Hydrolysable Tannin |
| ILRI | International Livestock Research Institute |
| ILCA | International Livestock C for Africa |
| ME | Metabolisable Energy |
| MPTS | Multipurpose Trees and Shrubs |
| MRR | Marginal Rate of Return |
| N | Total Nitrogen |
| NDF | Neutral Detergent Fiber |
| NDFICP | Neutral Detergent Fiber Insoluble Crude Protein |
| NEL | Net Energy for Lactation |
| NI | Nutrient Intake |
| ΔNI | Change in Net Income |

**LIST OF ABBREVIATIONS (*Continued*)**

| | |
|---|---|
| NRC | National Research Council |
| OGBE | Omo-Gibe Basins of Ethiopia |
| OM | Organic Matter |
| PA | Proanthocyanidins |
| PEG | Polyethylene Glycol |
| RCBD | Randomized Complete Block Design |
| SAS | Statistical Analysis System |
| SSA | Sub Saharan African |
| TBAS | Tannin Binding Agents |
| TDN | Total Digestible Nutrients |
| TR | Total Return |
| TRTS | Tannin Rich Trees and Shrubs |
| TVC | Total Variable Cost |
| VFI | Voluntary Feed Intake |
| WAD | World Agricultural Development |

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## ABSTRACT

*The study was conducted to evaluate the effects of dietary inclusion of $PEG_{6000}$ and wood ash in leaves of the condensed tannin rich trees (Albizia gummifera; Rhus glutinosa, Syzygium .guineense), feeding on nutrient intake; digestibility; weight gain; feed conversion efficiency and economic efficiency. A study was conducted at Jimma University College of Agriculture and Veterinary Medicine of Small Ruminant Research facility The twenty four intact male lambs with initial body weight of 23.42 ±0.080 SE kg and an average of 12 months old .were divided in to three blocks of eight animals per treatment based on their initial body weight in randomized complete block design with 3 treatments, 7 days adaptation;80 days of feeding trial and 7 days of digestive trial for data collection The dietary treatments consisted of T1(,40% hay , 150gm concentrate, + 30% A. gummifera , + 10%, R. glutinosa, + 20% S.guinessa ,) ,T2 (T1+ PEG 6000) and T3 (T1+wood ash). Animals were individually fed at 50 g DM/kg BW and had free access to clean drinking water and mineralized salt licks. Nutrient intake, apparent nutrient digestibility, nutrient conversion ratios; live body weight gains and economic efficiency of lambs were determined. Condensed tannin concentrations in TRTS, hay and CCM (commercial concentrate mix) were 140, bdl and bdl g/kg DM, respectively. The highest improvement in all essential nutrients intake was recorded in T3 than T2. Similarly, apparent nutrients digestibility and body weight change at T2 and T3 was significantly higher (P<0.001) than control (T1) group. The total return (TR) ETB/sheep was (**478**ETB), (**554**ETB), (**570** ETB) for T1, T2 and T3 respectively. From this study, sheep could efficiently use mixes of tannin rich feeds either as maintenance or production ration with the presence of tannin binding agents such as PEG and wood ash.*

*This result did not cover all agro ecological areas; animal species and all tannin rich plats in Ethiopia. As a recommendation similar research works would need to be implemented in Ethiopia by using all other remaining tannin rich trees and plants in different agro ecological zones on different animal species.*

**Key words:** *Albizia gummifera, sheep Digestibility, Economic feasibility Polyethylene Glycol, Tannin, wood ash*

# 1. INTRODUCTION

Ethiopia has the largest livestock herd in Sub-Saharan Africa, with an estimated sheep population of 25 million (EATA, 2013). Sheep are living banks for their owners and serve as source of immediate cash income and insurance against crop failure especially where land productivity is low and unreliable due to erratic rainfall, severe erosion, frost, and water logging problems (Tibbo, 2006). Despite the high population and wide distribution, the productivity of sheep in Ethiopia is very low (Alemu, 2008). For instance average meat production per sheep in Ethiopia is lower than the Sub-Saharan African countries produce (FAO, 2009b). There is a need to improve sheep productivity through feeding, conservation and sustainable utilization to meet the protein demand by the ever increasing human population and to improve the livelihoods of poor livestock keepers and alleviate poverty among the rural poor dwellers.

The low productivity of sheep in Ethiopia is mainly attributed to poor nutrition (Seyoum et al. 2007; Alemu, 2008 and EATA, 2013). Natural pasture, crop residues and other agricultural by-products are categorized as major components of sheep feed in the country (Alemu, 2008; Biruk, 2012; Tolera et al., 2012). In contrast, natural pasture and crop residues are low in metabolisable energy (ME) (avg. < 8 MJ/kg DM), dry matter digestibility (<50%), crude protein (CP) (<8%) and mineral as well as vitamin content (Yisehak et al., 2012, 13), which is very much below the requirement for adequate microbial function in the rumen of sheep and other ruminant livestock.

Foliages of tannin rich trees and shrubs (TRTS) are of importance in animal production by providing significant protein supplements, especially in the dry season. But, these feed resources are generally rich in nutrient anti-nutritional factors- particularly tannins (Yisehak and Geert, 2013). The amount of tannins that they contain varies widely and largely unpredictably, and their effects on animals range from beneficial to toxicity and death (Makkar, 2003). With a better understanding of tannin properties, effects and fate;

and with proper management they could become invaluable sources of protein for strategic supplementation (Getachew et al., 1998: Makkar, 2003).

Afework (2012) suggested dietary inclusion of tannin binding agents (TBAs) as best option for deactivating high tannin diet sources for herbivore livestock. Although TBAs are appropriate for tannin deactivation, they are less likely and frequently available for small holder farmers. Use of locally available, alternative and simple methods based on post-harvest technology and supplementation with tannin-complexing agents such as wood ash can enhance the feeding value of tannin-containing feeds through boosting the roles of rumen microbes in degradation and overcoming the detrimental effects of tannins. Wood ash (Makkar and Singh, 1992a), available easily and at small cost in villages, is a good source of alkali, which can be used traditionally for treatment of high-tannin-containing diets. Because of the presence of calcium carbonate in wood ash, it can act as increasing pH of the digestive organs that in turn reduces stability of tannins.

An *in vivo* comparison of polyethylene glycol (PEG) with wood ash treatment as a cost-effective way to deactivate tannins in TRTS has not been fully reported. The effects of graded levels of dietary tannin sources with wood ash and PEG on feed utilization and growth performance characteristics of sheep breeds such as sheep and others have not been also reported somewhere else. Moreover, there is a limited report on the tannin deactivating ability of wood ash. Therefore, the present study is planned to evaluate the:

- Effects of dietary inclusion of wood ash or PEG on nutrient utilization and growth performance, of sheep fed high tannin feed sources
- Economic feasibility of inclusion of wood ash or PEG

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# 2. LITERATURE REVIEW

## 2.1. Livestock Feed Resources in Ethiopia

Livestock in the Sub-Saharan Africa are dependent primarily on native grasslands and crop residues (Ibrahim, 1999). According to Alemayehu (2004), Ethiopia's Livestock feed resources are mainly natural grazing and browse, crop residues, improved pasture, and agro-industrial byproducts. The feeding systems include communal or private natural grazing and browsing, cut and- carry feeding, hay and crop residues. Among the feed resources, natural pasture and crop residues contribute the largest source of feed to livestock in the study area which is the case in most developing countries (Sere et al 2008). At present, in the country stock are fed almost entirely on natural pasture and crop residues. Grazing is on permanent grazing areas, fallow land and cropland after harvest (Stubble). The availability and quality of forage are not favorable year round. As a result, the gains made in the wet season are totally or partially lost in the dry season (Alemayehu, 2003). Inadequate feed during the dry season is a major reason that causes decline in the productivity of ruminants. In Sub-Saharan Africa, human population is increasing rapidly, forcing farmers to use grazing areas for arable farming. As a result, the smallholder farmers in this part of Africa have integrated their livestock into their cropping systems and used crop residues as a main livestock feed resources (Ibrahim, 1999).The availability of feed resources in the country depends on the intensity of crop production, population pressure, the amount of rainfall, and distribution pattern of rainfall and seasons of the year (Mohammed-Saleem and Abate, 1995). Pasture growth is a reflection of the annual rainfall distribution pattern (Seyoum et al., 2001). Livestock feed resources can be classified as follows;

1) **Natural pasture:** Are annual and perennial species of grasses, forbs and trees still the most important feed source for sheep and goats (Masiiwa, 1998). They comprise the

largest feed resource, for the largest share of the land surface of numerous tropical countries (Alemayehu, 1998a).

. Seasonal fluctuations in the availability and the poor quality of feeds are considered to be the main constraints on sheep production in arid regions (Guada, 1989).

According to NRC (1962), chemical analysis of range forage plants serves as a comparative measure of differences between species and change with season. They are also useful for measuring differences on the effect of the stage of growth and the quality of sites on chemical constituents. Simbaya (1998) reported that the quality of natural pastures is also influenced by the absence of legume species in communal grasslands. This tends to limit the nutritional quality of available fodder. As a result, animals are unable to meet their protein, energy and mineral requirements. Osuji et.al (1993) suggested that poor nutrition is one of the major constraints to livestock productivity in the Sub-Saharan Africa (SSA). This is because, in this part of the continent, animals predominantly depend for their feed on high-fiber feeds (straws, Stover's and native pasture hay) which are deficient in nutrients (nitrogen, Sulphure, minerals, phosphorus etc) and suitable for microbial fermentation. Consequently, the digestibility and intake of digestible nutrients are unavoidably low. However, these deficiencies can partly be mitigated by supplementing roughage diets with feeds containing the deficient nutrients.

