



BONGA UNIVERSITY
COLLEGE OF AGRICULTURE AND NATURAL RESOURCE
DEPARTMENT OF ANIMAL SCIENCE
GRADUATE EDUCATION PROGRAM COORDINATION

EFFECT OF NUTRITIONAL FLUSHING USING *Pentas schimperiana*
LEAF IN REPLACEMENT OF NOUG SEED CAKE ON GROWTH
PERFORMANCE AND REPRODUCTIVE PARAMETERS OF BONGA
EWES IN SOUTHWEST ETHIOPIA

MSc THESIS
BY
GELAYE YERKISHO GEBREYESUS

JUNE 2024
BONGA, ETHIOPIA



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**A THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCES,
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, GRADUATE
EDUCATION PROGRAM, BONGA UNIVERSITY FOR THE PARTIAL
FULLFILMENT OF THE REQIERMENTS OF THE MASTER'S IN ANIMAL
PRODUCTION**

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June 2024
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APPROVAL SHEET

The undersigned certify that they have read and hereby recommend to Bonga University to accept the thesis submitted by Mr Gelaye Yerkisho Gebreyesus entitled “Effect of nutritional flushing using *Pentas Schimperiana* Leaf in replacement of noug seed cake on growth performance and reproductive parameters of Bonga ewes in Southwest Ethiopia”.

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DEDICATION

I dedicate this thesis to my father Ato Yerkisho Gebreyesus, he passed away when I joined Wolaita Sodo University to pursue my B.Sc. degree.

DECLARATION

By my signature below, I declare and affirm that this thesis is my original work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. All scholarly matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

This thesis is submitted in partial fulfillment of the requirements for an MSc degree from Graduate Education Program Coordination of Bonga University. The thesis is deposited in the libraries of both Bonga University and International Center for Agricultural Research in the Dry Areas, and is made available to borrowers under the rules of the libraries. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author, Gelaye Yerkisho Gebreyesus was born on August 24, 1989 E.C from his father Yerkisho Gebreyesus and his mother Atoge Gebreyohanis in Sheda Kebele, Bitu District, Kaffa Zone, Southwestern Ethiopia. He attended his primary school education in Sheda Elementary School from 1995 to 2002 E.C. He continued his secondary and preparatory education in Bitu Millennium Secondary School and Shishinda Secondary and Preparatory School from 2003 to 2004 E.C and 2005 to 2006 E.C, respectively. Then, he joined Wolaita Sodo University in 2007 E.C to pursue his BSc study and graduated with Bachelor of Science degree in Animal and Range Sciences in June 2009 E.C with very great distinction academic status. Soon after graduation he was employed at Kaffa Zone, Decha District in youth and sport office from November, 2010 E.C to May, 2010 E.C and had served as rural entrepreneur position for six months. In May 2010 E.C, he was employed by Bonga University, department of Animal Science in a position of Technical Assistance from June, 2010 E.C to October, 2014 E.C. In November, 2014 E.C, he joined the School of Graduate Studies at Bonga University to pursue his postgraduate study in Animal production.

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LIST OF ABBREVIATIONS

⁰ C	Degree Celcius
AI	Artificial Insemination
AWAO	Adiyo Woreda Agricultural Office
AV	Artificial Vagina
BARC	Bonga agricultural research center
CL	Corpus luteum
CSA	Central Statistics Agency
g	Gram
GnRH	Gonadotropin-Releasing Hormone
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
Kg	Kilogram
m.a.s.l.	Meter above Sea Level
ME	Metabolizable Energy
MJ	Mega Joule
NAAS	National Academy of Agricultural Sciences
PGF2 α	Prostaglandin
RCBD	Randomized Complete Block Design
SWPRS	South West Peoples Regional State

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EFFECT OF NUTRITIONAL FLUSHING USING *PENTAS SCHIMPERIANA* LEAF IN REPLACEMENT OF NOUG SEED CAKE ON GROWTH PERFORMANCE AND REPRODUCTIVE PARAMETERS OF BONGA EWES IN SOUTHWEST ETHIOPIA

ABSTRACT

*In Ethiopia, there are large number of sheep population, their productive and reproductive performance is hampered by inadequate and poor-quality feeds due to diminished pasture land, the use of multipurpose shrub particularly *Pentas schimperiana* is an alternative replacement option. Providing energy and protein availability improves ewes' productive and reproductive efficiency if they are flushed 2-4 weeks before breeding. This study was aimed to evaluate the effect of nutritional flushing by using *Pentas schimperiana* leave in place of Noug seed cake on growth performance and reproductive parameters of Bonga ewes fed on natural pasture as a basal diet. The study involved, 48 Bonga ewes with an IBW of 26.66 ± 1.66 kg (mean \pm SD) and used a RCBD with 6 treatments and 8 blocks based on their IBW. Treatments involved 100% NSC (180g), and WB (270g) (T1), 75% NSC (135g), 25% PsL (45g), and WB (270g) (T2), and 50% NSC (90g), 50% PsL =90g and WB=270g) (T3), 25% NSC=45g, 75% PsL=135g, and WB=270g) (T4), 100% PsL=180g and WB=270g) (T5), and (WB=270g) control (T6). The ewes were maintained on a uniform feeding until lambing, and they were given flushing feeds for 2 weeks prior to and 2 weeks after mating. All the ewes were synchronized with PGF2 α injection on the 1st and 11th days of trial, and on 14th day, the ewes on heat were inseminated artificially. The statistical analysis system's GLM (SAS, version 9.4) was used to analyze BW, BCS, LBW, LS, GP, OE and DE. The ER, CR, LR, and FR were examined by using X² test. Natural pasture, WB, NSC, and PSL had CP contents of 6.7, 16.3, 27.1, and 20.7%, respectively. The findings demonstrated that the mean BW of the ewes under T1 (30.08), T2 (29.99), T3 (29.73), and T4 (29.49) was considerably ($P < 0.05$) higher than that of T5 (28.78) and T6 (27.75) during mating. Compared to T5 (2.81) and T6 (2.69), the ewes under T1 (3.13), T2 (3.06), T3 (3.00), and T4 (2.94) had a considerably ($P < 0.05$) higher mean BCS at mating. In comparison to T5 (38.48) and T6 (45.96), the OE was extremely significant ($p < 0.05$) under T1 (30.25), T2 (32.51), T3 (34.73), and T4 (33.25). In comparison to T4 (34.65), T5 (29.66), and T6 (25.51), the mean time to DE under T1 (37.50), T2 (35.13), and T3 (30.73) indicated a longer duration of estrus. High ER ($P < 0.05$) was recorded in T1 (100%), T2 (100%), T3 (87.5%), and T4 (87.5%), but lower in T5 (75%) and T6 (62.5%). The CR of T5 (66.67%), and T6 (60%), showed lower ($p < 0.05$) than T1 (100), T2 (87.5), T3 (85.7%), and T4 (85.7%). Compared to T5 (75%), and T6 (66.67%), the LR of T1 (100%), T2 (100%), T3, and T4 (83.3%) were higher ($P < 0.05$). Compared to T4 (133.3%), T5 (100%), and T6 (66.7%), the FR in T1 (175%), T2 (171.4%), and T3 (150%), was significant ($P < 0.05$) higher. Compared to T6 (1.46), T5 (1.50), and T4 (1.59), the LS under T1 (1.75), T2 (1.70), and T3 (1.63) was significant ($P < 0.05$). Birth weight of lamb T1 (3.51), T2 (3.33), T3 (3.26), and T4 (3.17), was substantially ($P < 0.05$) higher than T5 (2.79), and T6 (2.53). Body weight was correlated with LW ($r = 0.91$), OE ($r = 0.89$), and DE ($r = 0.79$). The study indicated replacing up to 75% of PSL improved growth and reproductive traits of the Bonga ewes, but more research is required to evaluate its effect at different times of the year to establish a comprehensive nutritional package appropriate for each season.*

Key words: Bonga ewes, flushing, body weight, body condition, reproductive performance, productive performance, *Pentas schimperiana*

1. INTRODUCTION

1.1. Background and Justification

The livestock sector plays a great role in the national economy, and it accounts for a large portion of agricultural activities. Sheep and goats are the major economically important livestock in Ethiopia, playing an important role in the livelihood of resource poor farmers and they are integral part of livestock keeping in Sub-Saharan Africa that are mainly kept for immediate cash sources, milk, meat, wool, manure, saving and risk distribution (Kosgey *et al.*, 2004). Ethiopia has the largest livestock population in Africa, with 70 million heads of cattle, 42 million heads of sheep, 52 million heads of goats, 8 million heads of camels, 56 million chickens, 2 million heads of horses, and 10 million heads of donkeys. Of the 42 million heads of sheep, approximately 70.05% are indigenous breeds (CSA, 2021).

Sheep are an important income source, a source of food, and serve as a raw material source for industry. Despite the large population of sheep, their performance per individual animal and population is hampered by inadequate and poor-quality feed, disease and parasites, underdeveloped infrastructure, and the lack of organized breeding programs and policies. Improved reproductive performance of sheep is crucial to realizing the potential of the sector in the country. It has been reported that the reproductive parameters of small ruminants are positively related to feeding management, particularly energy balance (Scaramuzzi *et al.*, 2006). Enhanced energy intake during the early breeding season is essential to improving reproductive performance.

One of the methods for raising the reproduction performance of sheep is flushing. Flushing is a temporary but purposeful increase in the level of nutrition around breeding season. Increasing the availability of energy and protein improves reproductive efficiency in ewes, and ewes should be flushed (2-4 weeks) before and during mating (Allaoui *et al.*, 2018). Nutritional flushing increases the number of blood metabolites, such as glucose, which may play a vital role in folliculogenesis and ovulation processes (Zabuli *et al.*, 2010; Archer *et al.*, 2002). Depending on the animal's energy level, neuroendocrine cells are produced to control the secretion of gonadotropin-releasing hormones (Karikari *et al.*, 2009). This consequently affects follicular development and ovulation. In addition, improving the quality of feed and feeding practices for livestock is an essential strategy to improve the ovulation rate and reproductive efficiency in animals. Livestock flushing around the breeding season has attracted attention

from sheep farmers to boost ovulation, conception rates, and the total number of lambs born. In sheep, nutritional status, adequate energy balance, and protein absorption are key factors that regulate the ovulation rate and overall reproductive performance. The interface between reproduction and nutrition in sheep has been reported by Urrutia-Morales *et al.* (2010). Studies of related types of animals indicated that flushing enhances ovulation and uterine implantation of the fetus (Habibizad *et al.*, 2015).

1.2. Statement of the problems

Feed shortages, particularly during the dry season, severely limit animal production and reproduction in Ethiopia. The major ruminant livestock feed supplies in Ethiopia are green fodder from natural pastures and crop residue with low nutritional value (CSA, 2021). In many parts of the country, available feed resources are insufficient to meet the nutritional needs of animals throughout the year due to a lack of supply or poor quality (Mengistu *et al.*, 2017). According to Abebe *et al.* (2015) one of the solutions to combating the existing livestock nutritional constraints is the use of locally cultivated multipurpose forages as livestock feed. Indigenous forages are familiar to smallholder farmers, grow with low inputs, and are adaptable to different agro-ecological conditions. As indicated by Shapiro *et al.* (2015) the use of indigenous forages as a feed resource is appealing under the present Ethiopian conditions to increase the production and productivity of livestock. Thus, one of the interference areas to boost livestock production in Ethiopia includes using local forages as a major source of livestock feed.

The Bonga breed is regarded highly in Ethiopia for its high growth performance and reproductive capacity (Haile *et al.*, 2013). However, flushing to increase reproductive performance in Bonga ewes is yet to be studied. Increasing energy and protein availability improves ewes' productive and reproductive efficiency if ewes are flushed 2-4 weeks before breeding. Farmers rely on commercial concentrate to supplement livestock productivity, there is a high cost of concentrates, limited access, and limited availability. To promote the sustainable uptake of improved flushing strategies, it is imperative to develop feeding strategies based on locally available feed resources easily accessible to farmers.

Pentas schimperiana, named after Georg Heinrich Wilhelm Schimper, who collected it primarily in Ethiopia and is known locally as *Naachi Buuto*, is one of the locally available livestock feeds in the Adiyio districts of the Kafa zone. The plant is a woody herb up to 2.5 meters tall, with primarily oblong, twinkle broad leaves. It is a locally known indigenous

fodder, that provides valuable benefits such as a source of traditional medicine and livestock feed, especially during the dry season and the leaves and twigs of *P. schimperiana* were preferred by the various livestock groups in terms of palatability (Woretaw *et al.*, 2022).

Bonga ewes are predominantly found in the southwestern regions of Ethiopia. In the study area, livestock producers feed their animals with leaves from the *Pentas schimperiana* plant alone or as a supplement to crop residue feeds during prolonged dry periods. Due to diminishing pasture land, the usage of *Pentas schimperiana* leaves and other types of forage has increased over time. The high crude protein content in the *Pentas schimperiana* leaves makes it a valuable fodder for livestock. *Pentas schimperiana* leaves is widely introduced and utilized by sheep in the study area. Still, no adequate study has been conducted, and information does not need to be available for users regarding its role as a sheep feed. The optimum nutritional flushing level of protein above farmers practice that could boost the productive and reproductive traits of Bonga ewes has not been clarified, and the amounts of proteins required to improve the productive and reproductive traits of Bonga ewes are not yet determined in the study district. As a result, this study proposes to investigate the role of *Pentas schimperiana* leaves as sheep feed with the following objectives:

1.3. Objectives

1.3.1. General Objective

- ❖ To evaluate the effect of nutritional flushing by using air-dried *Pentas schimperiana* leaves in place of Noug seed cake on the growth performance and reproductive parameters of Bonga ewes

1.3.2. Specific Objectives

- ❖ To evaluate the effect of nutritional flushing by using air-dried *Pentas schimperiana* leaves in place of Noug seed cake on the growth performance of Bonga ewes
- ❖ To evaluate the effect of nutritional flushing by using air-dried *Pentas schimperiana* leaves in place of Noug seed cake on reproductive parameters of Bonga ewes

2. LITERATURE REVIEW

2.1. Sheep Production Systems in Ethiopia

Ethiopia, with the largest number of sheep and great variation in climate and topography, indicates a good reservoir of sheep genotype. Ethiopia has a varied sheep population estimated at 42.9 million (CSA, 2021), and its distribution is paralleled by its diverse ecology. It is grouped into fourteen indigenous sheep populations, with more than eighteen breed types widely distributed across the different agro ecological zones, as reported by Gizaw *et al.* (2007). However, sheep are reared mainly by smallholder farmers and grazed in small flocks on open natural pasture and crop residue, as reported by CSA (2021). Indigenous sheep breed productivity and performance vary due to environmental factors (Petrovic *et al.*, 2012) and these variations in sheep performances of sheep in Ethiopia are also aroused from within and between breeds and management practices.

