EVALUATION OF REPLACING WHEAT BRAN WITH *ENSETE VENTRICOSUM* CORM ON FEED INTAKE, WEIGHT GAIN, IN-VITRO DIGESTIBILITY AND ECONOMIC EFFICIENCY OF DOYOGENA SHEEP

MSc THESIS

By

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A THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, COLLEGE OF AGRICULTURAL SCIENCE, SCHOOL OF GRADUATE STUDIES, WACHEMO UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ANIMAL PRODUCTION AND HEALTH.

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This is to certify that the thesis entitled **"EVALUATION OF REPLACING WHEAT BRAN WITH *ENSETE VENTRICOSUM* CORM ON FEED INTAKE, WEIGHT GAIN, IN-VITRO DIGESTIBILITY AND ECONOMIC EFFICIENCY OF DOYOGENA SHEEP"** submitted to partial fulfillment of the requirements for the degree of Master of Science in Agriculture with a specialization in ANIMAL PRODUCTION AND HEALTH of the Graduate Program of the Department of Animal Science, College of Agricultural Sciences, **Wachemo University**. The thesis is a record of original research carried out by **MULATUA ABEBE** Id. No **WCU1401581**, under our supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during this investigation have been duly acknowledged. Therefore, we recommend that it will be accepted as fulfilling the thesis requirements.

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We, the undersigned, members of the Board of Examiners of the final open defence by having read and evaluated her thesis entitled "**EVALUATION OF REPLACING WHEAT BRAN WITH *ENSETE VENTRICOSUM* CORM ON FEED INTAKE, WEIGHT GAIN, IN-VITRO DIGESTIBILITY AND ECONOMIC EFFICIENCY OF DOYOGENA SHEEP** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in Animal Sciences with Specialization in Animal Production and Health.

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I hereby declare that this MSc thesis Specialty or equivalent thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged. I submit this thesis to Wachemo University in partial fulfillment of the requirements for the Degree of Master of Science. The thesis is deposited at the library of the University to be made available to borrowers for reference. I solemnly declare that I have not so far submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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This is to certify that the thesis entitled "submitted in partial fulfilment of the requirements for the degree of **Master's** with specialization in **Animal Production and Health**, the Graduate Program of the Department of Animal science School of Agriculture, and has been carried out by **MULATUA ABEBE Id.No WCU1401581**, under my/our supervision. Therefore we recommend that the student fulfil the requirements and hence hereby can submit the thesis to the department for defence.

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DEDICATION

I dedicate this thesis manuscript to all members of my family.

BIOGRAPHICAL SKETCH

The author, Ms. Mulatua Abebe, was born on November 18, 1985, in Jajura Administration, Hadiya Zone, Central Ethiopia region from her father Ato Abebe Gaenamo, and her mother W/ro Almaz Fiseha. She attended her elementary education (Grades 1 to 6) at Jajura St. Piter School, a primary school in Jajura primary school from 1991-1999, and Secondary education at Gimbchu Secondary School from 2000 to 2001. She joined Wolaita sodo ATVET College in the Animal Science department from 2004 to 2007 graduating with a Diploma. She was employed in the Hadiya Zone Soro Woreda Agricultural Office in Hangeda Kebele for one year, Sundusa Kebele for 2years, and Bona Kebele for 3 years total of 6 years in a government work development agent position later she joined Wolayita Sodo University's Department of Animal Science and Range Management by B.Sc. degree she complete her journey in 2018 after completing she also represent for Hadiya Zone Soro woreda Livestock and Fishery Office Deputy Head for 2 years.

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LIST OF ABBREVIATION

ADF	Acid detergent fiber
ADG	Average daily gain
ADL	Acid detergent lignin
BWC	Body weight change
CBBP	Community-Based Breeding Program
CP	Crude Protein
DAGRIS	Domestic Animal Genetic Resources Information System
DDFEDO	Doyogena District Finance and Economy Development Office.
DM	Dry matter
DMI	Dry matter intake
EAR	Ethiopian Agricultural Research
EARO	Ethiopian Agricultural Research Organization
Ec	Enset corm
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization
FCE	Feed Conversion Efficiency
HH	House hold
ICARDA	International Centre for Agricultural Research in Dry Areas,
LSD	Least Significant Difference
NDF	Neutral detergent fiber
NH3	Ammonia

NI	Net income
NP	Natural pasture
NR	Net revenue
NSC	Noug seed cake
RCBD	Randomized complete block design
SAS	Statistical Analysis Software
SE	Standard error
TR	Total return
TVC	Total Variable costs
VC	Variable costs
Wb	Wheat bran

Evaluation of Replacing Wheat Bran with Enset Ventricosum Corm on Feed Intake, Weight Gain, In-Vitro Digestibility and Economic Efficiency of Doyogena Sheep

ABSTRACT

The objective of the study is to evaluate the effect of replacing different levels of wheat bran by Ensete ventricosum corm on weight gain, feed intake, in-vitro digestion, and economic efficiency of Doyogena sheep. Forty-two Doyogena yearling rams with an initial body weight of 28.95kg (mean±SE) were randomly divided into six feeding groups of seven animals per treatment in a completely randomized block design. The experiment was conducted for 90 days of feeding trial and 14 days of adaptation. All collected data throughout the experimental period were analyzed using one-way analysis of variance (ANOVA) in the statistical analysis software SAS (9.2 version). All animals were fed on natural pastures and nuge seed cakes. The supplements were offered at the rate of 300 g/day, which were offered twice per day during morning and night; (T1)control group grazing only+120 nuge seed cake, (T2) grazing+180gwheat bran+120g nuge seed cake, (T3) grazing+135g wheat bran+120g nuge seed cake + 45g corm (T4) grazing+90g wheat bran+120 g nuge seed cake + 90g corm,(T5) grazing+45g wheat bran+120 g nuge seed cake +135g corm and T6 grazing+0 g wheat bran+120 g nuge seed cake+180gr corm.. Higher weight gain of the sheep was recorded for sixth treatment (16.5kg/90d) days. FCE was higher for those sheep fed on 180g enset corm compared to sheep fed 180g wheat bran. The partial budget analysis shows that the change in total variable cost of all treatment groups was positive, but the net return was obtained in the order of T3>T6>T4>T5>T2>T1. The result of the present study has indicated that in areas where access to wheat bran is absent, enset corms could be used as a potential alternative to replace wheat bran as long as it is economically feasible and easily accessible for smallholder production systems. Thus, based on the present finding, it can be concluded that enset corm has the potential to be a 100% replacement for wheat bran in terms of energy feed without compromising the growth performance and financial effectiveness of sheep fattening.

Keywords: Doyogena sheep; Digestibility; Enset corm; Economic efficiency; Wheat bran; Weight gain

1. INTRODUCTION

Ethiopia has the largest livestock population in Africa, including 65 million cattle, 40 million sheep, 51 million goats, 8 million camels, 49 million poultry and 6.96 million bee hives. It is estimated to be found in sedentary rural and pastoral areas of the country. (CSA, 2020). Sheep are exceedingly versatile to a wide extent of situations claimed by smallholder ranchers as a necessary portion of the animal sub-sector (Zelalem, 2016). Roughly 75% of the sheep are kept in smallholder blended ranches within the good country ranges, which cover zones of over1500 height and get over 700 mm of yearly precipitation, whereas the remaining 25% are found within the marshes. Sheep are customarily kept in smallholdings and are related to the small-scale asset destitute animal’s guardians (Zewdu, 2008). Indigenous sheep in Ethiopia have a multipurpose part for smallholder agriculturists as sources of wage, meat, skin, fertilizer, and coarse fleece or long bushy downy. They are too implies of chance evasion amid trim disappointment. In this way, expanding the current level of efficiency of sheep is basic to meet the requests of the ever-increasing human populace (Mengesha and Tsega, 2012).

Lacking and low-quality diets are major confinements that decrease sheep efficiency (Belete, 2009; Alemu, 2008). The most common cause of nourishment shortage these days is the diminished brushing arrives owing to an assortment of components. As a result, one of the numerous tactics that investigation ought to illuminate is building the most excellent Zero-brushing nourishing framework (EIAR, 2018). Creating the most excellent bolster for indoor sheep meat generation is basic these days, particularly if this action is to be included in endeavors to make strides in nourishment security and occupations. Indoor bolstering of sheep with new or green feed grass is invaluable in numerous ways. In any case, due to a need to arrive, restricted supply, and costly costs, grass hay-based sheep fattening isn't regularly utilized. Other nourishing choices, such as edit buildups, are becoming progressively vital as sources of roughage bolsters for ruminants (EIAR, 2017).

Feed supply from natural pasture fluctuates following seasonal dynamics of rainfall (Alemayehu, 1998; Solomon *et al.*, 2008b). Poor grazing management contributed to a shortage of feed resources as a result of the replacement of productive and nutritious flora by unpalatable species (Ahmed, 2006). The quality of native pasture is very low especially in the dry season due to their low content of digestible energy and protein and high amount of fiber. This is much worse for crop residues owing to their lower content of essential nutrients (protein, energy, minerals, and vitamins) and lower digestibility and intake (Chenost and Sansoucy, 1991; Zinash *et al.*, 1995). Natural pasture is the major feed source for livestock in many parts of Ethiopia. However, productivity and availability of pasture are gradually decreasing because of increased cultivation area, overstocking, and resultant overgrazing.

Therefore, it is important to find alternative sources of supplements that could easily be obtained by farmers and have food-feed value. Such sources of supplement could be *enset (Ensete ventricosum)* under small-scale production systems in the central and southwestern parts of Ethiopia. *E. ventricosum* originated in Southeast Asia. Nevertheless, the wild representatives of the genus *Ensete* are found throughout Africa and Southern Asia Kress *et al.*, (2001).

In Africa, it occurs widely across the continent in the western, central, eastern, and southern parts Jones (2000). Unlike its widespread distribution, *enset* has only ever been domesticated in Ethiopia. Even within Ethiopia, *enset* cultivation as a food crop is confined to a relatively small region of the southwest, in areas inhabited by speakers of Semitic, Cushitic, and Omotic languages. R. Blench, (2007). *E. ventricosum* is a multipurpose crop commonly known by its vernacular name enset and widely cultivated in south and southwestern Ethiopia. It is a traditional crop that makes up the *enset*-based farming system.

