UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF ENSILED ELEPHANT GRASS (Pennisetum purpureum) SUPPLEMENTED WITH RUMEN DIGESTA-BASED CONCENTRATE ON FEED INTAKE, DIGESTIBILITY, AND GROWTH OF DJALLONKÉ SHEEP IN THE SAVANNAH ECOLOGICAL ZONE OF GHANA

APOGURA JUSTINE

2024

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRICULTURE, FOOD, AND CONSUMER SCIENCES

DEPARTMENT OF ANIMAL SCIENCE

EFFECTS OF ENSILED ELEPHANT GRASS (Pennisetum purpureum) SUPPLEMENTED WITH RUMEN DIGESTA-BASED CONCENTRATE ON FEED INTAKE, DIGESTIBILITY, AND GROWTH OF DJALLONKÉ SHEEP IN THE SAVANNAH ECOLOGICAL ZONE OF GHANA.

BY

APOGURA JUSTINE (BSc. Agricultural Technology)

INDEX NUMBER (UDS/MAN/0006/21

THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, FOOD, AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN ANIMAL SCIENCE

(Nutrition Option)

JULY, 2024

DECLARATION

Student

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere. All cited literature in the text has been well-referenced and any assistance received in writing the thesis is duly acknowledged.

Candidate's Signature…… ……………...Date…01/03/2025……………

Name: APOGURA JUSTINE

Supervisor

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of the thesis laid down by the University for Development Studies.

Principal Supervisor's Signature…… ………...Date…01/03/2025

Name: PROF. TERRY ANSAH

ABSTRACT

The study was conducted to assess the effects of ensiled elephant grass supplemented with rumen digesta-based concentrate on neutral detergent fibre digestibility, growth performance, and serum biochemistry profile of djallonké sheep. Nine (9) djallonké rams with an initial average body weight of (8.4±0.385kg) were randomly assigned to three treatments and replicated three times over 56 days in a completely randomized design (CRD). The treatments were T_0 (free range), T_1 (12.5% concentrate + 37.5% silage), and T_2 (25% concentrate + 75% silage). The concentrate was formulated with 10% rumen digesta (DRD). Most chemical analysis on experimental diets were significantly different ($p<0.05$). Organic matter was higher in T_0 while T_1 and T_2 were similar. Crude protein ranged from 100.7 -109.8 g/kgDM in this study. Neutral detergent fibre and acid detergent fibre were lower in T_0 as compared to T_1 and T_2. Most serum biochemistry parameters were significant ($p<0.05$). Urea, albumin, globulins, and total protein were higher in T_0 compared to T1 and T2. All in vitro NDF digestibility parameters estimated in this study were not significantly different ($p>0.05$) across treatments. All growth performance parameters assessed differed ($p<0.05$) in this study. Animals on T_0performed better than T_1 and T_2 while T_1 and T_2 had similar performance in this study. Average daily weight gain for T_0, $T_{1,}$ and T_2 was 107g, 68g, and 53g respectively. An average total weight gain of 6.00 kg, 3.83kg, and 3.00 kg was recorded for T_0, $T_{1,}$ and T_2 respectively in this study. The average daily dry matter intake recorded for T_0, $T_{1,}$ and T_2 was 114.1g, 62.8g, and 182.3g respectively. Supplementation of rams with DRD concentrate diet improve dry matter intake, with no adverse effect on blood biochemical indices but however, did not improve the weight gain of the rams. Farmers should

supplement ensiled elephant grasses with a DRD concentrate diet to improve the nutritive value of the diet.

Key words: Elephant grass, Growth performance, Rumen digesta, Serum biochemistry.

ACKNOWLEDGMENT

I wish to express my sincere thanks to the Almighty God for giving me the life and grace to complete this work. My sincere thanks go to Prof. Terry Ansah, my able supervisor, for his guidance, constructive criticisms, technical and fatherly advice in the design and successful execution of this project. The good Lord will grant you more years to continue your good works at UDS. I would like to also express my sincere gratitude to my co-supervisor Mr. Cudjoe Shadrack for his invaluable brotherly support during the project, may the good lord continue to guide you in all aspects of your life. My appreciation also goes to the Head of the Department and all the Lecturers of the Department of Animal Science, UDS, for their care, support, constructive criticism, and encouragement.

I would like to thank Ibrahim Osman and Tenakwa Emmanuel Afirifa for the help they provided me during my laboratory analysis and other data for the completion of the project. Not forgetting Mr. Moses Dramani and Ayuba for their help during the feeding trials. May God richly bless you all.