2. **Crop residues**: Crop residues are mainly fibrous material that is by-products of crop cultivation. Due to the intensity of an emphasis on crop production in Africa and Asia, great amounts of several by-products are produced annually. While these feed sources, particularly cereal straws, provide the bulk of livestock feed, their nutritive value is often so low that farmers must supplement them with feed grains and other concentrates. (Tesfaye, 2008) reported that crop-residues have been the main source of livestock feeds especially for ruminant animals during the dry season next to natural pasture. They also serve as a source of fuel, construction and sale (Van Raay and de Leeuw, 1970).

Most common crop residues (i.e. straws and stubble) have low crude protein content, in the range 2-5% on a dry matter (DM) basis. This suggests a basic limitation in the value of some of the residues (e.g. wheat and barley straw) around the border line of the 6-7 per cent dietary crude protein level required for promoting voluntary feed intake (VFI). (de Leeuw and Van Rey, 1995). Most of the residues are deficient in fermentable energy, as reflected by the relatively low organic matter digestibility, and also the limited availability of minerals.

According to with the report of Ngongoni *et al.(*2006) for the majority of smallholder farmers, crop residues constitute 50-70% of total DM intake, especially during the dry season. The quantity of DM that can be obtained from crop residue is estimated from grain yield (FAO 1987) based on established conversion factor with a utilization factor of about 90% and 10% is used for other purposes like fuel and wastage .In the medium and low altitude zones, teff straw was the primary source of animal feed.

Cereal straws: Straws correspond to the residue (leaves, awns, stems) remaining after the mature crop (i.e. grains) has been harvested. Straws may have high market values in times of drought and other harsh conditions when roughages are scarce and grains have to be imported. Cereal crop residues are expected to provide energy for ruminants in the form of digestible fibre. It is generally agreed that they should be accompanied by small amounts of suitable nitrogen supplement, such as oilseed cakes. If their nutritive value is low or the desired level of production is well above maintenance, farmers, must in addition, feed an energy supplement such as cereal grain to ensure biological and economical efficiency.

3. **Stubbles*:*** Stubbles refer to those residues left after grain harvesting and straw collection. They include stems, small portion of leaves, grains and weeds. Although stubbles provide important biomass for ruminant animals, their feeding value and strategy for efficient integration into livestock feeding are still poorly investigated (Seyoum *et al.* (2001) .Available studies showed that total biomass measured after straw removal was 4 to 6 t DM/ha, including wheat stubble and weeds (Guessous *et al*., 1989). Some previous studies have dealt with the feeding value of stubbles and their effect on sheep performance. Botanical composition of stubble and chemical composition vary greatly with grazing period. Large amounts of grains are available in the beginning of the grazing period. According to Guessous *et al*. (1989) and Outmani

*et al.* (1991), the nutritive value of diet off taken by stubble grazing ewes, mainly crude protein and energy contents decreased with the number of week of grazing. Crude protein content of stubble was below 5% DM and this crop residue was high in fibre. Such supplement feeds are often more expensive than crop residues. Improving the nutritional value of straws and the efficiency of their use in mixed diets is an attractive option for increasing livestock production.

4. **Agro-industrial by-products**: The increasing human demands for several foods (i.e. olive oil, vegetables, wine, fruit juices, etc.) led to a considerable increase of lands occupied by crops producing these feeds. Consequently, huge amounts of agro-industrial by-products are available in numerous African countries these include oilseed cakes, flour mill by -products and grain screenings, molasses, brewer's grain, coffee pulp and slaughter by-products which are still not fully utilized in livestock feeding (Kindu *et al*., 2008). Most of these AIBPs are low in, and/or not balanced for, main nutrients. Moreover, the difficulty of the use of these feed sources as fresh material for extended periods and the lack of efficient ways for their integration in feeding calendars may account for their under-utilization. Sisay (2006) reported that feeding of agro-industrial by-products are prioritized based on the productive potential of animals.

5. **Trees and Shrubs:** Foliages of multipurpose trees and shrubs are generally richer in protein and minerals (Alonso- Diaz *et al*., 2010) and thus have the potential to be an inexpensive, locally produced protein supplement that plays an important role in the nutrition of grazing animals. Unfortunately, they contain nutrient activating factor such as condensed tannins (CT) that varies widely and unpredictably (Babayemi et al., 2004). Great levels of CTs in edible parts of plants restrict the nutrient utilization and decrease voluntary food intake, nutrient digestibility, and nitrogen (N) retention (Silanikove et al., 1996; Makkar, 2003). The CT concentration in plants is influenced by plant species (Ozturk *et al*., 2006), 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 herbi**v**ores including insects (Makkar and Singh, 1991).

- **Browse species**: One potential way for increasing the quality and availability of livestock feeds is the use of various multipurpose trees and shrubs (MPTS) (Ngodigha and Anyanwu, 2009). Leaves and fruits 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 (Yisehak *et al*., 2009, 2012). Currently small-holder farmers of Sub- Saharan African countries in general (Aremu and Onadeko, 2008) and Ethiopia in particular (Yisehak and Belay, 2011; Yisehak *et al*., 2012) are increasingly relying on various potential MPTS that can provide a green feed throughout the year which may be particularly useful as feed supplements to the typical low-quality diets. A variety of MPTS is growing in Omo- Gibe basins of Ethiopia (OGBE) (Yisehak *et al*., 2010), mainly due to the suitability of the environment and the need to use them as fire wood, local construction material, mulch, and shade for cash crops like coffee and spices. They replenish soil fertility, serve for human and veterinary medicine, and also serve as environmental conservation. Among MPTS growing in the OGBE, Syzygium guineense, Albizia gummifera, and *Rhus glutinosa* are widely abundant and greatly preferred by farmers. They are evergreen throughout the year, yield a good biomass, and can serve a multiple purpose.

- **Syzygium guineense** is one of the plants that belong to the family Myrtaceae that has a synonym Sysygium owariense commonly known as water berry in English (Agwu and Okeke, 1996), “Dokma” in Amharic, “Ocha” in Gamo and “Karava” in Gurage ”Dubancho” in Hadiya “Badesa“ in Afaan Oromo. Syzygium guineense (water berry tree), a dense, leafy forest tree around 30 meters high; bark flaky, grayish-white; leaves broadly lanceolate, opposite, entire to the branch; fruit ellipsoid drupe, purplish in color (Bekele, 1993; Abebe and Debela *et al*. 2003). The plant is found in the altitude range 2,300 - 2,700 m. It has edible fruit, with higher nutritional value (Figure 1 and Figure 3) (Saka and Msonthi, 1994; Tadesse and Hedberg, 1995; Nievergelt *et al*. 1998).

**Figure 1. Pictures of** *Syzygium guineense*

**Figure 2 .*Syzygium guineense* with edible fruit**

❖ **Albizia gummifera:** Belong to the family Fabaceae – Mimosoideae and its common name is (peacock flower) in English. Botanically, Albizia gummifera is a large deciduous tree 4.5-30 m, branches ascending to a flat top. Crown flat; bark smooth and grey.

Flowers white-pink clusters with long hanging stamens; exerted for 15-28 mm. Fruit glossy (reddish or purplish brown) and numerous, 10-21 by 2- 3.4 cm glabrous or nearly so; flat with raised edges. Two varieties are recognized var. gummifera with leaflets conspicuously auriculate on the proximal side of the base and var. ealaensis without auriculate leaflets on the proximal side. The genus was named after Filippo del Albizzi, a Florentine nobleman who in 1749 introduced A. julibrissin into cultivation. The specific epithet 'gummifera' means the gum bearer (Orwa et al.2009).

The seeding time is spread but January and February seems to be the peak period. A.gummifera is hermaphroditic and reportedly hybridizes with A. grandibracteata, the hybrid being intermediate in attributes.

A.gummifera is common in lowland and upland rain-forest, riverine forest, and in open habitats near forests. It occasionally appears as a pioneer species in forests and in thickets. (Orwa et al.2009).

**Figure 3. Pictures of Albizia gummifera**

❖ **Rhus glutinosa (Rhus abyssinica)**: is a fast-growing, evergreen shrub or small tree growing up to 7-12 meters tall. Its common name Rhus glutinosa obtusifoli*a* in English. The plant is gathered from the wild as a source of timber and tannins for local use and as a food and medicine**.** The wood is used for chew sticks, which are sold in local markets. Its location ranges Tropical Africa - Ethiopia, eastern DR Congo, Uganda, Kenya, Rwanda, Burundi, Tanzania, Angola, Zambia, Malawi, Zimbabwe and Mozambique. Its habitat is also Savannah, thickets, woodlands of various types, forests, etc.

Its edible uses are, Fruit – raw. The reddish, globose drupe is 3 - 7mm in diameter. It is small though, carried in clusters on the plant so can be harvested fairly easily .And the medicinal use is, decoction of the root is drunk as a treatment for malaria .A decoction of the root, combined with the leaf sap is used as a laxative and abortifacient.

tropical.theferns.info/viewtropical.php?id=Rhus+abyssinica

**Figure 4. Rhus glutinosa**

## 2.2. Anti-Nutritional Factors in Feed Resources

Anti-nutritive factors **(**ANFs**):** are those substances generated in normal metabolism of natural feedstuffs by animal species which affect feed breakdown and utilization (Aganga and Tshwenyane, 2003).

Globally, there are problems related to ruminant animal feeding in terms of matching the available feed resources with their nutrient requirements and this has been a major concern of researchers, part of their effort to finding solution to this problem is the use of tropical browse and shrub legumes plant.

Tropical trees and shrubs have been found to contain anti-nutritional factors which tends to affect both their intake and digestibility (Babayemi *et al*., 2006). Most of the leguminous browse and shrubs produces seed and fruit which have been found containing higher crude protein and other nutrients. Studies have shown that the seeds produce higher volatile fatty acid**s** on degradation by rumen microbial organisms which tend to be beneficial to ruminant animals (Babayemi *et al*., 2004) showing the potential of browse tree seeds in livestock production. *E. cyclocarpum* (Ear pod tree) is a medium sized to a large tree growing to 25-30 m tall and with a trunk diameter up to 3.5 m. It is high in crude protein and other nutrients (Babayemi *et al*., 2004) and the seeds contain an anti-nutritional factor.