Enset is broadly developed in southern Ethiopia basically for human utilization. The clear-out and leaf midrib of the inset constitute 23 % of the full dry matter of the *enset*, which is tall in crude protein. In this manner, clear out-of-onset might be utilized as a source of protein supplement to destitute quality nourishment (Fekadu and Ledin, 1997; Nurfeta *et al.*, 2008a). *Enset* leave can play a critical part in supplementing the diet of animals, and creatures, particularly amid the dry season and dry spells a long time. *Enset* is developed at heights extending from 1200 to 3100 meters over ocean level with normal yearly precipitation prerequisites extending from 1100 to 1500 mm, temperatures extending from 10 to 22°C, and relative mugginess extending from 63 to 80% in most inset-growing areas. Decently acidic to soluble soil with a pH of 5.6 to 7.3 is great or ideal for *enset* development Bezuneh (1966) and Addis (2005). *Ens*et has been traditionally ranked first as a planted staple food crop in the highlands of central, South, and southwestern Ethiopia, and it is cultivated as a food security crop, source of nutrition, and generation of revenue. Kocho, bulla, and *amicho* are the most common traditional food products prepared from *enset*. The major food product, *kocho,* is prepared by fermenting a mixture of scraped pulp from the pseudostem, pulverized corm, and inflorescence stalk. The average *kocho* per plot yield is relatively low in the cold wet mid-altitude zones above 3000 meters above sea level and warm sub-humid lowlands below 1900 meters above sea level while the highest yield is produced in the humid to mid-highland zones between 2000 and 3000 meters above sea level (Sahle *et al.*, 2018).

The corm can be harvested at almost any stage during the growing season. The energy yield of onset is significantly more than that of several bowls of cereals as well as potatoes, sweet potatoes, and bananas (Pijls *et al.*, 1995).In the 2020 cropping year, 157,705,763 *enset* trees were harvested across *enset*-growing regions in Ethiopia. As a result, the total output in *amicho*, *kocho*, and Bula was approximately 4,408,830.98; 4,894,387.77; and 147,503.96 metric tons (Mt.), respectively (CSA, 2021). The corm *(amicho)* has the highest concentration of most soluble carbohydrates and starch, and the least protein, fiber, cellulose, and sugar, while the pseudo stem has the least lignin (Mohammed *et al.*, 2013). The corm, botanically the underground stem of enset, is used for vegetative propagation of *enset*. The corm can be processed with a pseudo-stem to produce *kocho*. It is also cooked and eaten like a potato. It is a sustainable food source, which can be uprooted and used at any time during the life span of the plant, particularly during an extended drought. Mohammed *et al*. (2013) reported that *ens*et corm contained 17 of the 20 amino acids, in concentrations ranging between 1.2 and 8.7g per 100 g of protein and between 25.6 and 186.6 mg per 100 g of the corm, and the amounts of most amino acids are higher than that of potato while amino acids not present in a sufficient amount in *ense*t corm are aspargine, glutamine, and tryptophan. Ajebu and Eik (2014) indicated that corm could be used as an alternative energy source in the diet of sheep. Similarly, Ajebu *et al.*, (2008) observed the highest non-fiber carbohydrate contents in *enset* fractions, especially in pseudostem and corm than the leaf lamina. The Corm had 11.9MJ/ kg DM metabolizable energy while the pseudostem had 11.7 MJ/ kg DM (Mohammed *et al.*, 2013). In the Southern and Southwestern parts of the country, *enset* provides human food, animal feed, fiber, construction materials, and pharmaceuticals to more than 20% of Ethiopia's population (Azerefegne *et al.*, 2009; Borrell *et al.*, 2019).

1.1. Statement of Problem

Wheat bran is not accessible for people who are living in remote areas, constraints of wheat bran can include limit availability due to transportation challenges, higher costs due to logistics, and potential spoilage if not stored properly. Wheat bran is susceptible to spoilage, and high transportation costs because of remote locations, and communities might lack the infrastructure or knowledge to utilize it effectively as animal feed. For this reason, alternative energy feed resources that smallholder farmers can get easily must be mentioned like *enset* corms either raw or processed providing them with essential nutrients and energy to maintain their health and productivity. *Enset* corms are rich in carbohydrates, making them a valuable energy source for livestock, particularly in times of scarcity or during the dry season when another fodder source may be limited. Sheep can consume *enset* corms, either raw or processed, providing them with essential nutrients and energy to maintain their health and productivity. *Enset* corm is economically feasible and can provide small-scale farmers with a stable source of income, as it is a perennial crop that requires minimal inputs once established.

1.2. Objectives of the study

1.2.1. General objective

To evaluate the impact of replacing wheat bran with *ense*t corm on feed intake, weight gain in vitro digestibility, and economic efficiency in Doyogena sheep.

1.2.2. Specific objective

- To evaluate the effect of substituting varying degrees of wheat bran with *Enset* corm on the weight gain and feed intake of Doyogena sheep.
- To assess *in-vitro* digestibility and the economic efficiency of Doyogena sheep fattened on *Enset* corm in place of wheat bran.

1.3. Significance of the study

The significance of this study lies in its exploration of alternative feed sources for sheep, specifically, in this case, replacing wheat bran with *enset ventercosum corm*. Understanding its effects on feed intake, weight gain, digestibility, and economic efficiency can provide valuable insights for sustainable livestock farming practices and potentially reduce dependency on conventional feed resources, potentially minimize costs associated with livestock farming *enset ventercosum* corm proves to be a viable alternative to wheat bran, farmers could reduce their expenses on feed procurement. This could lead to improved economic efficiency and profitability in livestock production. *Enset ventercosum* corm is locally available or can be cultivated easily, it could further contribute to minimization by reducing transportation and procurement expenses.

2. LITERATURE REVIEW

2.1. Sheep Feed Resources in Ethiopia

Sheep are selective in their feeding behavior if they have a choice of feed resource. A given choice to sheep is natural grass, therefore grazer, in which the animal obtains natural or cultivated forage directly from the field. By spatial restricting the sheep's freedom. However, man can influence the way forage is used and the amount consumed Abegaz and Solomon (2007). The major basal feed in the highlands of Ethiopia are a natural pasture, crop residue, and stubble grazing, and their contribution to the total feed resource varies from area to area based on cropping intensity (Seyoum *et a*l., 2001).Feed resources as reported by (Adugna *et al.*, 2012) can be classified as natural pasture, crop residue, improved pasture and forage, and agro-industrial by-products of which the first two contribute the largest share. The fibrous agricultural residues contribute a major part of livestock feed especially in densely populated areas where land is prioritized for crop cultivation. The same authors reported that crop residues contribute about 50% of the total feed supply in Ethiopia. Similarly, naturally occurring grasses, legumes, herbs, shrubs and tree foliage is used as animal feed (Adugna, 2008). The availability of feed resources in the Highlands of Ethiopia depends on the mode and intensity of crop production as well as population pressure (Seyoum *et al*., 2001). Crop residues represent a large proportion of feed resources in mixed crop-livestock systems (Malede and Takele, 2014). Reliance on crop residues for animal feed is increasing from time to time as more land is cropped to feed the fast-growing human population. Feeds can be classified according to some of their general properties. Feedstuffs can be classified as either concentrates or roughages (Birhanu *et al.*, 2009).

2.1.1. Natural pasture

Natural pasture is an important source of ruminant livestock feed in developing countries (FAO, 2001; Solomon 2008). Similarly, the major contributor of livestock feeds in Ethiopia is natural pasture or grazing lands (CSA, 2015) and it is reported that about 56.23 % of the total feed resources is derived from grazing on natural pasture. Natural pastures include annual and perennial species of grasses and herbaceous legumes (FAO, 2001). The availability of natural pasture in the highlands of Ethiopia depends on the intensity of crop production, population pressure, the amount of rainfall, and the distribution pattern of rainfall and seasons of the year (Mohammed and Abate, 1995). The contribution of these factors to the total feed resource base varies from area to area based on cropping intensity (Seyoum *et* *al.*, 2001). The reliability of natural pasture as a source of feed in Ethiopia is restricted to the wet season (Zinash *et al.,* 1995). And yet grazing lands play a significant role in livestock feeding and support a diverse range of grasses, legumes, shrubs, and trees. Feed values of natural pasture fluctuate considerably in quality based on components such as protein and fiber, which are generally inversely proportional to each other. Natural pastures are categorized as poor-quality roughage with low intake (Berhanu *et al.,* 2009), tough texture, poor digestibility, and nutrient deficiency, particularly that of crude protein and metabolizable energy with the requirements of the animals (Mupangwa *et al.,* 2002).

Table 1 Proportion of Animal Feed Resources in Ethiopia

S.no	Feed Type	Percentage
1	Grazing	56.23
2	Crop residue	30.6
3	Hay	7.44
4	Agro-industrial byproducts	1.21
5	Others feed/concentrate feeds	4.76
6	Improved fodder or pasture	0.3

Source: CSA (2015)

2.1.2. Crop residues

Crop residues are abundantly produced in almost all parts of the world where there is crop production is produced. Cereal straws such as *Teff*, barley, wheat, and pulse crop residues are stalked after threshing and fed to animals during the dry season when the quality and quantity of available feed from natural pasture declines drastically in different parts of the Ethiopian (Ketema, 2014). The sizes of farm holdings for crop production were highly variable, ranging from 0.5 hectares to 5 hectares. Some of the cereal grain by-products, particularly fermentation residues from alcoholic drinks and beverages are abundant in most parts of the country. Improved pastures and forages play varying roles in different livestock production systems. In general, they are important as adjuncts to crop residues and natural pastures and may be used to fill the feed gaps during periods of inadequate crop residues and natural pasture supply. Even in the presence of abundant crop residues, which are often free-fed to ruminants, improved forage crops especially legumes are needed to improve the nutritional values of crop residues. Improved forages also provide benefits such as soil fertility through their nitrogen-fixing ability and reducing soil erosion (Yami *et al.*, 2012). Due to its positive biological impact on degraded lands, the government of Ethiopia has given due attention to stock exclusion and watershed areas. However, not much progress achieved till recently. Similarly, (Rich *et al.*, 2008) reported unsatisfactory and limited success rates of improved forage development because of a shortage of land in the mixed crop-livestock system, technical problems such as planting and managing the seedlings, insect damage, and low interest of farmers were some of the reported reasons for poor adoption of improved forage production (Hussein, 2017).

Crop residues refer to the parts of plants left in the field after harvest. In the mixed cereal-dominated crop and livestock farming system of the Ethiopian highlands, crop residues provide about 50% of the total ruminant livestock feed resource. The contributions of crop residues could be as high as 80% during the dry seasons of the year (Adugna, 2007). The high dependency on crop residues as livestock feed is expected to be higher and higher, as more and more of the grazing lands are cultivated to satisfy the grain needs of the rapidly growing human population.