TABLE OF CONTENT

Table of Contents

LIST OF TABLES

LIST OF PLATE

CHAPTER ONE

1.0 Introduction

Sheep as a small ruminant have greater environmental adaptability, faster growth rates, shorter production cycles, low investment capital, ease of management, and low feed requirements in comparison with large ruminants (FAO, 2002;Estefanos *et al*., 2015). Sheep production also has numerous benefits of rearing over large ruminants in the conversion of crop residues and other agro-industrial by-products into high-quality products for consumption by smallholder farmers (Bettencourt *et al*., 2015). In northern Ghana, sheep are essential for the smallholder agricultural system due to their unique biological characteristics such as high prolificacy, high feed conversion efficiency from coarse roughages, short gestation period, rapid growth rate, and high tolerance to diseases (Lebbie, 2004; Peacock, 2005).

Globally, small ruminant nutrition depends mainly on naturally growing pastures which fluctuate both in quality and quantity within the year (Wanapat, 2000; Amole *et al.*, 2021). Drought and inadequate rainfall caused by changes in extreme weather and climatic conditions influence the availability and quality of feed resources such as pasture negatively thereby compromising animal productivity, and inadequate supply of feed, inefficient utilization of available feed resources, and poor nutritional quality of available feed material are major nutritional challenges in sheep production (Dehouegnon *et al*., 2017).

Furthermore, the utilization of silage as a roughage source for animals is a commonly employed method to combat food shortages during dry seasons (Rigueira *et al*., 2017). Ensiling, which involves preserving raw plant materials through controlled fermentation under anaerobic conditions, is the primary technique used for this purpose, relying on spontaneous lactic acid production (Oliveira *et al*., 2017). The ensiling method for forage preservation has garnered significant attention for its ability to provide a consistent and reliable feed supply for ruminant production (Oliveira *et al*., 2017). The main objective of ensiling feed resources is to ensure year-round forage availability without compromising quality, thereby enhancing the economic and environmental sustainability of silage production (Soundharrajan *et al.*, 2021). However, the high moisture content in grasses, particularly when their nutritional value is at its peak, poses a challenge to their use in silage production due to undesirable fermentation outcomes (Oliveira *et al*., 2017).

In Ghana, the primary feed resources for ruminant livestock production consist of natural forage crops, pastures, and plants, predominantly low-quality grasses that are scarce during the dry season (Wachiebene, 2021). The shortage of feed and poor quality of forage crops in Ghana present significant obstacles to the development of the ruminant industry, particularly in sheep farming (Konlan, 2018). To address these issues, feeding sheep with preserved forages in Ghana is crucial for ensuring successful sheep production. Elephant grass (*Pennisetum purpureum*) is a standout tropical forage due to its high dry matter production, ease of cultivation, acceptance by animals, and nutritional value (Dórea *et al*., 2013; Lobo *et al.*, 2014). Research by Nmoandor *et al.* (2020) in Ghana highlighted the use of cow dung, grasscutter droppings, and NPK fertilizer to enhance the dry matter yield and nutritional value of elephant grass, emphasizing the impact of fertilization on vegetative growth, biomass production, and nutrient content.

Another challenge faced during the dry season is the poor nutrient content of pastures, leading to low protein levels, reduced animal intake, and digestibility. In addition to feed scarcity in Ghana, the inadequate protein content of available feed resources necessitates supplementation with locally sourced protein to meet sheep requirements (Rufino *et al*., 2013; Fernandez, 2017). Dried rumen digesta (DRD) emerges as a valuable protein source for ruminant livestock, including sheep, derived as a by-product from slaughterhouses (Adeniji and Balogun, 2002; Dairo *et al.*, 2005). With a crude protein content ranging from 9-20% of dry matter, properly processed DRD can serve as an alternative protein source for animal nutrition, offering economic and environmental benefits (Adeniji and Balogun, 2002; Esonu *et al*., 2006; Agbabiaka *et al*., 2011; Agolisi, 2019). The use of DRD as a protein source can enhance profitability, reduce production costs, and promote environmentally friendly waste management practices (Sakaba *et al*., 2017).

Limited information exists on the feeding of ensiled elephant grass supplemented with DRD concentrate and its impact on the growth performance of djallonké sheep. Grasslands in tropical regions provide a cost-effective nutrient source for ruminants but necessitate supplementation with agro-industrial by-products and crop residues to maintain optimal productivity and growth rates (Aruwayo, 2018). These grasses require fewer inputs and are easier to establish compared to corn, making them a viable alternative for consistent daily nutrition. It is within this context that this study was conducted to assess the nutritional value of ensiled elephant grass and dried rumen digesta concentrate on intake, digestibility, and growth performance of djallonké sheep in the Northern Savanna zone of Ghana.

1.2 Main objective

The objective of this experiment was to assess the effect of ensiled elephant grass supplemented with processed rumen digesta concentrate on the growth performance of djallonke sheep.

1.2.1 Specific objectives

- ❖ To determine the chemical composition and NDF digestibility of ensiled elephant grass.
- ❖ To estimate the growth performance of djallonké sheep fed ensiled elephant grass and rumen digesta based concentrate.

