EFFECTS OF SUPPLEMENTING VARYING LEVELS OF SAPIUM ELLIPTICUM LEAVES WITH CONCENTRATE MIX ON NUTRIENT UTILIZATION, GROWTH PERFORMANS AND ECONOMIC EFFICIENCY OF BOS TAURUS × BOS INDICUS BULLS

MSc. Thesis

GETAHUN SHITA BERHANU

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Jimma, Ethiopia

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By

GETAHUN SHITA BERHANU

A Thesis Submitted to The School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, Department of Animal Science, In Partial Fulfillment of The Requirements for The Degree of Master of Science in Agriculture (Specialization: Animal Production)

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Major Advisor :- Yisehak Kechero (associate professor) ……………….. ……..…………………..

Name Signature Date

Co-Adviser:- Taye Tolamariam (Professor) ………………. … …………………..

Name Signature Date

Internal Examiner (If Depends on the Verdict)

Name Abagaz Beyene (PhD) signature_____________ date______________

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DEDICATION

This Thesis is dedicated to my beloved mother W/ro Tadelech Alula and to my father Shita Berhanu for their love, proper guidance and support contributed a lot in my career and day to day life.

STATEMENT OF AUTHOR

I, the undersigned, hereby declare that the thesis “Effects of supplementing varying levels of *sapium ellipticum* leaves with concentrate mix on nutrient utilization, growth performance and economic efficiency of *Bos taurus* × *Bos indicus* bulls in Jimma University Kito Furdisa development enterprise Jimma zone, western Ethiopia is the outcome of my own work and all sources of materials used have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University and is deposited at the University Library to be available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree. I concede copyright of the thesis in favor of the Jimma University, Collage of Agriculture and Veterinary Medicine.

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Place: Jimma University, Collage of Agriculture and Veterinary Medicine.

Date of Submission: _________

BIOGRAPHICAL SKETCH

Getahun Shita Berhanu, the author was born on July 26, 1982. in Babu kebele, Limmu Kossa Woreda of Jimma Zone, Oromia Region. He attended his elementary and junior education at Babu Junior School in 1993-2001. He completed his secondary education at Jimma Senior Secondary School in 2001-2004. He joined Haramaya University in 2004 and graduated with BSc degree in Animal science on 7th July, 2007. After graduation he served as animal production expert in Limmu Kossa District of Livestock Development and Health Care Agency from 2007-2011. Currently he's serving in Jimma University Kito Furdisa General Development Enterprise as senior dairy cattle expert starting from July, 2011. He joined Jimma University, School of Graduate studies to pursue his Master of Science degree in Animal Production in 2013.

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LIST OF ABBREVIATIONS

BW	Body Weight
CP	Crude Protein
CM	Concentrate Mix
CSA	Central Statistic Agency
DM	Dry Matter
ETB	Ethiopian birr
FAO	Food and Agriculture Organization of the United Nation
GDP	Gross Domestic Product
ILRI	International Livestock Research Institute
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
KFGDEDF	Kito Furdisa General Development Enterprise Dairy Farm
LTF	Low Tannin containing Forage
LW	Live Weight
MoA	Ministry of Agriculture
NRC	National Research Center
ME	Metabolizable Energy

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Abstract

Smallholder cattle farmers in Ethiopia face inadequate feed supply in terms of quality and quantity as well as poor storage facilities. Dietary inclusion of the new potential feed resource such as *Sapium ellipticum* (Jumping - Seed Tree) would be a reliable substitute either as a sole feed or a multi-nutrient supplement in such fragile environments. The effects of supplementing varying levels of *S. elipticum* leaves with concentrate mix (CM) on nutrient utilization, growth performance and economic efficiency was studied in *Bos indicus* × *Bos taurus* bulls fed grass based diet. Twelve bulls with average initial live body weight of 118.11± 0.84 kg and 16.5 ± 2.12 (Mean±SEM) months of age were selected for 84 days fattening and 10 days of digestion trial. A randomized crossover design with 4 diets and 4 periods was used. The four dietary treatments included were hay + 400 g DM CM (T_1), hay + 200 g *S. elipticum* + 400 g DM CM (T_2), hay + 400g *S. elipticum* + 400 g DM CM (T_3), and hay + 600g *S. elipticum* + 400 g DM (T_4). The concentrate mix was made up of DM 947g/kg CM, ASH 100g/kg DM, CP 186g/kg DM, EE 50g/kg DM, NDF288g/kg DM ME17.11MJ/kg DM and ADF235g/kg DM. The smallest nutrient intake was observed in bulls feed $T_{1;}$ however, the highest feed intake was recorded for diet T_4 (P<0.001). The difference between treatments and periods are highly significant (P<0.001). Average daily gain was 123, 207,251 and 334 g/day, respectively for T_1, T_2, T_3 and T_4 (P<0.001). Feed conversion efficiency ranged between 35 (T1) and 18 g ADG/g DM intake (T4) (P<0.001). Further, T_4 was found to be the most profitable diet compared to other dietary treatments (P<0.001). A positive relationship observed between increasing graded levels of *S. ellipticum* with improved animal performance could indicate the potentiality of the plant to replace other protein and energy sources from concentrate mixes.

Key words: Average daily gain; *Bos indicus*; *Bos taurus*; Concentrate mix; Digestibility; *Sapium elipticum*

1. INTRODUCTION

Ethiopia has the largest livestock population in the African continent, yet productivity is generally lower than other African countries. The national and per capita production of livestock and livestock products, export earnings from livestock and per capita consumption of food from livestock origin have declined since 1974 (FAO, 2011; CSA, 2013). The low productivity of livestock is associated with various technical and non-technical factors. Among many other factors, shortage of feed supply (both quality and quantity) is considered to be a major factor affecting performance of livestock in Ethiopia (Benin *et al*. 2003; Jabbar *et al*. 2007; Negassa *et al*. 2011; Solomon *et al*. 2003). It is often argued that increasing population pressure has led to deforestation and conversion of pastureland into cropland, leading to overgrazing and degradation of pastures in marginal areas. Crop residues are increasingly used as feed and fuel rather than as mulch to maintain soil moisture and fertility, due to shortage of pasture and fuel wood. Similarly, dung is used as fuel rather than as manure. All of these contribute to land degradation through enhanced erosion and nutrient depletion (MacDonald and Simon, 2010; Matouš *et al*., 2013; CSA, 2013).

While efforts are being made to intensify and industrialize the sector, questions arise as to how Ethiopia can develop and expand its livestock population when the country already struggle to gain access to good soil, grazing land, and water (MacDonald and Simon, 2010). As Ethiopia increasingly experiences the effects of climate change, drought, and desertification, experts predict that "Ethiopia will have to open its markets to grain imports in order to keep up with the growing demand for meat, milk, and eggs (USG, 2009; MoFED, 2010; CSA, 2013).

Supplementation of animals with mixes of concentrates (CM) such as agro-industrial by-products to be used as protein and energy sources with low quality roughages are becoming the most popular in improving the nutritive values of low quality feeds (McDonald *et al*., 2010; Sayed *et al*., 2012). Improving energy and protein requirement of a farm animal under different production status is adhering to better market price, quality and quantity of animal products (Osuji *et al*., 1993; NRC, 2013). Foliages of tanniferous trees and shrubs can provide a significant proportion of the diets of most domestic animals. These fodders may be obtained either from passive production systems where naturally occurring woody species are cut or browsed opportunistically as and when they occur, or from more active, planned agro-forestry systems where selected tree species are planted and managed in conjunction with crops on the farm for more sustained fodder production over time.