2.1.3. Indigenous fodders trees

Indigenous fodder trees are tree species that are native to a particular region and are used as a source of fodder for livestock. These trees have adapted to the local environment and often provide nutritious leaves, pods, or other parts that are sustainable agriculture as they require less water and maintenance compared to introduced species, and they help preserve biodiversity and ecosystem resilience. Shrubs and fodder trees play a significant role in livestock production in all agro ecological zones of tropical Africa. Fodder tree foliage is commonly browsed directly on trees, or after lopping by livestock herders. They are also offered as cut-and-carry feed install-fed situations (Atta-Krah, 1990). The importance and availability of fodder trees in tropical Africa are influenced by several factors such as the natural distribution of trees within the agro ecological zones, the distribution, types, and importance of livestock, the integration and role of livestock within the farming system, and the availability of alternative sources of fodder in livestock feeding in the agro-ecological zone (Atta-Krah, 1990). The productivity of the fodder trees in terms of foliage production per unit area is linked with habitat and soil texture.

2.1.4. Improved forages

Improved forages refer to cultivated plants that have been selectively bred or genetically modified to enhance their productivity, nutritional value, and resilience to environmental stresses. These forages are specifically developed to meet the needs of livestock production systems. They can include grasses, legumes, and other plants that provide a balanced diet for animals like cows, sheep, and goats. Introduction, popularization, and utilization of improved multipurpose forage crops and trees such as Sesbania spp., Leucaenaleucocephala, Calliandra spp., and Chamaecytisuspalmensis through integration with food crops cultivation in the mixed crop-livestock system in Ethiopia started in the 1970s aimed at supplementing the widely available roughage feed resources (Alemayehu, 2006).

2.1.5. Agro-industrial by-products

Concentrates have low fiber content and a high content of either protein energy or both. Cereal grains for example are considered as primary energy sources but also contribute a significant amount of protein. A feed or feed mixture that has high amounts of protein, carbohydrates, and fat, contains less than 18% crude fiber and is usually low in moisture. Concentrates are rich in either energy or protein and are thus expensive. Agro-industrial by-products that result from the processing of agricultural produce such as wheat bran, oilseeds, sugarcane, and citrus, and from slaughterhouses during the slaughter and processing of livestock are examples of concentrates. In comparison to crop residues, these products are very good in their composition of useful nutrients and digestibility. The feeding value of such by-products varies considerably.

Energy source concentrates include cereal grain (corn, sorghum, and buckwheat), grain milling byproducts (wheat bran and corn gluten meal), root and tubers (cassava and potatoes), food processing byproducts (molasses, bakery waste, citrus pulp distiller and brewers by-products), industrial by-products such as wood molasses.

Protein source concentrates: Protein supplements generally are products with more than 20% crude protein. Some of these feeds are; oil seed meals (soybean, cottonseed, rapeseed, canola, linseed, peanut, sunflower, and sunflower meals), grain legumes (beans, peens, and lupines), and animal protein (meat meal, tank ages, fishmeal's and whey (Birhanu *et al.*, 2009).

2.2. Effect of Concentrate Proportion in the Diet

High levels of grain-based concentrate on methane reduction have also been reported by Beauchemin, *et al.*, (2005), and McAllister, *et al*., (2008). Cereal grains, which contain much more storage carbohydrates than forage, are easily digested by rumen microorganisms such as starch-fermenting bacteria. Higher proportions of concentrates in the feed decrease methane emissions. A diet comprising 45% starch decreased methane production by 56% compared to diets containing 30% starch without affecting animal health. For every gram of cellulose digested, methane emissions are nearly five times that of the soluble residue. In high-starch diets, the percentage of methane corresponding to the gross energy intake can be as low as 3% as compared to 6 to 8% in diets with forages as the main feed component.

However, this marked decrease is only observed at levels of intake that are equal to or above 2.5 times the intake required for maintenance and when the concentrate represents more than 50% of the ratio Sauvant, *et al*., (2007) - Morgavi *et al.,* (2011). Starch in cereal grains is readily fermented by rumen microorganisms. The reduction of methane in diets rich in rapidly fermentable carbohydrates was explained by an increased production of propionate at the expense of acetate, pathways consuming and producing dihydrogen, respectively, by a decrease in rumen pH, a decrease in the concentration of protozoa, high producers of dihydrogen, or by a combination of these three factors Morgavi., *et al.*, (2011)., Martin, *et al*., (2010). While some starch-digesting bacteria produce significant amounts of propionate, many fiber-digesting bacteria produce large amounts of succinate, which is finally converted to propionate.

2.2.1. Concentrate supplementation

The use of concentrate feed can reduce enteric CH4 production in ruminants. This is achieved mainly through shifting the fibre-based fermentation to starch fermentation Beauchemin *et al*., (2008). Pesta, A.C. (2015). The fermentation of starch creates an alternative hydrogen sink in the rumen by lowering the ruminal pH and inhibiting the growth of methanogens, thereby promoting more propionate production Haquse, M. (2018). Investigated the effects of different levels of concentrate supplementation (20, 40, and 60%) on the CH4 emission from Murrah buffalo calves housed in a well-ventilated shed and reported a reduction in daily CH4 emission and yield while using the SF6 technique to measure CH4. Jiao *et al*., (2014). fed perennial ryegrass grazing Holstein Friesian dairy cows with different ranges of concentrate feeding levels (2 kg, 4 kg, 6 kg, and 8 kg as-fed basis) and reported a decline in CH4 emission (using SF6) with the increase in the level of concentrate supplementation when expressed in terms of emission per unit of feed intake and energy corrected milk.

2.2.2. Agro-industrial by-products

Agro-industrial by-products have special value in feeding livestock mainly in urban and peri-urban livestock production systems, as well as in situations where the productive potential of the animals is relatively high and requires a high nutrient supply. The major agro-industrial by-products commonly used are obtained from flour milling industries (wheat bran, wheat short, wheat middling, and rice bran), edible oil extracting plants (nouge cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake, etc), breweries and sugar factories (Molasses). The current trend of increasing urban population has a significant effect on the establishment of agro-industries due to the corresponding increasing demand for edible main products (Dereje, 2012). Feed resources of agro-industrial origin include by-products of cereal milling and by-products of cooking oil extractions, both of which are good sources of easily fermentable energy and protein. Wheat bran is a readily available and cheap agro-industrial by-product that could be used in animal feeding (Alemu *et al.,* 1989). Wheat bran is one of the most popular and important supplementary concentrate livestock feeds. It is highly palatable and has a mild laxative effect. The bran is the outermost layer of the seed, which is high in fiber, but also contains some flour and is relatively higher in CP content than the seed (Cheeke, 1991). Oilseed cakes (oilseed meals) are by-products from processing a variety of oil crops such as groundnut, sunflower, and soybean. Nouge seed cake is high in feeding value and could be included as good quality protein concentrate for all classes of livestock. (Abebe, 2008).

2.2.3.. Effect of forage type on global change

The composition and quality of forage along with the level of intake significantly influence the rumen fermentation Iqbal1 *et al.,* (2014), Johnson. *et al.,* (1995). Ruminants fed low-quality roughages could release large amounts of methane. Feeding crop residues to ruminants is a common practice in many developing countries due to which methane emission from ruminants especially cattle is significant. When viewed in isolation, increasing forage digestibility increases daily methane emissions because of increased intake. However, at high intake levels, the proportion of energy lost as methane decreases as the digestibility of the diet increases Iqbal1 *et al.,* (2014), Johnson, *et al.,* (1995). In addition, improving forage digestibility will improve productivity because DM and energy intake are increased Benchaar *et al.* (2001). A speculated 15% reduction in methane production by increasing the digestibility of forages and 7% by increasing feed intake was observed.

Ryegrass varieties containing high soluble sugar contents (i.e. 20.5 g/kg DM) have been shown to decrease methane production per kg of live weight gain by up to 25% in growing lambs Morgavi. *et al.,* (2011), Kim *et al.,* 2011.

2.2.4 Nutritional requirement of sheep

Nutrition is the process of providing feed necessary for the health, maintenance, and growth of sheep. It plays a major role in the overall productivity, health, and well-being of fattening sheep, so sheep fatteners must give nutritional management the highest priority. There are five main categories of nutrients required by sheep. These are water, energy, protein, vitamins, and minerals (Wamatu *et al.,* 2021).

Table 2. Feed intake of sheep for maintenance and growth

Weight of sheep in (Kg)	DM intake in (Kg)	% live weigh
5	0.10	2.0
10	0.18	1.8
15	0.26	1.7
20	0.41	2.0
25	0.47	1.9
30	1.15	3.8
40	1.43	3.6
50	1.69	3.4
60	1.94	3.2
70	2.18	3.1
80	2.41	3
90	2.63	2.9

2.2.4.1. Feed resource for sheep production in doyogena

The main feed sources for animals included *Enset,* products of *Amicho* (corm), crop residue, improved forage/grass, crop aftermath, kitchen leftovers, and purchased concentrates. Flocks graze with tethering in the small private land. Feeding in the daytime and housing at nighttime is practiced. Often one big house was constructed from bamboo or locally available materials, and shelter for sheep was constructed inside one main house. Kebede. *et al.*, *(*2020).

2.2.4.2. Feed intake

Feed intake is the first parameter that determines animal production (Savadogo *et al.*, 2000), which is likely to be influenced by the animal, characteristics of the feed, and other environmental factors. The dry matter intake is dependent on many factors like the density of energy in the diet, digestibility, succulence, amount of crude fiber, and the physical nature of the feed (Rehrahie *et al.*, 2003). Feed intake in ruminants consuming fibrous forages is primarily determined by the level of rumen fill, which in turn is directly related to the rate of digestion and passage of fibrous particles from the rumen (McDonald *et al.*, 2002). Feeds that are digested rapidly are also of high digestibility and promote high intake. The author also noted that the faster the rate of digestion, the more rapidly the digestive tract is emptied and the more space is made available for the next meal. There is a positive correlation between the digestible fraction of the feed and DM intake. Feed intake is negatively impacted by the number of indigestible fractions (such as lignin) or fractions with low digestibility like NDF and ADF content due to the need for more retention time in the rumen for further fermentation (Bruinenberg *et al.*, 2003). The high NDF and ADF contents in the diet are expected to increase resistance to physical breakdown and contribute to more ruminal fill resulting in a lower voluntary intake. Feed that is low in protein and high in fiber content results in low digestibility and voluntary feed intake (Adugna *et al.*, 2002).