There are many factors (Plant and animal) that affect feed intake of small ruminants, of which smell is often the most important, According to recent concepts, voluntary food intake of ruminants is best understood as an outcome of the interaction between taste and postingestive feedback (Isaac M.*et al*., 2008).

### 2.2.1. Tannins

Tannins are oligomeric compounds with multiple structure units that have free phenolic groups. They range anywhere from 500 to sometimes greater than 20,000 in molecular weight. Tannins are usually soluble in water (Haslam, 1989) except for some with high molecular weight structures. They are also capable of binding proteins and forming soluble and insoluble tannin-protein complexes. Based on their chemical structure and properties there are two chemically distinct types of tannins, soluble tannins (hydrolysable tannins (HT) and condensed (CT) (proanthocyanidins), (Bederski,1991, Athanasiadou et al., 2001).

**Hydrolyzable Tannins**: Are molecules with a carbohydrate, generally D-glucose as a central core. The hydroxyl groups of these carbohydrates are partially or totally esterified with phenolic groups like gallic acid (gallotannins) or ellagic acid (ellagitannins) (Waghorn and McNabb, 2003). Hydrolyzable tannins are usually present in low amounts in plants (Mueller-Harvey, 2001). These tannins are found in oak (*Quercus* spp.), Acacia, Eucalypts and a variety of browse and tree leaves (Waghorn and McNabb, 2003). The browse that contain these leaves and apices can contain anywhere from 200g per kg of dry matter (DM) and in some species they can contain phenolic compounds that can exceed 500g per kg of dry matter (Reed, 1995; Lowry et al., 1996). Hydrolyzable tannins are potentially toxic to animals, but most ruminants can adjust to a diet of these tannins (Waghorn and McNabb, 2003). Ruminants are able to adjust to these toxic tannins by reducing their urinary excretion of degradation products, thus allowing them to consume these diets (Lowry et al., 1996). Although ruminants have this ability, an excessive amount of this tannin diet can lead to liver and kidney lesions, as well as death (Waghorn and McNabb, 2003). Death usually occurs five to ten days after the first excessive consumption; the toxic compound responsible is not known. Information concerning the digestion, absorption, and impact on metabolism and productivity of Hydrolyzable tannins is rare.

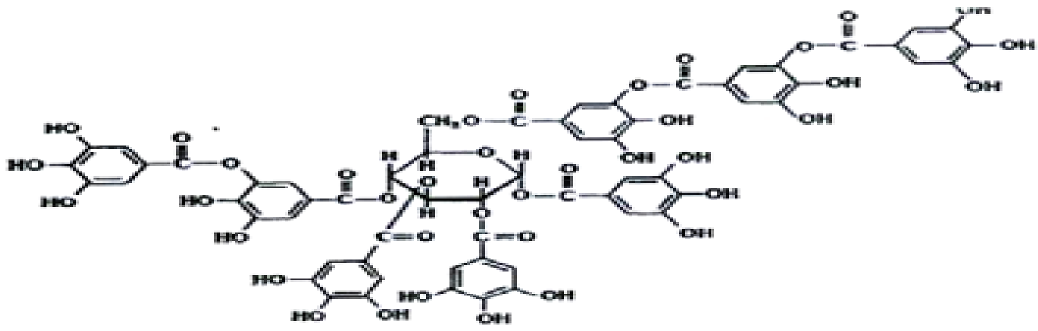

Figure 5. Chemical structures of hydrolysable tannins

**Source: Haslam, 1989)**

**Condensed Tannins**: Of the tannins, condensed tannins are the most widely distributed. Condensed tannins are oligomers or polymers of flavanoid units linked by carbon-carbon bonds (Waghorn and McNabb, 2003) not susceptible to cleavage by hydrolysis (Reed, 1995). They are called condensed tannins because of their condensed chemical structure. CT, are also termed proanthocyanidins (PA), which is derived from the acid catalyzed oxidation reaction that produces red anthocyanidins through heating of PA in acidic alcohol solutions (Haslam, 1982). Cyanidin (procyanidin) and delphinidin (prodelphinidin) are the most common anthocyanidins produced (Reed, 1995). Condensed tannins can contain as little as two or greater than fifty flavanoid units. Due to the variability of flavanoid units to some substituents and because of the variable sites for interflaven bonds, condensed tannin polymers have complex structures. Condensed tannins may or may not be soluble in aqueous organic solvents, depending on their chemical structure and degree of polymerization.

Condensed tannins have a complex chemistry. The heterocyclic C-rings can be formed via 2, 3-cis or 2,3-trans, which determine “how monomeric units are attached relative to one another” (Barry et al., 1999). The number of monomeric units are variable (Foo *et al.*, 1996, 1997) making an “infinite variety of chemical structures, which in turn affect the biological properties of the condensed tannins” (Barry et al., 1999). For example, *Lotus* *corniculatus* and *Lotus pedunculatus* are considerably different concerning their chemical structure (Foo *et al*., 1996, 1997).

It is speculated that plants containing condensed tannins evolved over time to implore them as a defense mechanism, which protected them against pathogenic microorganisms and against being consumed by insects or grazing animals (Swain, 1979). Now they are being extracted from various plants to be used in improving animal health. Extraction of these condensed tannins was once performed using acetone-water, but full extraction of the CT was not obtained with this method (Barry et al., 1999). Now condensed tannins are being detected even at trace levels using NMR spectrometry and anthocyanidins formation (Jackson et al., 1996).

Condensed tannins found in tropical forages are thought to promote plant growth by reducing the release of leaf litter into the soil (Palm *et al*., 1991) and reducing the release of animal feces (Waghorn and McNabb, 2003). Because of the substantial benefits of condensed tannins for ruminant health and productivity, much of research has been focused on these tannins (Waghorn and McNabb, 2003).

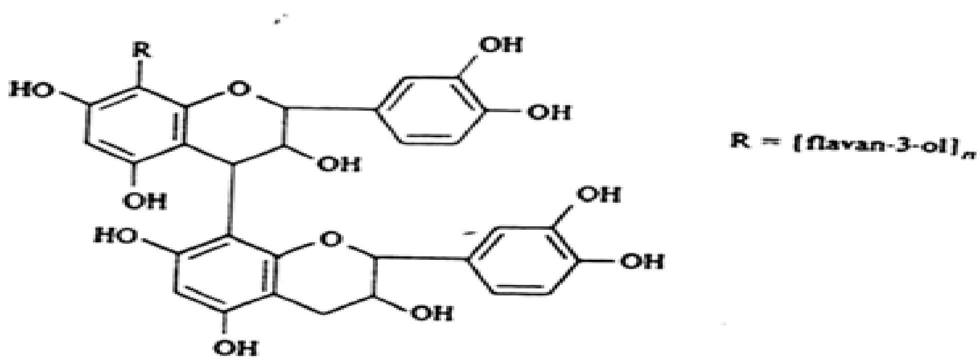


**Figure 6. Chemical structures of condensed tannins**

**(Source: Butter, 1992)**

Synthesis**:** In tropical forages, condensed tannins are often one of several polyphenolic compounds, which may include hydrolysable tannins, other secondary metabolites and can exceed 300 g/kg of the dry matter (DM) (Lowry et al., 1996; Rittner and Reed, 1992; Mueller- Harvey, 1999; Reed *et al*., 2000). Very high CT concentrations limit the amount of DM available for digestion, but hydrolysable tannins may provide nutrients for absorption, especially following a period of adaptation (Lowry *et al*., 1996). Measurement of total phenolics as well as CT concentrations in browse provides a more informative overview of forage quality, than CT alone.

Condensed tannin synthesis originates in the cell cytoplasm from phenylalanine and acetate precursors (Mueller-Harvey and McAllan, 1992) to form catechin units in the cell vacuole. Lees *et al*. (1995) showed that CT formed in very young sainfoin leaves and concentrations increased as leaves matured. There was a progressive depletion with senescence until very little CT remained in yellow leaflets. Condensed and hydrolysable tannins were also mobilised from oak (*Quercus*) leaves prior to senescence (Grundhofer *et al*., 2001). The reduction in CT content of senescent leaves would facilitate degradation and nutrient recycling in soils.

The reason for CT synthesis and mobilization are speculative. Suggestions include protection against herbivory, plant defense against pathogens, energy conservation (for mobilization in times of need) and nitrogen conservation. If CT are intended to protect against herbivory they are remarkably ineffective, with sheep and goats inevitably selecting leaf in preference to stem, despite much higher concentrations of CT in leaf. The possibility that CT conserve nitrogen (N) in an ecosystem has credibility in low fertility environments because CT always increase the N content of faeces and decrease urinary N output (Waghorn and McNabb, 2003). Faecal N is more likely to be retained in the soil than urinary N, which is subject to volatilization in warm climates and leaching in wet conditions. These attributes will benefit forage trees in arid conditions.

Structure: The CT are termed "proanthocyanidins" because HCl /butanol treatment releases bright red anthocyanidins chloride. Condensed tannins are polymers of flavanol (flavan-3-ol) units, linked by carbon–carbon bonds that are not susceptible to anaerobic enzyme degradation (Lowry *et al*., 1996; McSweeney *et al*., 2001).

Condensed tannin polymers in temperate forages may range in chain length from dimmers to over 20 flavanol units, and there are usually several flavan-3-ol structures within each polymer. Mueller-Harvey (1999) presents diagrams of both CT and hydrolysable tannin structures. Principle structural variations within CT include: the number of hydroxyl groups on the “A” and “B” rings of the flavanol units; positions of the hydroxyl groups, stereochemistry at carbons 2, 3 and 4 of the “C” ring; position and type of linkages between flavanol units and number of flavanol units.