Many indigenous multipurpose tree species are used as fodder in the south western regions of Ethiopia, mainly due to the suitability of the environment and the need to use them as fuel wood, construction, mulch, and shade for cash crops like coffee and spices. In the coffee area of the Jimma zone, a survey of 360 farms showed that 50 local species were commonly used as fodder (Yisehak and Geert, 2013). Of these, *S. ellipticum* was used by 87 percent of the farms surveyed. *S. elipticum*, a valued multipurpose tree, is often pruned for feeding to livestock. Farmers grow *S. elipticum* for several reasons such as to replenish soil fertility, are sources of human and veterinary medicine, and also serve as environmental conservation. The chemical analysis result also revealed that *S. ellipticum* (Jumping - Seed Tree) can be a potential source for digestible proteins and carbohydrates. The low content of condensed tannins (25g/kg DM) in the leaves of the plant can be serving as antioxidant for several oxidative reactions in the animal body. However, there is limited information regarding the effect of dietary inclusion *S. ellipticum* with or without concentrate mixes on weight gain performance, nutrient use and economic efficiency of *Bos taurus* × *Bos indicus* bulls. Therefore, the present study was planned to investigate the following specific objectives.

1. To determine the effects of supplementing of different levels of leaves of *S. ellipticum* (Jumping - Seed Tree) with concentrate mix (CM) on weight gain performance and nutrient utilization efficiency parameters,
2. To evaluate the economic feasibility of feeding different levels *S. ellipticum* (Jumping - Seed Tree) with concentrate mix in *Bos taurus* × *Bos indicus* cross bulls.

2. LITERATURE REVIEW

2.1. Economic importance of livestock in Ethiopia

Ethiopia is a home for many livestock species and suitable for livestock production. Ethiopia is believed to have the largest livestock population in Africa (CSA 2013; Solomon et al. 2003; Tilahun and Schmidt 2012). The total cattle population is about 54 million, 25.5 million sheep and 24.06 million goats. From the total cattle population 98.95% are local breeds and the remaining are hybrid and exotic breeds (CSA 2013).

The livestock subsector has an enormous contribution to Ethiopia's national economy and livelihoods of many Ethiopians, and still promising to rally round the economic development of the country. Livestock plays vital roles in generating income to farmers, creating job opportunities, ensuring food security, providing services, contributing to asset, social, cultural and environmental values, and sustain livelihoods. The subsector contributes about 16.5% of the national Gross Domestic Product (GDP) and 35.6% of the agricultural GDP (Metaferia et al. 2011). It also contributes 15% of export earnings and 30% of agricultural employment (Behnke 2010). The livestock subsector currently support and sustain livelihoods for 80% of all rural population. The GDP of livestock related activities valued at birr 59 billion (Metaferia et al. 2011).

Despite high livestock population and existing favorable environmental conditions, the current livestock output of the country is little. This is associated with a number of complex and inter-related factors such as inadequate feed and nutrition, widespread diseases, poor genetic potential of local breeds, market problem, inefficiency of livestock development services with respect to credit, extension, marketing, and infrastructure (Benin et al. 2003; Jabbar et al. 2007; Negassa et al. 2011; Solomon et al. 2003). In Ethiopia, livestock production and markets vary substantially across space due to different reasons including topographical variations, market access, feed and water availability, and population characteristics. Studies indicate that livestock production is higher in areas nearer to the major livestock market centers. In 2007/08, more than 75% of cattle in the four major highland regions of Ethiopia were located within 5 hours travel time of a livestock market. On the other hand, the Ethiopia lowland pastoral areas which are affected by recurrent drought found to have spares livestock population (Tilahun and Schmidt 2012). However, no convincing study has been made so far to analyses the degree in which these factors hamper the production and distribution of livestock.

In rural households, there is change in the meat consumption response among the surveys although the consumption responses were lower than urban once. Rural meat consumption showed considerable improvement between 1996 and 2000 but lost most of the gain between 2000 and 2004. The average per capita rural meat consumption increased by 11% between 1996 and 2000, whereas, urban per capita consumption remained relatively unchanged from the 1996 level (see Figure 4).

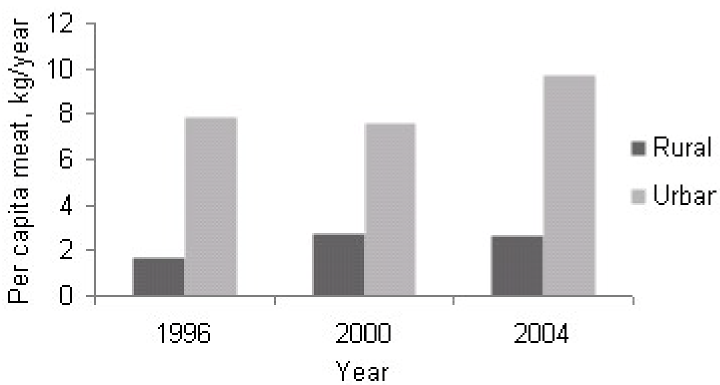

Figure1. Changes in average urban and rural per capita meat consumption between 1996 and 2004 (Shawel and Kawashima, 2009).

Both urban and rural households in the lower quintiles have had very low meat consumption because they had little extra income to spend on meat. However, with small change in household income, urban households showed rapid increase in meat consumption compared to rural households. Moreover, the change in consumption between consecutive income groups in rural households was smaller.

One of the factors that limit meat consumption in rural Ethiopia has been the absence of meat retail market (Shawel and Kawashima, 2009). In rural areas people often consume meat during holidays or special occasions and it is considered rather as luxury food than essential component of daily household nutrition. During these occasions, commonly, a group of 10 to 20 people buy a live animal, slaughter and divide the meat among them. Therefore, the change in household income alone can hardly change rural meat consumption unless accompanied by change in market arrangements and culture of food consumption (Shawel and Kawashima, 2009).

Livestock have diverse functions for the livelihood of farmers in the mixed crop livestock systems in the high lands of east Africa. Livestock provide food in the form of meat and milk, and non-food items such as draft power, manure and transport services as inputs into food crop production, and fuel for cooking. Livestock are also a source of cash income through sales of the above items, animal hides and skins.

Cattle are kept for multipurpose. However, purposes vary with production system. Traction (males) ranked highest, followed by milk (females) and reproduction/breeding (males and females) in both crop-livestock and agro pastoral systems (Alemayehu, 2004). Manure production also considered important by most crop/livestock and agro pastoralist farmers, but as secondary rather than a primary purpose. In contrast, reproduction/breeding requirements received higher ranks in pastoralist systems and, for female, requirements for breeding outranked the importance of milk production (Workneh, 2004).

In Ethiopia, 45% of livestock owners are women and 33% of livestock keepers households are headed by women in Addis Ababa city. Women are usually responsible for feeding large animals, cleaning the barns, milking dairy cattle, processing milk and 16 marketing livestock products. But they receive assistance of men, female children and/or other relatives, young children, especially girls between the ages of 7 and 15, are mostly responsible for managing calves, chicken and small ruminants. Older boys are responsible for treating sick animals, constructing shelter, cutting grass and grazing of cattle and small ruminants. The role of women managing animals that are confined during most of the year is substantial and they are critically involved in removing and managing manure, which is made in to cakes and used or sold as fuel (Azage, 2004).

In North-western Ethiopia, the small holders rear cattle, primarily for the supply of oxen power for crop production. Dairy, food, cash source, manure, fuel and fuel security are secondary. Cattle and equine provide smallholder farmers with vital for crop cultivation and transportation (Alemu, 1998). Livestock products, especially dairy, can make unique contribution to human nutrition of the poor in developing countries by providing micronutrients in bio-available form such as vitamin A, in addition to carbohydrates, protein and calcium. Thus, dairy producers by making more milk available for human consumption (Ahmed *et al*, 2003).

Fattening enterprises in western countries typically take immature feeder animals and bring them to market weight for sale to slaughter. Cattle in these enterprises normally enter the feedlot at well under one year old and are fattened for six months. Smallholder cattle fattening is also a traditional occupation with in some regions in Ethiopia.

In Ethiopia the existing livestock and their products marketing system is generally under developed. The low level of facilities is not conducive to efficient marketing. Transportation is on-hoof, which leads to considerable weight loss of animals as well as physical injuries and health. Trucking is very limited and used only during holidays and festivals to move finished cattle and small stock to city centers and exportable animals to ports. Poor infrastructure development hampers the flow of trade stock from pastoral areas to consumption sites (Belete, 2006).