CHAPTER TWO

2.0 Literature review

2.1 Importance of Sheep Production in Ghana

In northern Ghana, small ruminants are essential for the smallholder agricultural system due to their unique biological characteristics such as high prolificacy, high feed conversion efficiency from coarse roughages, short gestation period, rapid growth rate, and high tolerance to diseases (Lebbie, 2004; Peacock, 2005). In northern Ghana, small ruminant production has not been fully exploited due to high mortality rate and low productivity (Baah *et al*., 2012). Although sheep production is predominant and homogeneous across the regions of Ghana, the Northern region is considered to be the region with the majority of the nation's livestock (Koney, 2004). Because of the unpredictable nature of weather patterns and the rising need for meat to feed the world's expanding population, the increase in livestock production, for example, sheep has given farmers possibilities to add value and diversify (FAO, 1995; Koney, 2004).

The djallonke sheep is the most common throughout the nation and is heavily utilized by individual farms and breeding stations in breed improvement initiatives. They are well-known for their adaptability, tolerance to trypanosomiasis, fertility, and ability to reproduce throughout the year. Male adult djallonke sheep generally weigh (25 -30 kg), while females weigh (20 - 25 kg) as reported by Opong-Anane (2006). The normal colors of this breed are white, black, brown, or a motley combination of white and black, with the white color dominating the middle region and the black color restricted to the headquarters and hindquarters (Wilson, 1991; Payne and Wilson, 1999; Animut *et al*., 2002; Suleman, 2006). The breed average reproductive performance is 1.28 lambs per ewe per year, and the lamb mortality rate from birth to weaning is 0.3, according to Mourad *et al*. (2001). For djallonke sheep kept in the conventional production method, the death rate is around 21% and the depletion rate (percentage of animals sold or devoured each year) is 38%. On the other side, Sahel breeds are tall, with shoulders that measure about 84 cm. They have long, drooping tails, long legs, and long ears. Male sheep weigh 55 kg on average and 45 kg on average for mature females.

Smallholder farmers, especially women, frequently keep small ruminants (sheep and goats) despite having few resources and no access to basic medical care (De Haan *et al.*, 2015). Small ruminant systems also serve as income-generating enterprises and sources of raw materials for nearby and regional businesses (Wodajo *et al.*, 2020). Additionally, they serve several sociocultural functions such as dowries in marriages, presents, almsgiving, and inheritances. Keeping these animals frequently serves as a dependable source of emergency cash for the commitments and personal demands of the majority of herders.

Small ruminants are frequently converted to ATMs, providing their owners with regular and rapid access to cash to pay urgent costs for healthcare, education, and medication, as well as agricultural and off-farm investments, social activities, and restocking (Kosgey *et al.*, 2008; De Haan *et al.*, 2015). Owning small ruminants may be a sign of wealth or social standing in some communities and can make it easier to obtain certain financial services in both official and informal marketplaces (Pica-Ciamarra *et al.*, 2011). Overall, their ownership constitutes one of the most significant wealth accumulation activities among smallholder families in Sub-Saharan Africa because of their relatively tiny size, high mobility, and ease of purchasing and selling (De Haan *et al.*, 2015). Rural households in developing nations depend on small ruminants like sheep and goats for their livelihoods and food security. The easiest and most practical way to help the world's poorest people eat better is by providing them with animal-based proteins. Small ruminants are an essential way to help the impoverished improve their standard of living because of their tiny size, low cost per capita, and quick reproduction. According to Jeffrey *et al*. (2016) small ruminants are suited to a broad range of habitats and frequently forage in areas with minimal agricultural potential. The farming of sheep and goats is regarded as a significant livestock industry with many financial advantages for the farmers' way of life.

The trade of vegetables and animals helps low-income individuals finance their daily costs as a key communal economic activity (Abdullah *et al*., 2015). Traditional livestock systems (Adams *et al*., 2021) in which animals find their food, water, and shelter with little to no veterinary care (Covarrubias *et al*., 2012) are reflected in livestock farming in the dry parts of sub-Saharan Africa. However, animals are grown to help subsistence farmers achieve a variety of objectives (Onyango *et al*., 2015). Small ruminants are raised for socioeconomic advantages as well as financial gain, such as skin, fertilizer, insurance against agricultural failures, a source of medium-term savings, a way to diversify investments, and the provision of social and cultural services (Weyori *et al*., 2018). Sheep and goats also have an edge over other animals when it comes to producing high-quality, value-added food for domestic use from fodder like straw and grasses as well as other byproducts like kitchen scraps and other waste products (Bettencourt *et al*., 2015).