Animal researchers evaluating forages containing CT will need to be familiar with terms describing structure and stereochemistry. Procyanidin is a generic term referring to polymers of catechin and epicatechin stereoisomers, both of which have two hydroxyl groups attached to the “B” ring of the flavanol (monomer). Prodelphinidin is the generic term for polymers of gallocatechin and epigallocatechin stereoisomers, each with three hydroxyl groups on the B ring. The need for detailed information about the structure of CT is driven in part by a need to understand biosynthetic pathways to express CT in foliage of high quality temperate forages, such as Lucerne or white clover, but structure will also affect differences in reactivity.

Astringency***:*** Astringency is a measure of protein binding (and precipitating) capacity, or capacity to affect changes to enzymatic activity. Comparisons between lotus species in their CT chemistry and impact on microbial or ruminal activity have shown the CT in birds foot trefoil to be less astringent than that from lotus major. The CT in birds foot trefoil comprises mainly catechin and epicatechin monomers (Procyanidin) whereas lotus major has a predominance of epigallocatechin extender units (Prodelphinidin) and mixed terminal units. The dominance of Procyanidin in birds foot trefoil may be associated with beneficial effects on animal performance and amino acid absorption when fed as a sole diet, compared to the mild anti-nutritional effects of CT from lotus major (Waghorn and Shelton, 1997). However, comparison between accessions of Calliandra calothyrsus showed dominance of Prodelphinidin in the extractable tannin fraction was associated with higher intakes and digestibility than that when Procyanidin were dominant (Lascano *et al*., 2003). Attempts to relate CT chemistry to physiological effects and animal production are made difficult by contrasting extraction and assay protocols for the CT. Although some generalizations can be made about the proportions of flavanol monomers between species, there can be a significant variation within a species, e.g. L. cornicu*latus* (Hedqvist *et al*., 2000), sainfoin (Marais *et al*., 2000) and most probably other species as well.

Other examples of differences in astringency include the CT in dock (Rumex obtusifolius), where only 3 g/kg CT in the dietary DM prevented bloat in dairy cows (Waghorn and Jones, 1989). Diets containing only 26 g/kg of carob (Ceratonia siliqua) CT in the DM reduced lamb growth from 140 to less than 50 g/day (Priolo et al., 2000) whereas the CT in Sulla (72 g/kg DM) did not reduce daily gain of lambs (279 g/day) over a 17 weeks grazing trial (Douglas *et al*., 1999).

Comparisons between sources of CT must be made using similar concentrations and this usually requires purified material. Molan et al. (2002) illustrated differences between sources of CT by incubating Trichostrongylus colubriformis gastro-intestinal parasite larvae in media with a range of CT concentrations to determine theLD50.Values were 92g CT/ml with birds foot trefoil but only 59g/ml for lotus major. Only CT from dock (R. obtusifolius) was more potent in that study. Other comparisons have yielded less repeatable results and McAllister et al. (2005) recommend biological assays using rumen bacteria be used in conjunction with chemical assays. They measured binding capacity of CT extracted from nine forage species and showed CT were more effective precipitating bovine serum albumin than fraction 1 plant protein (Rubisco). There was a two-fold range in astringency, but rankings differed for inhibition of cellulose digestion, demonstrating the importance of biological assays to identify the most appropriate CT for affecting specific nutritional outcomes.

### 2.2.3. Effect of Tannins in Ruminant Nutrition

Silanikove *et al.* (1999) and Yisehak et al. (2012) reported the following biological effects of tannins in studies where its anti-nutritional effects were partially or completely neutralized by variable levels of PEG (polyethylene glycol) or wood ash extract supplementation.

**Effects on feed intake** : The effects of tannins on feed intake depends on the kind and concentration amount of tannins .According to Mueller-Harvey (2005) conclusion even less amount of hydrolysable tannins are harmful to animals than condensed tannins and they account less than 5% of the DM in feed. There is inverse relationship between high CT level in forages (more than 50 g CT/kg DM) and their voluntary feed intake. (Silanikove et al., 1996). Therefore, according to these researcher's result high concentrations of condensed tannins have been reported to depress voluntary feed intake.

a) Effects on digestion: Levels of CTs above approx. 5-6% reduced digestibility of fibre in the rumen (Reed *et al.*, 1985; Shelton, 2004). High concentrations of condensed tannins have been reported to depress voluntary feed intake and rumen carbohydrate digestion and depressed rates of body and wool growth in grazing sheep (Barry and McNabb, 1999). Diaz *et al.* (1993) demonstrated that high levels of saponins and/or tannins in diets resulted in decreased apparent digestibility, especially in nitrogen. Therefore, organic matter, protein and cell wall digestibility are inversely related to tannin concentrations.
b) Inducing digestive responses: If a significant amount of tannins reach the duodenum, they may induce a marked depressive effect on the intestinal activity of pancreatic enzymes and hamper amino acid absorption from the intestine. Condensed tannins depresses the rumen fluid and particulate content of the rumen, accelerate the passage of liquid from the abomasum and delay the passage of digesta in the intestine. Silanikove *et al*. (1999) concluded that the overall effect is a delay in the passage of fluid and particulate matter throughout the entire gastrointestinal tract. They hypothesized that these responses are largely the consequence of the interaction of tannins with digestive enzymes and the epithelium lining the digestive tract.

Tannins can be beneficial or detrimental to ruminants, depending on which (and how much) is consumed, the compound's structure and molecular weight, and on the physiology of the consuming species (Hagerman and Butler, 1991). It is important to remember that all the quantities mentioned in this revision should be taken with great caution since different analytical methods, and especially different standards (e.g., quebracho, tannic acid, catequin, cyanidin, delphinidin, or internal standards from the plant itself etc.) can provide very different —and therefore ambiguous— results (Giner-Chavez, 1996; Schofield *et al*., 2001).

c) On growth performance**:** Condensed tannin containing forages have different benefits for ruminants, depending on the species of plant. Condensed tannins have been efficient in improving live weight gain (Wagham, *et al*., 1999). In sheep, they have been shown to improve lambing percentages (Min *et al*., 1999). Barry (1989) suggested that condensed tannin level at 2-4% of DM in the diet will increase protein flow into duodenum which ultimately will improve the protein fraction absorbed; hence animal's growth is improved.

d) Feed conversion efficiency**:** According to Waghorn *et al.* (1999) the presence of CT at dietary concentrations below approximately 100 g/kg DM in the diet may increase the feed conversion efficiency of the ruminant. Several tannin-rich legumes (Makkar, 2003) and Acacia (Ben Salem et al., 2005) were suggested to be used advantageously to increase bypass protein to improve ruminant feed conversion efficiency .Several fodder shrubs and tree leaves rich in tannins have been shown to be able to partially or totally replace concentrate feeds without decreasing digestion or growth of sheep and goats (Mui *et al.*, 2002; Dung *et al.*,2005).

e) Nitrogen retention**:** a low level of tannin will improve nitrogen utilization by ruminants since many types of tannin can alter the site of protein digestion and thereby improve amino acid absorption (Jones & Mangan, 1977; Perez-Maldonado & Norton, 1996). This has been referred to as rumen escape protein and leads to higher growth rates, milk yield and fertility (Mueller- Harvey, 2005) since tannins form stable and insoluble complexes with proteins at $_{p}$H 3.5-7.0, but these complexes dissociate at pH<3.5 (Jones & Mangan, 1977). Therefore, dietary proteins fixed to tannins escape rumen degradation and are released in the abomasum. Absorption of amino acids from the small intestine would then be possible.

f) Micro-organisms: There is abundant evidence that tannins exert inhibitory effects on micro-organisms from many different ecosystems, including the rumen. For example, Jones *et al*. (1994) reported that condensed tannins of the legume sainfoin (Onobrychis vicifolia) inhibited proteolytic activity and growth of several species of rumen bacteria. The inhibition of attachment of Fibrobacter to cellulose was reported by Bae *et al*. (1993).

## 2.3. Attempts to Deactivate Tannins in Fodder Shrubs with Physical and Chemical Treatments

There are many methods used to deactivate tannins and other secondary compounds in temperate and tropical forages in order to improve the nutritive value of these feeds. The methods are based on the theory that tannins are hydro soluble polymers, which form complexes, essentially with proteins. These complexes are broken under conditions of high acidity (pH<3.5) or high alkalinity (pH>7.5). Russel & Lolley (1989) and Makkar & Singh (1993) found that treatment of tanniniferous feed sources with alkalis (urea, sodium hydroxide, potassium hydroxide, etc.) and oxidizing agents (potassium dichromate, potassium permanganate, etc) decreased their total extractable phenols and tannins and/or condensed tannins contents. However, the main disadvantage of these chemical treatments is the loss of soluble nutrients. Ben Salem *et al*. (2005) found that soaking Acacia in Acacia wood ash solution (120 g of wood ash DM/L of water, pH=12.4) decreased total extractable phenols, total extractable tannins and extractable condensed tannins, but also reduced OM and CP content. Feeding Acacia treated with wood ash solution did not affect intake and OM digestibility of the diet, but increased CP and NDF digestibility of Barbarine rams.

### 2.3.1. Management of dietary condensed tannins

There are several methods for reducing the impact of dietary condensed tannins, but not all will benefit production. Drying or wilting browse is an inexpensive option, and can irreversibly bind the CT to protein in the forage. Drying may prevent CT from damaging the gastro-intestinal tract, but overall benefits of the protein to performance will usually be minor (Degen et al., 2000). Condensed tannins can be diluted with other forages but nutritional benefits will only occur if dietary CP concentration is increased, which is unlikely in hot environments and impractical for farmers with small flocks of sheep or goats.