2.2. Cattle fattening systems in Ethiopia

According to MOA 1996, in Ethiopia there are three types of fattening systems.

2.2.1. Traditional systems

In such type of systems, oxen are usually sold after the plowing season when they are in poor condition. Meat yields are low, the beef is of poor quality and the farmer returns are often inadequate to buy a replacement ox. This is obvious scope to improve this traditional and inefficient system through strategic feeding of good quality forage to fatten animals before they are sold, or to buy and fatten animals sold by others. In the low lands, where pastoralists do not use cattle for draft, cattle are sometimes fattened on natural pasture in good seasons. In average or poor seasons, low land cattle are rarely fattened and often have to be sold in poor condition at low prices.

2.2.2. By-product-Based fattening

This is a type of fattening in which the agro-industrial by-product such as molasses, cereal milling by-product and oilseed meals are the main sources of feed. In this system grazing land is completely unavailable and crop-residues are only significant roughage source.

2.2.3. The Hararghe fattening system

In this system peasants buy young oxen from the adjacent lowlands pastoral areas, use them for several years, and then fatten and sell them before they become old and emaciated. The systems is largely based on cut-and carry feeding of individual tethered animals. Grazing is rare. Few concentrate are used.

2.3. Available Feed Resources in Ethiopia

Natural grazing land is a predominant feed source for livestock in Ethiopia. Very little land is planted to introduced pasture or forage crops. This is especially true for the pastoral and agro-pastoral areas. Grazing areas are usually communally owned. Crop-residue and agro-industrial by-products represent a large proportion of feed resource in mixed crop-livestock system. Reliance on a crop residue for animal feed is ever-increasing or more land is cropped to feed the fast-growing human population (Alemu, 2009).

2.3.1. Natural pasture and browse

Natural pasture supply the bulk of livestock feed which is composed of indigenous forage species and is subjected to overgrazing. Grazing occurs on permanent area, fallow land and a land following harvest. Both fallow land and crop stubble provide poor grazing for a very short period just after harvest of crops. The availability and quality of native pasture varies with altitude, rainfall, soil type and cropping intensity. The higher rainfall area of the pastoral zone is characterized by dense thorn bush of low carrying capacity. The basic types of grazing system are continuous grazing and rotational grazing (Yayneshet, 2010).

2.3.2. Conserved pasture forage

Preserving of forage is a means of distributing forage throughout the year and is usually in excess during spring and early summer and in deficient for the rest of the year. So forage conservation is desirable to provide feed during the dry season. Conserved pasture forage can be categorized in to standing hay, harvested hay and silage. Oat, barley and wheat plant materials are occasionally cut green and made into hay for animal fodder; however they are more usually used in the form of straw, a harvest by-product where the stems and dead leaves are baled after the grain has been harvested and threshed. Straw is used mainly for animal bedding. Although straw is used as fodder, particularly as a source of dietary fiber, it has lower nutritional value than hay (Solomon, 2009).

2.3.3. Crop residues

A wide variety of arable crops is grown on subsistence farm holdings and many of these crops have residues which can form an important source of livestock feed, following the harvesting of grain Livestock in mixed crop-livestock farming systems two to three months into a dry season feed on cereal straws, stubble or other leftovers such as maize stove. The potential and abundance of crop residues that could be used for livestock feeding in Ethiopia in most cases drown from grain yield, using multiplier is 13.7 million ton (13.6 million ton in the rural area and 136 thousands ton in urban areas) from cereals having CP value ranging from 3.1 - 6.7% with digestibility level about 40.7-54.1%. They are suited for all classes of livestock in the country according to their nutritional characteristics. Stover is the leaves and stalks of corn (maize), sorghum or soybean plants that are left in a field after harvest. It can be directly grazed by cattle or dried for use as fodder. Stover has attracted some attention as a potential fuel source and as biomass for fermentation or as a feedstock for cellulosic ethanol production (Yayneshet, 2010).

Straw is an agricultural by-product, the dry stalks of cereal plants, after the grain and chaff have been removed. Straw makes up about half of the yield of cereal crops such as teff, barley, oats, rice, rye and wheat. It has many uses, including fuel, livestock bedding and fodder, thatching and basket-making. It is usually gathered and stored in a straw bale, which is a bundle of straw tightly bound with twine or wire. Bales may be square, rectangular, or round, depending on the type of baler used (Tesfaye and Chairatanayuth, 2007). Crop residues contributed the largest share of feed supply to cattle in Horor Guduru Wollega of western Ethiopia (Kassahun *et.al*, 2016).

2.3.4. Fodder trees and shrubs

Fodder trees are the leaves, pods of trees and shrubs and twigs growing on shrubs, woody vines and trees available for animal consumption (Alemayehu, 2006). Foliage of trees such as different acacia species and *Balanites aegyptiaca* as well as the pods and fruits of trees/shrubs can be used as substitute for concentrate supplement. Fodder trees and shrubs are important animal feeds in Ethiopia especially in arid, semi-arid and mountains zones, where large number of the country`s livestock is found (Alemayehu, 2004).Their importance increases in arid areas (Getachew, 2002). The importance and availability of trees and shrubs in tropical Africa are influenced by the distribution, type and importance of livestock, their integration and role within the farming systems and availability of alternative sources of feed (Getachew, 2002).

The legume trees have an enormous potential for ruminants in the tropics (Coates, 1995; Poppi & Norton, 1995) and produce large quantities of high protein leaves for animal consumption (Man *et al.*, 1995). Many browse and pasture legumes species are endowed with the important attributes of high protein content, palatability and digestibility (Devendra, 1992; Coates, 1995). The message from these earlier studies is that legumes are introduced into diets because they are supposed to increase protein supply to the animal. The relative low solubility of protein fractions in some legumes usually is a further advantage in ruminant feeding as a result of high by-pass protein levels. Another advantage is the component of tannin binding proteins in tropical legumes (Poppi & Norton, 1995). The authors supposed that tropical legumes also have anti-protozoal properties which can be exploited to manipulate rumen microbial ecology. These factors enhance voluntary feed intake of ruminants offered leguminous forage and thus improve animal performance. However, there are data showing that legumes increase protein intake, but they generally do not increase intestinal protein supply per unit of DM intake (Minson, 1990; Mupangwa *et al.*, 2000). This was explained by the fact that tropical legumes are likely to lose significant amounts of protein as ammonia from the rumen due to microbial degradation. Losses of up to 43% protein in the rumen of cattle when fed the legume Aeschynomene americana have been found (Higgins *et al.*, 1992). This is especially the case for legumes with low digestibility that provide insufficient energy for microbes to utilize the degraded protein. If the ratio of CP/kg of digestible OM (DOM) in a legume exceeds the approximate value of 210 g CP/kg of DOM these results in losses of protein or incomplete net transfer (Beever *et al.*, 1986; Ulyatt *et al.*, 1988; AFRC, 1992; Cruickshank *et al.*, 1992). The high rumen ammonia concentrations in the absence of a readily fermentable energy source result in energy limiting microbial growth and a significant loss of 20 legume protein N in net transfer to the small intestine. Providing supplements with relatively high protein concentrations to ruminants consuming low-quality roughage has been shown to enhance roughage utilization and livestock performance (Gilbery *et al.,* 2006).

The main role of condensed tannins (CTs) in tropical legumes has been reported as reducing ruminal degradability, but they have potential anti-nutritional effects in terms of overprotection (Poppi & McLennan, 1995). On the other hand, CTs are reported to reduce voluntary intake through astringency, an unpleasant puckering sensation in the mouth brought about by the complexing of tannins with salivary glycoproteins (Kumar & D'Mello, 1995). Some aspects of tannins in the feed in inhibiting the microbial activity or microbial enzymes resulting in reduction in ruminal turnover and rate of digestion have been recorded (Muhammed *et al.*, 1994; Salawu, 1997). The conditions also place more pressure on the utilization of legumes in supplying protein for ruminants, and this is possible if the negative impacts of anti-nutritional factors in legumes are overcome and the deficiency of a readily fermentable energy source in diet when animals are fed a sole legume feed is dealt with. Mupangwa *et al.* (2000) suggested that adding such energy sources can result in increasing ammonia utilisation and microbial protein production when feeding rations based on forage legumes.