2.2 Systems of sheep production in Ghana

The intensive or semi-intensive, extensive, and traditional systems are the common systems for small ruminant production in Ghana, particularly in the Northern region (Adam, 2015). The four systems of ruminant production in Ghana particularly the northern region is a continuous series moving from one system of production to another system of production (Oppong-Anane, 2011). Small ruminant farming has traditionally been practiced in the three administrative districts of northern Ghana (Suleman, 2006). According to Faizal and Kwasi (2015) the average number of livestock per person or family is 1 to 10 heads, with goats typically outnumbering sheep (FAO, 2012). According to Turkson and Naandam (2006) the traditional or landless and extensive systems characterized by low production costs and poor output, and exploiting natural grazing land in open regions and agricultural wastes from farms are the main systems in northern Ghana. Because traffic accident mortality is high and scavengers receive little attention, labor expenses are minimal (Alenyorege *et al*., 2010). Other forms of agricultural systems have arisen as a result of increasing urbanization, a reduction in soil fertility, and technological improvement (Oppong-Anane, 2011). The extensive system is similar to the normal outdoor system, with the distinction that the former receives extra management and attention as well as feed supplementation during specified seasons (faizal and Kwasi, 2015). According to Suleman (2006) the average farm has around the same number of animals as a free-range system, which has two to ten animals per home.

In contrast to the extensive system, the semi-intensive system has restricted grazing and relies on family employment, free time, and fodder availability for barn feeding. According to faizal and Kwasi (2015) grazing often takes place in the late morning or evening. Simple kraals are often constructed using locally accessible materials including wood, bamboo, branches, and mud; the roofs are typically made of leaves, split bamboo, or sheet metal (Opong-Anane, 2011). In this system, popular feed sources include household food waste, cut-and-carry forage, agricultural wastes, and crop residues (Duku *et al*., 2010).

Under this arrangement, it is prohibited for kraal animals to graze on public property. The kraals are where all of the food is kept (Oppong-Anane, 2011). The intense system also makes use of domestic garbage, crop wastes, and zero-grazing. This approach is used to fatten sheep and goats as meat products for city markets on festive and religious occasions. This production system is common in peri-urban and urban areas. Although some farmers still self-medicate with various herbal medicines, access to veterinary care is expanding (Oppong-Anane, 2006). Ghana uses tethered, extensive, intensive, and semi-intensive sheep farming techniques. The vast technique of sheep production is the one that Ghana uses most frequently.

Under the extensive system, animals are free to search for food on their own, explore the area around the house, and consume any uncultivated land or leftover kitchen trash (Gatenby, 1985). Owners must provide food and water to the animals in order to keep their crops secure throughout the primary cropping season (Charray *et al*., 1992). The system's incapacity to manage pastures results in low production, but it is easy to use and enables the confinement of several animals on a small plot of ground. According to Gatenby (1985) Muslim communities in Ghana use this procedure to fatten rams for festivities like Eid-ul-Fitr.

2.3 Challenges of sheep production in Ghana

Lack of resources for feeding sheep, particularly during the dry season, is Ghana's biggest problem. Forage is accessible during the wet season, but farmers must tether or stall-feed their livestock throughout the growing season, which frequently restricts access (Awuma, 2012). Natural pastures and agricultural leftovers are the principal sources of accessible feed, with agro-industrial by-products providing less (Amankwah *et al*., 2012). Metropolitan farmers are under more pressure to find alternate sources of feed, including agricultural leftovers, as a result of the loss of natural pasture in metropolitan areas as a result of infrastructure development. The 2010 census of Ghana's population indicates a 51% growth in urbanization, which has led to a decline in grazing grounds for ruminants, according to MoFA (2011). Livestock producers in Sub-Saharan Africa are concerned about a shortage of nutritious feed and a lack of feed supplies during the dry season (Jutzi, 1993). Inadequate nutrition during the dry season is blamed for

Ghana's low ruminant livestock production. According to Jones and Wilson (1987) the principal factors restricting livestock productivity during the dry season are a lack of green and high-quality feed. From November through April, the northern areas of Ghana have severely dry and hot weather.

Ruminant animals on natural pastures encounter challenges such as very low nitrogen feed quality, a paucity of grazing area, and a lack of drinking water during this season. The animals lose weight as a result (Alhassan and Karbo, 1993). There aren't enough grazing sites for livestock smallholders in cities (Charray *et al*., 1992). According to Karbo *et al*. (2002) the majority of Ghana's livestock species are located in the northern section of the country. However, the primary barriers to livestock production remain a paucity of improved breeds, a scarcity of inexpensive, good-quality feed, poor management, a defective livestock extension system, a lack of proper equipment, and a scarcity of veterinary care for animals. Forages expand rapidly during the rainy season, but when theyend, they start to become fibrous. The poor nutritional value of the majority of herbage is due to the high rate of lignification in the tropics. In most locations, bushfires make the issue even worse. Unfortunately, crop wastes utilized as supplements have a low nutritional value due to their high fiber and lignin concentration (Agolisi, 2019).