A more promising mitigation for CT is through provision of a tannin-binding compound in the diet, such as PEG and Wood ash extract. This approach will improve animal performance, but the value of gains in productivity must exceed the cost of the PEG and wood ash. The cost of PEG is likely to limit its use by farmers and Ben Salem et al. (2005a) have shown that chopping and soaking leaves of Acacia (*A. cyanophylla* Lindl.) in solutions of wood ash can de-activate the CT and increase organic matter digestibility and nitrogen retention by sheep. Ongoing investigations (Ben Salem et al., 2005b) include soaking in water and water with urea to lessen the impact of tannins in tanniniferous plant leaves. These options are less costly for farmers in many regions but will require harvest and processing of foliage.

Genetic merit of the animals may also affect their response to PEG and wood ash extract, and responses by native or unselected animals to PEG or wood ash extract supplements may be less than anticipated (Gilboa *et al*., 2000). Conversely, high producing animals must be well fed in order that they may express their genetic potential.

### 2.3.2. Wood ash

**Wood ash**: is the residue powder left after the combustion of wood, such as burning wood in a home fireplace or an industrial power plant. It is used traditionally by gardeners as a good source of potash for domestic gardens or any garden.

Effect of wood ash on tannins

The primary anti-nutritional agents in browses are condensed tannins, which reduce the digestibility of dry matter, organic matter and crude protein (Reed 1995, Ben Salem et al 1998). The options used to inactivate the deleterious effects of tannin include air drying, wood ash solution, the use of chemicals such as Calcium hydroxide and polyethylene glycol (Getachew 200, Makkar 2003). The effect of drying largely depends on the initial moisture continent of the plant, the deactivation effect being high when the moisture content is high (Makkar 2003). The effect of wood ash solution is attributed to oxidation of phenolics at high pH value (Makkar 2003). Treating tannin rich feeds with calcium hydroxide alone did not decrease the level of tannin in Albizia procera (Alam *et al* 2005). Although the use of calcium hydroxide under smallholder framers situation casts doubt owing to its exorbitant costs, the use of wood ash can be promising as the traditional cooking method produces large quantities of wood ash, which is locally available, cheap and safe to utilize in treating tannin-containing feeds.

### 2.3.3. Means of administering and effect of PEG on sheep

In some early trials there was significant effect of PEG on sheep total intake was reported and other authors found an increase of DM intake in sheep supplement-ted with PEG. This effect was higher in sheep than goats, probably because sheep are less adapted to digest tannin-rich plants (Kumar and Vaithiyanathan, 1990). Silanikove *et al*. (1996) found an increase in the intake of goats dosed with PEG and fed with tannin-containing leaves. However, their goats were fed only foliage from tanniferous species, without supplementation of concentrate, (M. Decandia et al., 2000). As a finding of M. Decandia *et al*. (2000) PEG supplement have an effect of a higher N loss in the urine, this is due to their higher requirements for metabolisable protein. In this study PEG increased the proportion of tannin-rich species in the diet and crude protein digestibility, allowing a better utilization of woody species and in the mean time enhancing the efficacy of concentrates supplementation. PEG can improve the nutritive value of this feed source and hence optimizing sheep's performance (M.Decandia *et al*., 2000).

Study held by N. Moujaheda *et al*., 2005 on Noire de Thibar breed sheep fed with air-dried Acacia cyanophylla foliage (acacia), Irrespective of the frequency of administration-Acacia had a relatively high content of condensed tannins (41 g kg-1 of DM) and acid detergent lignin (176 g kg-1of DM); PEG had no effect on acacia and water intakes for both sheep and goat species. While OM and CF digestibility of diets was not affected by PEG supply, but there was a significant increase of CP digestibility of acacia-based diets in animals receiving PEG daily or every 2 days. Polyethylene glycol (PEG) absorbs condensed tannins and PEG has been used to neutralize the negative effects of tannins on feed intake and digestibility in sheep, goats, and cattle (Landau et al., 2000a). Sheep increase intake of PEG as tannin concentrations in their diet increase (Provenza *et al*., 2000), perhaps because they recognize the positive “medicinal” effects of PEG and associate PEG with recovery from the aversive effects of tannins.

Invitro Study held by Getachew et al. (2001) shows the improvement of the nutritive value of diets resulted in increased growth rates in sheep and got responses obtained with 18 and 24 percent PEG in feed blocks were similar, so the authors recommended limiting the level of PEG to 18 percent to obtain an optimal positive effect from feed block use. Sheep given feed blocks containing 18 percent PEG consumed approximately 23 g PEG/day. The slow release of PEG, and therefore the synchronized consumption of tannins and PEG, is probably the main explanation of the beneficial effect of PEG-containing feed blocks.
Ben Salem *et al*., (2002),on lambs confirmed the contention of one of the authors (H.P.S. Makkar) that inclusion of high levels of urea in PEG-containing blocks may not be necessary since PEG is expected to dissociate tannin-protein complexes, and thus increase the level of available nitrogen. similar to findings from *in vitro* investigations (Getachew, Makkar and Becker, 2001), findings on acacia foliage shows the levels of NH3-N and the concentration of volatile fatty acids were significantly increased with PEG supply. The extent of this increase was highest with PEG-containing concentrate, while PEG in drinking water or in feed blocks resulted in similar increases in NH3-N in the rumen fluid of sheep on (+34 and +31 percent, respectively)FAO(2007).

Indeed, PEG-containing concentrate is consumed rapidly by sheep in a few minutes, in contrast the presence of salt restricts free intake of the block and obliges the animal to consume small amounts continually over the day. This results in slow release of nutrients and of PEG but it is evident that increased water consumptions. However, the increased water consumption by sheep receiving PEG-containing blocks is surprising in the absence of any variation in block and total diet intakes between groups with PEG-containing or PEG-free blocks ( Moujahed *et al*.,2000) .

Irrespective of administration mode, PEG supply increase urinary excretion of allantoin and consequently microbial nitrogen supply. The response was more pronounced when PEG was included in concentrate or feed blocks than when in drinking water or sprayed as solution on browse foliageFAO (2007).

Priolo et al. (2002) was evident from his work that sheep meat from browse plant with CT = 60.0 g, Using PEG as the tannin-neutralizing agent, affected lean color and lightness. The lightness was higher in those lambs that did not receive PEG, indicating that CT can make meat lighter in colour. Meat from sheep that received supplementation of concentrate had lower values for Warner-Bratzler shear device resistance compared with those that received blocks. Generally meat from concentrate-receiving lambs was more tender than that obtained from block-receiving lambs. PEG introduced in either concentrate or blocks increased intensity of flavour, but had no effect on overall acceptability (FAO, 2007).

CT lower blood hemoglobin level and it is correlated with muscle lightness according to priolo et al (2002) and Priolo and Ben Salem (2003). Increased meat lightness is probably a consequence of reduced muscle iron content in animals fed CT-rich diets (FAO, 2007;Ben Salem *et al*.,2002 and Priolo *et al*.,2002) concluded that increasing the energy level of feed blocks by including energy rich ingredient such as molasses might result in a significant positive improvement in the nutritive value, growth and meat quality of lambs feed tannin rich diets.

### 2.4. Economic Benefits of Browse Supplementation

In an *ex ante* analysis of the economics of alley farming with small ruminants, Sumberg et al., (1987) will be used with the following assumptions: (a) marginal productivity of mulch N (kg maize/kg mulch-N) is 5 for surface mulching and 10 for mulch incorporated under the soil, (b) daily feed intake of goats and sheep is equal to 5% of the animal's live-weight of which 25 or 50% is tree foliage, (c) animal productivity increases by 10 to 40% due to browse supplementation.

The outcome of this model indicated that using tree foliage as feed was uneconomic in relation to mulching for maize unless animal productivity increased 20 to 10  30% with 25% supplementary feeding. These were high targets for WAD goats and sheep. Agronomy trials on-station and on-farm have shown that the assumed crop response to mulching was significantly on the high side which required animal response to supplementation to be very high to be competitive with maize (ILCA, 1992).

# **3.** MATERIAL AND METHODS

## 3.1 .Experimental Animals and Study area

Twenty-four intact male lambs with initial average body weight of 23.42 ± 0.080 (mean ± SEM) kg of 12.0 months old were purchased from Seka local livestock market of Jimma zone, southwest Ethiopia. Care was taken to minimize variation in age determined by dentition and birth history. The animals were quarantined for 14 days in order to adapt to the experimental conditions and feeding trail for 80 days. During this period, they were de-wormed (drenched) with a broad-spectrum anti-helmentic (Albendazole) against internal parasite and sprayed with acaricides (vetacidin 20% EC) against external parasites.

The experiment was conducted at small ruminant Research facility site of Jimma University College of Agriculture and Veterinary medicine (JUCAVM) south western Ethiopia located at 7°40′0″N and 36°5′0″E / 7.667, 36.833_and at an altitude of 1780 m above sea level. Pens were in a well-ventilated shed with one side open to natural light and roofing to protect animals against sun and rain. Animals were randomly housed in individual holding pens (1.5 × 2.5 m2) with concrete floors on an open-air platform.

## 3.2. Preparation of experimental diets and Feeding

The high tannin containing plants Rhus. glutinosa Albizia. gummifera and Syzygium. guineense leaves were collected from the Kitimbile village of Kersa district (7°45′0″N, 37°5′0″E, altitude 1782 m.a.s.l.), Jimma zone, southwestern Ethiopia. Kitimbile is characterized as semi-humid tropical with bimodal rainfall, ranging from 1200 to 2800 mm per year. In the last twenty years, mean annual minimum and maximum temperature of the area were 11°C and 30°68 C, respectively (GOR 2006).