The common browse species indentified in Ethiopia are: *Acacia ask, Acacia lahai, Acacia oerfeta*, *Acacia Senegal*, *Acacia tortilis*, *Albizia amera*, *Balanites aegyptiaca*, *Boswellia papyrifera*, *Ficus glumosa*, *Ziziphus spina-christi*, *Acalypha fruticosa, Xanthum spinosa, Ziziphis Mauritania* (Teferi, 2006; Adugna *et al*., 2007). *Acaccia abyssynica, Cordia Africana, Croton macrostachyus*, *Ekebergia capensis*, *Erythrina abyssyinica*, *Euclea divinorum*, *Ficus ovate, Ficus sycomorus, Ficus vasta*, Prunus *Catha edulis* Africana, *Sapium elipticum, Syzygium guineense , Carica papaya, Calpurnia subdecandra, Carissa edulis, Catha edulis, Coffee Arabica, Dodonaea angustifolia, Maytenus obscura, Morus alba , Myrica salicifolia , Ocimum lamiifolium, Premna schimperi, Rhamnus staddo, Rhus glutinosa, Sida tenuicarpa Saccharum officinarum,* (Yisehak and Geert, 2013).

Production of cultivated forage and pastures depends on availability of species that are adapted to the climatic, edaphic and biotic factors prevailing in the environment in which they are to be utilized. Suitability of a forage species to a given area is judged based on dry matter yield potential, persistence, adequate feed quality, compatibility with other species and ease of propagation and establishment. Cultivated forage and pasture crops are mainly important as cut-and-carry sources of feed and as a supplement to crop residues and natural pastures. The type of cultivated forage crop produced is variable from place to place depending upon the prevailing climatic and edaphic factors. The most common cultivated forage crops include grasses like elephant grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), guinea grass (*Panicum maximum*) and oats (*Avena sativa*) in the highlands. Among the herbaceous legumes, the most common ones include desmodiums (*Desmodium* spp.), vetch (*Vicia* spp.), Lucerne (*Medicago sativa*), lablab (*Lablab purpureus*), cowpeas (*Vigna unguiculata*) while the most common fodder tree legumes include Leucaenas (*Leucaena* spp.), Sesbania (S*esbania* spp.), *Calliandra calthyrsus*, *Gliricidia sepium*, pigeon pea (*Cajanus cajan*) and others. Tagasaste (*Chamaecytisus palmensis*) is important in the highlands (Adugna, 2008).

Most browse species maintain their greenness and nutritive value throughout the dry season when grasses dry up and deteriorate both in quality and quantity. They are generally rich in CP and minerals and they are used as a dry season supplement to poor quality natural pasture and fibrous crop residue (Devendra, 1990). Animals grazing mature grass pasture are often able to supplement their diet by consuming the foliage of trees and shrubs, many of which are legumes. They are high in protein (200-3000g/kg DM) and minerals, but also high in fiber (500-600g/kg neutral detergent fiber).and foliage of some species also has a high concentration of condensed tannins (McDonald *et al.*, 2002).

The contribution of browse species as a source of animal feed is influenced by a number of factors such as the natural distribution of the browses within the agro-ecological zones, the distribution, type and importance of livestock, their integration and role within the farming system and availability of alternative sources of fodder for livestock in the agro-ecological zone.

One potential way (Solomon 2004; Mekoya *et al*. 2008) for increasing the quality and availability of feeds for smallholder ruminant animals in the dry season may be through the use of various locally available fodder trees and shrubs (IFTS). Fodder trees and shrubs of tropical origin are important in livestock production because they can supply significant amounts of protein. Unfortunately, their content of anti-nutrients like condensed tannins (CTs) vary widely and unpredictably (Babayemi *et al*. 2004b). Their effect on animals ranges from beneficial to toxicity and death (Makkar *et al*. 2003). A first step in the targeted use of shrubs and trees as feed resource is the analysis of their nutritive value, and identification of environmental factors that may affect their nutritive value.

2.3.5. Agro-industrial by products

By-products from sugar: The sugar industries in Ethiopia have factories at three sites (Wonji, Shoa and Methara). The during that time, area of cane is 13,000 ha and the estimated yield of cane tops is 6 tones dry matter per hectare or 78,000 tones dry matter per year. Production of molasses in 1981/82 was 51,100 tons of which 29,000 tones were exported. At that time, the use of a molasses/urea mixture as a drought-relief feed has been started in a pilot scheme run jointly by the Ministry of Agriculture, the Ministry of State Farms and ILCA (FAO, 1985) cited by (Yayneshet, 2010).

Oil-cake: Oil cakes are an excellent concentrate feed for ruminant livestock in Ethiopia which grows most of the temperate and sub-tropical oilseed plants such as linseed, groundnuts, rape, sesame, sunflower, cotton and Nug. Nug is a native annual composite, which produces Niger seed for oil, is also grown. The processing factories of oil seeds is widely practiced on a family basis or in small village mills (FAO, 1985) cited by (Yayneshet, 2010).

Milling by-Products: The various milling by-products obtained through processing wheat, corn and barley are of great interest as livestock feed for state farms, city dairy holders and to a lesser extent for some dairy co-operatives. Wheat grain is processed in big mills, whereas in the case of teff, barley, maize and sorghum the whole grains are processed and used for food (Yayneshet, 2010).

Slaughter Product: Large numbers of livestock, mainly cattle, sheep and goats are slaughtered every year of these, only a small proportion of the cattle are slaughtered in abattoirs with processing facilities. Addis Ababa Municipality, which is responsible for the abattoirs, produces meat, bone meal and blood (FAO, 1985) cited by (Yayneshet, 2010).

Brewery by-Products: Brewer's grains are traditionally valued for lactating cows because of their palatability and milk-producing property (Yayneshet, 2010). Brewer's spent grain (also called spent grain, brewer's grain or draff) is the main by-product of the brewing process, it consists of the residue of malt and grain which remains in the mash-kettle after the mashing and lautering process. It consists primarily of grain husks, pericarp, and fragments of endosperm. As it mainly consists of carbohydrates and proteins and is readily consumed by animals, spent grain is used in animal feed. https://en.wikipedia.org/wiki/Brewing

2.4. Matching forage quality to animal needs

Animal performance is determined by feed availability, feed nutrient content, intake, extent of digestion, and metabolism of the feed digested, but availability and intake most often determine animal performance. A cow never produced milk or a steer never grew on feed that it didn't eat! With regard to the nutritive content of forage, digestible energy (digestibility) is the most common limiting factor. However, there are times when protein and minerals are the nutrients that limit animal performance, especially in grazing situations when supplementation is impractical. The amounts of digestible energy, protein, vitamins, and minerals needed for maintenance is low relative to other animal processes. In general, forages that contain less than 70% NDF and more than 8% crude protein will contain enough digestible protein and energy, vitamins, and minerals to maintain older animals. Thus, even many low quality forages and crop residues can meet the maintenance needs of some classes of animals, if protein and minerals are adequate (Ball, 2001).

3. MATERIALS AND METHODS

3.1. The Study Location

This study was conducted at Jimma University Kito Furdisa General Development Enterprise Dairy Farm (KFGDEDF) facility. KFGDEDF is located in Jimma city which is found in south western Ethiopia about 350 km south west of the capital city (Addis Ababa).The latitude and longitude of Jimma city are 7°40`N and 36°50`E, respectively. The average altitude of the city is 1760 m above sea level with a temperature range of 11 to 27°C (Mossie, 2002). Relative humidity is about 90% during raining season and 70% during dry season (http://meteocast.net/forecast/et/jimma/).