2.4 Dry matter and nutrient requirements of sheep

The essential elements needed by sheep for bodily development, maintenance reproduction, and production include protein, energy, minerals, and vitamins (Schoenian, 2003). Animal nutrient requirements directly rise with increased animal activity and production. The nutrient required by sheep for maintenance is increased by cold and harsh weather, thus more food will be needed to keep their bodies at a steady temperature. Nutritional requirements also increase during pregnancy, lactation, and future development. Per kilogram of dry matter, sheep consume feed equivalent to 2-4% of their body weight. The precise ratio changes depending on the animal's size or weight (Schoenian, 2003; Rayburn, 2013). Due to increased activity, the nutritional requirements of animals on pasture may rise by up to 25% (Rayburn, 2013). It is quite challenging to convey information gathered from all around the world on the nutritional needs of sheep. As a result, suggested minimum needs for sheep are made.

Current calorimetric research indicates that the Net energy requirement for sheep maintenance ranges from 0.267-0.298 MJ/kg $BW^{0.75}$ as reported by Rodrigues *et al*. (2016); Deng *et al*. (2014); Salah *et al*. (2014) which is greater than 0.234 MJ/kg $BW^{0.75}$ recommended by NRC (2007). Dawson and Steen (1998) recorded a higher ME requirement for maintenance for growing lambs than that of the Agriculture and Food Research Council. Recent studies have recorded higher ME requirements for maintenance (0.418-0.433 MJ/kg $BW^{0.75}$) for sheep using a calorimeter chamber (Cárdenas *et al*., 2018). It is often suggested that ME requirements for castrated male and female sheep are the same and are lower than intact male sheep as a result of high body protein content in male sheep (INRA, 2018; NRC, 2007). However, research studies by Rodrigues *et al*. (2016) indicate that the NEm values are similar between female, castrated, and intact male sheep.

Table 2.1:Recommended Digestible Crude Protein requirement range for maintenance and gain of sheep.

Species	Genotype	Digestible CP for maintenance (g/kg $LW^{0.75}$)	Digestible CP for gain (g/g ADG)
	Tropical	1.9 -4.4	0.2-0.3
Sheep	Temperate	2.1-3.2	0.2-0.2

Salah *et al*. (2014).

Table 2.2: Recommended daily feed intake range and average daily gain of sheep

Species	Parameters		
	DOMI (g/kg LW/day)	DCPI (g/kg LW/day)	ADG (g/kg LW/day)
Sheep	5.8-62.6	0.5-9.5	4.2-18.8

DOMI: digestible organic matter intake, LW: live weight, DCPI: digestible CP intake, ADG: average daily gain (Source: Salah *et al*., 2014).

2.5 Effect of supplementation on the growth performance of sheep in Ghana

Agolisi (2019) recorded an average daily gain of 48.21-56.47g/kg when djallonké rams were supplemented with graded levels of DRD-based concentrate and rice straw as a basal diet. Adu *et al*. (1992) also reported an average daily gain of (16-48g/kg) when sheep were fed with urea-treated sorghum or graded levels of lablab supplementation. However, Agolisi and Ansah (2023) recorded a lower average daily gain of (28.8-48.9g/kg) when Djallonké rams were fed with urea-treated DRD pellet concentrate while Baiden *et al*. (2007) reported a higher average daily gain of (79-91g/d) when West African dwarf sheep and goats were fed different inclusion levels of cassava pulp as a substitute for cassava peels. Konlan*et al*. (2019) reported an average daily gain of (31.45-46.23g/d) when Djallonké sheep were supplemented with maize bran (200g/d) and a mixture of maize bran (100g/d) + groundnut haulms (200g/d) respectively during the dry season. Additionally, an average daily gain of (25-60g/d) has been reported by Osafo*et al*. (2008) when grazing sheep were supplemented with concentrate. 71 and 74g/d average daily gain has also been recorded by Ansah*et al*. (2012) when djallonkè sheep were supplemented with a combination of 200 and 400g DM/d of agro-industrial by-products grazing on natural pasture during the wet season.