*Rhus . glutinosa, Albizia . gummifera* and Syzygium. guineense trees were selected because of their high crude protein (CP) content, superior fodder biomass, wide distribution in the study region and are commonly consumed by browsers (Yisehak *et al.* 2010). Fresh leaves of *R. glutinosa*, *A. gummifera* and *S. guineense* were hand collected from 30 randomly selected farm grown trees with 3.5±0.12 years on average age. Leaves from these three tannin rich trees were taken to the Small Ruminant Research facility of Jimma University College of Agriculture and Veterinary Medicine, within 40 minutes. After arrival, the fresh leaves were spread on a separate plastic sheet and left to dry for about 7 days under shade (25°C). After air-drying (> 90% DM) the leaves were packed in fiber bags/sacs (15 kg DM per bag) and stored under shade until used as the test diet. This drying approach was chosen because oven drying of CT- rich feeds, even at temperatures below 60ºC, is known to polymerize tannins, and increase neutral detergent fiber (NDF), fiber bound nitrogen and lignin contents (Makkar, 2003).

The basal diet (hay) was harvested from a natural pasture at Kito Furdisa campus of Jimma University (37°039’57”N, 37°48’59” E, and 1705 m.a.s.l.). The nutrient composition of the natural pasture prepared into hay was assessed directly before harvest and the biomass proportion was expressed on dry matter basis following Baars et al. (1997). The hay was composed of about 52.0% Poaceae, 30.0% Asteraceae, 17.5% Fabaceae, 0.50% Cyperaceae and Juncaceae. The pasture was left to dry for 7 days to average of 90% DM); and stored in bales under shade to maintain quality and used as basal diet throughout the experimental period.

Tannin free basal diets were offered at 08:00 hours whereas tannin rich diets at 16:00 hours Clean drinking water was offered at free choice. Experimental animals were fed individually by weighing their daily allowance feed after removing the previous day’s refusal. The three treatment diets were randomly assigned to each animal in a block, making eight animals per treatment.

The supplemental diets were weighed separately and thoroughly mixed before offered to animals. All animals had free access to mineralized salt lick and clean water. The ash used in this particular study was from a mixed wood sources (crude ash ≥99 g/kg DM) namely *Cordia Africana, Ficus vasta and Erythrina abyssyinica*. The woods were collected from Jimma University College of Agriculture & Veterinary Medicine (JUCAVM) student cafeteria. The woods were burned to obtain wood ash. Ash was sieved with 1 mm mesh to separate it from incompletely burned material and other impurities. This wood ash was soaked based on the ratio of 1kg: 20L wood ash and water respectively. After over night of wood ash solution, its $_{P}$H reading was measured to found alkaline (=9.7 $_{P}$H). According to the suggestion of Makkar (2003), 200ml wood ash solution for 1kg of tannin sources had offered to each lamb where as Polyethylene glycol powder was mixed in water at a rate of 0.5 g PEG/ml (Getachew et al 2001). The PEG solutions were offered to every sheep at rate of 40mg PEG for 1 kg of tannin rich mix sources per day.

## 3.3 Chemical analysis

Diet and fecal samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract, and total ash according to the were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Van Soest *et al.* (1991) and contents).Apparent digestibility and digestible coefficients of nutrients were calculated according *to* McDonald et al. (2010). Metabolisable energy intake (MEI) (kJ/kg BW0.75) was estimated according to McDonald et al. (2010).

## 3.4. Measurements of animal performance

### 3.4.1. Dry matter intake

.Dry matter (DM) intake and body weights were recorded during a 80-day feeding trial. Daily feed offered and the corresponding refusal of every animal was measured throughout the experimental period. Both basal and supplement diets were offered separately and intake were determined by the difference between the amount of feed given and refused every day (24 hours) on DM basis. Samples were taken from batches of feed offered and orts, thoroughly mixed and sub-sampled (10%) for chemical analysis. The sub-samples were kept frozen (-20 $^{\circ}$C) until analyses.

### 3.4.2. Body Weight Change and Feed Conversion Efficiency

Initial body weights of each animal were measured by taking mean of two consecutive day's weight after overnight fasting. Body weights of animal were measured during the feeding period of 80 days, after overnight fasting. Weekly live body weights were taken in the morning before feeding and watering by using spring balance. The weight was recorded for each sheep against its identification number on a weight register book. A body weight change was determined as a difference between the final and initial body weight. Average daily body gain was calculated as the difference between the final and initial body weight of the sheep divided by the number of feeding days.

Weight gain = final body weights - initial body weights

$$\text{Average daily body weight gain} = \frac{\textit{Final body weights} - \textit{Initial body weights}}{\textit{Number of feeding days}}$$

Feed conversion efficiency was calculated as the proportion of daily live weight gain to daily DM intake.

$$\text{Feed conversion efficiency} = \frac{\textit{Average daily body weight gain in gram}}{\textit{Daily dry matter intake in gram}}$$

The metabolisable energy intake (MEI) (kJ/kg $BW^{0.75}$) was estimated according to (McDonald et al., 2002).

$$ME=5.34-0.1365CF+0.6926NFE-0.0152NFE^2+0.0001NFE^3$$

### 3.4.3. Digestibility Trial

After an adaptation period of 30 days, animals were harnessed with fecal bag to collect feces. After adjustment period of three days to fecal collection bags, feces were collected for seven consecutive days. Each day total fecal output of the animal was collected and weighed, 10% of the fecal output was sub-sampled and stored frozen at -20$^0$C, and pooled over the collection period. Samples of the ort for individual animals during digestibility and feeding trial was separately collected, bulked and pooled over treatment according to MAFF (1975).

The digestibility coefficient (DC) of the dry matter and nutrients was calculated as:

$$DC\ (\%) = \frac{Total\ amount\ of\ nutrient\ in\ feed - Total\ amount\ of\ nutrient\ in\ feces}{Total\ amount\ of\ nutrient\ in\ feed} x100$$

### 3.4.4 Data Analysis

Data were subjected to a two-ways analysis of variance (ANOVA) using GLM procedure of SAS (2002 version 9.0 (TS M0)) in RCBD model. Treatment means were compared by using Turkey HSD and significant differences were declared when P<0.05. The following statistical model was used in analyzing the data:

$$Y_{ij} = \mu + \alpha_i + \beta_j + eijk$$

Where:

Yij = response variables

μ = Overall mean

αi = i$^{th}$ treatment effect ( i=1-3)

βj =j$^{th}$ block effect (j=1-3)

eijk = random error term

### 3.5. Experimental Design and Treatments

The experiment was conducted using completely randomized block design (RCBD) with three dietary treatments consists of eight sheep per treatment. Initial body weight was taken after overnight fasting of the experimental sheep at the end of 30 days adaptation period. After one month of the quarantine period, the experimental lambs were blocked into three treatment groups of eight lambs in each based on their initial body weight. Lambs within a block were assigned to one of the three treatment diets (Table 1) and assigned in an individual pens. The experimental animals were used for digestibility trial that lasted for 7 days and feeding trial of 80 days, respectively

**Table 1. Combination of dietary treatments.**

| Treatment | Composition in (%) |
|---|---|
| 1 | 40 % hay, 60 % *tannin rich trees and shrubs (TRTs)*, 150g CM |
| 2 | T1+ 0.5gm PEG/1kg *tannin rich trees and shrubs (TRTs)*/1L $H_2O$ |
| 3 | T1+ 200ml wood ash/1kg *tannin rich trees and shrubs (TRTs)* |

*CM, commercial concentrate mixture; PEG: Polyethylene Glycol,*

*Total daily ration amount was based on 50gm feed /1kg of live body weight of experimental animal*

*T1=Hay; 40% + tannin rich trees and shrubs (TRTs),60% ( A.gummifera, 30%; R.glutinosa,10%;S.guineense,20% )+ 150 gm Commercial concentrate mixture (CCM).*

*T2=Hay + tannin rich trees and shrubs (TRTs) 60% ;( A. gummifera, 30%; R.glutinosa,10%;S.guineense,20% ) +150 gm Commercial concentrate mixture (CM).+ PEG (T1+ PEG)*

*T3=Hay + tannin rich trees and shrubs (TRTs)60% (A.gummifera, 30%; R.glutinosa,10%;S.guineense,20% ) + 150gm Commercial concentrate mixture (CM). + Wood ash solution (T1+ Wood ash).*

## 3.6 Partial Budget Analysis

Partial budget analysis involved calculation of the variable cost of experimental animal, feeds and benefits gained from the result. The purchasing prices of the feeds and animals and selling price of animals were used for partial budget analysis. The difference between selling and purchasing price in each experimental treatment were used to determine the total return (TR). The net income (NI) was calculated as the amount of money left when total variable costs (TVC) are subtracted from the total returns (NI = TR –TVC). The analysis considered Partial budget was used to calculate the potential profitability of supplementing PEG and wood ash. The most important parameters of partial budget analysis are the change in net return and MRR. This is due to the fact that MRR measures the net return increment associated with each additional units of expenditure (TVC) and NI shows the net return of feeding regime by considering expense costs and return.

# 4. RESULTS AND DISCUSSION

## 4.1. Chemical Composition of the Experimental Feeds

The results of chemical analysis of feeds used in the study are shown in Table 2. The CP content of the hay used in this study is 6.4% and the NDF and ADF contents of hay are relatively high. These values indicate that the basal feed has a poor nutritional potential and may fail to support the maintenance requirements of sheep as it contains CP below the minimum level of (7%) required for microbial function for adequate intake of forages (Van Soest, 1994; Norton, 2003).

The low CP and high NDF contents of the hay used in this study might be due to the fact that as the maturity stage advances, there will be low CP and high NDF content expectation. Advance in maturity of plants was reported to be associated with low CP and high cell wall content (McDonald *et al., 2002*). The NDF and ADF values of grass hay are lower than the 70 and 47% reported by Yihalew *et al (2005*) and the 70 and 40% reported by Yayneshet *et al (2009)* for native grass hay in Ethiopia.

Despite their high contents of tannins (>100g/kg DM), the CP content of tannin rich browse mixes ( *A.gummifera , A.sygium and R.glutinosa*) was 14% higher than the basal diet (hay) and commercial concentrate mix. It has been reported that CT values above 50 g/kg DM can become a serious anti-nutritional factor in plant materials fed to ruminants and are even toxic (Leng 1997). Higher tannin levels become highly detrimental as they reduce digestibility of fiber in the rumen by inhibiting the activity of bacteria (Chesson *et al.* 1982) and anaerobic fungi (Akin and Rigsby, 1985). High levels also lead to reduced intake (Yisehak *et al.*, 2014).