2.3. Socio-economic and Cultural Values of *Enset*

Enset could be a perennial evergreen crop with many aesthetic values and multipurpose within south and southwestern Ethiopia. Its many material uses and socio-cultural values. An oversized number of *enset* plants around houses provide comfort, shading for people, and a few crops like coffee, which require only moderate sunshine Shigeta.M (1991). The employment of *enset* and its products for various purposes like food *amicho* (corm), bulla, and kocho, medicine, rituals, and construction purposes could be attributed to the existence of assorted *enset* varieties. Birmeta.*et al*., (2004). Enset garden is usually an indicator of the economic status of farmers; many types of the more mature and enormous number of *enset* plants are found within the gardens of wealthier households Negash and Niehof (2004). Gurage people depend much on *enset* socially and economically to get their essential needs. Once it reaches a certain stage of growth, cultivated *enset* will utilized for several purposes throughout the year.

Furthermore, botanical parts of *enset* are good fodder for livestock. It is drought resistant because it contains plenty of water in the pseudo-stem and is used for cattle stall-feeding especially within the season when the grass is scarce. It provides good fiber, a by-product obtained from decorticating the leaf sheaths, and therefore the dried fibers are strong enough to create prime-quality ropes. The pseudo-stem yields very strong fibers, even the unprocessed leaf sheaths are employed for tying livestock, bundling harvests from fields, and fencing. The fiber has excellent structure and its strength is adored by the fiber of abaca, an excellent fiber crop. In rural areas, the fiber is employed to create sacks, bags, ropes, cordage, mats, construction materials, and sieves.

Fresh *enset* leaves are used for wrapping foods, portion plates, and pit linings to store kocho for fermentation. Men sometimes make caps from *enset* and therefore the fresh leaves are used as clothes for women's skirts, infrequently worn within the markets and ceremonies. The dried petioles and midribs have been used as firewood, to form mats, and as tying materials for house construction. For cleaning rags, brushes, baby cushions, pot stands, as wrappers for butter, kocho, and other items to move to local market. Specific varieties and *enset* parts are used medicinally for both humans and livestock for problems like diarrhea, contraception (as an abortifacient), and supporting to discharge placenta. *Enset* has cultural values through wedding and funeral ceremonies. During a wedding, *enset* leaves will used on tables for serving food and as skirts for girls in some cases additionally to being the main food for the ceremony. Elucidated that at a funeral ceremony, people beat the pseudostems of *enset* laid on the bottom in a circle like drums and that they associate with *enset* leaves on their hands. The members of the lineage cut all the *enset* plants when the top of the household dies, to specific their sorrow and desperation. The *enset* plant may also sold in some cases and processed products like kocho and bulla are sold anytime within the rural markets and towns. Therefore, it has an on-the-spot cash income source for a family to shop for their daily needs.

In densely populated areas of southern Ethiopia, *enset* is regarded as a food security crop. The presence of *enset* in this farming system contributes significantly to the sustainability of food supply by several mechanisms. The primary strategic importance of *enset* in food security is that *enset* helps prevent famine by surviving drought when other food crops fail. Once *enset* plants are established in areas of sufficient rainfall, they can tolerate occasional years of very low rainfall or a short rainy season. Secondly, it gives a higher yield per unit area than other crops thus supporting the densely populated areas in the country (Brandt *et al*., 1997). Third, *enset* foods can be stored for long-term uses. The ability to store *kocho* and *bulla* for longer periods with little storage loss provides households with a mechanism to smooth consumption during food shortage periods. Fourth, *enset* plants can be harvested at any time and any stage of growth, allowing households to weather out periods of food shortage. Despite all these desirable attributes, the *enset* farming system received very little research attention as compared to that given to cereal-based systems (Brandt *et al*., 1997). According to Kefale and Sandford (1994), *enset* yields 1.3 to 3.5 times much more food energy per hectare as compared to maize grown under similar management conditions. Thus, for households facing a shortage of land, the higher energy productivity of *enset* relative to cereals makes *enset* an important food security crop.

2.4. Morphology of *Enset* Crop

The crop *enset* looks like bananas. Large leaves, a subterranean corm, and a bundle of leaf sheaths forming the pseudo stem are features shared by *enset* and banana. Compared to bananas, *enset* leaves are longer, broader, and more erect. Unlike other plants, banana plants do not typically generate suckers or clusters at the base. *Enset* is composed of three components. The upper-most component is the pseudo stem, which is comprised of a system of closely clasping leaf bases or leaf sheaths. Depending on the species and agroecological state of its cultivation, the pseudo stem height ranges from 2 to 5 m Taye (1984). On short petioles that are roughly five meters in length, leaves are born on the pseudo stem nearly at the same spot. The underground portion of the plant consists of a corm, which is 0.70 to 1.8 m long with a circumference of 1.5 to 2.5 meters at maturity. *Enset* has a fibrous rooting system that grows out from the corm.

2.5. *Enset* as Livestock Feed

Enset (Enseteventricosum) is a perennial herbaceous plant that grows 4-11 m in height. It is commonly known as a “false banana” for its close resemblance to the domesticated banana plant. It is Ethiopia’s most important root crop; a traditional staple crop in the densely populated South and South-Western parts of Ethiopia (George, 2004). *Enset* varies within the species due to altitude, soil, and climate. This allowed widespread cultivation in the mid to highlands of western Arsi-Bale, the Southern Nations and Nationalities People Regional State (SNNPRS) current central Ethiopia and Western Oromia including West Shewa, Jima, Ilubabor and Welega Fekadu and Ledin (1997). Farmers provide inset leaves, corm, pseudo stem, fluid, and processed inset by-products for their livestock during the dry season. According to Sidama Concern, (2008) the whole *enset* plant is chopped and fed to livestock during the dry season. Parts of the *Ense*t growing area experience a rainy season with surplus vegetation followed by a dry season with a shortage of livestock feed; in these areas plant material not used for *kocho* could be chopped into old fermentation pits and stored for dry season livestock utilization. Since the technology of producing livestock silage is similar to that of fermenting *kocho*, additional forage could be stored during the growing seasons. Sidama Concern, (2008).

The Central and southwestern part of Ethiopia, where *enset* is the main staple food crop for a population of 20 million people, is one of the centers of diversity and origin for *enset* Borrell *et al.,* (2020). *Enset* represents about 65% of the total crop production in the southern region of Ethiopia Assefa and Fitamo (2016) and plays an important role in household food security. Hundreds of clonal varieties were identified in the region and many are yet to be identified. For instance, the Sidama botany recognizes 103 *enset* varieties of which 79 are grown (Bizuayehu, 2008), and varieties identified in other areas were summarized by Borrell *et al.,* (2020) and Yemataw et al. (2018). Southwestern Ethiopia was called the *enset* culture complex area, due to the existence of various cultural traits associated with *enset*. The dominantly representative *enset* growing tribes in Ethiopia are the Gurage, Gedeo, Hadya, Kambata and Tambaro, Sidama, Wolayta, Darassa, Alaba, Konso, Gamo, and Gofa (Doda, 2006; Struik, 2018). The Oromo people bordering the Sidama and Southern Nations and Nationalities also use several *enset* varieties as food and feed. For instance, in the Kofele district of the Oromia region, where pastoralism has been the dominant form of livelihood, the role of *enset* increases with increasing altitude. Livestock mortality associated with feed scarcity is a common phenomenon during the drought season in Ethiopia Desta and Oba, (2004). Drought events are challenging for farmers in all agroecology and cause forage deficit and increase vulnerability to livestock disease (Senbeta, 2009). During droughts livestock physical deterioration due to heat stress and long-distance travel for water and pastures is a common phenomenon. The vulnerability of livestock was exacerbated by the restricted mobility of pastoralists, hiking feed prices, low livestock prices, drying water sources, and depletion of grasses and crop residues. Market imbalance aggravates the problem of pastoralists by shifting the terms of trade in favor of their purchases rather than their sales (Futterknecht 1997 as cited in Ahmed *et al.,* (2002). The price of feed: *fagulo* (oil by-product), *atela* (residue of local drink), and *gleba* (crop residue) increased by more than four-fold during past drought periods as compared to normal times. The household study in the West-Arsi zone by indicated that 31% of livestock per household died during the 2006/07 drought season. The corm has the highest concentration of most soluble carbohydrates and starch, and the least protein, fiber, cellulose, and sugar, while the pseudo stem has the least lignin (Mohammed *et al.,* 2013). Similarly, Nurfeta *et al.*, (2008) observed the highest non-fiber carbohydrate contents in inset fractions, especially in pseudo stem and corm than the leaf lamina. The corm had 11.9MJ/ kg DM metabolizable energy while the pseudo stem had 11.7 MJ/ kg DM (Mohammed *et al.,* 2013).

2.5.1. Distribution and agro-ecology of *enset*

Enset is widely distributed and economically important in the central, southern, and southwestern parts of Ethiopia. It also grows in the Northern highlands around Lake Tana, the Semien Mountains, and Adigrat in Southern Eritrea (Brandt *et al*., 1997). Furthermore, *Enset* grows naturally throughout Asia and tropical and sub-tropical Africa. *Enset* cultivation is usually limited to homesteads in Ethiopia. *Enset* landraces vary within species, altitude, soil type, and climate (Admasu, 2002). The natural habitat of this plant lies between 1500-3200 meters above Sea level (masl), but it is extensively grown at altitudes between 2000 and3200 masl Bezuneh (2012). At higher elevations, low temperature and frost hamper growth, and maturation may take twice as long, or more, than in lower regions. Temperatures are about 16-20°Care optimal, but growth is possible from 5 to 25°C. Average annual rainfall of 1100-1500 mm is recommended for optimal growth but can withstand dry periods of up to five months. *Enset* grows well in most fertile and well-drained soils. It prefers soil pH between 5.5 and 7.3.