2.6 Feed resource for ruminant production

2.6.1 Pasture or Range land

According to Addo (2007) a pasture is a piece of land utilized for grazing that is covered in feed crops, typically grasses and legumes. For animal performance, milk production, and conception rates in the animal production industry, good pasture management is essential (Arseneau, 2010). A good pasture should be productive and high-yielding forage per hectare, perform well under any environmental conditions, ability to recover and tolerate grazing pressure, be easily established and adaptable, have high palatability, and be nutrient-rich (Addo, 2007). There are two categories of pasture: naturally occurring grassland and artificially created or produced pasture. Rangelands that are covered in fodder crops, either annual or perennial, that were not planted by anyone are known as natural pastures. Nearly 30% of the world's population lives on rangeland, which makes up about 54% of the terrestrial ecosystem (Estell *et al*., 2012). Natural pastures can be enhanced by adding manure or leguminous crops to enhance nitrogen fixation in the soil. Natural pastures are usually unimproved or have a low nutritional value. The pasture species have adapted to the environment of the area and can endure bushfires. In Ghana, examples include the guinea savanna, coastal savanna, and derived Savanna as reported by Addo (2007). Ansah *et al*. (2012) reported that the natural pastures in northern Ghana constitute the primary source of feed for ruminants. Artificial pastures are established and maintained by using irrigation systems, fertilizer application, weed control, rotational grazing, reseeding, and grazing at the optimum stocking density. In this setting, annual, perennial, irrigated, and ley/rotational pasture species might all be used (Addo, 2007). Bahama grass (*Andropogon gayanus*), Guinea grass (*Panicum maximum)*, giant star grass (*Cynodonplectostachyus*), Elephant grass

(*Pennisetum purpureum*), and Carpet grass (*Axonopuscompressus*) are the main grasses used for pasture establishment in Ghana (Arseneau, 2010).

2.6.2 Browse plants, shrubs, and forbs as ruminant feed resources.

The term "browse" describes leaves and twigs from shrubs and trees that are available as food for ruminants and may include flowers, fruits, and pods (Sanon, 2007). During the dry season, browses, which are a good source of minerals and protein, could be utilized to enhance the ruminant diet (Le Houérou, 1980). Forb species of trees are core components of grassland biomass which represents the bulk of grassland diversity and are widely used in the restoration of habitat (Meissen *et al*., 2017; Smith 2017; Freund *et al*., 2020). Forbs are predominant in many savannas and grassland (Peterson, 2007). Numerous forb species are compatible with pasture and traditional rangeland species depending on their composition and growth habits could enhance the grazing behavior and selectivity of livestock. Forb species provide high-quality herbage at times forage is insufficient in perennial grass-based pasture systems (Belesky *et al*., 2020). Shrubs and forage trees are very essential means of cheap locally available feed materials for ruminant production during the dry season when crop residues and natural pastures are unavailable (Franzel *et al*., 2014). Shrubs and trees are highly recommended as feed due to their high production of biomass, nutritional value, and adaptability to less fertile soils and harsh environmental conditions (Pello *et al*., 2021). Shrub inclusion in the diet of ruminants enhances the palatability, digestibility, feed intake, and performance of animals (Derero and Kitaw 2018; Osuga *et al*., 2011).

According to estimates, diverse tree crops occupy 16% of the land in Ghana. Tropical kudzu (*Pueraria phaseoloides*), pigeon pea (*Cajanus Cajan*), Centrosema (*Centrosemapubescens*), and stylo (*Stylosanthesgraccilis*), are suitable tropical fodder legume plants for pasture establishment in Ghana (Addo, 2007). Certain agricultural groups in northern Ghana utilize browse plants to enhance the feed of ruminants. Ansah and Nagbila (2011) have identified 31 plants and browse plant species in the Talensi-Nabdam district in the Upper East region of Ghana which are used for feedingruminants. During the dry season, cattle herders in Benin rely significantly on *Khaya senegalensis, Afzeliaafricana,* and *Pterocarpus erinaceus* for fodder (Brisso *et al*., 2007). Konlan *et al*. (2015) reported that local browse leaves of *Pterocarpuse vinaceus, Afzelia species,* and Ficus species were among the ruminant feeds identified in northern Ghana. According to Issaka and Ansah (2018) local browsing plants such as *Faidherbia albida, Afzelia africana, Pterocarpus erinaceus, Ficus gnaphalocarpa,* and *Leucaena leucocephala* were utilized by farmers in Ghana's Kumbungu District to augment cattle feed.

2.6.3 Agro-industrial by-products as ruminant feed

Agro-industrial by-products are industrial by-products derived after processing agricultural commodities. Agro-industrial by-products are less costly, have less fiber content, are primarily concentrated, and are particularly nutritious when compared to crop waste. Feeding animals with agro-industrial by-products in underdeveloped countries will reduce feeding costs (Aguilera, 1989). Examples of agro-industrial by-products include; maize bran, rice bran, molasses, pineapple waste, palm oil mill effluent, and coconut cake as reported by (Devendra, 1987). Aregheore (2000) classifies agro-industrial by-products as protein, energy, or combined protein/energy sources. Sindhu *et al*. (2002) reported that protein can be found in oilseed after oil extraction and animal wastes. Major sources of protein in cow diets are cakes and meals. Energy sources of agro-industrial by-products are low in protein and high in fermentable carbohydrates. Consider molasses, a by-product of sugarcane with CP (4.1%), DM (75%), and (12.7 MJ/kg) DM of gross energy reported by Sekondi, (1991). Cereal by-products that combine protein and calories include wheat, rice, and maize bran, as well as brewers' leftover grains (Cheeke, 1991).