**Table 2 Chemical composition content of experimental Feeds)**

| Diet sources | DM | Ash | OM | EE | CP | NDF | ADF | HC | CF | CT | NFE | ME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hay | 900 | 75 | 925 | 27 | 64 | 442 | 378 | 64 | 310 | bdl | 464 | 10 |
| Browser mix | 898 | 69 | 931 | 33 | 184 | 601 | 483 | 122 | 185 | 140 | 527 | 12 |
| Concentrate | 839 | 101 | 900 | 50 | 156 | 680 | 287 | 393 | 126 | bdl | 668 | 13 |

*bdl; below determinant level*

*DM, dry matter; OM, organic matter; EE, ether extract; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, Hemi-cellulose; CF, Crude fiber; CT, condensed tannin; NFE, Nitrogen free extract; ME, metabolisable energy.*

## 4.2 Average Daily Nutrient Intakes

Average daily intakes of feed nutrients are presented in Table 3. The highest DMI (P<0.001) was recorded for lambs fed T3compared to other treatments. In the present trial, feeding grass based hay + browse mix with PEG and wood ash significantly (P<0.001) improved DMI of sheep compared with non-PEG and wood ash groups.

**Table 3. Mean daily nutrient (g) and Metabolisable energy (MJ) intake**

| | Treatment, Means | | | | | |
|---|---|---|---|---|---|---|
| Nutrient | T1 | T2 | T3 | SEM | P-value | CV% |
| DMI | $1243.7^{c}$ | $1285.5^{b}$ | $1399.84^{a}$ | 80.84 | <0.001 | 0.97 |
| OMI | $1142^{c}$ | $1180^{b}$ | $1285^{a}$ | 73.85 | <0.001 | 1.6 |
| CPI | $100.6^{b}$ | $134.4^{a}$ | $157^{a}$ | 28.7 | <0.001 | 15.34 |
| EEI | 39.4 | 39.5 | 50.05 | 6.12 | 0.272 | 18.2 |
| NDFI | $714.8^{c}$ | $755.32^{b}$ | $830.24^{a}$ | 15.7 | <0.001 | 6.44 |
| ADFI | $445.2^{b}$ | $519.9^{a}$ | $539.5^{a}$ | 49.8 | 0.005 | 10.82 |
| CFI | $259.13^{c}$ | $265.6^{b}$ | $287.2^{a}$ | 14.7 | <0.001 | 1.3 |
| MEI | $1014.61^{b}$ | $1275.89^{a}$ | $1305.93^{a}$ | 160.23 | <0.001 | 18.3 |

[a,b,c] Means with different superscripts in the same row are significantly different ($P < 0.05$)

*DMI, dry matter intake; CPI, crude protein intake; EEI, ether extract intake; OMI, organic matter intake, ADFI, Acid detergent fiber intake; NDFI, neutral detergent fiber intake; MEI, metabolisable energy intake; SEM, standard error of mean; T1= Hay + tannin rich trees and shrubs (TRTs)+ Commercial concentrate mixture(CM); T2= T1+PEG; T3=T1+ Wood Ash.*

The higher DMI in wood ash (T3) received group may be associated with higher level of minerals in wood ash that abounding better mineral to rumen microbial activity. Wood ash has also been found to serve as a mineral supplement (Ndlovu, 2007*;* Phoso, 2009). The results indicated that wood ash treatment was more effective in neutralizing tannins in tannin rich feeds. It was concluded that wood ash, which is an inexpensive source of alkali, has the potential to improve the nutritive value of these underutilized, high-tannin feeds under small holder conditions in Ethiopia.

The higher improvement of DM intake in high tannin containing treatments (HT) after PEG and wood ash inclusion could be connected with the selective tannin binding power of PEG and wood ash alkalinity. PEG has a higher affinity to tannins than do proteins (Hagermanand Butler 2010). Likewise, the improved intake of all other nutrients measured in the present study could be associated with the tannin complexing competence of PEG and wood ash. Our finding has shown that the intake of each nutrient was significantly different at T2 and T3 than control group (T1) , Generally, the greatest improvement of all essential nutrients intake was recorded in wood ash and PEG inclusion group than control group could be a good indicator for there was higher affinity of wood ash and PEG to tannins than do proteins. According to this finding, wood ash could be a good option for proper use of proteins from tannin rich feedstuffs for small holder farmers. Goats secrete proline-rich proteins constantly while sheep only produce when consuming tannin rich plants (Austine *et al* 1989). Tannin-binding proteins in the saliva might be responsible for minimizing tannin related negative effects by forming soluble protein tannin complexes (Fickel et al 1999) and these are considered to be counter-defenses acquired in the course of evolution by animals whose natural forage contains such tannins (Van Soest 1994, Clauss et al 2005). The increased total

DMI observed in the wood ash supplemented sheep is due to the fact that higher CP intake results in a large number of micro-flora in the rumen that can facilitate the digestibility of fibrous feeds (Van Soest 1994). On another hand, the higher nutrient intake improvement in sheep can be a good scientific evidence for improvement of sheep nutrition under smallholder farming settings in all environmental conditions through feeding tannin rich feedstuffs. Similar finding of research works by inoculation of PEG to sheep and goats was reported by Kibreab (2013), which stated that PEG inclusion resulted in higher nutrient intake than control group ($P$<0.001).

### 4.3. Apparent Nutrient Digestibility

Apparent digestibility coefficients of nutrients in each treatment are presented in Table 4. In this trial, sheep received PEG and wood ash had shown better apparent DM and other essential nutrient digestibility compared with control group (P<0.001).

**Table 4** Apparent dry matter and nutrient digestibility

| Digestibility (%) | Treatments | | | SEM | p-value | CV% |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | | | |
| DM | $61.1^{b}$ | $80.8^{a}$ | $78.0^{a}$ | 10.7 | <0.001 | 13.07 |
| OM | $55.1^{b}$ | $75.5^{a}$ | $74.0^{a}$ | 11.4 | <0.001 | 15.03 |
| CP | $79.6^{b}$ | $97.4^{a}$ | $96.2^{a}$ | 9.96 | <0.001 | 3.95 |
| EE | $69.7^{b}$ | $80.15^{ba}$ | $81.3^{a}$ | 6.4 | 0.032 | 11.65 |
| NDF | $50.44^{b}$ | $79.44^{a}$ | $69.93^{a}$ | 14.8 | <0.001 | 16.7 |
| ADF | $38.8^{b}$ | $76.8^{a}$ | $62.2^{a}$ | 19.21 | <0.001 | 18.3 |

*[a,b,c] Means with different superscripts in the same row are significantly different (P< 0.05). SEM: standard error of mean; ADF: acid detergent fiber CP: Crud protein; DM: dry matter; NDF: neutral detergent fiber; OM: Organic matter; T1=Hay + tannin rich trees and shrubs (TRTs) + 150 gm Commercial concentrate mixture (CCM);*

*T2=Hay + tannin rich trees and shrubs (TRTs) +150 gm Commercial concentrate mixture (CM).+ PEG (T1+ PEG)*

*T3=Hay + tannin rich trees and shrubs (TRTs) + 150gm Commercial concentrate mixture (CM).+ Wood ash solution (T1+ Wood ash).*

The deactivation efficiency of the wood ash solution might be due to the high pH value of the ash content. High alkalinity of wood ash solution is considered the main reason for the reduction of tannin content (Ben Salem *et al*., 2005). Other researchers (e.g. Ramirez *et al*., 1992) also observed similar increases in the final pH. The pH value of wood ash solution used in this study was 9.7. The effect of wood ash solution is attributed to oxidation of phenolics at high pH value (Makkar, 2003).

The improvement of DM digestibility in sheep against the high tannin diets (CT>100 g $kg^{-1}$ DM) might be associated with their adaptation to tannins. Several authors reported tannins challenge feed digestion of ruminants at concentrations over 50 g CT $kg^{-1}$ DM; yet, in the present study it has been clearly observed that lambs were using tannin rich diets with modest limitations improvement of DM digestion. Dietary inclusion of high tannin feed stuffs (>100 g/$kg^{-1}$ DM) at rate 60% of total ration could be considered acceptable allowance for sheep feeding. The higher nutrient digestion coefficients of PEG and wood ash treatment combinations over control treatment might be associated with the help of PEG and wood ash for efficient utilization of protein and other essential nutrients in the sheep rumen due to tannin binding effect of both serving as by-pass protein. Similar researches carried out by Biruk (2012) and Kibreab (2014), using various level of PEG support the present study's result.

The low CPD both in sheep for non-PEG treatments might be associated with protein binding effects of CTs. It has been reported that zebu cattle fed with dried leaves of several tanniferous trees and supplemented with PEG6000 showed an increase of in vivo CP digestibility (Yisehak *et al.* 2014). Several authors have reported a reduction in protein digestibility in ruminants fed diets containing high levels of CTs (McSweeney et al. 2000; Halin *et al*. 2010). In addition to complexion with dietary proteins, CTs combine with, and hinder digestibility of cellulose, hemicelluloses and pectin either by preventing microbial digestion or by directly inhibiting cellulolytic microorganisms (McSweeney *et al*. 2000; Frutos *et al*. 2004). Further, CTs were reported to form combination with proteins in the rumen rendering them unavailable for digestion and consequently increase their output in faeces (Robins and Brooker, 2005).

A better fibre digestibility (ADF, NDF) in PEG and wood ash treatment combination over control group of high tannin load reflects better influential power of the both agents by making a favorable rumen environment for fiber utilizing capability of microbial than non supplemented groups.