2.5.2. Nutrient composition of *enset* corm

The corm has the highest concentration of most soluble carbohydrates and starch, and the least protein, fiber, cellulose, and sugar, while the pseudostem has the least lignin (Mohammed *et al.,* 2013). Similarly, Nurfeta *et al*. (2008) observed the highest non-fiber carbohydrate contents in *enset* fractions, especially in pseudostem and corm than the leaf lamina. The corm had 11.9 MJ/ kg DM metabolizable energy while the pseudostem had 11.7 MJ/ kg DM (Mohammed *et al.,* 2013). According to Tsegaye (2010), kocho has a high carbohydrate (96%) content compared to maize (83%). The pseudo stem of 3-selected *enset* varieties on average was reported to have 7.2 (%CP) (Fekadu and Ledin, 1997). The CP value of (21.9 g/kg DM) for kocho was reported by (Ajebu and Eik, 2014). Melesse (2013) also reported 3.96% CP from *kocho* processed by traditional method. Similarly, Brandt *et al*., (1997) observed a CP content of 26 g/kg DM of *kocho*.

2.6. Constraints of *Enset* in Ethiopia

Several biotic and abiotic factors affect the quantity and quality of *enset* production. Land scarcity, plant diseases, and insect pests; lack of improved clones with high yields, disease and insect resistance, and drought tolerance; labor scarcity; lack of improved processing and storage technologies; traditional agronomic practices; and the crop's long-term maturity (perennial) behavior; and food insecurity are all major challenges in *enset* production (Shumbulo *et al.,* 2012; Teshome, 2016). Diseases caused by bacterial wilt, root-knot nematodes (Meloidogyne spp.) and lesion nematodes (Pratylenchus spp.), mammals, and sucking insect pests, such as mealy bugs have all been recognized as major biotic constraints (Tadessa and Shigeta, 2016; Belachew and Aklilu, 2018). *Enset* bacterial wilt is known to be an important and major disease affecting *enset* production and productivity in Ethiopia (Tewodros and Tesfaye, 2014; Tadessa and Shigeta, 2016; Teshome, 2016; Adanech, 2017).

2.7. Health and Traditional Medicine Benefits of *Enset*

Enset is broadly considered and very important medicinal plant in Ethiopia, with remarkable consistency across diverse ethnic groups in its reported uses, and the phenotypic traits that characterize medicinal values. Plants used medicinally mostly, but not consistently have red or reddish-purple leaf blades with midribs and pseudo-stems that are red to varying degrees R. Shank and C. Ertiro, (1996). There are two principal medicinal properties commonly accredited to *enset.* First, boiled corm *(amicho*) of different varieties, often consumed with milk, allegedly cures fractured or broken bones, second, the *amicho* of various varieties is consumed with milk and butter to facilitate placental discharge in both humans and cattle. In some cases, it's going to also induce abortion identified a unique phenylphenalenone in *Enset*, yet as compounds already known from other Musaceae A. Tsegaye, (2002). Phenylphenalenones may have anti-cancer, anti-bacterial, and nematicide properties and are used by the corm or other parts of specific *Enset* landraces to cure cirrhosis, diarrhea, or venereal diseases B. A. Gashe, (1987), A. Tsegaye,(2002). The following are a number of the *Enset* clones that are claimed to own medicinal and ritual values by farmers A. Negash, (2001). Moreover, Choro is fed to a woman immediately after baby delivery to stimulate the discharge of the placenta. In terms of formality significance, planting this clone in their backyard deters the devil or evil spirits of Kaffa farmers. The *bulla* or corm of Tayo is consumed for bone fractures, backache, and swelling displacement of joints treatment. Shasiwagi (Wagibeli) is suggested for a girl to forestall uterus contraction and relieve stomachache after baby delivery. The corm of Ariko is boiled and fed when an individual catcher's fluid. Additionally, children eat its uncooked stem to stay healthy and gain weight. However, the scientific clinical studies of those inset medical uses have not been reported. Its potential use as a glucose source has been recommended thanks to its rich carbohydrate content. Focusing totally on the corm (*amicho)* by the farmers signifies their appropriate cognitive content of its better nutrient composition.

2.8. Nutritional Interventions as One of the Important Methane Mitigation Options

Among various CH4 mitigation strategies, nutritional intervention or dietary manipulation is the most effective and increasingly used strategy to mitigate enteric CH4 emission in ruminant livestock Jayanegara, A. (2021), Sejian, V.; *et al.,* (2011). Emissions from animal facilities primarily consist of animal respiration and enteric fermentation. In addition, emissions from manure storage are also believed to be a potential source of CH4 Sejian, V.; *et al., (*2011). Ruminant livestock such as cattle, buffalo, sheep, and goats contribute the major proportion of total agricultural emission of methane Lassey, K.R., (2007), Chhabra, A., (2009). Ruminants are categorized by the presence of rumen, a special digestive organ, in the body. Besides having the unique ability to digest fibrous and low-grade roughage/plant material, it is also a major producer of methane, a potent greenhouse gas. Methane production is released due to the release of digestible energy to the atmosphere and therefore inefficient utilization of feed energy. Methane emission from ruminants provides enough scope for easy and practical management for a reduction in methane emission Mc Michael *et al*., (2007).

2.9. Ecosystem Services of *Enset*

Enset, also known as “false banana”, offers several ecosystem services; Soil conservation, carbon sequestration, biodiversity support, water regulation, and traditional knowledge preservation. Ecosystem services are defined as the desired benefits and life-supporting services provided by the ecosystem to human well-being. Agricultural ecosystems are modified by humans to enhance the production of specific services of food, fiber, and fuel (Bennett *et al.,* 2009; Zhang *et al.,* 2007). *Enset* farming system provides multiple interdependent webs of ecosystem services.

2.9.1. Provisioning services

In the face of global crises such as climate change the priority of the agricultural sector in developing countries like Ethiopia should focus on improving provisional services and adaptive capacity (Campbell *et al.,* 2014). *Enset* is a multipurpose crop and provides provisioning services such as starchy food products, animal feed, fiber, wrapping material, and traditional medicine. *Enset* supports high population density compared to other crops and cropping systems in the same agroecology and with the same input (Shack, 1963; Spring *et al.,* 1997). It has a high yield per unit of land and sustainable intensification with low off-farm input is possible. Yet, the productivity of *enset* per pseudostem or hectare of land depends on the agroecology, landrace, and age of the plant.

However, the presence of *enset* at-home gardens improved the adaptive capacity of households to climatic shocks. *Enset* remains green throughout the year and serves as a suitable feed when other feeds are scarce. The use of *enset* as livestock feed during the dry and a wet season is a common practice in *enset* producing areas. The interlinkages and complementarities between livestock and *enset* production are strong. The livestock provides easily available animal manure which farmers consider very essential for *enset* cultivation and the *enset*, in turn, provides feed for animals. Moreover, the presence of legume trees in *enset* agroforestry systems such as acacia leaves also serves as the best feed for small ruminants to increase milk yield, and body weight, and increase farm income. (Senbeta, 2009).

2.9.2. Resilience of *enset* to climate change

Resilience is an ecological term and is defined as the ability of a system to absorb disturbance without shifting to an alternative state and without losing important functions and services (Côté & Darling, 2010). *Enset* demonstrates remarkable resilience to climate change due to several factors; drought tolerance, temperature, adaptability, carbon sequestration, biodiversity, and cultural importance. The term also refers to the speed and degree to return to the system's original state after perturbation. Resilience is widely used in global change management such as climate change. The term again has come to the forefront as a useful organizing principle in the light of the COVID-19 pandemic crisis to study food system transformations (Gillespie, 2020). In 2020, East Africa was hit by drought, flooding, locust swarms, and the COVID-19 pandemic. In light of multiple crises facing the region the resilience of a local farming system, in terms of resistance to a shock and recovery after disturbance, needs to be explored.

2.9.3. *Enset* farm resistance to disturbance

Enset has a high drought, flood, and frost-withstanding capacity, and can be harvested for food over long periods and the fermented product can be stored for several years. The farmers mix *enset* age groups and clonal varieties to ensure continued food supply through time, enhance yield and quality of food, maintain garden structure and achieve permanent production, and safeguard against pests and disease (Bizuayehu, 2008). To improve drought resistance farmers use methods such as mulching, bending *enset* leaves during the rainy season to increase water holding capacity, cutting older leaves, and covering the exposed root of the plant using soil. In terms of food and nutritional security, the presence of other component plants (cereals, fruits, root crops, and trees) as intercrop in the *enset* farming system increases farm diversity, and nutritional diversity and serves as insurance during a shortage of food and income.

2.9.4. *Enset* farm recovery after climatic shock

Farmer recovery from climatic disturbances is always a challenge in cereal production systems. After the disturbance, like in other natural ecosystems, farmers face another new stable state with less adaptive capacity and higher vulnerability. This is because the aftermath of climatic disturbances cereal farmers face a shortage of food and farm inputs such as fertilizer and new varieties). Drought agents (oxen) also die by drought events or get very much weaker (Senbeta & Olsson, 2009). The situation is aggravated by the absence of social institutions providing credit systems and other supports. Therefore the option available for poor farmers is renting their land to rich farmers with low prices and for long years, which makes the recovery very difficult. In *enset* farming systems, recovery is easy and rapid. The plant is easy for vegetative propagation and requires easily available farm inputs. The farmers get the propagules for free, exchange them with other *enset* clonal varieties, or for a cheap price.

3. MATERIALS AND METHODS

3.1. Description of Study Area

The feeding trial was conducted in the Doyogena district. The district is one of the districts in the Kembata Zone, Central Ethiopian Region. The area is about 258 km from Addis Ababa in the Southern direction and 171 km Southwest of Hawassa. The district comprises mostly high land agro-ecological zone and its altitude ranges from 1900 to 2800 m.a.s.l. Annual rainfall is 1200–1800 mm and the mean temperature varies from 10 to 18°C (DDFEDO, 2017). The total population of the district is 116,048, comprising 56,863 males and 59,185 females. The district has a total of 32,920 sheep, out of which 10,534 were improved. In terms of the farming system, the community practices animal rearing and crop production (mixed farming system).