3.2. Sample Collection

The leaves of test diet, *Sapium ellipticum*, were collected from Jimma University Institute of Technology campus. The top part of green leaves of *S. elipticum* were hand plucked from farm grown trees. The average age of mother trees was about 5.0 years old. The fresh leaves were spreaded on plastic sheet, dried under shade for about 3 days, pooled together, and put in fiber sacs. After drying (≥ 90% DM), leaves was packed in fiber bags in amounts of about 50 kg per bag and stored for use. The under shade drying was chosen because oven drying of feeds that contain proanthocyanidins, even at temperatures below 60ºC, polymerizes tannins, polysaccharide carbohydrates, fiber bound nitrogen and lignin (Makkar, 2003; Yisehak et al., 2010). The *S. elipticum* was selected because it is wealthy in essential nutrients, widely distributed in the study region and many other tropical countries have higher fodder biomass and are collectively consumed by browsers (Yisehak and Geert, 2013).

3.3. Animals, Experimental Design and Feed Management

Twelve *Bos taurus* × *Bos indicus* bulls about 16.5 ± 2.12 month of age, with an average initial live weight (LW) of 118.11± 0.84 kg, were used for the study. The animals were obtained from local dairy farm of KFDF. Animals were allowed to adapt to the experimental conditions and basal diet for one month. Prior to experiment, the animals were dewormed and vaccinated (drenched) against common diseases of (anthrax, blackleg, foot and mouth disease livestock skin disease) cattle in the area. They were (penned) 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 an individual holding pen (1.5× 2.5 m^2) with concrete floors on an open-air platform.

A randomized crossover design, with 21 days for each period, 2 weeks for adaptation and 7 days for data collection. In the beginning and last day of each of the experimental periods, all animals were weighed individually following overnight fasting to avoid gut content variation and diet allowance for the next period was recalculated according to body weight. Body weight was measured using a manual weighing balance (calibrated manually) and once animals stand calmly on it.

During the whole experimental trial, animals had free access to clean drinking water and mineralized salt licks. Test diet was provided once daily at 8:00AM prior to the provision of pasture hay and concentrate at 10:30 AM in a separate feeding trough individually opened for each pen. The four dietary treatments were consisted of the following:

1. Hay + 400 g DM CM
2. Hay + 400 g DM CM+ 200 g SE
3. Hay + 400 g DM CM + 400g SE, and
4. Hay + 400 g DM CM+ 600g SE

Where, DM, dry matter; SE, *S. elipticum; CM, concentrate mix,* the concentrate mix was made up of DM 947g/kg CM, ASH 100g/kg DM, CP 186g/kg DM, EE 50g/kg DM, NDF288g/kg DM, ADF235g/kg DM, ADL48g/kg DM, ME17.11MJ/kg DM and HC53g/kg DM.

3.4. Feed and Feces Sample Collection

To assess total diet digestibility, total fecal collection was performed. For this, bulls were fitted with fecal collection bags made from polyester clothing material using harnesses. Animals were allowed to adjust to the fecal collection bags 3 days before true collection for adaptation. Feces was quantitatively collected on a daily basis from each animal, weighed and 1% was sub-sampled, pooled on animal basis per period and frozen (-20°C) until chemical analysis. Feed leftovers was removed daily at 08:00 AM and weighed. During the collection period, samples of test and basal diets and refusals were collected, composited by animal per period, ground (1 mm screen) and kept frozen (−20°C) until laboratory analysis.

3.5. Chemical Analysis of Feed and Feces

Samples of feedstuffs, feed refusals and feces was analyzed for DM, CP, total ash, crude fiber (CF) and ether extract (EE) contents according to AOAC (1995) guidelines. Neutral detergent fiber (NDF) (Van Soest *et al*., 1991) and acid detergent fiber (ADF) and acid detergent lignin (AOAC, 1995) was followed. Determination of total extractable CT was based on oxidative depolymerization of CTs in butanol-HCl reagent using 2% ferric ammonium sulfate in 2N HCl catalyst (Porter *et al*. 1986). For chemical analysis (excluding N), the feces samples was oven dried at 105 °C for overnight. But to determine CP, wet mixed feces were directly used for N analyses. All chemical analyses were carried out in duplicate.

The following standard equations were used to estimate the compositions of feeds and performances of the animals;

The crude protein content (CP/kg) was calculated following (AOAC, 1995) as:

CP (g/kg DM) = % N × 6.25 …………………………………………….. [eq.1]

Where, 6.25 is the protein-nitrogen conversion factor for forages and mixed feedstuffs.

Average daily gain *(*ADG*)* was calculated (McDonald *et al*, 2010) as:

ADG (g/day) = [Weight at end of trial (g)-weight at start of trial (g)]/days in trial---- [eq. 2]

Daily feed intake (DFI) was calculated as (McDonald *et al*, 2010):

DFI = Total feed consumed (g)/days in trial --- [eq.3]

Feed conversion ratio (FCR) was calculated as (Ball and Pethick 2006):

FCR = Feed consumed (g)/body weight gained (g) -------------------------------------- [eq.4]

Apparent digestibility of nutrients in diets (g/kg DM) was calculated as (Osuji *et al*., 1993):

[(Nutrient consumed (g) - Nutrient excreted (g))/ Nutrient consumed] x 1000)) ------- [eq.5]

Metabolizable energy intake (MEI; kJME/kg $BW^{0.75}$) was estimated according to Luo *et al*. (2004) as:

MEI = 533 + (43.2 × ADG (g/kg $BW^{0.75}$)) -- [eq.6]

Metabolisable energy (ME; MJ/kg DM) contents of total diets were predicted from the equations of Abate and Meyer (1997) as:

$ME = 5.34 - 0.1365CF + 0.6926NFE - 0.0152NFE^2 + 0.0001NFE^3$ -------------------- [eq.7]

Where NFE, nitrogen free extract

Protein efficiency ratio (PER, McDonal *et al.,* 2010) was determined as follow:

PER = % Protein in diet × weight of diet consumed ---------------------------------- [eq.8]

Energetic efficiency (EnE, McDonald *et al.,* 2010) was determined as :

EnE = MEI/ADG... [eq.9]

3.6. Statistics Analysis

A three-way ANOVA was carried out following repeated measures design using mixed model procedures (PROC MIXED) of SAS 2013 version 9.4. Turkey's post-hoc test procedure was used to obtain confidence intervals for all pair-wise differences between means. Mean differences was considered significant at $P \leq 0.05$. The appropriate statistical model used was indicated below:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \beta\gamma_{jk} + \sum_{ijk}$$

Where, Y_{ijk} = the response due to the animal i; period j; treatment k; period treatment interaction effect;μ = the overall mean effect; α_i = the random effect of the i^{th} bulls (subjects; i = 1, 2, 3… 12); β_j = the fixed effect of the j^{th} experimental period (j = 1, 2, 4); γ_k = the fixed effect of the k^{th} treatment (k = 1, 2, …4); $\beta\gamma_{jk}$ = the interaction effect between feeding period j and treatment k; $\sum_{ijk}$ = the experimental error

Kendall's tau-b correlation coefficient was used to verify the magnitude and direction of relationships between growth performance and nutrient use efficiency parameters.

3.7. Cost-Benefit Analysis

Cost analysis was followed partial budget analysis procedure. Cost of the ingredients in each group, subjects, and labor cost was used for the cost comparison in relation to growth and feed intake. Experienced bull dealers were used to estimate the possible selling price of experimental bulls. The buying and selling price differences of the bulls in each treatment before and after the experiment was considered as total return (*TR*) in the analysis. For the calculation of the variable costs, the expenditures incurred on various feedstuffs were taken into consideration. The costs of the feeds were computed by multiplying the actual feed intake for the whole feeding period with the prevailing market prices. The prevailing prices of the feeds included in the transportation cost incurred to transport them to the experimental site. The labor cost was assumed to be constant across the treatment groups.