Table 2.3: Some agro-industrial by-products and their CP levels

Agro-industrialby-products	CP levels (%)
Blood meal	80
soybean	48
Groundnut cake	40-48
Fishmeal	55
Palm kernel meal	18
Meat meal	50-55

Sekondi (1991).

2.6.4 Maize bran

Maize bran is a by-product of the processing of maize and the manufacturing of starch, ethanol, and foods containing maize. Maize bran is described as aby product with a relatively variable content because of the mixing of bran fraction, coastlines, and other products (Kalscheur *et al.*, 2012). Milled maize bran is mixed with broken kernels, germ fragments, endosperm, and pericarp to form hominy food (Stock *et al.*, 1999). According to Mulumpwa and Kang'ombe (2009) it has grown to be a crucial item for human and animal use in emerging nations, which may restrict its availability to smallholder livestock farms. Corn bran (MB) is a by-product of the food industry that has been widely utilized as animal feed due to its low cost and widespread availability. It is high in insoluble fiber and is mostly composed of arabinoxylan (Damen *et al.*, 2011).

2.6.5 Soybean meal

Soybean meal (SBM) production has expanded as a consequence of its usage as a protein source in animal feeding. In terms of the soybean, 18.6% is oil, 78.7% is meal, and 2.7% is trash

(FEFAC, 2007). The nutritional makeup of these goods varies. When properly processed, they have high protein contents that have a good amino acid balance and are high in calories, but they have low methionine and fiber amounts (Grieshop *et al*., 2003; FEFAC, 2007). Except for methionine, SBM has a comparable amino acid profile to fishmeal, according to INRA (2004). Soybean meal has more total digestible amino acids and crude protein than other protein sources from vegetables. Soybean meal protein is around 85% digestible in chicken, while the digestibility of amino acids varies from (82%-94%) as reported by Woodworth *et al*. (2001). Because of the restricted number of amino acids in vegetable protein and cereal-based sources, soybean is largely used as a protein source in cattle and poultry feeding (Stein *et al*., 2008). Soybean by-products include; soybean hulls, soy protein isolate, concentrate, and full-fat soybeans. These by-products are used to varied degrees in the diet of animals due to their distinct nutritional properties (Stein *et al*., 2008). Soybean meal, however, has limitations such as oligosaccharides and trypsin both of which produce flatulence (Grieshop and Fahey, 2000). Ogunbosoye *et al*. (2022) experimented using soybean cheese trimming inclusion levels and found that as the amount of soybean cheese trimmings in the formulated diets grew, so did mean feed intake and mean weight growth. The group of sheep given 0% soybean cheese offal had the highest feed conversion ratio (FCR). All growth parameters examined in this study had significant differences ($p<0.05$).

2.6.6 Cassava peels

A mature cassava plant’s major component is made up of 50% stored roots, 44% stem, and 6% leaves. Cassava's leaves and roots, which are also potential feed sources, are its nutritional components. Cassava tubers and leaves chemical compositions are determined by the age, variety, and technique of processing (Smith, 1988). The presence of cyanogenic glucosides in cassava and its by-products poses challenges for their use in animal feed, impacting the digestion and absorption of nutrients (Francis *et al*., 2001). Fresh cassava leaves, tubers, and peel contain anti-nutrient components such as tannins, alkaloids, saponins, and cardiac glycosides (Ebuehi *et al.*, 2005), leading to periportal necrosis in the livers of goats and sheep fed fresh cassava leaves (Rosly *et al.*, 2010). Various processing methods, including chemical, biological, or physical treatments, have been proven effective in reducing cyanogenic glycosides in cassava tubers and by-products (Maciel *et al.*, 2015; Cardoso *et al.*, 2016; Jiwuba and Ezenwaka, 2016). Although cassava peel can offer sufficient energy to ruminants as a dietary supplement, its high cyanogenic glycoside content necessitates processing methods like fermentation, ensiling, and sun drying to reduce cyanogenic glycoside levels (Smith, 1988). Digestibility values for dry matter (DM) and organic matter (OM) in cassava peels were reported as 78% and 81%, respectively, by Heuzé *et al.* (2012).

Feeding small ruminants processed cassava roots and by-products has been linked to improved growth and blood parameters (Fasuyi and Aletor, 2005). Cassava root meal exhibited the highest crude fiber content, followed by cassava husk meal and ensiled cassava husk meal, with cassava root sifted meal showing the lowest content (Tion and Adeka, 2000; Dierenfeld and Fagbenro, 2014). The high-fiber content in cassava root meal, cassava peel meal, and ensiled cassava peel meal makes them valuable fiber sources for small ruminants, given their digestive systems' ability to handle high-fiber diets effectively (Jiwuba *et al*., 2021).