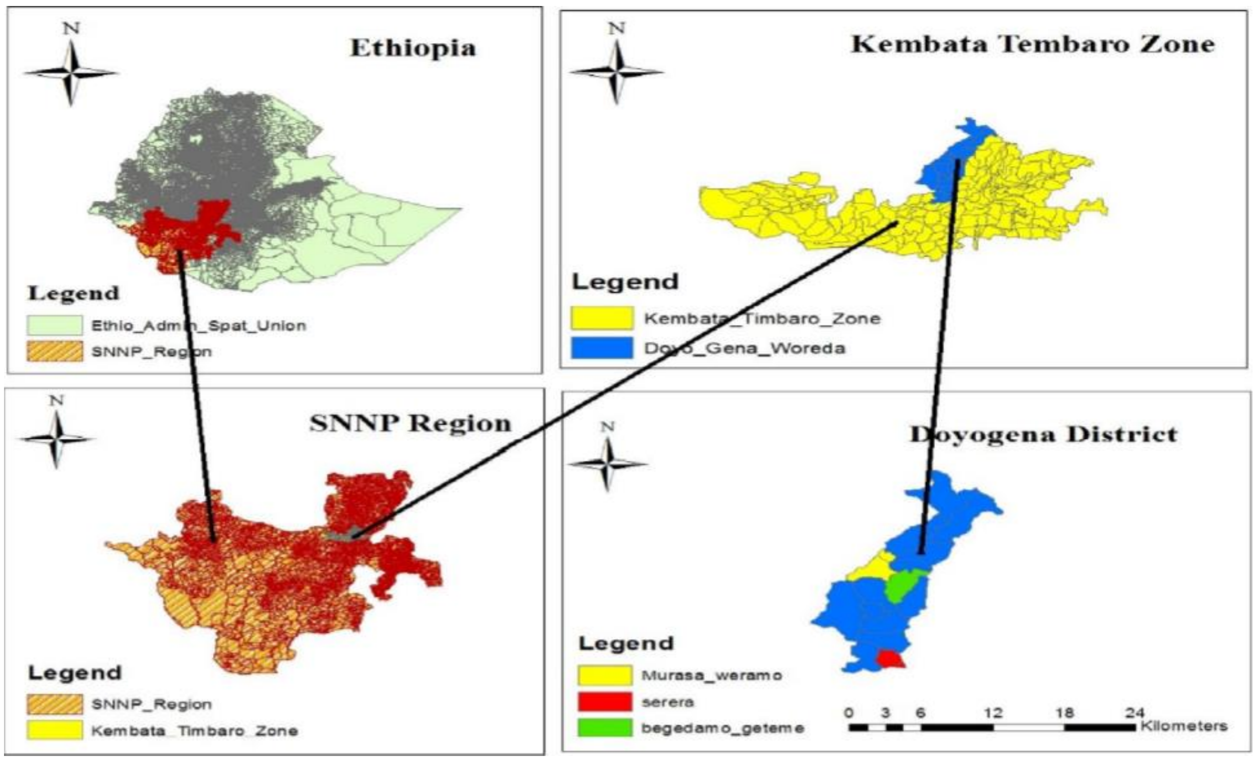

Figure. 1 Kembata zone map.

3.2. Experimental Animals and Their Management

Forty-two intact male yearling rams were selected from the Doyogena community-based sheep breed improvement scheme. The rams were those left (3rd ranked) after the selection of elite rams as breeding males for the improvement of the next generations. The age of the animals was determined by dentition and based on information obtained from owners. Experimental animals were identified using ear tags. The animals were de-wormed against internal parasites by ivermectin 1% injection and after 2 months again dewormed by albendazole bolas. The experimental animals were carefully observed for the occurrence of any ill health and records were taken for any physiological disorder during the experimental period. After 14 days of adaptation period, the animals were blocked based on their initial body weight into 6 blocks, and 7 animals were randomly assigned to each treatment using a completely randomized block design. The body weight of the animals was taken at the beginning of the feeding trial after overnight fasting and every 14 days during the 90 days of the feeding trial. All animals were weighed in the morning hours after overnight fasting before feed provision using a weighing balance.

3.3. Experimental Feeds and Feeding

Ensete corm was bought from farmers in the study area. The corm was chopped manually into small pieces and dried by wilting under a shed. Sheep in this study were generally managed under community-based sheep-fattening program members. The main feed sources for the animals included *Enset* (E. *ventricosum*) part called *Amicho* (corm), natural pasture Wheat bran and nuge seed cake were bought from Hosanna town. The animals were allowed to free graze for 8:00 hours on natural pasture (3:00 am to 11 pm local time) and water was available on an *adlibtum* basis 150g of the experimental diet was offered in the morning and 150g in the night. The experiment lasted 90 days targeting the Ethiopian festive season new year (*Enkutatash*).

3.4. The Experimental Design and Layout

The experimental design was conducted using a randomized complete block design (RCBD). The experimental animals were 6 dietary treatments in 7 replication. The experimental yearlings were selected for the experimental feed trial; because of similar age and weight for the supplement feed trial effect. Yearlings were blocked based on their initial body weight weightings' after overnight fasting. They were grouped into 6 blocks of 7 animals for each treatment. Diets were randomly assigned to each group. Then the sheep were randomly assigned to one of the 6 dietary treatments using lottery method for treatments as control, natural pasture (T1), natural pasture +120g nouge seed cake, (T2), natural pasture+120g nouge seed cake+180g Wheat bran, (T3), natural pasture+120g nouge seed cake+135g Wheat bran+45g *enset* corm, (T4), natural pasture+120g nouge seed cake+90g Wheat bran+90g *enset* corm, (T5), natural pasture+120g nouge seed cake+45g Wheat bran+135g *enset* corm, (T6),), natural pasture+120g nouge seed cake +180g *enset* corm. The amount of concentrate offered per day was 300 gm/head and basal diet of natural grass through free grazing was fed to all animals ad libitum and supplemental feeding was on a DM basis.

Table 3 Layout of the experiment

Treatments	No of animal per treatment	Basal diet		Supplement feeds g/day		Total Supplemet g/h/day
		Grazing on NP	NSC	Wb	Ec	
T1:	7	*Adlibtum*	120	-	-	-
T2:	7	*Adlibtum*	120	180		300
T3:	7	*Adlibtum*	120	135	45	300
T4:	7	*Adlibtum*	120	90	90	300
T5:	7	*Adlibtum*	120	45	135	300
T6:	7	*Adlibtum*	120	-	180	300

NP = natural Pasture, NSC = Nougseed cake, Wb = Wheat bran, Ec = Enset corm

3.4.1. Feed intake

Daily offered diet was measured and recorded throughout the experiment period for each experimental animal. Daily feed intake of individual sheep was calculated as a difference between feed offered and refused on a DM basis. Feed conversion efficiency was computed as a proportion of average daily weight gain to average daily dry matter intake.

3.4.2. Feeding Trial

The feeding trial was conducted after the digestion trial for 90 days. Daily feed offered to the experimental sheep and the corresponding refusals were recorded and measured during the experimentation period to determine daily feed intake. Representative samples of feed offer per batch and refusal per animal were collected and stored based on the type of feed, pooled over the experimental period, and sub-sampled for chemical analysis. Daily feed intake of individual sheep was calculated as the difference between the amounts of feed offered and refused. Substitution rate was calculated as the difference between basal diet intake of the un-supplemented and supplemented treatments divided by the amount of supplement offered (Ponnampalam *et al.*, 2004).

3.4.3. Body weight change and Feed conversion efficiency

The body weight of the animals was taken at the beginning of the feeding trial after overnight fasting and every 15 days during the 90 days of the feeding trial. The initial and final body weights of experimental sheep were measured using a suspended weighing balance at the beginning and at the end of the experiment, respectively for two consecutive measures after overnight feed withdrawal, which was done in the morning before the provision of feed and water. To determine the weight change, subsequent body weight measurements were made at 15-day intervals throughout the experimental period. Body weight changes (BWC), average daily gain (ADG), and feed conversion efficiency (FCE). A lower feed conversion ratio indicates higher efficiency, meaning that less feed is required to produce a unit of weight gain. FCE can be calculated by dividing the amount of feed consumed by the weight gain achieved over a specific period. Were calculated as:

$$\boldsymbol{BWC = Final\ Body\ Weight\ (FBW) - Initial\ Body\ Weight\ (IBW)}$$

$$\text{ADG} = \frac{\boldsymbol{Final\ Body\ Weight - Initial\ Body\ Weight}}{\boldsymbol{Number\ of\ Feeding\ Days}}$$

$$\text{FCE} = \frac{\boldsymbol{Average\ daily\ weight\ gain(g)}}{\boldsymbol{Daily\ dry\ matter\ intake(g}}$$

3.5. Chemical Analysis of Feed

The feed samples used in the feeding (offered and refused) samples were analyzed for their chemical composition at the ILRI laboratory. Samples of feed offered were collected from each treatment while samples of refusal were taken from each sheep daily. Collected samples were pooled per treatment over the experimental period and stored in plastic bags pending analysis. The sub-samples of feed offered and refused were ground to pass a 1mm sieve screen and were ready for chemical analysis. Offered and refused samples of feed were dried at 105^{o}C overnight in a forced draft oven for DM determination while the ash content was determined by burning/igniting feed samples in a muffle furnace at 550^{o}C. The DM, Ash, crude protein and Organic matter contents of the feed samples were determined following the procedure of AOAC (2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to the procedure of Van Soest and Robertson (1985).

Crude protein was determined by the Kjeldahl method (AOAC,2016), official method 2001.11.1 g of the sample was weighed into a digestion flask and 12 ml of concentrated H2SO4 was carefully added to each flask and 3 ml of 30% hydrogen peroxide was added step by step after mixed carefully. As soon as a violent reaction ceased, the tubes were shaken and 3 g catalyst, a mixture of copper sulphate with potassium sulphate was added and digested by heating at 420°C. After the digestion had been completed, the digestion flasks were connected to a receiving flask containing 2% boric acid and indicators methyl red and bromocresol green. The solution in the digestion flask was then made alkaline by addition of 40% NaOH to liberate ammonia gas into receiving flask where it converts the boric acid to the borate ion. Finally, the distillate was titrated with standard 0.1 M HCl and crude protein content was calculated as total nitrogen, according to AOAC (2016).

The in vitro organic matter digestibility (IVOMD) and Metabolizable energy (ME) content of the experimental feeds were estimated using the equation of Menke and Steingass (1979). Content of *enset* corm was analyzed by atomic absorption and vanado-molybdate methods, respectively (AOAC, 1998) and beta-carotene content of enset corm was determined by spectrophotometer (AOAC, 1998). Metabolizable energy (ME) content of the experimental diets was calculated by indirect method from the equation proposed by Wiseman (1987) as ME (Kcal/kg DM) = 3951 + 54.4EE - 88.7CF - 40.8 ash. In vitro dry matter digestibility (IVOMD) was measured by the procedure as described by Tilly and Terry, (1963). Samples about 0.5 grams in triplicate were incubated in 60ml centrifuge tubes fitted with Bunsen valve. Rumen liquor was collected from a rumen-fistulated animal. Rumen liquor was filtered through double layers of muslin cloth and mixed with buffer solution 1:3 ratio. An aliquot of 10 ml was dispensed in each tube with simultaneous flushing of CO2 to establish anaerobic conditions in the tubes. The tubes were closed and incubated at 37 ºC for 48 hours. Tubes containing rumen fluid without samples and tubes with standard samples were also included in each run for the determination of blank values. All possible measures were adopted to maintain the micro flora of rumen liquor during collection, filtration, and dispensing. The contents of the tubes were mixed two times by gentle swirling at twelve-hour intervals. On termination of the incubation (48 hours), the tubes were centrifuged at 3000 rotations per minute for 5 minutes. The supernatant was discarded. The tubes with the precipitate were dried in an oven at 70-72 ºC. Finally, after cooling in desiccators the tubes were weighed.