Our country's major sheep production systems include the traditional sheep production system, which consists of mixed crop livestock systems and pastoral and agro-pastoral systems, and government ranches for breeding and multiplication centers characterized by different production goals, management strategies, and practices (Tibbo, 2006). According to Adane (2017), sheep production systems are one of the major parts of the livestock production system in Ethiopia. They are categorized using criteria that include a level of integration with crop production and contribution to livelihood, level of input and intensity of production, agro-ecology, length of the growing period, relation to land, and type of commodity to be produced (Getachew *et al.*, 2017). According to the above classification criteria, the sheep production systems practiced in Ethiopia are the Highland sheep barley system, mixed crop livestock system, pastoral and agro-pastoral production system, ranching, and urban and peri-urban sheep production systems (Worku and Yadav, 2017).

2.1.1. Mixed crop livestock production systems

The production system is found in areas where the altitude ranges between 1500 and 3000 meters above sea level. Crop production and cattle rearing are the dominant agricultural practices, and sheep and goats are kept to meet small and immediate cash needs. In this farming system, sheep mainly depend on grazing fallow lands, natural pasture, and crop residues with no surplus supplement and receive minimum health care. According to Yoseph (2007), in

humid, sub-humid, and highland agro-ecological zones, sheep are kept by smallholders and grazed together with goats and other livestock, such as cattle. Hence, productivity is depressed due to nutritional stress for much of the year and carries heavy internal and external parasite burdens (EARO, 2000), as pointed out. Besides, the enhanced human population has reduced farm size and a gradual shift from keeping large to small ruminants, mainly sheep, in central Ethiopia (Peacock, 2005).

2.1.2. Highland sheep barley system

The production system prevails in the high-altitude areas (>3000 m.a.s.l.), where the major crops grown are barley and pulses such as faba beans and lentils. Sheep are the dominant livestock species in this production system. The main feed resource includes wasteland grazing, stubble, and sometimes straw. Sheep flock sizes range from 30 to several hundred heads and are reared mainly for meat, skins, and coarse wool production for the cottage industry of the central highlands, which is a subsidiary product (Gizaw *et al.*, 2008).

2.1.3. Pastoral and agro-pastoral systems

The production systems are found at altitudes below 1500 meters above sea level, mainly integrated with a large livestock population and with or no crop agriculture due to low rainfall. They are also found below 1500 meters above sea level in areas with higher rainfall to support short season crops compared to the pastoral system. The report of Mengistu *et al.* (2017) indicated that, in the pastoral system, even if there is cultivation in some areas, livestock production forms an integral part of socioeconomic life for the vast and diverse human population. In the lowlands of the country, livestock is comprised of large flocks and herds of sheep and goats, cattle, and camels, mainly transhumance, where the only surplus is sold at local markets or transported to major consumption centers.

Sheep are highly produced in pastoral and agro-pastoral systems, but larger flocks are maintained in the lowlands (agro-pastoral systems). Major sheep feed resources include grazing on communal natural pasture, crop stubble, fallow grazing, roadside grazing, crop residues, browses, and non-conventional feeds like household food leftovers, weeds, crop tillers, and fillers. Production of improved forages, improvement of low-quality feed sources such as crop residues, and supplementary feeding except fattening are almost nonexistent (Gizaw *et al.*, 2008).

2.1.4. Urban and peri urban systems

The system is characterized by the production of small ruminants within and at the periphery of cities. Numerical data is not available on the importance of urban and peri-urban production systems, but it is common to observe sheep and goats in urban areas including Addis Ababa. The major feed resources for sheep are usually leftovers from home, market area, mill, by-products, and roadside grazing (in particular the peri urban system) (Gizaw *et al.*, 2008). This system can be an important entry point for poverty alleviation and employment for household family members (FAO, 2009). Sheep keeping in urban areas has little difference in management practices and flock productivity from those in rural areas (Barbara *et al.*, 2006).

2.1.5. Ranching system

This production system can be undertaken in high land, arid or semi-arid areas either intensively or extensively, in which it is possible to produce sheep that are more uniform and targeted to satisfy the increasing export and domestic markets. This system is a range-based system of livestock production related to pastoral systems, but with different production parameters, livestock functions, and management. The system can be considered a modern land use system, and its main function is to generate cash income. Both highland and arid or semi-arid ranching can be undertaken in Ethiopia (Gizaw *et al.*, 2008).

2.2. Breeds of sheep in Ethiopia

Sheep are believed to be the first animals to be domesticated, followed by the dog and goat. The hair sheep of Africa and Asia are thought to have descended mainly from the urial (Gizaw *et al.*, 2007). According to DAGRIS, (2006), Ethiopia has a genetically diverse sheep population, three-quarters of which is found in the highlands, where mixed crop livestock and sheep barley production systems dominate. Sheep breeds in Ethiopia are classified into fourteen traditional populations in nine breeds within six major breed groups. There are about 14 traditionally recognized sheep breeds (Gizaw *et al.*, 2007) and he further indicated that sheep types in Ethiopia are highly affiliated with specific ethnic communities, and several traditional breeds are reared by and named after specific communities. According to Gizaw *et al.* (2008), morphological and molecular characterization of Ethiopian sheep breeds by targeting populations traditionally recognized by ethnic and/or geographic nomenclatures, nine genetically distinct breeds were identified.

The community-based breeding program was initiated by ICARDA, ILRI, the Austrian University of Natural Resources and Applied Sciences, and the Agricultural Research Systems in Ethiopia starting in 2009. Bonga sheep is one of the sheep breeds that have been considered for CBBP in Ethiopia (Gizaw, *et al.*, 2007). According to Haile *et al.* (2014) and Gutu *et al.* (2015), preliminary results of the evaluation carried out on the performance of the breeding programs indicated a promising result of the breeding programs in three communities (Bonga, Menz, and Horro), and the efforts of CBBP for sheep and goats were successful in the country. Gizaw *et al.* (2008), traditionally recognized that local sheep types in Ethiopia are categorized into fourteen based on their geographic distribution, distinguishing physical features and population sizes, and these are Bonga, Siemen, Sekota, Farta, Tikur, Wollo, Menz, Gumuz, Washera, Horo, Adilo, Arsi, Afar, and Blackhead Somali breeds.

2.2.1. Distinct features of the Bonga sheep breed

Bonga sheep are native to the Kaffa zone of southwestern Ethiopia and one of the fourteen indigenous sheep breeds of Ethiopia reared in the highlands of the Kaffa, Sheka, and Bench Sheko zones of southwestern Ethiopia. The name 'Bonga sheep' commonly used was derived from the town of Bonga where the breed is marketed, which is not familiar to the owners of the breed. Earlier, the sheep was known as the 'Kaffa sheep' that was bred during the administration of the last ruler of Kaffa, *Tatto Gaki Sharocho*, as indicated by (Metsafe *et al.*, 2017). The breed is mostly mutton type, with a higher body weight at maturity, and the ewes are moderately prolific. When compared with other Ethiopian indigenous sheep breeds, Bonga sheep have larger skeletal and are tolerant of many locally prevalent diseases (Haile *et al.*, 2013). In the past, Bonga sheep were considered a subtype of Horro sheep, but the findings conducted by Gizaw *et al.* (2007) showed that Bonga sheep are distinctly different from Horro sheep.

The breed is geographically distributed and reared in the Kaffa, Sheka, and Bench Sheko zones of southwestern Ethiopia. But the breed has been widely spread to the neighboring areas of the kaffa zone that share the same geographical boundary and market. Bonga sheep is classified as long-fat tailed, fatty long tail, and short hair. As reviewed by (Gizaw *et al.*, 2007). The breed is one of the known sheep breeds with a high growth rate or high weight gain and a high eating quality of meat under poor management, especially poor grazing on natural pasture (Edea *et al.*, 2012). As reviewed by Gizaw *et al.* (2007), sheep are highly adaptable to a range of environmental conditions and widely distributed across different agro-ecological zones of the

country. Due to their adaptation to harsh environments and their ability to produce in limited feed resources, they are considered investments and insurance. According to Gutu *et al.* (2015), the Bonga sheep breed presents good maternal characteristics and marked by a good litter size, and the breed exhibits a very high variability of fecundity within the population.

2.3 Major Sheep Feed Resources in Ethiopia

Nutrient are the most important requirements for metabolic activities, maintenance, pregnancy, and the body condition of livestock. For optimal stock productivity, the available feed resource should match the production systems practiced and the number of animals in a given area (Assefa and Nurfeta, 2013). The availability and relative importance of various feed resources vary from place to place and from time to time, depending on agro-ecology, livestock production systems, and the seasons of the year. In Ethiopia, the small-holder livestock production system is characterized by low growth rates, extended calving and lambing intervals, and a relatively late age at maturity (Bereda *et al.*, 2014).

2.3.1. Natural pasture

The productivity and nutritional quality of grazing natural pastures are influenced by various factors, such as ecological conditions and management schemes. The ecological factor mainly includes climatic conditions like rainfall and soil type. According to Mengistu *et al.* (2017), natural pastures are naturally occurring grasses, legumes, herbs, bushes, and shrubs that are used as animal feed. They contain the most important feed resources, however, estimates of the contribution of feed resources range greatly, and about 75 to 80 % of the estimated livestock feed in Ethiopia is received from natural pasture.

2.3.2. Improved Forages

Improved forages can play an important role in animal production systems. Improved pasture yield is higher than that of natural pasture, and a higher nutritional value, and longer productive season. It can improve the productivity of natural pastures by improving the fertility status of the soil and also improve the feed value of natural pastures when grown in mixed stands as Admassu *et al.* (2008) found. These fodder tree species were extensively distributed in most parts of Ethiopia due to their adaptation to a wide range of soils, moisture regimens, ease of establishment, and rapid growth rate. According to ESGPIP, (2008) there are several improved forage varieties of both grass and legume species-appropriate for various agro-

ecology. From these, desho grass, oat, and vetch forage species are widely known and distributed.

2.3.3. Concentrates

Concentrates are low in crude fiber content but high in both energy and protein. Supplementary concentrate feeding is required when the pasture supply is scarce in terms of either quantity or quality and in time of feed shortages. Under the current Ethiopian situation, the highest demand for supplementary concentrate feeding comes from modern dairy production and fattening animals Mengistu *et al.* (2017).

2.3.4. Agro-Industrial By-Products

It is the by-products of the primary processing of crops, along with bran and related by-products of flourmills, oilseed cakes from small and large-scale oil processing plants, and by-products of the sugar plant like molasses. Agro-industrial byproducts like Noug seed cake, wheat bran, and molasses are important sources of relatively high-quality feeds usually utilized in urban and peri-urban animal production (Gizaw *et al.*, 2017).

2.3.5. Crop Residues and Crop aftermath

The by-products of the crop residues that are received from the cultivation of cereals, pulses, oil plants, roots, and tubers can be used as an important feed resource for ruminant animals, in particular in the subsistence type of farming. Animals are allowed to graze on crop residues of wheat, tef, barley, sorghum, and pulses after harvesting, depending on the availability of the crop grown. Livestock owners used crop residues and crop aftermath to their animals until almost the second short rain came (Tonamo *et al.*, 2015).

2.3.6. Non-Conventional Feed Resources

Non-conventional feed sources usually refer to all those feeds that have not been traditionally used for feeding livestock and are not commercially used in the production of livestock feeds. As reviewed by Amata, (2014), non-conventional feeds, along with vegetable refusals, sugar cane leaves, and Inset leaves, are used as animal feed. As indicated by Tonamo *et al.*, (2015). Non-conventional feeds, such as the leftover injera and Porridge, were supplemented with livestock.

2.3.7 Fodder Trees and Shrubs

Fodder trees and shrubs are potential protein supplement feeds for small ruminants. According to Ngodigha and Anyanwu, (2009) fodder trees and shrubs contain a considerable amount of nutrients that are scarce in other dry period feeds, including grasses, indicating that shrub trees and shrubs could be used as livestock feeds. These types of feeds are generally rich in protein, vitamins, and mineral elements and can be used as dry season feed sources and additional feeds to improving the nutritive value of low-quality grasses and crop residues. According to Yayneshet *et al.* (2009), shrub trees and shrub fruits from successfully constructed enclosures might be used as important dry season protein dietary supplements, thereby increasing the economic benefits of enclosures. But shrub species offer fodder for ruminants in many parts of the globe because most of them preserve their greenness and nutritive value throughout the dry season when grasses dry up and deteriorate in quality as well as quantity (Bruh, 2008).

2.4. Nutrient Needs for Sheep

In relation to other animals' energy, protein, minerals, vitamins, and water are the most important nutrients essential for sheep (Alemu *et al.*, 2018). According to Van Soest (1994), the most recommended dry matter intake for small ruminants was (2-4%) of the body weight of the animal and 7-7.5% crude protein for maintenance to function microbial activity properly. The energy need for sheep is largely met through the consumption and digestion of roughage, pasture, and hay but, the requirement is affected by body weight, the extent of growth, and the protein content of the feed.

2.4.1. Protein requirements

Common protein supplements for ruminating animals include oil-seed cakes like cottonseed, soybean, sunflower, linseed, and peanut meals. Oil-seed cakes contain about 31-39.38 % of crude protein and 17.8-21.8 kJ of gross energy but, high-quality legume hay can contain from 12-20 % protein). As indicated by Lee (2018), the amount of fiber contained within plant material ranged by 23–90%, protein by 2–36%, lignin by 1–21% and minerals by 2–22%. As reviewed by Ranjhan (1993), a 25 kg weighing sheep requires 806-891g DM and 94-137g Crude Protein for a mean daily body weight gain of 64-101g/hr/day.

2.4.2. Energy Requirements

The important sources of energy for sheep are hay, pasture, silage, and grains, barley, corn, oats, and wheat can also be used to raise the energy level of the diet when necessary (McDonald *et al.*,2010). The energy requirement of sheep was varied depending on the temperature of the environment, type of breed, body weight of the animal, and weight gain. Sheep having 20, 30, 35 and 40 kg with 50g and 100g daily gain that requires 4.8, 1.69, 1.9 and 2.11 MJ/day (McDonald *et al.*,2010), respectively.

2.5. Challenges of sheep production systems

Most sheep in Ethiopia are kept in traditional, low input and subsistence-oriented production systems. In such a production system, sheep are the main source of cash income, manure, meat, skin, coarse wool, security, gifts, religious rituals, and medicine (Abebe and Hirpha, 2008). Sheep production systems in the country are characterized by non-specialized multipurpose breeds, extensive production systems, and little control over breeding animals (Abebe and Hirpha, 2008). As reviewed by (Addis *et al.*, 2015) extensive systems are characterized by small flock sizes, communally shared grazing, uncontrolled mating, absence of recording, low productivity per animal, a relatively limited use of improved technology, and use of on-farm products rather than purchased inputs. In mixed crop-livestock systems, relatively high inbreeding coefficient due to uncontrolled mating and the absence of sharing communal land for communal herding might potentially increase the risk unless proper measures are taken (Edea, *et al.*, 2012). Flock management in groups due to resource endowment, parity, litter size, and season were important factors that needed to be considered in the sheep improvement plan.