Partial budget measures profit or losses (Scott *et al*., 1995), which are the net benefits or differences between gains and losses for the proposed change. The amount of money left when total variable cost (*TVC*) is subtracted from total return (*TR*):

i. $NI = TR - TVC$

The change in net income (ΔNI) was calculated as the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC) as follows

ii. $\Delta NI = \Delta TR - \Delta TVC$

The marginal rate of return (*MRR*) measures the increase in net income (ΔNI) associated with each additional unit of expenditure (ΔTVC) and was calculated as

iii. $MRR = (\Delta NI/\Delta TVC) \times 100$

4. Results and Discussion

4.1 Chemical composition of experimental diets

The feed ingredients and their chemical composition are presented in Table 2. The NDF and ADF contents of the basal feedstuffs used in this study were higher by 103% and 93%, respectively than that of test diet. Likewise, the CP content of tannin rich browse mix was higher by 97% than that of hay used for basal feeding. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents of the test diet, *Sapium ellipticum,* was found to be fair- meaning that fibre composition less than 50 g DM/kg is considered to be fair (ARC, 1980; McDonald et al., 2010). Leaves of *Sapium ellipticum* could be also good sources of CP (crude protein) and Metabolizable energy for *Bos taurus* × *Bos indicus* cattle.

Table 2.Chemical composition (g/kg DM) and metabolizable energy content (MJ/kg DM) of the feedstuffs included in the study

Diet sources	DM	Ash	EE	CP	NDF	ADF	ADL	HC	CT	ME
Hay	904	115	39	65	651	510	127	141	0	9.70
S. elipticum	910	71	18	132	320	264	52	56	2.5	9.30
Concentrate	947	100	50	186	288	235	48	53	0	17.11

DM, dry matter; EE, ether extract; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; HC, hemicelluloses; CT, condensed tannin; ME, Metabolizable energy

As indicated in the Table 2 the basal diet, natural pasture hay, contained low proportion of crude protein (65 g DM/kg) and high proportion of dietary fibers (> 50 g DM/kg). Crude protein content of the hay recorded in the present study was lower than 67 g CP /Kg DM reported by Aschalew and Getachew (2013). As expected, the CP content of hay is lower than values recorded for other treatment diets. The CP content was lower than the lower limit of 70 g CP /kg DM required for optimum rumen function (Van Soest, 1994). As a result, the natural pasture hay diet one (T1) could not satisfy the maintenance requirements of ruminant animals. When the CP content of roughages is below 70 g/kg DM (Topps, 1995), there will be impaired rumen function resulting in poor digestion of feeds, low DM intake and poor animal performance.

The NDF content of hay observed in this study was lower than values (740 g/kg DM) reported by Aschalew and Getachew (2013), but higher than 625 g DM/kg D (Biru, 2008). The ADF and ADL contents of the hay were also higher than 487 g ADF/kg DM and 85.1g ADL/kg DM values reported by Aschalew and Getachew (2013) and 436 g ADF/kg and lower than180 g ADL/kg contents reported by Biru (2008) for natural pasture grass hay.

The tannin content (2.5g/kg CT) recorded for *S. elipticum* established to have beneficial effect for the studied bulls. At lower concentrations tannins have antioxidant, anti-helminthes and anti-microbial effects (Makkar, 2003, Frutos *et al*., 2004; Chufamo *et al*., 2013). Animals respond differently to dietary tannins in part because of the variation in the biological activity of the tannins themselves (Reed, 1995; Makkar *et al*., 1995). It has been believed for some considerable period that tannin above 50 g/kg DM can become a serious anti-nutritional factor in plant materials fed to ruminants (McLeod, 1974; Makkar, 2003). Barry (1983) and his colleagues have demonstrated with *Lotus pedunculatus* that the ideal concentration of condensed tannins in this forage legume is between 2-4 % of the diet dry matter, at which level they bind with the dietary proteins during mastication and appear to protect the protein from microbial degradation in the rumen. Thus a low level of tannin in plant materials has been usually accepted as being able to protect protein of forages and allow a higher efficiency of feed utilization by the animal. Yet, the anti-nutritional effects of tannins did not affect growth and nutrient utilization of tropical sheep and goat breeds (Yisehak et al., 2016). If the protein-tannin complex dissociates under acid conditions, then the protein can be digested in the lower gut.

4.2. Effect of Sapium ellipticum leaf supplementation on feed intake

The average feed and nutrient intakes of *Bos taurus* × *Bos indicus* bulls fed different level of diets are shown in Table 3. It is evident from the table that the lowest DM intake was observed in group of bulls fed diet T_1 and the highest value was recorded for diet T_4 (P<0.001). Dietary inclusion of *S. elipticum* with commercial concentrate mix had a significant improvement of feed intake with increasing trends from T_2 through T_4 compared to non- *S. elipticum* supplemented group (P<0.001). The difference between treatments and periods are also highly significant (P<0.001). Animals received concentrate mix with different levels of *S. ellipticum* (diets T_2, T_3 and T_4) and hay consumed significantly (P<0.001) higher amounts of DM than those received hay and concentrate (T_1) alone. It is evident from the intake data of the present experiment that supplementation of *S. ellipticum* with concentrate mix based diet did not depress the intake of hay or total dietary intake rather it stimulated the total feed intake. As it is clearly recorded the present study that there was a significant effect on total DM intake with increasing *sapium elipticum* levels across treatments. These results agree with the reports of Devendra, (1990) and Yisehak and Geert (2013) in that increases in the supply of good quality forages and dietary nutrients for the animals is there for especially important to improve the prevailing low level of animal performance.

Total nutrient supply is the summation of intake and digestibility, which depends on adequate dietary nitrogen. The extent and rate of digestion of fibrous feeds are increased by nitrogen supplements, resulting in a greater DM intake. This could be reflected in the extent of live weight change of animals (Preston and Leng, 1987; Balic et al., 2000). Feed intake in ruminants fed on high energy diets is controlled metabolically, but in those fed on forages it is limited by the rate at which feed can be digested in the rumen and addition of CP supplement may stimulate efficient rumen fermentation, more passage rate and intake. This indicated that there is direct relationship between CP content of feeds and feed intake (McDonald *et al.*, 2010). Increased CP intake with increasing CP levels in supplements in the present study corresponds well with other findings (Gilbery *et al*., 2006). Average daily ME intake was significantly (P<0.001) higher in animals fed diet T2, T3 and T4 compared to T1 which is consistent with the findings of Yasmin (2006).

The increased organic matter OM intake significantly high ($P<0.001$) in T2, T3 and T4 compared to T1 as the level of *S. ellipticum* increased. Similarly, the intake of NDF, ADF, ADL and EE significantly high ($P<0.001$) in T2,T3 and T4 compared to T1which is indicate that intake of total OM and CP as well as ME followed a similar trend to that of total DM intake, and as such increased with increasing level of *S. ellipticum* supplementation. The higher level of energy in *S. ellipticum* than the hay was apparent from greater differences in ME intake among treatments in this study. On the other hand, despite the lower CP level in *S. ellipticum* than the hay used in the current study, intake of CP increased with rise in the level of supplemental *S. ellipticum*, indicating that improvements in total DM intake to be a major factor to greater intake of nutrients by *Bos taurus* × *Bos indicus bulls* in this study. In general, forages that contain less than 700 g NDF/kg DM and more than 80 g CP/kg contains enough digestible protein and energy, vitamins, and minerals to maintain older animals. Thus, even many low quality forages and crop residues can meet the maintenance needs of some classes of animals, if protein and minerals are adequate (Ball, 2001).

Bulls in the (T_1) consumed less DM of grass hay as compared to different levels of *S. ellipticum* supplemented treatments, because the present study indicated that as levels of *S. ellipticum* increase the intake of bulls increase. The feeding value of roughages such as natural pasture hay is usually limited because they are low in nitrogen, are high in ligno-cellulosic compounds and, therefore, low in fermentable carbohydrates (Preston and Leng, 1987). The higher nutrient intakes particularly higher CP intakes helped the bulls acquire protein required for growth better than the bulls on natural grass hay supplemented with concentrate mix indicating the advantages of *S. ellipticum* supplementation to improve intake of nutrients specially protein than basal diets. The increase in DMI and CPI as a result of supplementation of legumes to grasses was reported by (Abraha, 2013).