The IVDMD was calculated as under:

$$IVDMD\% = (A-(B-C))/A \times 100$$

A = weight of sample (DM)

B = weight of undigested dried residues in a tube.

C = weight of undigested dried residues of rumen fluid in the blank tube.

3.5. Data Analysis

All collected data throughout the experimental period were analyzed using one-way analysis of variance (ANOVA) in the statistical analysis software SAS (9.2 version) (SAS, 2012). Following the significant mean differences, Dunne's multiple mean comparison was used to locate differences between the treatment means.

$$\mathbf{Y_{ij} = \mu + T_i + \beta_i + \epsilon_{ij}}, \quad \mathbf{\epsilon_{ij} \sim N(0,\ S^2)}$$

Where:

Y_{ij}= Response variable

μ = Overall mean

T_i = Treatment effect

β_i = Block effect, and

ϵ_{ij} = Random error

3.6. Partial budget and economic efficiency analysis

The feed cost per unit live weight gain was determined by using the feed cost of the respective treatment feed divided by live body weight gain. To estimate, the economic benefit of supplementing *enset* corm and conventional feed for sheep was calculated according to Upton, M. (1979). Variable costs (feed cost, medicine cost, transport cost, labor cost, and water through cost), selling and purchasing price of experimental sheep were included in the calculation. Total return (TR) was calculated as the difference between the selling and purchasing price of the experimental animals. Net income (NI) was calculated as the amount of money left when total variable costs (TVC) were subtracted from TR.

$$\text{NI} = \text{TR} - \text{TVC} \quad \text{MRR} = \frac{\Delta\text{NR}}{\Delta\text{TVC}}$$

4. RESULT AND DISCUSSION

4.1. Chemical composition of the experimental feed ingredients

The chemical compositions of the feeds used in the current study are presented in (Table5). Variations were observed in chemical compositions, the DM content of wheat bran in the present study is 89.3%, which is lower than the report of Mamo *et al. (*2021) and Ajebu *et al.,* (2012) who reported 91.09% and 94.0%, respectively. The DM content of *enset* corm in this study is 90.6% is higher compared to the report of Nigussu *et al, (*2016) 86.3%. The Ash content of wheat bran is 4.0% which is lower than *enset* corm 6.2%. CP content of *enset* corm is 3.8% this is in line with the report of Nigussu *et al,*.(2016) who reported 3.2%, but a higher value than Ajebu and Eik (2014) who reported that the CP content of *enset* is 2.2%. The lignin content of corm in this study is 1.8% which is lower than the result of Mohammed *et al. (*2013), 2.11%. Laboratory analysis indicated that *Enset* corm has slightly higher DM and lower CP, NDF, ADL, and IVOMD than wheat bran.

The CP contents of corm (38g/kg DM) as observed in this study are higher than the results (33.3 g/kg DM) (Ajebu, 2010) reported and (36.5 g/kg DM) by Mohammed *et al*. (2013). The ME content (3718 kcal/kg DM) of *enset* corm noted in the current study is higher than the value of 3330 kcal/kg DM reported by Tadessa and Shigeta (2016), (3718 kcal/kg of DM) (3378 kcal/kg of DM) reported by (Nigussu F. *et al*., 2016), and Mohammed *et al*. (2013) respectively. Variety and age of enset plant may have contributed to the variation in ME content of enset corm (Melesse 2013).

Table 4. Chemical composition of feed ingredients used in the experimental diets (g/kg DM**)**

Chemical Composition of feedstuff	**Wheat bran**	***Enset* corm**	**Nuge seed cake**
DM%	89.3	90.6	93.9
Ash%	4.0	6.2	12.2
CP%	15.1	3.8	27.0
NDF%	39.1	28.1	34.5
ADF%	11.2	11.7	31.9
ADL%	2.8	1.8	11.6
IVOMD (%)	67.9	68.9	60.7
ME(kcal/kg)	2607	3718	2390

*DM = Dry matter; CP = Crude protein; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin; IVODM = In vitro dry matter degradability; ME= Metabolizable energy; kcal/kg = kilocalorie per kilogram***.**

4.2. Dry Matter and Nutrient Intake

The mean daily DM and nutrient intakes of sheep-fed corm as a substitute for wheat bran are presented in Table 6. In the current study, experimental animals showed there were no significant differences (P>0.05) in the intake of DM. In this study DM and Ash content in all treatments is similar, CP, in T2, is higher than from other treatments, and in T6 is lower than in T5, T4, and T3 respectively. NDF in T2 is higher than and T3, T4, T6, and T5. ADF in T2 and T6 is statistically significance among the treatments. ADL in T2 is higher than T3, T4, T6, and T5 respectively. ADF and NDF in the diet are higher the ingested feed is retained longer in the rumen, and it is expected that the animal would consume less feed, because of the occupied space or 'gut fill' Grovum and Williams (1977) . IVOMD T6 is higher than T2, T3, T4, and T5 respectively. The metabolizable energy (ME) in T6 is higher than in T4, T3, T5, and T2.

Table 5. Daily dry matter intake doyogena sheep.

Parameters	Treatment's						
Intake g/day	T2	T3	T4	T5	T6	Mean	P- value
DM	275.48	275.41	275.28	274.86	275.04	275.21	0.4608
Ash	26.81	26.81	26.61	25.41^{b}	26.33	26.351	0.0005
CP	51.58^{a}	45.70^{b}	38.81^{c}	37.68^{d}	30.84^{e}	40.925	0.0000
NDF	127.31^{a}	116.50^{b}	109.13^{c}	91.82^{e}	93.33^{d}	107.62	0.0000
ADF	59.65^{a}	58.25^{b}	56.82^{c}	56.23^{d}	59.55^{a}	58.096	0.0000
ADL	19.38^{a}	18.82^{b}	17.94^{c}	16.14^{d}	17.96^{c}	18.051	0.0000
IVOMD	188.43^{b}	184.01^{c}	179.42^{d}	177.06^{e}	192.11^{a}	184.20	0.0000
ME	27.13^{e}	32.56^{c}	34.69^{b}	28.71^{d}	44.83^{a}	33.584	0.0000

a, b,c Means within rows with different superscripts differ (p < 0.05).

4.3. Chemical Compositions and Nutrient Digestibility of Treatment Diets

The results of the chemical composition nutrient intake and digestibility of the treatment diet are presented in Table 7. There was no significant difference (p>0.05) among treatments on DM and nutrient intake. The similarity in TDM intake among treatments could be attributed to the similar offer of total supplement DM. The Ash content T5 is significant (p<0.05) the other treatments are similar, CP intake observed for sheep fed with T2 is higher than T3, T4, T5, and T6 respectively, but statistically significant. In the current study, the lower digestibility in NDF T5 and T6 might be the major factor contributing to increased intakes of the supplement diets by reducing gut fill and optimizing the rate of passage. ADF was higher (P<0.05) for sheep fed in T2 and T6 diets than T3, T4, and T5. Acid detergent lignin (ADL), is higher in T2 than T3, and statistically similar in T4 and T6. In vitro, dry matter degradability (IVODMD) and metabolizable energy (ME) intake was observed sheep fed on T6 is higher (p<0.05)

Table 6. The chemical composition of the experimental diets and refusals are presented.

Chemical Composition	Offered				
	T2	T3	T4	T5	T6
DM%	92.4	92.2	92.1	91.9	91.9
Ash%	9.3	8.9	8.9	8.5	8.8
CP%	17.3	15.3	13.0	12.6	10.3
NDF%	42.7	39.0	36.6	32.7	31.2
ADF%	20.0	19.5	19.0	18.8	19.9
ADL%	6.5	6.3	6.0	5.4	6.0
IVOMD (%)	63.2	61.6	59.4	59.2	57.0
Me(MJ/kg	13	14	12.7	13	15
	Refusal				
	T2	T3	T4	T5	T6
DM%	91.3	91.3	91.4	91.4	91.1
Ash%	7.3	8.0	7.3	7.7	7.5
CP%	7.1	8.5	6.4	6.8	6.0
NDF%	33.1	32.2	30.1	31.1	29.3
ADF%	15.6	16.0	14.1	15.7	14.8
ADL%	3.2	3.8	2.9	3.6	2.6
IVOMD (%)	59.3	59.8	59.1	57.8	58.1
Me(MJ/kg	12	13.2	13	12.7	12

T1 = grazing + 120 nuge seed cake; T2= grazing+180gram wheat bran+120gram nuge seed cake; T3= grazing+135gram wheat bran+120 gram nuge seed cake + 45gram corm; T4=grazing+90gram wheat bran+120 gram nuge seed cake + 90gram corm; T5= grazing+45gram wheat bran+120 gram nuge seed cake +135gram corm and T6= grazing+0 gram wheat bran+120 gram nuge seed cake+180gram corm.

4.4. Body Weight Change and Feed Conversion Efficiency

The body weight change of the doyogena sheep trend over 12 weeks is presented in Table 8. Generally, sheep weight increased progressively for 90 days of the experimental period. There was no statistically significant difference in the change in body weight between the treatments during the second week of the trial. This could be due to feed adaption issues. In week 4, body weight gain is significantly ($p<0.05$) higher for T3, T4, and T6 than for T1 and T2. In week 6, the body weight of experimental sheep is significantly ($p<0.05$) higher for T3, T4, and T6 as compared to T1 and T2. The reason for the absence of statistical difference in body weight gain ($p>0.05$) between Week 1 and Week 2 might be due to feed adaptation of new treatment diets.

Table 7. The body weight change of doyogena sheep.