2.5.1. Shortage of feed

Deficiency of sufficient feed resources as the main constraint to animal production was more pronounced in the mixed crop-livestock systems, where most of the cultivated areas and high human population are located (Yenesew *et al.*, 2013). Many scholars have described the seasonal feed shortages both in quality and quantity and the related reduction in livestock productivity in different parts of Ethiopia (Getahun, 2008; Shimelis *et al.*, 2021). Survey by Mesay *et al.* (2013), in Lemu-Bilibilo district in Arsi zone reported that, feed shortage at the end of the dry season when all crop residues have been consumed and pasture growth is poor,

was the major constraint for livestock production in the area, and the feed shortage also appears even in the rainy seasons since many of the lands are occupied by crops.

2.5.2. Shortage of water

Limitation of water may result in poor nutrition and digestion, because there is a relationship between water intake and consumption of roughage, particularly during dry season. Prolonged distance travel by sheep, goats, and cattle in searching for water was another difficulty (Mesay *et al.*, 2013). Water deficiency is a limiting factor in most lowland areas and, to a limited extent, in mid altitudes. According to Belete, (2009), in the eastern, north eastern and south eastern parts of the country there is also a critical deficiency of water; however, there are breeds adapted to lowland agroecosystems through their physiological adaptation mechanisms.

2.5.3. Diseases and parasites

The high prevalence of diseases and parasites is one of the most serious challenges for sheep production in the country. According to Tibbo (2006), and Abraham (2021), this problem causes high mortality among lambs and decreasing the benefits of their high reproductive performance. Those animals with good adaptive potential are needed in these stressful environments to sustain the livelihoods of the communities (Edea, *et al.*, 2012; Helen *et al.*, 2013).

2.5.4. Environmental factors

Suitable environmental areas such as good feeding and management have the same influence as selection, and more multiple births occur under suitable conditions (Petrovic *et al.*, 2012). Previous reports by José *et al.* (2016) supported that environmental factor such as lambing year, lambing season, parity number, plan of nutrition, lamb survival, disease, and parasite infection have significant effects on the reproductive and productive performance traits of ewes. Thus, quantifying and understanding the effects of non-genetic factors and devising mechanisms to minimize the negative effects of such challenges should get due attention to raise production.

2.5.5. Market access and information

Poor infrastructure, such as road accessibility and marketing facilities, is contributing to the reduced benefit made from the sale of animals by the producers (Tibbo, 2006). Reviews

indicated that because of lack of standardized marketing systems with transparent market price information, farmers cannot receive a sufficient return from sheep production as they gain according to trader prices, and also that a lack of access to domestic and export markets holds them back from obtaining incentive benefits. The extension system provides little or no technical support to farmers regarding the production, preservation and marketing of skin (Gizaw, *et al.*, 2008). Therefore, to enhance the enormous contribution of the livestock sector to the national economy, improving animal productivity and establishing standardized marketing systems are very imperative.

2.5.6. Climatic conditions

Climate changes, particularly increases in ambient temperature, affect livestock production by both direct and indirect means (Tibbo, 2006). The production loss of the direct impact of climate change on livestock production mostly comes from heat stress which includes increased ambient temperature, reduction of milk production, reproductive efficiency, feed intake of animals, and animal health directly and indirectly through reduction of feed and water resource availability, increasing disease occurrence by decreasing environmental adaptation mechanisms of livestock through this climate change affect the livestock production and productivity which directly affect the farmers that depends up on livestock and use the livestock resources for food source, wealthy and social well-being.

2.6. Reproductive performances of sheep

Reproductive performance is the net biological achievement of all reproductive activities (Kutluca and Emsen, 2016). Reproductive performance is an integrated process encompassing both extra-ovarian signals like gonadotrophins and intra-follicular factors such as locally produced growth factors and environmental factors (Gurdeep *et al.*, 2014). The sheep's reproductive performance is the product of fertility, fecundity, and the lambs' survival (Hristova and Stoycheva, 2019). So, limiting days of age at first lambing, increasing the number of lambs per lambing, limiting the number of days for lambing interval, and limiting lamb mortality are indicators of reproductive efficiency (Yadav *et al.*, 2013).

Reproductive and growth performances of sheep and goats are important factors influencing flock productivity. All forms of end products, including milk, meat, wool, and skins rely on these factors. The factors vary mostly between and within the breeds in a given population

(Azage, *et al.*, 2010). These factors are influenced by many factors, including genotype, nutrition, and diseases, and these performance parameters are not a single trait but the combination of other several traits that determine their expression (Belete, 2009).

2.6.1. Factor that affects sheep reproductive performance

Reproductive performance is influenced by several factors, including the genetic potential of the animal, nutritional status, environmental factors (Mukasa *et al.*, 2002) and health status (Aragaw, *et al.*, 2011). Reproductive parameters are difficult to measure and are strongly influenced by management (Notter, 2000; Regassa, 2018). Fertility and reproductive behavior are considered the most prominent characteristics in breeding because these traits are the ultimate points in both reproduction and well as production of animals so; properly managed nutrition provides desired fertility. Hafez (2000) recommended that the effects of nutritional restrictions on fertility are more notable in female than the male animal. As reviewed by Ahmad-Fazel *et al.* (2014) and Robinson *et al.* (2006) nutrition is a critical influencing factor of fertility in reproduction by influencing the development of oocytes, egg laying, and fetal survival through blood metabolites. As indicated by (Mohsin *et al.*, 2012) in order to get the desired production from the animals, it is must access the required nutrients in the feed stuffs, increasing cost of feed stuffs in animal production is a great challenge in meeting the demand for animal protein especially in developing countries.

2.6.2. Effect of nutritional flushing

Sheep feeding is one of the most important factors that influence the fertility of sheep so, high level of energy feed may increase the ovulation rate and this result in a higher lambing percentage by increasing the number of twin births, this process is known as nutritional flushing. Specific care must be paid to mineral and vitamin supplements (Petrovic *et al.*, 2012). Nutritional flushing is understood as the rapid increase in the ovulation rate of ewes receiving nutrient supplementation before mating. Lassoued *et al.* (2014) display important interactions between reproduction and levels of nutrition. Positive energy balance occurs when the nutrient requirement of an animal is less than the nutrient intake, resulting in the storage of surplus nutrients. It is also associated with increased body weight and ovulation rate. As reviewed by Walkden- Brown and Bocouier (2000), nutritional flushing prior to the beginning of the breeding season positively affects body condition score, and improves the reproductive performance of small ruminants. According to (Ricardo, *et al.*, 2000 and Fouladi, *et al.*, 2009),

supplemental fats improve ovarian follicle development and corpus luteum activity and are important precursors for the synthesis of reproductive hormones such as steroids and prostaglandins.

Flushing increases the proportion of females that exhibit estrus. Encouraging these increases in lambing and kidding rates by 10-20%, and these increases is important because a flock's lambing or kidding rate is one of the primary factors hindering its economic viability (Kerr, 2006). As reported by (Liker *et al.*, 2010), this condition could be maintained through pregnancy, yet the growth and viability of the fetus will increase, which will reflect on birth weight. In another way, El-Shahat and Abo-El Maaty, (2010) reported that, supplementation of energy (fatty acids) to the basal diet had caused significant improvement in the number and size of ovarian pre- ovulatory follicles and ovulation rate of ewes. Titi *et al.* (2008) reported that, flushing has also been shown to increase the body condition and weights of ewes or does not only at mating, but also during their post-partum period, responses to flushing (Sormunen-Cristian and Jauhiainen, 2002; Chemineau *et al.*,2004).

In general speaking, flushing is a well-managed flock's nutrition and reproduction program to ensure that female sheep gain an appropriate amount of weight before being mated. It is utilized to increment the conception rate of the flock and ensures that more ewes that are mated conceive (Petrovic *et al.*, 2012). This practice is predicated on the understanding that there's distinct relationship between nutrition and reproduction and their interaction has far fetching implications for reproductive competency in small ruminants. Hence, getting the balanced nutrition at the proper time is important for the reproductive successes that drive profitable production of small ruminants (Allaoui *et al.*, 2018).

2.7. Effect of nutritional flushing on ewe productive performance

2.7.1. Effect of nutritional flushing on ewe body weight gain

Body weight plays an important role in determining various characteristics of the farm animals, especially the ones having economic importance (Pesmen and Yardimci, 2008). Since body weight and body measurement parameters vary with breed and environment, breed specific models need to be developed (Yakubu *et al.*, 2011). According to (Ndlovu *et al.*, 2007), body weight evaluation is commonly used to monitor the nutritional status and growth of animals. Karikari and Blasu, (2009), indicated that, the body weight does increase through nutritional

flushing. IlkerSerin *et al.* (2010) reported that, BW and BCS were significantly affecting pregnancy rates and suggested the necessity of using higher energy feeding in shoats with lower BW and BCS before breeding season.

According to Liker *et al.* (2010), flushing may be maintained during pregnancy, but it increases fetal growth and survival and affects birth weight. As indicated by (Bosso *et al.*, 2007), weight gains in pregnant dams often indicate prenatal development of the fetus and a significant correlation between offspring birth weight and maternal weight. Flushing of ewes increased the birth weight of Malabari progeny by 1.08kg (Prasad *et al.*, 2016). Flushing ewes before breeding resulted in a significant increase in the average daily gain of lambs before weaning, according to Idri *et al.* (2011). Vatankhah *et al.* (2012) found that increasing sheep body condition scores during mating resulted in an increased total litter birth weight.

2.7.2. Effect of nutritional flushing on ewe body condition score

Flushing purpose is to bring ewes body condition scores up to 2.5 to 3.0 before breeding and into the first stage of gestation, and getting ewes to this condition can lead to optimal conception and embryo survival rates. Flushing with protein is better if animals are on an insufficient protein diet like low-protein pasture, and improving protein levels from 10-16 of the total diet is ideal for reproductive well-being. Response to flushing is highest in animals with low body condition scores. Thin ewes respond more than those in above-average conditions (Birhane *et al.*, 2020), mature ewes show a higher response than yearlings; prolific breeds are least responsive (Allaoui *et al.*, 2018).

For a satisfactory response in breeding programs, ewes must be nourished and maintained in good body condition. It is clear that, ewes with a good nutrient intake respond most rapidly to the onset of the breeding season and continue to respond with an increase in ovulation rate (Fukui *et al.*, 2010). Lassoued *et al.* (2014) indicated important interactions between reproduction and levels of nutrition. In this sense, highly prolific ewes' high levels of nutrition prior to and during mating were related to improved reproductive performance. A high body condition score has been associated with an increase in ovulation at the beginning of the breeding season (Forcada *et al.*, 1992). Most scholars recommend a body condition score of 2.5 to 3.0 either for naturally or artificially breeding (Contreras-Solis *et al.*, 2009). Fukui *et al.* (2010) generalized that body condition is an important factor, next to ewe age, that influences the fertility of ewes after AI. The nutritional status of ewe affects reproductive

performances by hindering ovarian activity and the duration of seasonal anestrus, which influences fertility. According to Taherti and Kaidi (2016), as BCS at breeding increases, fertility and prolificacy improve.

2.7.3. Effect of nutritional flushing on lamb birth weight

Flushing diets that contain 17.5% crude protein and 2.9 Mcal/kg of metabolic energy were provided one month before and one month after the breeding season, resulting in enhanced animal sexual behavior. Besides, this supplement has a positive effect on the birth weight of lamb (Fazel and Daghighkia, 2014). Similar to the report of Sabra and Hassan (2008), consuming protein sources with average rumen degradation and energy sources in flush rations improved the birth weight of lambs. During the mating period, higher lambs (79.2%) and conception rates (73.7%) were obtained by flushing with 1.5% body weight concentrate compared to unflushed ewes (Chaturvedi *et al.*, 2018). According to Urrutia-Morales *et al.* (2010), dams experience reduced conception rates, low-level lambing rates, and reduced birth weight and weaning when their body condition score is low due to non-flushing. The changes in weight in pregnant dams indicate prenatal development of the fetus, as proved by the significant correlation between lamb birth weight and maternal weight (Liker *et al.*, 2010). The report by Idri *et al.* (2010) indicates that, flushing ewes before breeding resulted in a significant increase in the mean daily gain of lambs before weaning.

2.8. Effect of nutritional flushing on ewe reproduction performances

The system of feed flushing has been incorporated into the small ruminant management system to increase the seasonal breeding period (Seegers *et al.*, 2011), and this is based on the realization that the interaction between nutrition and reproduction has a vital role in small ruminant reproductive efficiency (Somchit *et al.*, 2007). According to Barhane *et al.* (2020), nutritional flushing is a temporal feeding management practice that focuses on the supply of high proteinaceous and high calorific value diets before, during, and after mating. Rekik *et al.* (2007), working with small ruminants, reported that short, medium, and long-term dietary alterations can influence reproductive traits. Reviews suggest that nutrition is generally a major regulator of reproduction; hence provision of extra feed to increase nutrient intake, particularly preceding mating, is known to enhance reproductive traits due to the dynamic effects of nutrition on ovulation rate (Barhane *et al.*, 2020). Due to this, nutritional flushing stimulation

is a preferred option for the management of reproduction through modulating some aspects of reproductive traits (Fatet *et al.*, 2011).

Various diets and their compositions have been used for flushing with various consequences that affect reproductive performance. The outcomes of the flushing research were based on differences in the flushing diet (Rekik *et al.*, 2012), and the period of flushing (Habibizad *et al.*, 2015). Supplementing with conventional concentrates is economically unsuitable, so more cost effective and sustainable alternative feeding strategies need to be developed. Flushing rations, along with both energy and protein sources, improve sheep and goats' sexual behavior. According to Garcia-Garcia (2012), the availability of energy has a key influence on reproductive performance, due to the sensitivity of the reproductive axis to the adequacy of nutrition and stores of metabolic reserves. The high level of flushed concentrated feed induced more energy to mate and conceive than those flushed with a low level of concentrated feed and no supplementation. However, flushing with high level concentrate supplementation is not effective in reducing abortion as Berhane *et al.* (2020) found. According to Edmondson *et al.* (2012), both energy and protein deficiencies can result in embryonic loss, depressed placental growth, fetal mummification, and the birth of weak young.