Table 3. Least square means for daily nutrient (g DM /d) and energy intake (MJ/kg DM) in *B.taurus* × *B.indicus* bulls fed hay and concentrate mix with varying levels of *S. ellipticum*

	Treatment, mean.					***P***		
Nutrients	**T_1**	**T_2**	**T_3**	**T_4**	**SEM**	**B**	**C**	**B×C**
DM	4343^{d}	4878^{c}	5465^{b}	6112^{a}	2.453	<0.001	<0.001	<0.001
CP	531^{d}	584^{c}	642^{b}	707^{a}	4.261	<0.001	<0.001	<0.001
EE	117^{c}	128^{bc}	141^{b}	155^{a}	2.205	<0.001	<0.001	<0.001
OM	3264^{d}	3691^{c}	4160^{b}	4676^{a}	3.552	<0.001	<0.001	<0.001
ADF	1094^{d}	1304^{c}	1534^{b}	1787^{a}	4.846	<0.001	<0.001	<0.001
NDF	1158^{d}	1374^{c}	1612^{b}	1873^{a}	5.114	<0.001	<0.001	<0.001
ME	4110^{d}	4621^{c}	5183^{b}	5801^{a}	5.326	<0.001	<0.001	<0.001

*DM, dry matter; CP, crude protein; EE, ether extract; OM, organic matter, ADF, Acid detergent fiber; NDF, neutral detergent fiber; ME, Metabolizable energy; SEM, standard error of mean; B, period, C, treatment; B×C, interaction effect of species & treatments; P, probability; [a,b]Means with different superscripts in the same row are significantly different (P< 0.05);***P<0.001 T_1,treatment one, T_2, treatment two, T_3, treatment three and T_4, treatment four*

4.3 Effect of S. ellipticum leaf supplementation on apparent digestibility

The effects of supplementing varying levels of *S. ellipticum* leaves with hay and concentrate mixes on apparent digestibility is presented in Table 4. The DM digestibility of diets in T_2, T_3 and T_4 were significantly (P<0.001) higher than that of diet T1. As it is shown in Table 4, it is evident that the digestibility of DM increased significantly (P<0.001) with the increased level of S. *ellipticum.* This could be attributed to increasing concentrations of protein, minerals and carbohydrate digestion due to supplementation of the browse plant. Beaty *et al*. (1994) established the positive associations between DM digestibility and increased crude protein content of feed supplements. Greathouse *et al*. (1974) reported considerably existence of lower digestibility of DM due to lower amounts of protein in Hereford steers, which do agree with the present findings. In actual fact, CP digestibility improved linearly with the increase of protein supplementation in the *S. elipticum* based diet. Greathouse *et al*. (1974) and Umunna *et al*. (1980) observed gradual increase in protein digestibility with increased protein levels. Chowdhury (1999) also stated that increasing levels of mustard oil cake in diet improved CP digestibility. Mupangwa *et al.* (2000) suggested that adding such energy sources can result in increasing ammonia utilisation and microbial protein production when feeding rations based on forage legumes. As such may be the reason for improvement in DM and nutrient digestibility with greater amount of *S. ellipticum* supplementation.

Digestibility of OM was also found to be highly significant among treatments (P<0.001). The apparent digestibility of OM was greater (P<0.001) for the highest level of *S. ellipticum* supplemented groups compared to control treatment (T1) and values for T2, T3 and T4 (P < 0.001). The improvement in apparent digestibility of OM is associated with *S. ellipticum* leaf supplementation. That means, as the level of S. ellipticum increase the digestibility of OM was increased.

Table 4. Least square means for apparent digestibility of nutrients (%) in *B. taurus* × *B. indicus* bulls fed hay and concentrate mixes with varying levels of *S. elipticum*.

	Treatment, mean					***P***		
Nutrients	**T_1**	**T_2**	**T_3**	**T4**	**SEM**	**B**	**C**	**B×C**
DM	50^{d}	64^{c}	69^{b}	75^{a}	2.406	<0.001	<0.001	<0.001
CP	53^{d}	67^{c}	72^{b}	82^{a}	1.566	<0.001	<0.001	<0.001
EE	52^{d}	64^{c}	73^{b}	83^{a}	2.367	<0.001	<0.001	<0.001
OM	53^{d}	67^{c}	72^{b}	81^{a}	3.156	<0.001	<0.001	<0.001
NDF	49^{d}	55^{c}	64^{b}	75^{a}	2.477	<0.001	<0.001	<0.001
ADF	46^{c}	51^{bc}	59^{b}	69^{a}	3.368	<0.001	<0.001	<0.001

*DM, dry matter; CP, crude protein; EE, ether extract; OM, organic matter; NDF, neutral detergent fiber; ADF, Acid detergent fiber; SEM, standard error of mean; B, period, C, treatment; B×C, interaction effect of period & treatment; P, probability; [a,b]Means with different superscripts in the same rows are significantly different (P< 0.05);***P<0.001 T_1,treatment one, T_2, treatment two, $T_{3,}$ treatment three and $T_{4,}$ treatment four*

4.4 Effect of S. ellipticum leaf supplementation on growth performance and feed conversion efficiency

The live weight of experimental animals increased with increasing levels S. *ellipticum* (*P*<0.05). Accordingly, 123, 207, 251 and 334 grams of ADG were recorded for the respective treatments (Table 5). Increasing the level of S. *ellipticum* in the diet had a positive influence on feed conversion ratio of DM and CP compared to the control group (T1). The lowest efficiency of feed utilisation was observed in animals offered only hay with concentrate mix (T1). The present study agrees with the findings of McDonald *et al.* (2010) in that forage legumes improve the growth performance of young ruminants on fibrous diets through the provision of more nutrients and optimization of fermentative digestion in the rumen- the meaning is that growth performance of animals on poor-quality roughages vary with the protein source. The factors responsible for variations in animal response may include solubility, rate and extent of degradability of protein in the rumen (Osuji et al., 1993; Norton, 1994). There is a considerable interest in protein sources that are slowly degraded in the rumen. These relatively resistant protein sources or intestinal digestion can have special value for young growing ruminants whose protein requirements are relatively high (Tamminga, 1979; Orskov et al, 1988). On the other hand, dietary protein consumed by ruminants that is degraded in the rumen (RDP) is available for use by the rumen microbes in order to make microbial protein (Nocek et al., 1980; McDonald *et al.*, 2010). When formulating diets for growth of ruminants, various criteria can be used to select the protein supplements including palatability, ruminal protein degradability, protein quality, intestinal absorption of amino acids and impact on animal performance (ARC, 1980; NRC, 2007; Castells et al., 2012).

Feed conversion ratio of animals fed diets containing different levels of *S. ellipticum* is shown in Table 5. The results revealed that there were significant (P<0.001) differences among the diets for converting feed into live weight gain. Previous works of Umunna et al. (1980) revealed that increase in protein levels after a certain level declined the feed conversion. In contrary, Greathouse et al. (1974) reported higher rate of feed conversion due to rising of protein level. The differences in results of the two authors might have occurred due to the breed difference as Rogerson et al. (1968); Zemmelink et al.(1973) reported that feed conversion ratio was very much related to animal species and breed differences. The results revealed that the protein efficiency ratio differed significantly (P<0.05) between unsupplemented and supplemented groups and highest value was observed in T4 (Table 5). Energetic efficiency of converting feed energy into live weight gain was significantly better in supplemented groups than unsupplemented group. The results of this study also agreed with the finding of Barry (1983) in that a low level of tannin in plant materials has been usually accepted as being able to protect protein of forages and allow a higher ratio of feed utilization by the animal.