## 4.4. Live Body Weight Gain and Feed Conversion Efficiency

The initial and final body weights, daily live weight gain and feed conversion efficiency of the experimental sheep are presented in Table 5. Animals in T2 and T3 had greater ($P<0.001$) final body weight (BW) and average daily BW gain (ADG) than animals in T1. The greatest body weight gain of sheep was recorded in T3 (3.75 kg) as compared to other treatment groups ($P<0.001$). There was a significant difference ($P<0.001$) in daily live weight gain between lambs with inoculation of PEG or wood ash than the control. Lambs fed on control group alone (T1) that means with no inclusion of PEG (T2) or wood ash (T3) showed lower live weight gain than lambs received PEG(T2) and wood ash (T3) throughout the experimental period. In the present study ADG (g/day) were 25, 44.7, and 46.87 in T1, T2 and T3 respectively. Feed conversion Ratio (FCR) also differed among treatments ($p<0.001$). Feed conversion ratio (FCR) of sheep observed in treatment T1 were significantly higher ($P<0.001$) than T2 and T3 probably due to lower DMI. Experimental animals with PEG had shown statistically similar ($p<0.001$) performance effect to the ones inoculated with wood ash group. This trial showed that PEG and wood ash inclusion further improved their feed conversion efficiency ratios considerably ($P <0.001$). This finding further agreed with Sisay, (2007);stated that feeding of complete mineral mix resulted in enhanced average daily weight gain and feed conversion ratio a*nd Mohammed et al.* (1989) reported that weight gains of Arsi sheep increased by an average of 19 ± 8 g/day when fed with natural mineral lick offered as free choice. Thus, in the present study PEG and wood ash inclusion resolutely improved nutrient digestion and absorption of protein that in turn contributed for the best average daily weight gain of experimental animals.

**Table 5 .Mean body weight parameters, feed conversion and protein ratios**

| Parameters | Treatment, mean | | | SEM | P-value | CV% |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | | | |
| IBW (Kg) | 23.25[b] | 22.5[c] | 24.50[a] | 0.080 | <0.001 | 0.96 |
| FBW (Kg) | 25.25[c] | 26.075[b] | 28.25[a] | 0.182 | <0.001 | 1.95 |
| BWC (Kg) | 2.00[c] | 3.575[b] | 3.75[a] | 0.227 | <0.001 | 18.07 |
| ADG(g/d) | 25.0[c] | 44.7[b] | 46.9[a] | 12.050 | <0.001 | 17.3 |
| FCR(DMI/ADG) | 51.5[a] | 30.2[b] | 30.3[b] | 12.3 | <0.001 | 10.2 |
| PER(g ADG/g,CPI) | 0.26 | 0.34 | 0.30 | 0.041 | 0.160 | 17.3 |
| FCE(g,ADG/g,DMI) | 0.02[b] | 0.035[a] | 0.034[a] | 0.008 | <0.001 | 0.15 |

*[a,b,c] means within a row bearing a common superscript are significantly different;(p<0.05)*

*IBW: Initial Body weight;* FBW: Final Body Weight; BWC: Body weight change;
*ADG: average daily weight gain; FCR: feed conversion ratio; PER: protein efficiency ratio; FCE=feed conversion efficiency; T: treatment; T1: Hay + tannin rich trees and shrubs (TRTs) + Commercial concentrate mixture (CCM); T2:T1+PEG; T3:T1+ Wood Ash; DMI: dry matter intake; SEM=standard error of mean;*

## 4.5 **Partial Budget Analysis**

Partial budget analysis of sheep fed hay, tannin rich plants and concentrate mix with PEG and wood ash inoculation was presented in Table 6.

The result of this study indicated that the higher total return on T3 (**570** ETB) obtained from sheep fed T1+ wood ash followed by T2 which fed T1+ PEG (**554**ETB). The least total return

(**478**ETB) was obtained from sheep assigned to control group. On another hand; the higher net income was recorded on T3 (465.25 ETB) and T2 (451.6 ETB), compared to T1 (371.65 ETB).When looking to the result of marginal rate of return; the higher value was recorded on T3 (4.44 ETB); T2 (4.41 ETB) and the least value was recorded on T1 (3.50 ETB).

**Table 6 Partial budget analysis**

| Parameters | Treatments | | | SEM | P-value | CV % |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | | | |
| Purchase price of sheep (ETB) | $650^{c}$ | $630^{b}$ | $680^{a}$ | 1.20 | <0.001 | 10.40 |
| Hay consumed (Kg/sheep) | 31.50 | 30.60 | 33.30 | 0.00 | - | 5.0. |
| A. gummifera consumed(Kg/sheep) | 31.40 | 30.40 | 33.10 | 0.00 | <0.001 | 5.01 |
| R. glutinosa consumed (Kg/ sheep) | 10.50 | 10.1 | 11.0 | 0.00 | <0.001 | 3.13 |
| S.guinessa consumed (Kg/sheep) | 20.90 | 20.30 | 22.00 | 0.00 | <0.001 | 4.10 |
| PEG consumed (gm/sheep) | - | 2.16 | - | 1.25 | <0.001 | 0.00 |
| CMM consumed (Kg/sheep) | 4.50 | 4.50 | 4.50 | 0.00 | - | 0.00 |
| **Feed Costs** | | | | | | |
| Cost of hay (ETB/sheep) | $17.00^{b}$ | $16.00^{c}$ | $18.00^{a}$ | 0.27 | <0.001 | 1.20 |
| Cost of A. gummifera (ETB/sheep) | $7.00^{a}$ | $6.00^{b}$ | $7.00^{a}$ | 0.25 | <0.001 | 0.92 |
| Cost of R. glutinosa (ETB/sheep) | 4.50 | 4.50 | 4.50 | 0.04 | <0.001 | 0.00 |
| Cost of S.guinessa (ETB/sheep) | $2.60^{b}$ | $2.00^{c}$ | $2.80^{a}$ | 0.04 | <0.001 | 0.72 |
| Cost of PEG (ETB/sheep) | $0.00^{b}$ | $1.62^{a}$ | $0.00^{b}$ | 1.12 | <0.001 | 0.00 |
| Cost of CCM (ETB/sheep) | 6.75 | 6.75 | 6.75 | 0.00 | - | 0.00 |
| Cost of wood ash (ETB/sheep) | - | - | - | - | - | |
| Cost of Drugs (ETB) | $8.00^{a}$ | $5.00^{b}$ | $5.00^{b}$ | 0.27 | <0.001 | 4.70 |
| Cost of Vaccination (ETB) | 0.50 | 0.50 | 0.50 | 0.00 | - | 0.82 |
| Labor cost (ETB) | 60.00 | 60.00 | 60.0 | 0.00 | - | 0.00 |
| TVC (ETB/sheep) | $106.35^{a}$ | $102.37^{b}$ | $104.75^{a}$ | 0.56 | <0.001 | 8.30 |
| Sheep selling price (ETB/sheep) | $1128^{c}$ | $1184^{b}$ | $1250^{a}$ | 0.58 | <0.001 | 10.20 |
| Total return (TR) (ETB/sheep) | $478^{c}$ | $554^{b}$ | $569.60^{a}$ | 1.43 | <0.001 | 14.60 |
| Net Income (NI) (ETB/sheep) | $371.65^{b}$ | $451.6^{a}$ | $465.25^{a}$ | 1.70 | <0.001 | 8.34 |

| | | | | | | |
|---|---|---|---|---|---|---|
| MRR ( NI/ TVC) | 3.50[b] | 4.41[a] | 4.44[a] | 0.04 | <0.001 | 7.24 |

*[a,b,c] means within a row bearing a common superscript are significantly different (p<0.05)*

*SEM: standard error of means, T: treatment; TRTS: Tannin Rich Trees and Shrubs*

*T1: Hay + tannin rich trees and shrubs (TRTs) + Commercial concentrate mixture (CCM); T2:T1+PEG; T3:T1+ Wood Ash; ETB: Ethiopian Birr CCM: commercial concentrate mixture; TVC: total variable cost; TR: total return; NI: net income; MRR: marginal rate of return*

The least MRR was obtained in T1 with significant difference (P<0.01) from T2 and T3 (T1<T2 = T3) and based on their RT they had significant difference among treatments (T1<T2<T3). These higher TR; NI and MRR at T2 and T3 was mainly might due to higher weight gain of experimental animals which resulted in higher selling price income obtained from animals assigned to wood ash (T3) and PEG (T2) compared to control group (T1). According to Scott (1995) partial budget profit and loss analysis, this study showed that feeding tannin rich plants and shrubs by inoculation of wood ash for fattening sheep is economically more profitable and efficient than PEG inoculated and non inoculated groups.

# 5. SUMMARY, CONCLUSION AND RECOMMENDATION

Sheep fed on natural pasture hay with 60% of high tannin diet and inoculation of PEG and wood ash (40 mg PEG to 1 kg and 200ml wood ash solution to 1 kg of high tannin feed mixes) appreciably improved the nutrient intake, digestibility, and growth performance. Using Wood ash is economically more cost effective and affordable in rural areas than PEG. However; it has slightly better or similar effect with PEG on feed intake, feed digestibility, weight gain and feed conversion efficiency of sheep. Therefore, there appears to be potential strategies for improving the utilization of tannin-containing feeds by the use of tannin-binding agents such as PEG and locally available wood ash without altering the natural nutrient content of tannin-containing plants. Although the use of PEG under smallholder framers situation could difficult, industries are more economically capable and can incorporate PEG in a pelleted diet composed of ingredients including tannin-rich byproduct(s). The use of wood ash can be promising as the traditional cooking method produces large quantities of wood ash, which is locally available, cheap and safe to utilize in treating tannin-containing feeds.

This result did not cover all agro ecological areas; animal species and all tannin rich plats in Ethiopia. As a recommendation similar research works would need to be implemented in Ethiopia by using all other remaining tannin rich trees and plants in different agro ecological zones on different animal species

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