Hence, nutritional requirements can vary throughout the reproductive cycle, and strategic feed supplementation can also be an important tool to increase reproductive efficiency. Nutrition is an important regulator of reproduction, and an improvement in the nutritional status of ewe, particularly before mating, is known to increase fertility in sheep and goats due to the dynamic effects of nutrition on ovulation rate (Silvestris *et al.*, 2019). In another study, the amount of energy and protein was restricted from the diet since day 70 of pregnancy to parturition, and negative effects were observed. First of all, mothers' behavior during the initial hour postpartum was poorer than that of well-fed females during pregnancy. According to Terrazas *et al.* (2012), mothers' care towards their second litter was more affected; thus, undernourished females spent less time licking their second newborn lamb in contrast to well-fed females.

2.8.1. Effect of nutritional flushing on ovulation and pregnancy rates

Ovulation rates and follicle development are the most determinant factors that influence the reproductive efficiency of ewes (Manman *et al.*, 2017) and are highly affected by both genetic and environmental factors (Kumar *et al.*, 2013). According to Darryl *et al.* (2007), a successful ovulation rate requires developmentally competent oocytes released with appropriate timing

from the ovarian follicle. Many sheep breeds have one or two ovulations, but there are wide differences in ovulation rates among different breeds influenced by genetic background, the effects of age, season, and nutrition (Montgomery *et al.*, 2001).

Flushing feed to ewes before breeding, has been shown to improve ovulation rate and embryo survival in sheep (Never Assan, 2022). According to Karikari and Blasu, (2009), feed supplementation before or during mating has a positive effect on fertility and ovulation rate. Never Assan, (2022) reported that, maternal nutrition, through its effect on body condition, is one of the factors that strongly influences ovulation rate. Prior to mating, enhancing ewes, nutritional status with high-quality feed ensures that they gain weight and improve their physical condition, which improves estrus activity, ovulation, and conception rates. Protein and energy based supplemental feeding during mating usually improves reproductive performance by increasing the expression of ewe estrus, conception, fecundity, and twin proportions (Rodriguez *et al.*, 2015). In the ewe, short term flushing stimulates folliculogenesis and enhances ovulation rate (Somchit *et al.*, 2007).

Unflushed dams had a shorter and false start of estrus prior to synchronization, in addition to delayed pregnancy and ovulation rates (Never Assan, 2022). For pre-mating feeding or flushing, Naqvi *et al.* (2011) found that, it enhances the ovulation rate in sheep and the birth of lambs. Ewes in low body condition had a delayed estrus, no matter the extent of nourishment that they had before entering. Within the same study, a far better body condition was connected to more ovulation. Never Assan, (2022) showed that decreased ovulation is due to malnutrition approximately months earlier than mating; on the other hand, it is now no longer as quickly compensated for via short flushing.

2.8.2. Effect of nutritional flushing on lambing and fecundity rates

Limitation of dietary energy intake pre-mating resulted in little body weight gain, delayed estrus following synchronization, and decreased litter size (Hafez *et al.*, 2011). Mohammed *et al.* (2016) indicated that increasing energy in the sheep ration can increase fertility and litter size (10% higher). Hafez *et al.* (2011) reported that, the twinning rate was significantly lower with the low energy treatment than the high level, but the medium level achieved satisfactory results in estrus rate, conception rate, lambing rate, and twinning rate.

The report by Fatet *et al.* (2011) indicated that malnutrition tends to harmfully affect reproduction when nutritional stress leads to long-term estrus and limited reproduction. In female animals, improper nutrition can cause irregular cycles, reduced ovulation, weakness in offspring, and decreased twins (Petrovic *et al.*, 2012). Several consequences of reproductive and malnutrition during pregnancy were reported to be poor pregnancy, severe fetal loss, and pregnancy toxemia, Terraza *et al.* (2012) and an unbalanced diet during pregnancy affect the fertility of offspring (Wilson *et al.*, 2001). Undernourishment is a major cause of reproductive disorders, but supercharging should be avoided in late pregnancy as it can increase the incidence of dystocia (NAAAS, 2013), and unbalanced nutrition in late pregnancy leads to weight loss at birth, which limits the survival rate of lambs and young animals.

According to Grazul *et al.* (2006), improper feeding, for instance, supplied of 60% of dietary requirements for eight weeks prior to oocyte recovery reduced oocyte capacity and fertilization and reduced early embryonic development. Besides, malnutrition during pre- and early-pregnancy folliculogenesis slows follicle development in sheep fetuses (Rae *et al.*, 2001). In other studies, prenatal malnutrition of 50% of energy requirements during the first 95 days of gestation reduced the ovulation rate of adult female sheep (Rae *et al.*, 2002). In addition, metaphase to late maternal malnutrition resulted in a decreased number of large corpus luteum in female offspring (Kotsampasi *et al.*, 2009), and the survival rate of embryos can be adversely affected by malnutrition (Martin *et al.*, 2004). This indicates that it needs to be supplemented at specific times to compensate for the increased ovulation so as not to affect the survival rate of the embryo soon after fertilization, to increase reproductive performance, it is better to change the flushing at the time of mating or stop the flushing during the period soon after mating.

2.8.3. Effect of nutritional flushing on litter size

Litter size is a trait that depends on ovulation rate and is affected by the number of fertilized oocytes. In Iranian Afshari flocks, Mohammadi *et al.* (2011) obtained the highest litter size to be at the sixth lambing period (1.25) and the lowest at the first lambing period (1.09). In west African sheep (Musa *et al.*, 2005) and the Djallonke sheep breed in West Africa (Gbangboche *et al.*, 2006), the accelerated lambing systems were estimated to be 1.24 and 1.4, respectively. On the other hand, Gutu *et al.* (2015) reported that the litter size of Bonga sheep was 1.62 at field conditions based on the recorded data. According to Shorten *et al.* (2013), prolificacy is a complex trait that is influenced by paternal and fetal effects.

The twinning rate was significantly lower for the low energy treatment than for the others, and we recommend the medium level to achieve satisfactory results in terms of estrus, conception rate, fecundity, and twinning rates (Acero-Camelo *et al.*, 2008). Protein and energy-based flushing around the time of mating usually improves reproductive performance by increasing the expression of estrus, conception, fecundity, and twinning rates in sheep (De Santiago-Miramontes *et al.*, 2008). Feed supplementation during the mating period improved ovulation and pregnancy rates in low yielding sheep (Rodriguez *et al.*, 2009). Munoz *et al.* (2009), showed that nutritional requirements during pregnancy are essential to support placental and fetal development, which is vital for lamb survival. The lower pregnancy rates observed in underfed ewes could be mediated through this alteration in the signal of maternal recognition of pregnancy, as Never Assan (2022) pointed out.

3. MATERIALS AND METHOD

3.1. Description of the Study Area

The study was conducted in Boka Kebele, Adiyo district of Kaffa Zone, and south-western Ethiopia. Kaffa zone is one of the six Zones of the Southwest Ethiopian people's regional government. Adiyo district is 509 km away from Addis Ababa. Kaffa is home to a great diversity of potential tourist attractions like ancient churches, natural forests, and unique wildlife. The district consists of 20.45% degas, 61.53% woinadega, and 18.02% kola. The study area is known for the mixed crop-livestock farming system as the dominant production system. Adiyo district is located at 07°17'30"N latitude and 36°25'0"E longitude; the altitude range of the study area is between 1600 and 3348 m.a.s.l, and the annual temperatures range between a maximum of 38°C and a minimum of 3°C, respectively (SUDAC, 2007). The

livestock populations in Kaffa zone are 12,500,870 heads, which accounts for 2,034,985 (16.3%) of the sheep population in Adiyso district (ADARDO, 2020).

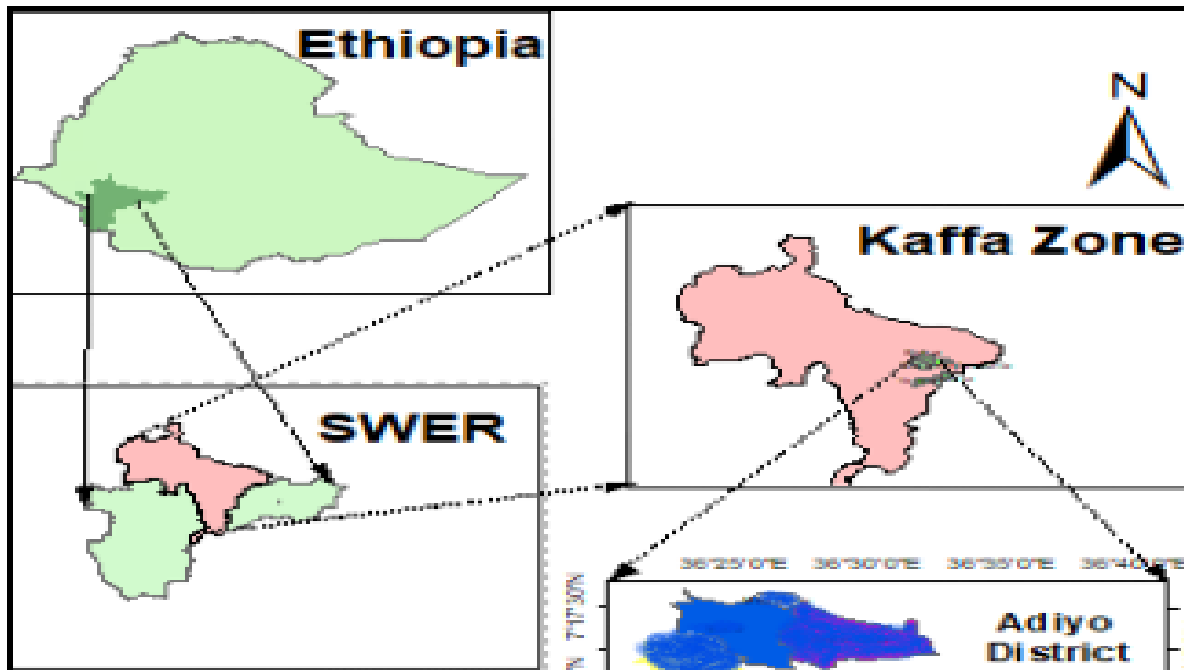


Figure: 1. Location of the study area

3.2. Sample Size and Sampling Techniques

The study was conducted by using 48 individual households and 48 ewes obtained through purposive selection based on sufficient ewe populations, farmer interest, and voluntary members that participated in CBBP. In a purposive sampling with one kebeles and six villages, 48 farmers with 48 ewes participated in the selection. At the end of the selection, awareness creation was given to all participant farmers, their sons and daughters who could read and write, data enumerators (project employed), and agricultural development agent workers on the aim and purpose of the research, how to supplement the animals, feed storage, feeding management, and data collection.

3.3. Experimental Animals and Their Management system

Forty-eight Bonga breed ewes, with an average initial body weight of 26.66 ± 1.69 (mean + SD), were selected from volunteer farmers and used for the experiment. Forty-eight Bonga breed ewes were selected based on health, age, body condition score, and body conformation. Bonga breed ewes aged between 2 to 3 years and with body condition scores of 2 to 2.5 prior to the feeding of flushing diets were included in the study (Santolaria *et al.*, 2011). The ewes used for

the experiment were not pregnant, and they were detected through CBBP data records and ultrasound (Handheld Wireless Mini Tub GmbH; Tiefenbach, Germany). The experimental ewes were housed individually and isolated from breeding rams. Ewes were ear-tagged for easy separation. All experimental ewes were checked for health status and vaccinated against common infectious diseases like ovine pasteurellosis and sheep and goats' pox. They were treated for internal parasites by albendazole (300 mg at 1 bolus/30 kg body weight, Ashish Life Science Pvt. Ltd, India) and also treated for external parasites by ivermectin, which was administered by subcutaneous injection (0.2 mg/kg body weight).

3.4. Experimental Feeds Preparation and Feeding Management

Fresh leaves of selected indigenous feed *Pentas Schimperiana* leaves were collected from moist forest edges and clearings, secondary forests, disturbed bush lands, road sides, damp wooded and shrubby places, river banks, grassy places, and fallow lands. It was harvested by both farmers and laborers with labor costing by the researcher, and the plant leaves were harvested manually with the leaf picking method 15cm from the tip of the plant. Mechanical chopping was made in to a size of approximately 2 to 3cm in length to facilitate drying. Immediately spread thinly on a plastic sheet under a shed in a well-ventilated room for drying with turning rate of 10 to 12 times per day.

The experimental diets were fed to the ewes for four weeks, i.e., for a period of two weeks before insemination and for two weeks after insemination. All ewes received supplements, twice a day, in the morning (8:00 a.m.) and evening (4:00 p.m.). Half experimental feed was given in the morning (8:00 a.m.) and half in the evening (4:00 p.m.) and they graze on natural pasture around their homestead and grazed land for 8 hours per day. Concentrates (wheat bran and Noug seed cake) were purchased from the Bonga flour factory and the Addis Ababa oil factory. Adequate supplies of the experimental feeds were stored for use during the whole study period. The feed was supplied based on their dry matter requirement and feeding trial adjustments for the experimental animal. The experiment was carried out for 28 days, after a 15-day adaptation period for the feed.

3.5. Experimental Design and Treatments

The experimental design was a randomized complete block design with six treatments and eight replications. Experimental ewes were blocked into six groups based on their initial body

weight and randomly assigned to one of the six supplementary treatments, including the control group. Before the commencement of the experiment, initial body weight and body condition scores were measured and recorded. The experimental animals were allocated to the treatment groups to ensure that all initial body weight groups were represented in the respective treatment groups and identified with ear tags for easy separation of the ewes for weighing and feeding. The amount of daily offered feed was 450g per day per head (60% energy and 40% protein) on DM base. Nutritional flushing was provided 14 days before AI and continued for 14 days after AI. At the end of the breeding season, all experimental ewes were kept on a similar feeding plan throughout the pregnancy period until giving birth.

Table 1: Feeding trials for the experiment

Treatments	Description	Supplement (g/day) on DM basis				
		GNP	WB	NSC	PSL	Total (g/day/h)
T1	100%NSC	Ad libitum	270	180	-	450
T2	75%NSC + 25%PSL	Ad libitum	270	135	45	450
T3	50%NSC + 50%PSL	Ad libitum	270	90	90	450
T4	25%NSC + 75%PSL	Ad libitum	270	45	135	450
T5	100%PSL	Ad libitum	270	-	180	450
T6	Control	Ad libitum	270	-	-	270

T=treatment; GNP=grazing natural pasture; WB=wheat bran; NSC=Noug seed cake; PSL=*pentas schimperiana* leave; g=gram; h=head(ewe).

3.6. Estrous Synchronization, Heat Detection and Insemination

To synchronize the onset of estrous, all ewes each received two intramuscular injections of 5 mg prostaglandin hormone (PGF2 α analogue dinoprost (1 mL Enzaprost®; CEVA laboratories, Libourne, France) on day 1st and 11th of nutritional flushing and were inseminated at the 14th days flushing. Estrous synchronization is the manipulation of the estrous cycle so that ewes come to estrous within a determined time frame (36 to 96 hours). In sheep and goats,

estrous synchronization is achieved either by injection of PGF2 α by reducing the length of luteal phase of the estrous cycle or by extending the cycle artificially with the application of exogenous progesterone/more potent progestogens (Abebe, 2008).