Table 5. Least square means for growth performance (g ADG /day), FCR (g DMI/ g ADG), PER (g ADG/g CP) and energetic efficiency (MEI/ADG) in *B. taurus* × *B. indicus* bulls fed hay supplemented with varying levels of *S. ellipticum* and concentrate mix

	Treatment, mean					*P*		
Parameters	T_1	T_2	T_3	T4	SEM	B	C	B×C
ADG	123^{d}	207^{c}	251^{b}	334^{a}	1.521	<0.001	<0.001	<0.001
FCR	35^{a}	24^{b}	22^{c}	18^{d}	1.443	<0.001	<0.001	<0.001
PER	0.067^{a}	0.041^{b}	0.034^{c}	0.026^{d}	1.245	<0.001	<0.001	<0.001
EnE	116^{d}	196^{c}	238^{b}	317^{a}	3.451	<0.001	<0.001	<0.001

*ADG, average daily weight gain; FCR, feed conversion ratio (DM intake /ADG); PER, protein efficiency ratio (*ADG/CPI*); EnE, energetic efficiency (MEI/ADG); SEM, standard error of means; B, period, C, treatment; B×C, interaction effect of species & treatment; P, probability;* ^{a,b}*Means with different superscripts in the same rows are significantly different (P< 0.05);***P<0.001* T_1*,treatment one,* T_2*, treatment two,* T_3*, treatment three and* T_4*, treatment four*

4.5 Correlation between growth performance and nutrient use efficiency parameters

The Pearson correlation coefficient between average daily weight gain, nutrient intake, and digestibility as well as feed conversion parameters is presented in Table 6. Dry matter intake was positively correlated (P<0.01) with average daily gain, most of feed intake, digestibility and feed conversion parameters. As the total DM intake increased from T1 through T4, the intake and digestibility of other nutritive value parameters increased significantly (P<0.05). This may be due to the reasonable CP contents and digestibility of *S. ellipticum*. Yisehak and Geert (2013) reported passable availability of digestible nutrients in *S. ellipticum* leaves that consecutively promote optimum functioning of rumen micro-biota. The modest concentrations of tannins in the *S. ellipticum* leaves might also help animal's growth and use nutrients efficiently. Brooker *et al*. (1999) also reported that livestock animals consuming tannin-rich diets fewer than 50 g CT/kg DM usually develop a positive nitrogen balance and gain weight and body condition.

Table 6. The correlation coefficient between average daily weight gain and nutrient use efficiency parameters

	DMI	OMI	CPI	NDFI	MEI	DMD	OMD	CPD	NDFD	ADG	FCR	PER	EnE
DMI	1.000												
OMI	0.581*	1.000											
CPI	0.660*	0.835*	1.000										
NDFI	0.281*	0.379	0.436**	1.000									
MEI	0.522**	0.417	0.630*	0.094	1.000								
DMD	0.569*	0.800*	0.144*	0.085	0.531**	1.000							
OMD	0.454**	0.831**	0.537**	-0.552**	0.494*	0.264*	1.000						
CPD	0.849**	0.513	0.624**	0.364**	0.694**	0.629**	0.729**	1.000					
NDFD	0.264*	0.104	0.252	0.065	0.383**	0.283*	0.004	0.446*	1.000				
ADG	0.565**	0.713**	0.517*	-0.009	0.533**	0.884**	0.633**	0.6311*	0.342*	1.000			
FCR	0.362**	0.551*	0.329*	-0.058	0.545**	0.484**	0.740*	0.795*	0.284*	0.981**	1.000		
PER	0.369*	0.443*	0.266*	-0.104	0.541**	0.499**	0.540*	0.829*	0.390**	0.924**	0.366*	1.000	
EnE	0.331*	0.458**	0.257*	-0.181	0.734**	0.543**	0.580*	0.517**	0.411**	0.866**	0.441	0.629**	1.000

*DMI, dry matter intake; OMI, organic matter intake; CPI; crude protein intake; NDFI, neutral detergent fiber intake; MEI, metabolizable energy intake ; DMD, dry matter digestibility; CPD, crude protein digestibility; OMD, organic matter digestibility; NDFD, neutral detergent fiber digestibility; ADG, average daily weight gain; FCR, feed conversion ratio; PER, protein efficiency ratio; EnE, energetic efficiency; **P<0.01*

4.6 Partial Budget Analysis

The partial budget analysis of the feeding regime used in this study is given in Table 7. The highest total income was obtained from bulls in T4 and the lowest was from non supplemented group. These values were directly related with the live weight gain, body conditions of bos taurus × bos indicus bulls and the prices of experimental feeds. The net income per animal was highest for the bulls in T4. Best net income gained in T4 were due to the highest level of S. ellipticum (600g/day) and its availability in the research area which is not costly, better feed conversion efficiency and better body weight gain of the bulls. On the other hand, the net income lowering of bull in T1 was due to low rate in body weight gain of bull during the experimental period. The change in net income was higher in T4 followed by T3 and T_2 in that order which is accompanied by higher marginal rate of return in the order of T4>T3>T2. This indicated that one ETB increment to purchase supplement feed would result to attain live weight that would bring a profit of 5.0 ETB for T4, 4.46 ETB for T2 and 3.60 ETB benefit for T3. Therefore, based on the results of animal performance and most of partial budget analysis results, T4 is a better dietary regime.

Table 7. Profitability of *Bos taurus* × *Bos indicus* bulls fed grass hay and supplemented with concentrate mix and varying levels of *Sapium elipticum* leaves.

Variables	Treatments, mean				SEM	*P*		
	T_1	T_2	T_3	T_4		B	C	B×C
Purchasing price of bulls (ETB/head)	1250	1250	1250	1250	1.199	-	-	-
Total hay consumed (kg/head)	450	477	504	530	3.204	0.022	0.047	<0.001
Cost for hay (ETB/Bull)	481	519	557	593	2.011	0.021	0.036	<0.001
Cost for labour (ETB/Bull)	150	150	150	150	0.314	<0.001	<0.001	<0.001
Total feed cost/TVC (ETB)	934	972	1,010	1,046	1.005	<0.001	<0.001	<0.001
Gross income (ETB)	2,400	2,600	2,750	3,000	0.576	<0.001	<0.001	<0.001
Total return/TR (ETB)	1,150	1,350	1,500	1,750	0.554	<0.001	<0.001	<0.001
Net income/NI (ETB)	216	378	490	704	0.267	<0.001	<0.001	<0.001
Δ NI (ETB)	162	274	488	541	0.259	<0.001	<0.001	<0.001
Δ TVC (ETB)	38	76	112	155	0.097	<0.001	<0.001	<0.001
Δ TR (ETB)	200	350	600	679	0.042	<0.001	<0.001	<0.001
MRR (%)	426^{bc}	360^{c}	446^{b}	500^{a}	3.410	<0.001	<0.001	<0.001

*TR: Total return; NI: Net income; TVC: total variable cost; ΔTVC: change in total variable cost; ΔTR: change in total return;ΔNI: change in net income MRR: marginal rate of return; ETB: Ethiopian Birr SEM, standard error of means; B, period, C, treatment; B×C, interaction effect of species & treatment; P, probability; ^{a,b}Means with different superscripts in the same rows are significantly different (P< 0.05);***P<0.001 $T_{1...}T_4$,treatment*

5. Conclusion and recommendation

From this experiment it can be concluded that supplementation of different levels of a mild tannin containing diet, *S. ellipticum* with same levels of concentrate mixes and hay based diet improved nutrient intake, digestibility and live weight gain of zebu hybrid (Bos *indicus*× *Bos taurus*) bulls. The size of weight gain and nutrient use parameters were increasing accordingly with the increased levels of *S. ellipticum* across the treatments. Furthermore, *S. ellipticum* (132 g CP/kg DM) with concentrate mixture having 186 g CP/kg DM may be supplemented at the rate of 10 percent of DM intake per day to the diets of zebu hybrid bulls for achieving optimum growth, nutrient use and economic efficiency. Accordingly, its more economically attractive to adopt *S. ellipticum* in Bos *indicus* × *Bos taurus* bull diets containing mild tannin, which would also play a pivotal role in preventing anthelmintic and microbial problems of the animals. A further research is required for comprehensive feeding value evaluation of the mild tannin containing diets inorder to carry out nutrient partitioning, bioavailability and energy supply, before farm-scale application is recommended.

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