				Treatments				
Body weight	T1	T2	T3	T4	T5	T6	Overall mean	p-value
Initial bwt.	28.92±1.88	27.57±3.10	29.57±2.37	30.71±2.62	28.21±4.52	28.5±4.0	28.91	NS
2wk	30±2.18	29±3.0	32.82±3.05	33.35±2.74	31±3.94	31.64±4.46	31.31	NS
4wks	$29.90±1.72^{c}$	$30.14±2.91^{bc}$	$36±2.58^{a}$	$35.37±2.33^{a}$	$33.28±3.63^{ab}$	$34.75±4.46^{a}$	33.24	***
6wks	$31.10±2.49^{b}$	$31.77±2.79^{b}$	$38.50±2.92^{a}$	$37.42±2.76^{a}$	$35.57±3.72^{ab}$	$37.21±4.0^{a}$	35.26	***
8wks	$32.10±2.65^{b}$	$33.42±2.80^{b}$	$40.78±2.56^{a}$	$40±2.91^{a}$	$37.50±3.79^{a}$	$40.57±4.11^{a}$	37.39	***
10wks	$33.58±2.85^{b}$	$34.64±2.28^{b}$	$42.64±2.28^{a}$	$41.74±3.13^{a}$	$39.71±3.90^{a}$	$43.10±4.19^{a}$	39.23	***
12wks	$33.92±2.65^{b}$	$36.20±1.88^{b}$	$44.70±2.15^{a}$	$43.71±3.14^{a}$	$41.71±4.0^{a}$	$45.14±4.70^{a}$	41.24	***

*a,b, Mean values in a row having different superscripts differ significantly from each other; ***p<0.05,*

NS: Non-Significant (p>0.05); T1=treatment1, T2=treatment2, T3=treatment3, T4=treatmentT4, T5=treatmentT5, T6=treatmentT6 bwt=body weight, wks=weeks.

4.5. Feed conversion efficiency and average daily weight gain

Final body weight (FBW), Average daily gain (ADG), total weight changes(BWC) and feed conversion efficiency(FCE) of yearling doyogena growing lambs fed on natural pasture and fed with *enset* corm, wheat bran, and Nouge seed cake Table 9. A significant ($p<0.000$) difference was observed in FBW, BWC, and ADG among treatments. Sheep fed on T6 diets gain higher FBW, BWC, and ADG, in T3 is statistically similar.

The findings showed an increment in the digestibility of nutrients particularly in T6. Sheep in T6, T3, and T2 had shown higher results in both final body weights. The improvement in weight gain and FCE in T6 and T5 observed in the current result might be due to the increase in nutrient supply as a result of the increase in digestibility. This is in agreement with Yilkal *et al*. (2014) and Yeheyis *et al*., (2012) studies on lupin grains. Final body weight and total gain were higher for sheep in T6 than those in other diets ($P<0.05$). Likewise, the sheep group fed with the T6 ration had significantly ($p < 0.001$) higher average daily gain (185g/day) than that of sheep groups in T2 (94 g/day). The trend of body weight change across the feeding period for Doyogena sheep in the current study growth performance had increased linearly during the 90-day feeding period in all experimental groups. There was an increasing trend for all treatment groups throughout the study period.

Table 8. Total body weight, daily weight gain, and feed conversion efficiency of sheep fed with air-dried *enset* corm replacement of wheat bran.

BODY WEIGHT	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**MEAN VALUE**	**SE**	**P-VALUE/SL**
IBW (KG)	28.92	27.57	29.57	30.71	28.21	28.5	28.91	1.21	0.4697

FBW (KG)	34.5	36^{b}	44.5^{a}	43^{a}	41.7^{a}	45^{a}	41.2	1.07	0.0001
BWC (KG., 90 DAYS	5.3^{c}	8.43^{c}	14.93^{ab}	12.29^{b}	13.49^{b}	16.5^{a}	11.87	4.0	0.000
ADG (G/HEAD/DAY)	58.80^{c}	94^{c}	166^{ab}	137^{b}	150^{b}	185^{a}	132.8	145.40	0.000
DMI		275.48	275.41	275.28	274.86	275.04	275.21	275.21	0.4608
FCE		0.3412^{e}	0.6027^{c}	0.4977^{d}	1.8324^{a}	1.4867^{b}	0.8626	0.57	0.000

a,b,c Means within rows with different superscripts differ ($p < 0.05$). IBW=initial body weight; FBW=final body weight; BWC=body weight change; ADG= average daily weight gain; FCR= feed conversion efficiency; SEM =standard error of means; NS=non-significant; kg= kilogram's; g= gram

4.5. Partial budget analysis

The economic return in terms of partial budget analysis from sheep sales and feed costs is presented in (Table 8). The result obtained from the partial budget analysis indicated that replacement of *enset* corm gave higher NR while the remaining treatments were ranked T3>T6>T4>T5 > T2 and T1. The change in total variable cost in all the treatment groups was positive. The highest net return from *ense*t corm diet is greater because of the higher body weight change production and the highest cost of the *enset* corm as compared to wheat bran. The highest profit was observed for T3 and the least from T6 this could be due to the difference in the feed composition. Sheep received in (T3) returned higher net income followed by sheep fed (T4) and (T6); and the lowest net return was scored for sheep Fed in (T1). The differences in total return, net return, and marginal rate of return (MRR) among the treatments are mainly associated with the differences in the selling price of the sheep and differences in intake and cost of the experimental feed among the treatments. Therefore, from this study, it can be said that, when available feeding sheep with sun-dried corm (T3) is recommended as economically profitable considering the net return and MRR. The change NR in T4, and T5 is negative because the total variable cost in T4, and T6 is higher than T1, T2, and T3. The MRR Table 8 implies that each additional unit of one ETB per sheep cost increment resulted in one kg weight of sheep and an additional 2.269231 and 1.439024 benefits for T3> T2> respectively. The MRR in T4 and T5 is negative because the change NR is negative. However, in this study, the cost of enset is increasing in each treatment but the corm is greater in availability, feed conversion, and digestibility.

Table 9. Partial budget and marginal rate of return analysis for Doyogena sheep fed on natural pasture and nuge seed cake basal diet and experimental feed *enset* corm and wheat bran.

			Treatments			
Parameters	T1	T2	T3	T4	T5	T6
sheep cost	4916	4686	5026	5219	4795	4845
cost NSC	432	432	432	432	432	432

cost of WB	-	324	242	162	81	-
Cost of *enset* corm	-	-	162	23	475.7	648
Labor cost	171	200	243	271	300	386
Feed and water trough	50	50	50	50	50	50
Medicinal cost	20.7	20.7	20.7	20.7	20.7	20.7
Transportation cost	429	429	486	600	671	786
TVC	6018.7	6141.7	6661.7	6777.7	6825.4	7167.7
TR	6900	7200	8900	8600	8340	9000
NR	881.3	1058.3	2238.3	1822.3	1514.6	1832.3
ΔNR	0	177	1180	-416	-307.7	317.7
ΔTVC	0	123	520	116	47.7	342.3
MRR	0	1.439024	2.269231	-3.58621	-6.45073	0.928133

TVC= Total variable cost; TR; = Total revenue NR; Net return; ΔNR=Change in net return; ΔTVC=Change in total variable cost

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

In this study evaluating the replacing of wheat bran with *enset* corm on feed intake, weight gain, in vitro digestibility, and economic efficiency in Doyogena sheep, replacing wheat bran with *enset* corm had a significant impact on the feed intake *enset* corm was found to be a palatable feed alternative, which led to adequate voluntary feed intake among the sheep. On weight gain resulted in comparable weight gain; this suggests that *enset* corm can effectively support growth and development in traditional feed components like wheat bran, in vitro digestibility of diets containing *enset* corm was assessed and found to be satisfactory. The digestibility metrics indicated that *enset* corm provides an adequate nutritional profile, making it a viable alternative to wheat bran in terms of nutrient availability and utilization. The economic analysis indicated that using *enset* corm as a substitute for wheat bran could reduce feed cost without compromising the growth performance of the sheep. This makes *enset* corm a cost-effective feed ingredients, especially in regions where enset is readily available and cheaper than wheat bran. Overall, the study concludes that *enset* corm can be a feasible and economical alternative to wheat bran in the diet of Doyogena sheep, promoting sustainable livestock production in regions where enset is cultivated. The replacement doesn't adversely affect feed intake weight gain, or digestibility, making it a practical option for sheep farmers looking to optimize feed costs while maintaining animal performance.

5.2. RECOMMENDATIONS

Based on the findings of this study, *enset* corm can be used as a complete replacement for wheat bran in the diet of doyogena sheep, improving feed intake, weight gain, in vitro digestibility, and economic efficiency. Further research is needed to investigate the effects on *enset* corm on other aspects of sheep production, such as

Carcass quality: - this includes measurements of carcass weight, dressing percentage, and meat quality traits such as tenderness, juiciness, and flavor.

Reproductive performance: - this include measures of reproductive efficiency, such as conception rate, lambing rate, and litter size.

Environmental impact: - this includes assessing the environmental impact of *enset* corm production and its use as a feed ingredient, such as greenhouse gas emissions and land use. This all will provide a more comprehensive understanding of the use of *enset* corm as a feed ingredient for Doyogena sheep and its implications for sustainable sheep production systems.

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LIST OF ANNEX

APPENDIX TABLE

Table 10. Table1 Completely Randomized AOVA for body weight change in weeks

Parameters	DF	GM	MS	SS	F-value	CV	Pr>f
Initial body weight	5	28.939	8.4778	42.389	0.79	11.30	0.5396
Wk2	5	31.302	18.6854	93.427	1.64	10.77	0.1744
Wk4	5	33.205	48.9033	244.516	5.03	9.39	0.0010
Wk6	5	35.198	66.6397	333.199	6.47	9.12	0.0002
Wk8	5	37.285	97.1510	485.755	9.30	8.67	<.0001
Wk10	5	39.122	116.045	580.227	11.09	8.27	<.0001
Wk12	5	41.203	136.557	682.78	12.45	8.04	<.0001

Table 11 Data for Analysis of ADWT, FCE, and DMI

Parameters	DF	GM	MS	SS	F-value	CV	Pr>f
ADWT	5	0.140237	0.01305162	0.06525812	556869	0.109168	<.0001
FCE	5	0.8626	3.30427970	16.52139850	140.97	16.70842	<.0001
DMI	5	275.21	43688.6385	218443.1923	56321.1	0.353467	<.0001

APPENDEX

Pictures captured during experimental period

Figure 2 Initial body weight measuring

Figure.3 Age determination of sheep by dentation

Figure. 4 Feed and water trough

Figure 5 Experimental feed preparation by air drying

Figure 6 Deworming of sheep by albendazole

Figure.6 After 2 month feeding of experimental feed