After injection of prostaglandins, ewes were observed for behavioral estrus manifestation for an hour three times daily for two consecutive days (48 hours), and behavioral observations were conducted by trained observers every day from morning 3:00-4:00am, from afternoon 8:00-9:00pm, from evening 12:00-1:00pm. After the second hormone injection and prior to artificial insemination, ewes at heat were identified using a proven ram fitted with an apron, which was used as part of the behavioral stimulus of the teaser ram effect to synchronize estrous in the ewes. Ewes were in estrous when they “stood to be mounted” by teaser rams. Other signs include active tail movement, inflamed red vulva, discharge of mucus, restlessness, frequent bleating, loss of appetite, and frequent urination (Gootwine, 2016).

To inseminate, fresh semen was obtained using an artificial vagina and promptly examined for characteristics like volume, color, sperm concentration, and motility. The processing includes dilution of the ejaculates with a semen extender in order to provide an insemination started 48 hours after PGF2 α administration. Ewes were inseminated with fresh extended semen using a vaginal speculum fitted with a light source and an insemination gun, and the semen was slowly released into the cervix (Faigl *et al.*, 2012). The average time elapsed between semen gathering and insemination was no higher than 10 to 12 minutes, and each ewe was artificially inseminated once. It was assumed that ewes were pregnant when lambing took place 150 \pm 5 days after the day of artificial insemination.

3.7. Data Collection Methods

The study was conducted for a period of 164 days, which included about 28 days (about two breeding cycles) and a pregnancy period of 150 days. The following productive and reproductive traits were recorded during the experimental period;

3.7.1. Productive performances

The body weight was recorded at weekly intervals until giving birth using a digital balance (Usine Ben Arous, Eta Torkhani, Model = ITlos Portable, max = 300kg and min = 2kg). Live weight records for all experimental ewes were taken at 8 a.m. in the morning before feeding

and watering. Besides, the dam's weight was measured before and after parturition to evaluate the loss in weight due to lambing, and finally, weight was expressed in kilograms (Kg).

The BCS of ewes was measured on a scale of 1 to 5 through the examination of the muscling and fat deposition surrounding and over the vertebrae in the loin by palpation (Abebe, 2008). This was started at the beginning of the experiment and continued until lambing.

Lamb birth weight is the weight that is measured immediately after birth, within 24 hours. It is the first productive trait to be assessed in newborns, as it has great importance in evaluating the growth performance and survival of lambs (Terrazas *et al.*, 2012).

3.7.2. Reproductive performances

Reproductive traits were calculated according to Landais and Cissoko (1986), as follows:

1. Time to onset of estrus (hours) = recorded by time interval of ewes to first expression of standing estrus after treatments and exposure to AI.
2. Duration of estrus (hours) = recorded by the time between the first and last standing estrus.
3. Estrus response (%) = number of ewes showing estrus per number of ewes treated with hormone x 100.
4. Conception rate (%) = number of ewes pregnant per number of ewes mated x 100.
5. Lambing rate (%) = number of ewes giving birth/number of pregnant ewes x 100.
6. Fecundity rate (%) = number of lambs born/number of ewes inseminated x 100.
7. Gestation period (days) = the period calculated from conception to parturition/giving birth.
8. Litter size (numbers) = number of lambs born per number of ewes lambbed.

3.8. Chemical Analysis of experimental feeds

Chemical analysis was performed in the animal nutritional research laboratory of the International Livestock Research Institute (ILRI) in Addis Ababa. After oven drying at 100 °C for 24 hours, samples were ground to pass through a 1 mm sieve mesh and analyzed using the conventional wet chemistry method. Dry matter was determined by oven drying at 105 °C overnight (Method 934.01). The ash value was determined by burning overnight in a muffle furnace at 500 °C (Method 942.05). Nitrogen content was determined by the Kjeldahl method using Kjeldahl (protein/nitrogen) Model 1026 (Foss Technology Corp.) (Method 954.01). A conversion factor of 6.25 was used to convert nitrogen to crude protein. Neutral detergent fiber,

acid detergent fiber (ADF), and lignin were determined as described by NRC (1985). The neutral detergent fiber was expressed as exclusive of residual ash. The acid detergent fiber was expressed without residual ash. Lignin was determined by the solubilization of cellulose with sulphuric acid. In vitro, organic matter digestibility was measured in rumen microbial inoculum using an in vitro gas production technique based on the procedures explained by Kears (1982). Gas production was recorded after 24 hours of incubation and used to calculate In-vitro Organic Matter Digestibility (IVOMD) according to (Nottle *et al.*, 1990). using suitable equations for legume hays as follows:

IVOMD (g/kg) = 14.88+0.889GP+0.45CP+0.0651XA, where GP: 24 hours net gas production (mL/200 mg), CP: crude protein (g/kg DM), and XA: ash content (g/kg DM).

Metabolizable energy (ME) was estimated from digestible energy (DE) and IVOMD using regression and summation equations developed by (Downing *et al.*, 1995): First, DE (digestible energy) was obtained using the formula:

DE = (0.01 × (OM/100) × (IVOMD + 12.9) × 4.4) – 0.3, then metabolizable energy could be calculated as follows: ME (Mcal/kg) = 0.82 × DE was calculated and converted to Kilogram ME (MJ/kg) = 4.184 × ME (Mcal/kg).

3.9. Data Analysis

The collected data were entered into Microsoft Excel spreadsheet (2010) and then edited, coded, and summarized by descriptive statistics like the mean. Finally, the data was subjected to ANOVA using the general linear model procedure of SAS version 9.4 in a completely randomized block design. Mean comparison was carried out using the Tukey HSD (Tukey honestly significant difference) test at the 5% level as described by Steel and Torrie (1980) for variables whose F-values indicated significant differences at P<0.05. Chi-square categorical analysis was also conducted for estrus response, conception rate, lambing rate, and fecundity rates. The correlation coefficient between productive performance and reproductive parameters was performed using the Pearson correlation test (Petrie and Watson, 1999).

The appropriate model used for data analysis was:

$Y_{ij} = \mu + T_i + B_j + e_{ij}$. Where:

Y_{ij} = dependent variables (body weight, conception rate, litter size);

μ = overall mean;

T_i = treatment (nutritional feeding effect);

B_j = block (body weight effect);

e_{ij} = random error

4. RESULT AND DISCUSSION

4.1. Chemical Analysis of Experimental Feeds and Treatments

The chemical composition of the feed used in this experiment is presented in Table 2. The DM content of NP offered in the study was akin with values of 91.3% (Lemma *et al.*, 2018), and 91.6% (Dessie *et al.*, 2019). But the current result is lower than the previous values of DM in NP (94.53%) and (95.75%) reported by Kibrom (2017) and Mezgebu *et al.* (2019), respectively. Variation might be due to species composition and stage of maturity. The CP content of the NP used in the study was below the maintenance requirement (7-7.5%) of sheep for microbial function (Van Soest, 1994), and this implies that the NP is of low quality, revealing the necessity of supplementary feeding for animals. The CP content of NP in the current study is higher than the previous report of Kebede *et al.* (2017), which was 3.73%, but lower than the value of 9.81% reported by Gebregiorgis *et al.* (2017). The OM content of NP

was similar to the results of Bimrew *et al.* (2010), who reported 88.8% OM, but lower than the OM of 91.5% obtained by Bruh (2008). The current NDF and ADF values were greater than to previous results of Dessie *et al.* (2019), who reported 58.68 for NDF and 41.2 for ADF. However, this agrees with the values of 71.23 for NDF and 46.43 for ADF reported by Bimrew *et al.* (2016). IOMD is the proportion of organic matter in the feed that is apparently digested in the total ruminant digestive tract and can be used to measure the energy available and to estimate the protein microbial synthesis in the rumen (Al-Arif *et al.*, 2017). The current IVOMD recorded from NP (50.67%) was higher than the 46.9-72.9% reported by Feyisa *et al.* (2022).

Pentas schimperiana leave has DM (92.5%), CP (20.7%), and ME (8.2%). The current result was in line with the report by Takele *et al.* (2014), who reported the nutrient compositions of *V. amygdalina* were 94.24% of DM and 19.25% of CP, and also agreed with Masho *et al.* (2023), who reported the chemical composition of the same species was 91.6% of DM and 9.00% of ME and disagreed with 15.1% of CP, which is lower than the current result. The DM content of *PSL* was higher than the value of 90%, the CP content was lower than the value of 28.9%, and the Ash and ME content of *PSL* are lower and slightly similar with the values of 7.7%, and 8.5MJ/kg, respectively, as reported by Yoseph *et al.* (2015) in Jimma Zone, Ethiopia. The OM of *PSL* is lower than the OM value of 90% noted by Alemu *et al.*, 2018. The current CP value was higher than the value of 16.69 and 17.15% reported by Hungnew and Birhan, (2016) and Tesfaye *et al.* (2018), respectively, and lower than the value of 24.42% reported by Bilatu *et al.* (2012) for *Vigina unguiculata*. However, in agreement with the reports of Ayana *et al.* (2013), Tesfaye *et al.* (2016), and Ayalew and Bewketu (2017), who reported 20.3%, 21.03%, and 19.62% of *V. unguiculata*, respectively, study found that the NDF content was lower than the value of 57.77, 47.38% of NDF, and higher than the value of ADF, which was 31.11 and 31.42%, as noted by Tesfaye *et al.* (2016) and Alemu *et al.* (2018), respectively. The current results of ADF, Ash, OM, and ADL are comparable with those of Masho *et al.* (2023), who reported that the chemical composition of *PSL* was 41.50% ADF, 11.18% Ash, 92.40% OM, and 14.60% ADL. The CP content of *PSL* (20.7%) was similar to that of *V. unguiculata* (19.5%), higher than that of *A. salina* (14.20%), and less than that of *S. sasban* (25.3%) (Michael *et al.*, 2014). Variation might be due to the stage of maturity, season of feeding, soil fertility, and method of feed processing.

Table 2: Chemical composition of feed used in the experiments

Feeds	DM (%)	Ash (%)	OM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)	ME (MJ/Kg)
T1	92.7	8	92	19.7	44.0	21.1	6.8	63.6	9.0
T2	92.4	8.3	91.7	18.9	44.3	20.6	6.0	65.2	9.3
T3	92.4	8.6	91.4	18.7	45.8	24.6	7.2	63.9	9.0
T4	92.1	8.6	91.4	17.8	47.3	23.8	6.2	65.7	9.3
T5	92.2	9.3	90.7	17.2	48.8	26.5	7.3	64.8	9.2
NSC	93.7	11.5	88.5	27.1	35.6	33.4	14.9	55.5	7.3
PSL	92.5	10.5	89.5	20.7	45.2	40.5	12.5	61.1	8.2
WB(T6)	91.9	5.1	94.9	16.3	49.4	15.7	2.8	72.0	10.6
NP	91.6	10.8	89.2	6.7	70.5	43.8	5.4	50.67	6.8

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; IVOMD: in-vitro organic matter digestibility, ME: Metabolizable energy, NSC: Noug seed cake, PSL: pentas schimperiana leave, WB: wheat bran, NP: natural pasture, T1: 100% NSC; T2: 75% NSC and 25% PSL; T3: 50% NSC and 50% PSL; T4: 25% NSC and 75% PSL; T5: 100% PSL.

The nutrient contents of WB were 91.9% DM, 5.1% Ash, 94.9% OM, 16.3% CP, 49.4% NDF, 15.7% ADF, 2.8% ADL, 72.0% IOMD, and 10.6% ME, respectively. The DM and CP values are comparable with 16.8% CP and 92.7 DM; however, the values of Ash, ADF, ME, and IOMD are lower than 6.6% Ash, 26.1% ADF, 11.8% ME, and 78.5% IOMD, respectively, and NDF is higher than the value of 42.9% NDF reported by Tsegaye (2016) and also in line with the CP value of 16.2% reported by (Michael *et al.*, 2014).

Noug seed cake has 93.7% DM, 27.1% CP, 7.3% ME, and 55.5% IOMD. The DM and CP for NSC were greater than the findings of Owen and Amakiri (2011), who reported that *V. amygdalina* has 86.40% DM and 21.50% CP. The CP of NSC used was lower than the values of 36.2% and 33.4% reported by Shashie *et al.* (2017) and Desta *et al.* (2017), respectively, but akin to the value of 28.2% reported by Gezu *et al.* (2017). The NDF content of NSC was lower than the 41.3% reported by Workneh and Getachew (2018). Variations might be due to variety of Noug seed used, soil types, and efficiency of the oil extraction methods.

4.2. Effect of Nutritional Flushing on Body Weight Gain of Bonga ewes

In the present study, the mean body weight at the beginning, during artificial insemination, at mid of pregnancy, and during lambing in Bonga ewes that were nutritionally flushed in

different treatments is presented in Table 3. The result showed that there was no significant difference ($P>0.05$) in the mean body weight of the ewes at the initial day of the trial and this confirmed that the animals were appropriately distributed within treatment.

The mean body weight (29.49-30.08 kg) brought by the groups fed on nutritional flushing containing up to 75% *Pentas schimperiana* leaves was significantly higher ($P<0.05$) than that of the control group in experimental ewes during breeding after flushing. On the contrary, there was no significant difference between the treatment groups fed on nutritional flushing containing only natural pasture (control) and 100% *Pentas schimperiana* leaves in the mean body weight ($P>0.05$). This study showed that during artificial insemination, the results obtained in treatment (T1, T2, T3, and T4) were highly significant ($P<0.05$) compared to the control group (T6) and 100% PSL (T5). The current result was lower than the results obtained by Tesfaye *et al.* (2023), who found that the mean body weight for Doyogena ewes was between 30.86-32.89 kg when ewes flushed 250-500 enset+250-500 concentrate g/day during the flushing period at mating. This result was higher than the previous results of Shafiullah *et al.* (2021), who obtained that the body weight of Marwari ewes was 26.9-28.08kg, when ewes were flushed with 300g of concentrate supplementation for 21 days.

This result is also higher than the results recorded by Njoya *et al.* (2002) who found that the average body weight for Fulbe ewes was 22.1kg at mating when ewes were supplemented with concentrate feed. Meanwhile, in the current study, the results were significantly higher ($P<0.05$) in T1, T2, T3, and T4 treatment groups of ewes as compared to the 100% PSL (T5) and control group (T6) at mid gestation. In the present study, at mid gestation, the mean body weight of Bonga ewes for T1-T6 was between 34.16-37.93kg. The variations might be due to breed types, and time of flushing. This result was higher than the results reported by Vasanth Kumar (2015), who found that the mean body weight in Madras Red ewes was (29.98-30.91 kg) when ewes were fed cottonseed meal at mid gestation. In the present study, the mean body weight of Bonga ewes during the lambing was 31.95-36.04kg. This result was inconsistent with the results obtained by Marzouk *et al.* (2018), who recorded that the mean body weight for Ossimi ewes was 52kg during the lambing period, when ewes were flushed with a concentrate feed mixture of 500 g/ewe/day up to 1kg/ewe/day, for one month. Reciprocally, the current result was lower than the earlier result obtained by Zanouny *et al.* (2018) who reported that the mean body weight for Ossimi ewes was 39.64kg at lambing when ewes were flushed with a

concentrate feed mixture of 500 g/ewe/day up to 1000g/ewe/day for 30 days. Variations might be due to breed types, nutritional content of feed, amount, and time of flushing.

Table 3: Effect of nutritional flushing on body weight gain of Bonga ewes

Treatment	Parameters			
	IWB (kg)	BBW (kg)	PBW (kg)	LBW (g)
T1	26.66 ± 0.11	30.08 ± 0.12 ^a	37.93 ± 0.09 ^a	36.04 ± 0.35 ^a
T2	26.71 ± 0.99	29.99 ± 0.13 ^a	37.81 ± 0.03 ^a	35.54 ± 0.14 ^b
T3	26.74 ± 0.10	29.73 ± 0.11 ^a	37.56 ± 0.06 ^b	35.13 ± 0.13 ^{bc}
T4	26.72 ± 0.11	29.49 ± 0.18 ^a	37.31 ± 0.12 ^c	35.06 ± 0.45 ^c
T5	26.73 ± 0.08	28.78 ± 0.17 ^b	36.21 ± 0.10 ^d	34.31 ± 0.27 ^d
T6	26.69 ± 0.09	27.75 ± 0.15 ^c	34.16 ± 0.07 ^e	31.95 ± 0.45 ^e
P - value	0.1392	0.0001	0.0001	0.0001

IBW: Initial body weight; BBW: Breeding body weight; PBW: Pregnancy body weight; LBW: Lambing body weight; significant at (P<0.05) and with the same letter (a, b, c or d) are not significantly differ.

The present result under T1-T4 during breeding ranged between (29.49-30.08kg) which was in line with the results recorded by Melese *et al.* (2013), who found that the mean body weight in Madras Red ewes was 29.98-30.91kg, when ewes were fed cottonseed meal. The present result was lower than that of Dorper and Egyptian Rahmani sheep reported in the range of 42.93-48.49kg (Ayele *et al.*, 2015 and Radwan and Shalaby, 2017) respectively. The variations might be due to amount, and types of feeds and management across the trial.

The mean daily body weight in (T1-T4) groups fed up to 75% *Pentas schimperiana* leaves showed higher increments of body weight from beginning to breeding/mating. This increase in body weight in the four treatment groups of T1-T4 compared to the control (T6) and T5 groups as a result of crude protein amount in the supplemental feeding during the experimental day. The conversion of flushing supplementation into body reserves and thereby increases in the body weight of treatment groups agree with the study done by Rafiq *et al.* (2003) who recorded an increase in body weight gain of ewes of Pakistan which were fed flushing diet and supplemental feeding of concentrate during breeding period. This result was in line with the report of Tesfaye *et al.* (2023) who recorded higher increments of daily body weight from beginning to mating when Doyogena ewes fed 400 enset+500 concentrate g/ewe/day and 500 enset+400 concentrate g/ewe/day for 21 days. Similar findings were also stated by Islam *et al.*

(2007) and Santos *et al.* (2009) in Corriedale ewes supplemental feeding on concentrate. The trend in live weight change of sheep over the trial period shows consistent increase throughout the feeding period. A number of studies on small ruminants in Ethiopia showed significant change in body weight gain when sheep with poor quality roughages are supplemented with diets rich in protein (Michaele and Yayeneshet, 2014; Hagos, 2014).

4.3. Effects of Nutritional Flushing on Body Condition Score of Bonga Ewes

In the present study, after flushing ewes, all nutritional flushed treatment groups up to 75% *pentas schimperiana* leaf revealed a significant replacement for Noug seed cake (T1, T2, T3, and T4) gained higher body condition scores that were recorded significantly ($P<0.05$) higher than that of control group (T6) and 100%PSL (T5).

In the present study, during mating, mid pregnancy and lambing period, flushing of ewes revealed that all nutritional flushed treatment groups (T1, T2, T3 and T4) gained higher body condition scores were recorded significantly ($P<0.05$) higher than that of (T5) and control group (T6) (Table 4). During breeding period, the values were significantly ($P<0.05$) higher in T1, T2, T3 and T4, than in the control (T1) and T5 groups. In the present study, the body condition score of ewes was 2.94-3.13 during the mating period. This result was akin to the findings of Ambreen, *et al.* (2014) who reported that Corriedale ewes supplemented with 500g concentrate /ewe/day at mating have higher body condition scores. Also, the result of Santos *et al.* (2009) for Markhoz and Awassi ewes that are fed on nutritional flushing agree with the current study. But this result was higher than the results of Idri *et al.* (2010), who found that the mean body condition score in Sudanese Desert ewes was between 2.6-2.9, when ewes supplemented with ration composed of groundnut seed cake.

The result of the mean body condition score of Bonga ewes in T1 (3.13) during mating was in line with the previous result reported by Njoya *et al.* (2002), who obtained that the mean body condition score for Fulbe ewes was 3.12 at mating period; when ewes supplemented with concentrate feed. Variations may be due to the management and duration of flushing. In the present study, the body condition score of Bonga ewes at mid pregnancy was 3.02-3.25. The present result was higher than the results reported by Idri *et al.* (2010), who obtained the mean body condition score in Sudanese Desert ewes was 2.6-2.7, when ewes supplemented with ration composed of groundnut seed cake. This variation might be due to the amount of replaced feed and flushing period.

During the lambing period, the mean body condition scores showed significantly differences in treatment groups. In this study, the body condition score during lambing ranged from 2.93-3.16 (T1-T4) was higher than the findings of Idri *et al.* (2010), who recorded that the mean body condition score in Sudanese Desert ewes was 2-2.3, when ewes were supplemented with ration composed of groundnut seed cake at lambing period. Similarly, the body condition score of Bonga ewes was highly increased after nutritional flushing. This finding is in line with the findings of Tesfaye *et al.* (2023), who recorded high body condition scores at mating when Doyogena ewes were flushed with 250-500 enset+250-500 concentrate g/day for 35 days. Variations may be due to the management conditions and duration of flushing.

Nutritionally improved performance is required for sheep having low body condition scores before mating and at mating periods since it must be ≥ 2 as reported by Meza-Herrera *et al.* (2008). Furthermore, Iiker *et al.* (2010) found that body condition scores ranged between 2 and 2.5 are optimal for most breeding seasons where it shows a significant effect on ovulation rate, conception rate, lambing rate, and fecundity rate and appeared to respond a short duration increase in energy. On the other hand, Koyuncu and Canbolat (2009) showed that increasing the level of dietary protein prior mating period (short term 14 days) improved reproductive performance of ewes.

Table 4: Effect of nutritional flushing on body condition score of Bonga ewes

Treatment	Parameters			
	IBCS	BBCS	PBCS	LBCS
T1	2.63 ± 0.12	3.13 ± 0.11 ^a	3.25 ± 0.16 ^a	3.16 ± 0.03 ^a
T2	2.62 ± 0.12	3.06 ± 0.06 ^a	3.19 ± 0.14 ^a	3.05 ± 0.01 ^a
T3	2.57 ± 0.16	3.00 ± 0.09 ^{ab}	3.07 ± 0.15 ^{ab}	3.01 ± 0.04 ^{ab}
T4	2.56 ± 0.15	2.94 ± 0.15 ^{ab}	3.02 ± 0.11 ^{ab}	2.93 ± 0.02 ^{ab}
T5	2.52 ± 0.13	2.81 ± 0.09 ^{ab}	2.95 ± 0.16 ^{ab}	2.87 ± 0.03 ^{ab}
T6	2.51 ± 0.13	2.69 ± 0.11 ^b	2.75 ± 0.13 ^b	2.72 ± 0.01 ^b
P-value	0.9029	0.0114	0.0129	0.0023

IBCS: Initial body condition score; BBCS: Breeding body condition score; PBCS: Mid pregnancy body condition score; LBCS: Lambing body condition score; Different superscripts within a column represent significance difference among treatment; significant at (P<0.05) and with the same letter (a or b) are not significantly different

4.4. Effect of nutritional flushing on Reproductive performances of Bonga Ewes

4.4.1. Effect of nutritional flushing on the onset of estrus (hours)

In the current study, the mean time to onset and duration of estrus data recorded from Bonga ewes fed on nutritional flushing with graded level PSL are presented in Table 5. The mean time to onset of estrus was highly significant ($p < 0.05$) and shorter in treatment groups T1, T2, T3 and T4 than that of T6 (control group) and T5 (100% PSL) where treatment groups T1, T2, T3, and T4 speed up the ewes to come into heat earlier than treatment groups T5 and T6. This might be due to higher nutritional supplementation of feed that contains sufficient crude protein. In long flushed ewes, the onset of estrus has highly significant ($p < 0.05$) difference among all treatment groups and control feeds. This result was in line with the finding of Shamble (2017), who reported a significant difference in the onset of estrus on Begait sheep breeds in Tigray, northern Ethiopia. Differences might be due to the environmental conditions of the study area, the performance of breed and management of experimental sheep and variation of nutritional composition in the treatment feed.

The mean time to onset of estrus in the treatment was T1 (30.25 ± 0.10), T2 (32.51 ± 0.72), T3 (34.73 ± 0.63), T4 (33.25 ± 0.11) hours after estrus synchronization. The mean time to onset of estrus in the treatment, T3 (50% NSC and 50% PSL) was 34.73 ± 0.63 . This result is nearly similar to the previous results of Naqvi *et al.* (2012), who found that the mean time to onset of estrus was 36.6 ± 3.4 hours for Malpura ewes after sponge removal that ewes flushed by concentrate supplementation. In the same way, in the present study, the mean onset of estrous was highly increased after nutritional flushing, this finding is also in agreement with the findings of Tesfaye *et al.* (2023) who recorded that high onset of estrous ($32.43 \pm 5.77 - 34.14 \pm 6.08$) hours when Doyogena ewes were supplemented with 250-500 g/day during the flushing period at mating. Variations might be due to the management conditions, amount, and types of feed flushed.

On the contrary, much higher intervals recorded by Naqvi *et al.* (2011) (60 ± 3 hours) for Malpura ewes after estrus synchronized when ewes fed on concentrate supplementation and also lower intervals recorded by Moghaddam *et al.* (2019), (29 ± 3 hours) Farahani ewes after synchronized with flurogestone acetate sponges, when the ewes were given 300 g/day/ewe concentrate. Such variations might be related to the breed difference and differences in the amounts and types of nutritional supplementation. The result obtained in the current study

indicates onset of estrus for ewes feed on T4 (33.25 ± 0.11) has shorter hours than Tezera, (2015) 50.10 hours onset of estrus for local sheep breed fed on local feed in south Wollo zone; Amhara region and Hashem *et al.*, (2015) who reported 50.4 ± 7.3 hour of onset of estrus for Menz and Awass crossbred sheep, but comparable with the report of Shambel, (2020) in Tigray, northern Ethiopia, who reported 33.4 ± 3.1 hours for Begait sheep breed. Similarly, the results were consistent with those reported by Martínez-Rodrigues *et al.*, (2015), who obtained onset of estrus presentation at 33.8 ± 4 hours. Variations might be due to the environmental conditions, and management of the study sheep.

In the present study, the mean times to onset of estrus in treatment groups (T2 and T4) were 32.51 ± 0.72 and 33.25 ± 0.11 hours, respectively. These results were nearly in line with the results obtained by Danjuma *et al.* (2015), who recorded that the mean time to onset of estrus was 33.48 ± 8.6 hours for Yankasa ewes, after ewes synchronized with $\text{PGF2}\alpha$ when ewes supplemented on cotton seed cake. On the other hand, this result disagrees with El-Shahat and Abdel (2011), who recorded that the mean time to onset of estrus was 18.3 ± 1.4 hours for Baladi ewes, when ewes fed on concentrate with selenium as basal diet supplemented with 0.3 mg/kg of selenium diet. In treatment group (T5), the onset of estrus in Bonga ewes was 38.38 ± 0.94 hours. This result disagrees with (Farrag, 2019), who recorded that the ewes come into heat within 40.54 ± 18.28 hours for Abou-Delik ewes after being synchronized with $\text{PGF2}\alpha$ when the ewes flushed by 300g of barley grain/ ewe/ day. This result is also varying from the previous findings recorded by El-Shahat and Abdel (2011) who reported that the onset of estrus was 16.4 ± 1.4 days for Baladi ewes, when the ewes fed on concentrate mixture with VitE2 as basal diet supplemented with 25mg/kg of Vit E in diet. These differences might be due to the species difference, amount, and time of flushing.

4.4.2. Effects of nutritional flushing on the duration of estrus (hours)

In the current study, the mean time to duration of estrus was found to be T1 (37.50 ± 0.72), T2 (35.13 ± 0.72), T3 (30.73 ± 0.71), T4 (34.65 ± 1.07), T5 (29.66 ± 0.94), T6 (25.51 ± 0.92) hours respectively with differences being highly significant ($P < 0.05$). Among the treatments T1, T2 and T4 showed the longer duration of estrus (Table 5). The estrus duration has a highly significant ($p < 0.05$) difference among treatments and control feeds. This agreed with the report of Tezera, (2015), who reported significant difference for duration of estrus among the treatment of his study for local sheep breed in south Wollo zone. The longer duration of estrus

recorded in the present trials in treatment groups T1, T2, T3, T4 and T5 than that of T6 might be due to higher supplementation of protein before mating.

The mean time to duration of the estrus of Bonga ewes for T1-T4 is ranged from 30.73-37.51 hours. The results of the present study are higher than the previous findings reported by (Montaser and Abd-Erahem, 2015) in native ewes (21-35.9) hours and disagree with Zohara *et al.* (2014) who reported 30.5-31.6 hours in indigenous ewes. And it also disagrees with Daghash *et al.* (2017) who reported that the duration of estrus in Egyptian ewes were 32.5 hours in the control group and 31.62 hours in flushed group and relatively similar with that studied by (Tezera, 2015) in Local ewes. In another way, Naqvi *et al.* (2011) recorded that the duration of estrus in Malpura ewes, which fed on concentrate mixture was earlier (22.7) hours when compared with the present study.

The duration of estrus in treatment groups T3 and T4 was 35.13 ± 0.72 and 34.65 ± 1.07 hours respectively. This finding agrees with the findings of Tesfaye *et al.* (2023), who recorded duration of estrous (34.63 ± 3.26 to 35.46 ± 3.47) hours when Doyogena ewes were supplemented with 250-500 enset+250-500 concentrate g/day for 21 days before mating. However, these results were higher than those reported by (Moghaddam *et al.*, 2019) and Danjuma *et al.* (2015), they reported that, the estrus duration were 20 and 25.3 hours in Farahani and Yankasa, when the ewes were flushed by concentrate mixture and cottonseed cake, respectively. The study was higher than previous findings of Farrag (2019), who obtained that the estrus duration was 31.27 hours in Abou-Delik ewes that flushed on 300g of barley grain/ewe/day. Variation might be due to types and amounts of flushing.

Whereas, under treatment groups (T5), and (T3), the duration of estrus was (29.65 ± 0.94 and 30.73 ± 0.71) hours respectively. This result was nearly similar to the previous results that reported by Naqvi *et al.* (2012), who recorded that the estrus duration was 31.08 ± 1.8 hours in Malpura ewes that fed on concentrate supplementation but, lower than the results of Zohara *et al.* (2014), who reported that the duration of estrus was 33.17 ± 3.01 hours for Indigenous ewes in Bangladesh which fed on concentrate mixture. Difference could be due to the duration and season of flushing. Generally, the highest estrus duration obtained in this study was in line with the estrus duration between 18-72 hours reported by Hashemi *et al.* (2015). When the duration of estrus increases, the chance of mating also increases, so these treatment feeds were comparably enough with agro industrial byproducts to attain proper breeding.

Table 5: Effects of nutritional flushing on onset and duration of estrus in Bonga ewes

Treatment	Parameters	
	OE (hours)	DE (hours)
T1	30.25 ± 0.10 ^c	37.50 ± 0.72 ^a
T2	32.51 ± 0.72 ^d	35.13 ± 0.72 ^b
T3	34.73 ± 0.63 ^d	30.73 ± 0.71 ^b
T4	33.25 ± 1.1 ^c	34.65 ± 1.07 ^b
T5	38.48 ± 0.94 ^b	29.66 ± 0.94 ^c
T6	45.96 ± 1.03 ^a	25.51 ± 0.92 ^d
P-value	0.0001	0.0001

Different superscript within a column represents statistical significance among treatment groups: significant at (P<0.05); OE: Onset of estrous; DE: Duration of estrous

4.4.3. Effect of nutritional flushing on estrus response rate in Bonga ewes

In the current study, the estrus response, conception, fecundity, and lambing rates for each treatment in the study had been presented in (Table 6). In the current study, the estrus response rate under treatment groups T1 and T2 were 100%, these results were in accordance with (Farrag, 2019) who recorded that, the estrus response rate in Abou-Delik ewes was 100%, when ewes received flushing ration (300g of barley grain/ head/ day). Also, these results were parallel with the results of El- Shahat and Abdel Monem (2011), who reported that the estrus response rate in Baladi ewes was 100%, when using dietary supplementation of vitamin E/Selenium. Additionally, these results agreed with the results of Daghigh *et al.* (2019), who reported that the estrus response rate in Ghezel ewes was 100%, when using a flushing diet containing barley grain selenium. On the other side, these results were nearly similar to those of Huseyin *et al.* (2006) who reported that, the estrus response rate in Akkaraman ewes was 98.33%, when the ewes were flushed with barley 700g/ewe/day for 35 days. On the contrary, the present results were higher than the result reported by (Mekuriaw *et al.*, 2015), who found that the estrus response rate in Turkey ewes was 39% when the ewes were flushed by barley grain. This difference might be attributed to differences in types of breeds and flushing diets.

The result obtained for estrus response in the current study was higher than the report of Tezera, (2015) who found 66.60% estrus response for local sheep breeds in south Wollo zone; Amhara region, and also higher than the report of Marzouk *et al.* (2018) who found that estrus response

rate of 65.00% for Menz and Awass cross bred sheep. On the contrary, Never Assan *et al.* (2022) reported a 93.30% estrus response for Barki ewes. The low estrus response obtained in T5 and T6 was an indication of their poor nutritional status (low crude protein level) as they were under nutrient requirements. The differences obtained in experimental feeds might be due to the nutrient contents of the feed and soil fertility. The highest result obtained in this study was higher than the finding of (Hashem *et al.*, 2015), who reported an estrus response rate range 58.80% for Menz and Awass crossbred sheep. The variation among various researchers might be due to environmental conditions, the amount of nutritional flushing and management practices of study areas and also genetic make-up of the study ewes.

In the present study, in the treatment groups T3 and T4 estrus response was 87.5%. This result was nearly similar with Sabra and Hassan (2008), who reported that the estrus response rate was 85%, when ewes flushed with a balanced mixture of crushed yellow corn 58% plus crushed soybean 41%. However, it was lower than the result of Sabra and Hassan (2010), who recorded that, estrus response rate was 100%, when ewes fed 500g sesban forage. Differences may be due to species difference, amounts of supplementation, nutritional value of experimental feeds and management during feeding trials.

The present results in T1 (100%) and T2 (100%) were higher than the previous findings that were recorded by Masho, *et al.* (2023), who obtained that the estrous response was 90%, when the ewes fed on 1000g bassela alba /day for 28 days nutritional flushing. In this study, under treatment groups (T3 and T4) estrus response rate was 87.5%. This result disagrees with (Rana *et al.*, 2014), who found that the percentage of ewes showing an estrus response was 100%, when Barki ewes were flushed by a pelleted concentrate feed mixture. Also, disagrees with (Abd-Erahem, 2015), who reported that the estrus response was 60% when Egypt native ewes flushed by 3 kg clover and 500gm concentrate. While; this result was also inconsistent with (Shambel, 2020), who stated that the percentage of ewes showed estrus response rate was 80%, when ewes were flushing under traditional management. This results in T1 (100%) and T2 (100%) were similar with the previous findings that were recorded by Tesfaye, *et al.* (2023), who obtained that the estrous response was 100%, when the ewes fed on 250-500 ensen+250-500 concentrate g/day for 35 days nutritional flushing.

4.4.4. Effect of Nutritional Flushing on Conception rate of Bonga Ewes

The conception rate in the present study revealed that treatment groups T1, T2, T3, and T4 had significantly higher values ($p < 0.05$) than that of T6 (control). T1, T2, and T3, T4, T5 and T6 were (100%, 87.5%, 85.71%, 85.71%, 66.67%, and 60.0%), respectively. In the present study, the conception rate, under the treatment group (T1-T4) disagrees with Shafiullah *et al.* (2021), who reported that the conception rate was 72.72%, when Marwari ewes were flushed by 300g/day concentrate supplementation for 21 days and also higher than (Ahmad-Fazel *et al.*, 2014), who reported that the conception rate was 70%, when Ossimi ewes were flushed with corn 500 g/ewe/day. The present result (T1-T4) is also inconsistent with that reported by Huseyin *et al.* (2006) who obtained that the conception rates was 83.33% when Akkaraman ewes were flushed by barley 700g/ewe/day for 35 days and lower than that reported by Archer (2019) who obtained 100% for and Abou-Delik ewes when the ewes were flushed 300g of barley grain/ewe day for 21 days. The present result in (T3-T4) was nearly similar to the previous findings that were recorded by Tesfaye *et al.* (2023), who reported the conception rate of 83.33%, from ewes that fed on 250-500 enset+250-500 concentrate g/day for 35 days nutritional flushing.

The present result in T2 (87.5%) was nearly similar with the previous findings that were recorded by Masho, *et al.* (2023), who obtained that the conception rate was 88.89%, when the ewes were fed on 1000g bassela alba /day for 28 days nutritional flushing. The conception rate, in the treatment groups (T1 and T2) were 100% and 87.5% respectively. These results were higher than those recorded by Abdulkareem *et al.*, (2014), who found that the conception rate in Awassi ewes was 66.6%, when the ewes were fed on 500 g/head/day of concentrate diet for 3 weeks before mating. Also, higher than that reported by Lassoued *et al.*, (2014), who recorded that the conception rate was from 52-68% for Barbarine ewes were supplemented with a diet composed of 500g of hay and 500g of concentrate per ewe per day. Variations might be due to the amounts of feed supplemented and method of feed prepared.

The conception rates of ewes under treatment groups (T3 and T4) in the current result are slightly comparable to the reports of Ravindranath *et al.* (2014) who reported conception rate was 83.3% for Nari Suwarna Ewes fed ragi straw and supplemented with concentrate feed. On the other hand, the result of the present study under T3 and T4 (85.71) was comparable to the results of El-Hawy *et al.* (2019), who reported the conception rate was 85% from Barki ewes fed on concentrate feed mixture and bean straw. Also, these results were

nearly similar with those reported by (Shambel, 2020) who found that, the conception rate in local ewes with flushing under traditional management was 83.3%. In the current study, the conception rate in the treatment group (T5) was 66.67%. This result was nearly similar to that of Venter and Greyling (1994) who stated that the conception rate was 69.2% for Merino ewes were allocated to flushing 600g/ewe/d of treated maize. However, this result was higher than the records of Abdulkareem *et al.* (2014), who reported that the conception rate was 50% for Iraq Awassi ewes allowed to flushing on extension farms. This result attributed to the high level of nutrition, may change ovulation rate. The result of conception rate observed in this study for treatments (T1-T4) was higher than the report of Shambel, *et al.* (2020), who found that the conception rate of 46.58% for Ethiopian highland sheep in Amhara region.

The result of the conception rate obtained in this study for treatment (T3 and T4) was nearly comparable with the finding of Shambel, (2020) who reported that conception rate was 83.3% for Begait ewes in Tigray, northern Ethiopia and higher than 77.75% of conception rate which reported by Muluken and Jane, (2020) for the same breed. The result variation among different researchers might be due to management, study season, and environmental conditions of the study area. The conception rates were higher in (T1-T4) as compared to (T5 and T6). This may due to the effects of increased levels of nutrition on the blood concentrations of reproductive and metabolic hormones in the ewe and some of the intraovarian changes that take place in response to nutritional stimulation. These findings are in line with the reports of Chaturvedi (2018), which suggest that short-term flushing with protein and energy rich feed resources might be beneficial to increment conception rate. Also, Downing *et al.* (2019) have revealed that the use of concentrate feed in flushing rations, improves reproductive performance and pregnancy. This might be due to increased levels of nutrition on blood concentrations of reproductive and metabolic hormones in the ewe and intraovarian changes that take place in response to nutritional stimulation, and it was a clear reflection of their poor nutritional status as they were not able to meet their nutrient requirements solely from natural pasture grass.

4.4.5. Effect of Nutritional Flushing on Lambing rate of Bonga Ewes

In the current study, the lambing rates of T1, T2, T3 and T4 treatment groups were significantly higher ($P < 0.05$) than those T5 and T6 and lambing rate in treatment group were (100%, 100%, 83.33%, 83.33%, 75% and 66.67%, respectively (Table 6). These results were similar with Blumer *et al.* (2015) and Sejian *et al.* (2013), who recorded that strategic supplementary feeding of ewes increased lambing rates of ewes. The current result of the

lambing rate in the treatment group (T1-T4) was higher than Ahmad-Fazel *et al.* (2014), who recorded that the lambing rate was 80%, when Ossimi ewes were flushed with soya bean 500 g/ewe/day and also Sabra and Hassan (2010) who reported that lambing rate in ewes was 80%, when ewes treated with 0.5 Kg sesban forage. Besides, the current result was higher than Venter and Greyling (1994), who stated that the lambing rate was 65.1% for Merino ewes were allocated to flushing 600g/ewe/d of treated maize. The present results in T1 (100%) and T2 (100%) were similar with the previous findings that were recorded by Tesfaye, *et al.* (2023), who obtained that the lambing rate was 100%, when the ewes fed on 250-500 enset+250-500 concentrate g/day for 35 days nutritional flushing. Such deviations may be due to the types and amounts of feeds, and duration of feeding days.

The present study showed that the lambing rate in treatments T1 and T2 was 100%. These results were in accordance with Farrag (2019), who reported that the lambing rate in ewes was 100%, when ewes treated with flushing ration (300g of barley grain/ head/ day), flushed group. On the other hand, the results of T1 and T2 were similar to Abdulkareem *et al.* (2014), who reported that the lambing rate was 100% for Iraq Awassi ewes allowed to flushing on extension farms. However, these were higher than Zounouy *et al.* (2018), who recorded that the lambing rate was 78% for Ossimi ewes flushed on concentrate feed mixture. Also, higher than that stated by Montaser *et al.* (2015), who reported that the lambing rates were from 43-84%. Variations might be due to duration of trial periods, and time of flushing.

This result obtained from the current study for T3, T4 and T5 were higher than 75.60% of lambing rate observed by Koyuncu, (2010), similarly Mekuriaw *et al.* (2015) reported 58.30% lambing rate for Menz and Awass cross sheep breeds. On the contrary, it was lower than the finding of Tezera (2015) who reported 90.13% of the lambing rate in south Wollo zone; Amhara region for local sheep breeds. Different results among different researchers might be due to external and internal factors like management of experimental feeds, environmental conditions and genetic potential of the studied breeds. The present result in T3 and T4 (83.33%) was nearly similar with the previous findings that were recorded by Masho *et al.* (2023), who obtained that the lambing rate was 85.71%, when the ewes fed on local feed (1000g bassella alba) per day for 28 days nutritional flushing. Variations may be related to adequate nutrient fulfillment to fetus. Flushing around breeding time increases the lamb crop by 20-30%, primarily by increasing the number of twins born (Michael *et al.*, 2017).

4.4.6. Effect of Nutritional Flushing on Fecundity rate of Bonga Ewes

This study revealed that the fecundity rates of treatment group T1, T2, T3 and T4 were significantly ($P < 0.05$) varied from treatment groups T5 and T6 (control). The fecundity rate in the treatment group (T5) was 100%. This finding agrees with Rana *et al.* (2014), who reported that the fecundity rate was 100%, when Barki ewes were fed on a pelleted concentrate feed mixture and ad libitum of Egyptian clover hay. Also, in agreement with Idri *et al.* (2010), who reported that the fecundity rate was 99%, when Sudanese desert ewes were supplemented with ration composed of ground nut cake, common salt, and salt lick. However, this result was higher than that reported by Zounouny *et al.* (2019), who stated that the fecundity rates were 75% for Ossimi ewes when ewes supplemented with concentrate diet 500g/ewe/day and 250g of concentrates/ewe/day. These deviations from the present results may be due to variations in breed used and time of flushing.

The current result indicated that, the fecundity rate in treatment groups T1, T2, T3 and T4 were 175%, 171.4%, 133.3%, and 133.3% respectively. This result was higher than that recorded by Venter and Greyling (1994), who found that the fecundity rate was from 104-123% for Merino ewes, which were allocated to flushing 600g/ewe/d of an alkali-inophore treated maize. Also, higher than that reported by Zounouny *et al.* (2019), they stated that the fecundity rates were 75% for Ossimi ewes when ewes were supplemented with concentrate diet 250g of concentrates/ewe/day. On the contrary, this result was lower than that reported by Dhahir *et al.* (2022), who stated that the fecundity rate was 200% for Awassi ewes when the ewes were fed on 800g carrot/ewe/day. The differences might be attributed to seasons, differences in breed, types, and duration of nutritional flushing.

The fecundity rates of Bonga ewes in treatment groups (T1-T4) ranged between (133.3-175%). This result was inconsistent with the reports of Njoya *et al.* (2002), who reported fecundity rate was 112.5% for Fulbe ewes supplemented on 200g cottonseed meal/ewe/day. Meanwhile, the results of the present study were also inconsistent with the results of Bahat *et al.* (2009), who reported the fecundity rate was 80% from Barki ewes fed on concentrate feed mixture. Also, these results disagree with the result reported by (Shambel, 2020) who found that, the fecundity rate in ewes with flushing under traditional management was 75%. But these results disagreed with Abdalla, *et al.*, (2014), who recorded fecundity rates 100% and 94%. The present results in T3-T4 (133.3-150%) were nearly similar with the previous findings that was recorded by Tesfaye, *et al.* (2023), who obtained that the fecundity rate was ranged from

133.3% to 157.1%, when the ewes fed on 250-500 enset+250-500 concentrate g/day for 35 days. Flushing increased lambing, prolificacy, fecundity and pregnancy rate as observed for Sudanese desert ewes, by Robinson, *et al.* (2006).

Table 6: Flushing effect on estrus, conception, lambing and fecundity rates of Bonga ewes

Parameters	Treatment groups						P-value
	T1	T2	T3	T4	T5	T6	
ER (%)	100 ^a	100 ^a	87.5 ^b	87.5 ^b	75 ^c	62.5 ^d	0.001
CR (%)	100 ^a	87.5 ^b	85.71 ^b	85.71 ^b	66.67 ^c	60 ^d	0.001
LR (%)	100 ^a	100 ^a	83.3 ^b	83.3 ^b	75 ^c	66.7 ^d	0.030
FR (%)	175 ^a	171.4 ^a	150 ^b	133.3 ^c	100 ^d	66.7 ^e	0.030

Different superscript within a column represents significance difference among treatment; significant at (P<0.05); ER: Estrus Response; CR: Conception Rate; LR: Lambing Rate; FR: Fecundity Rate

4.4.7. Effect of Nutritional flushing on Gestation period

The present result revealed that there was non-significant change among treatment groups in gestation length. The mean gestation periods were 150.13±0.31, 150.45±0.39, 150.35±0.29, 150.53±0.28, 150.64±0.24 and 150.93±0.43 days for T1, T2, T3, T4, T5, and T6, respectively. These results were contradictory with the results of Mekoya (2008), who recorded that the length of gestation period ranged between 151.8 and 152 days when menz ewes were supplemented with two levels of *Sesban Sesban*. The current results were akin with the result found by Gizaw, (2002), who found that the length of gestation period was 150 and 151 days in sheep supplemented with concentrate mixture and *S. sesban*. And also, this result was nearly similar to the previous findings that were recorded by Tesfaye *et al.* (2023), who obtained that the gestation period ranged in 149.07 and 151.43 days; when the ewes fed on 250-500 enset+250-500 concentrate g/day for 35 days nutritional flushing. However, the present result was higher than the previous findings of Khan *et al.* (2009), who reported that the gestation period was 144 to 147 days, when the ewes fed on concentrate mixture. On the other hand, the current result was lower than the previous result reported by Sabra and Hassan, (2010), who found that the gestation period was 167 and 168 days, in ewes supplemented with 500g *Sesban* forage. Differences might be due to differences in types of feed, amounts, and season of supplement during trial periods.

4.4.8. Effect of Nutritional Flushing on Litter Size

In the present study, there was an increase in litter size in the treatment groups T1 and T2 as compared to the other treatments. The mean litter size in treatment groups T1, T2, T3, T4, T5, and T6 was 1.75 ± 0.23 , 1.70 ± 0.25 , 1.63 ± 0.24 , 1.59 ± 0.21 , 1.50 ± 0.20 , and 1.46 ± 0.21 , respectively. The highest litter size was obtained in the treatment groups (T1 and T2), and this could be attributed to increased nutritional supplementary feeding during flushing (high protein content). This result agrees with those findings, which were recorded by Marzouk *et al.* (2018), who recorded that increasing ration during breeding period, is enough to improve the reproductive performance of Ossimi ewes. The present results in (T1-T4) disagree with Mekoya (2008) who reported that litter size was 1.00 ± 1.26 when Menz ewes supplemented with two levels of *Sesban sesban*. The present result in T1 (1.75 ± 0.23) was lower than the previous findings that were recorded by Tesfaye, *et al.* (2023), who obtained that the litter size was 1.83 ± 0.06 when the ewes fed on 250-500 enset+250-500 concentrate g/day for 35 days of nutritional flushing.

4.4.9. Effect of nutritional flushing on lamb birth weight

There were highly significant ($P < 0.05$) differences among the treatment groups in the reproductive characteristics of Bonga ewes. The birth weights of lambs in T1-T4 (PSL replaced up to 75%) were significantly ($P < 0.05$) higher than T5 (100% PSL) and that of T6 (control), which could be attributed to higher amounts of crude protein supplementation. These results were higher than the previous findings reported by Sabra and Hassan, (2008), who obtained that the lamb's birth weight ranged between 2.43 and 3.04 Kg, when ewes flushed by a balanced mixture of crushed yellow corn 58% and crushed soybean 41%. On the contrary, these results were lower than the result that were reported by Khan *et al.* (2009) and Sejian *et al.* (2013), who recorded that the birth weights were 4.01 ± 0.21 and 4.13 ± 0.5 Kg, respectively. Variations might be due to amounts of supplementation, types of feeds and management during the trial. The present result in T1 (3.51 ± 0.23) was higher than the previous findings that were recorded by Tesfaye *et al.* (2023), who obtained that lamb birth weight was in the range of 3.19 and 3.39, when the Doyogena ewes fed on 250-500 enset+250-500 concentrate g/day for 35 days of nutritional flushing.

Table 7: Flushing on gestation period, litter size and lambs birth weight in Bonga ewes

Treatments	Parameters		
	GP (days)	LS (Number)	LBW (Kg)
T1	150.13 ± 0.31	1.75 ± 0.23 ^a	3.51 ± 0.23 ^a
T2	150.45 ± 0.39	1.70 ± 0.25 ^b	3.33 ± 0.39 ^b
T3	150.35 ± 0.29	1.63 ± 0.24 ^c	3.26 ± 0.24 ^{bc}
T4	150.53 ± 0.28	1.59 ± 0.21 ^c	3.17 ± 0.28 ^c
T5	150.64 ± 0.24	1.50 ± 0.20 ^d	2.79 ± 0.43 ^d
T6	150.93 ± 0.43	1.46 ± 0.21 ^d	2.53 ± 0.20 ^e
P-value	0.2187	0.0019	0.0001

Different superscript within a column represents statistical significance among treatment; significant at (P<0.05) and with the same letter (a, b, c, d or e) are not significantly different; GP: Gestation period; LS: Litter size; LBW: Lamb birth weight

4.5. Correlation between productive and reproductive parameters of Bonga ewes

The genetic associations between body weight gain, body condition score, and the reproductive parameters of Bonga ewes are presented in Table 8. The BW was significantly correlated with LBW, OE, DE, LS and BC at (p<0.05). The BCS significantly correlated with LBW, OE, DE and LS at (P<0.05). The LBW was also significantly correlated with OE and DE at (P<0.05). The DE was also significantly correlated with OE at (P<0.05). The observed correlation among reproductive parameters in the present study agreed with the report of Mohammadi *et al.* (2015), who reported similar finding with the present study in Lori sheep breed. These genetic associations were also similar to those reported by (Safari *et al.*,2007) and (Abegaz, 2002) estimated, for Australian Merino and Horo sheep, respectively.

The report of Sugiyono (2007) found that the correlation coefficient between (0.001-0.200) indicates very weak correlation, correlation coefficient between (0.201-0.400) indicates weak correlation, correlation coefficient between (0.401-0.600) indicates correlation strong enough, correlation coefficient between (0.601-0.800) indicates strong correlation and correlation coefficient between (0.801-1.000) indicates very strong correlation. The results of correlation coefficient 0.91, 0.92 and 0.93 between BW and LW, OE and DE, LW and OE respectively showed a positive and very strong correlation and this result agrees with Sugiyono (2007). A close relation between the body weight of the ewe and its reproductive performances observed in the current study agreed with Abdulkareem *et al.* (2014), who reported a strong correlation

between the fertility of the Corriedale ewes and body weight at the time of mating on supplemental feeding of concentrate.

Table 8: Correlation between production and reproduction parameters of Bonga Ewes

	BW	BC	LS	LW	GP	DE	OE
BW	1	0.50**	0.15*	0.91***	0.32ns	0.79***	0.89***
BC		1	0.09*	0.46**	0.01ns	0.45**	0.48**
LS			1	0.18ns	0.16ns	0.2ns	0.23ns
LW				1	0.31ns	0.88***	0.93***
GP					1	0.3ns	0.36ns
DE						1	0.92***
OE							1

NS=Non-Significant), BW = Body Weight, BC = Body Condition, LS = Litter Size, LW = Lamb Weight, GP = Gestation Period, DE and OE = Duration and Onset of Estrous

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study was conducted in Adiyio district Boka Kebele with the objective of evaluating the effect of nutritional flushing by using air-dried *Pentas schimperiana* leaves in place of Noug seed cake on the growth performance and reproductive parameters of Bonga ewes. The experiment was conducted by using 48 Bonga ewes with a mean initial body weight of (26.66±1.69kg) used in the trial for 28 days excluding a 15 days adaptation period. The experiment was employed a randomized complete block design with 8 replications and 6 treatments. The treatments included 180g (T1), 135g (T2), 90g (T3), 45g (T4), and 0g (T5) NSC replaced with 0g (T1), 45g (T2), 90g (T3), 135g (T4), and 180g (T5) air dried *Pentas schimperiana* leave and control group (T6) with addition of similar amount of WB (270g) for all treatments including control group per ewe per day. The productive and reproductive parameters of Bonga ewes were recorded throughout the study period and samples of feed offered were analyzed for chemical composition.

The supplemental nutrition provided to Bonga ewes seems necessary to maintain a high level of productive and reproductive performance. It could be concluded that long term nutritional flushing of Bonga ewes by *Pentas schimperiana* leave in place of Noug seed cake enhanced body weight gain, body condition score, onset of the estrus, duration of the estrus,

estrus response, conception rate, lambing rate, fecundity rate, litter size and birth weight of lamb. But gestation period was not affected by nutritional flushing supplemented on *Pentas schimperiana* leave in place of Noug seed cake.

Generally, the current experiment result indicated that nutritional flushing of Bonga ewes for two weeks before mating and two weeks after mating can improve productive performances which influences the reproductive parameters of Bonga ewes. The current study revealed that replacing up to 75% of the *Pentas schimperiana* leaves improved growth parameters and reproductive performance of Bonga ewes. Also highlights the positive potential of the dried *Pentas schimperiana* leaves mixture as a supplement to small ruminants on a basal diet of fibrous feed. Prior to mating season, the natural pasture's low protein content makes it impossible for ewes to achieve their nutritional needs, so it seems necessary to provide Bonga breed ewes with additional nutrition.

5.2. Recommendations

- ❖ Since the study was limited to one season further research is required to evaluate the effect of nutritional flushing in all seasons of the area.
- ❖ Further research is needed to fully understand the potential year-round availability of this browsing tree and the anti-nutritional composition.
- ❖ Extension works to encourage farmers to use this feed as replacement to feed sheep.
- ❖ In light of the current state of concentrate feeds, accessibility, and costs associated with agro-industrial leftovers, it is strongly advised to use browsing multipurpose trees, such as these ones, as a supplement to small ruminant feeding in these places.

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7. APPENDICES

Appendices I. Analysis of the Various Outcome Variables (ANOVA)

Variables	Source of variation	Degree of Freedom	Sum Square	Mean Square	F-Value	P-Value
Initial body weight	Treatment	5	0.035	0.007	1.80	0.1392
	Block	7	3.240	0.463	118.73	0.0001
	Error	35	0.136	0.004		
	Total	47	3.412			
Breeding body weight	Treatment	5	30.604	6.121	39.91	0.0001
	Block	7	0.608	0.087	0.57	0.7779
	Error	35	5.368	0.153		
	Total	47	36.579			
Pregnancy body weight	Treatment	5	83.444	16.689	678.71	0.0001
	Block	7	2.418	0.345	14.05	0.0001
	Error	35	0.861	0.0246		
	Total	47	86.723			
Lambing body weight	Treatment	5	84.079	16.816	193.98	0.0001
	Block	7	1.246	0.178	2.05	0.0756
	Error	35	3.0342	0.087		
	Total	47	88.359			
Initial body condition	Treatment	5	0.167	0.033	0.31	0.9029
	Block	7	1.250	0.179	1.67	0.1496
	Error	35	3.750	0.107		
	Total	47	5.167			
	Treatment	5	1.667	0.333	3.50	0.0114

Breeding	Block	7	1.167	0.167	1.75	0.1293
body	Error	35	3.33	0.095		
condition	Total	47	6.167			
Pregnancy	Treatment	5	1.297	0.259	3.41	0.0129
body	Block	7	1.745	0.249	3.28	0.0087
condition	Error	35	2.661	0.076		
	Total	47	5.703			
Variables	Source of variation	Degree of Freedom	Sum Square	Mean Square	F-Value	P-Value
Lambing	Treatment	5	11.667	2.335	4.67	0.0023
Body	Block	7	15.015	2.143	4.29	0.0016
Condition	Error	35	17.510	0.050		
	Total	47	44.167			
On set of	Treatment	5	1279.143	255.827	961.95	0.0001
estrous	Block	7	2.491	0.356	1.340	0.2617
	Error	35	9.312	0.266		
	Total	47	1290.941			
Duration of	Treatment	5	767.882	153.576	160.84	0.0001
estrous	Block	7	7.739	1.106	1.16	0.3513
	Error	35	33.418	0.955		
	Total	47	809.039			
Gestation	Treatment	5	2.926	0.585	1.49	0.2187
period	Block	7	3.958	0.565	1.44	0.2218
	Error	35	13.766	0.393		
	Total	47	20.650			
Liter size	Treatment	5	0.497	0.099	3.39	0.0019
	Block	7	4.819	0.688	2.71	0.6237
	Error	35	8.903	0.254		
	Total	47	14.219			
Lamb birth	Treatment	5	5.335	1.067	145.25	0.0001
weight	Block	7	0.056	0.008	1.08	0.3963
	Error	35	0.257	0.007		
	Total	47	5.648			