Cassava tuber, ensiled cassava peel meal (ECPM), and fermented cassava peel meal (FCPM) have been suggested by Unigwe *et al*. (2017) as partial replacements for maize in ruminant diets. The reported energy value by Unigwe *et al.* (2017) is lower than the value previously reported by Olafadehan (2011) for ensiled cassava peel meal (16.23 MJ/kg), highlighting the influence of cassava cultivar, hulling process, and processing methods on the nutritional composition of cassava, as confirmed by Dierenfeld and Fagbenro (2014). Santos et al. (2015) examined the impact of various levels of cassava husk inclusion (0, 25, 50, 75, and 100) on feed consumption and nutritional digestibility.2.6.7 Rice bran

Rice bran, an important by-product of rice processing, is commonly contaminated with rice hulls. It is fairly pleasant to animals and contains between 10 and 15 percent crude fiber and 14 to 18 percent oil (Göhl, 1982). About 60% of milled rice bran is made up of hulls, 35% of bran, and 5% of polishing. Sheep appear to benefit from the addition of full-fat rice bran to their baseline meals; however, the levels of inclusion ranged from less than 20% to more than 40% depending on the baseline diet (Melakuand Nega, 2009). Food industry by-products and residues, such as rice bran, were suggested as ruminant rationing choices. Rice bran enhances energy concentration in the diet and hence lowers grain intake due to its high energy content of 4.8 Mcal/kg (Magalhes *et al*., 2006). Darley *et al*. (2012) reported that a proportion of 60% roughage and 40% rice bran had no significant effect on growth performance in sheep. Dietary intake of rice bran affected feed intake, possibly due to high ADF and low NFC values.

2.6.8 Shea nut by-products

Wild vegetation known as the shea tree (Vitellaria paradoxa) in West Africa grows naturally in the dry savannah zone (Hatskevich *et al*., 2011; FAO, 2014). Shea nut production is predominantly concentrated in Ghana's guinea savannah area, covering approximately 77,670 km2, as reported by Hatskevich et al. (2011). Ghana's annual production of shea nuts amounts to 73,500 metric tons (FAOSTAT, 2013). By-products of the extraction process include shea nut meal (SNM) from solvent extraction and shea nut cake from mechanical extraction (Oddoye et al., 2012; FAO, 2014). Approximately 55% of the by-products from butter-producing facilities are discarded as waste without any monetary value, as stated by Heuze' and Tran (2011). The nutritional content of shea nut by-products may vary based on the oil extraction method and the treatment of shea nuts before processing (Dei et al., 2007). These by-products contain varying levels of nutrients, with crude fiber ranging from 53-138 g/kg-DM, ash from 33-76 g/kg-DM, crude protein from 80-250 g/kg-DM, ether extract from 17-362 g/kg-DM, and nitrogen-free extracts from 318-675 g/kg-DM. The actual metabolizable energy of shea nut cake corrected for nitrogen balance ranges from 12.6 MJ/kg-1 to 15.1 MJ/kg-1 for multiple SNC samples.

Research indicates that shea nut by-products are rich in nutrients (Dei et al., 2008; Oddoye *et al*., 2012; Agbo and Prah, 2014). However, they have been associated with poor performance in pigs (Rhule, 1999), sheep (Konlan *et al*., 2012), poultry (Dei et al., 2008; Zanu *et al*., 2012), and rabbits (Ansah *et al*., 2011). Various studies have recommended maximum inclusion levels of 25 g/kg for poultry, 50 g/kg for pigs, and 100 g/kg for sheep (Osei Amaning, 1993; Rhule, 1995; Atuahene *et al*., 1998; Olorede and Longe, 1999). However, research by Ansah *et al.* (2012) and Konlan *et al.* (2012) found that sheep given a shea nut cake-based supplement exhibited increased feed intake, weight gain, serum biochemical parameters, and hematology. Additionally, Okunlola *et al.* (2021) reported that shea cake significantly increased weight gain in West African dwarf sheep at intake levels of 0%, 10%, 15%, and 20%, with the highest value observed at 15% intake. The feed consumption was substantial for all treatments, with 15% shea butter accounting for the highest amount at 63.50 kg.

2.6.9 Crop residues

Crop residues (CR) are plant biomass or agricultural crop residues such as wheat straw, rice straw, sorghum straw, maize straw, sugar cane bagasse, and so on. Crop residues are mostly composed of cellulose, hemicellulose, and lignin, with trace quantities of pectin, nitrogen compounds, and mineral leftovers (Andlar *et al*., 2018). Crop leftovers are a great source of animal feed since they may be utilized to replace soil nutrients as well as feed animals. Agricultural wastes are best used by feeding them to sheep (Gertenbach and Dugmore, 2004). According to Devendra (1997) the majority of agricultural waste has a high biomass, a low crude protein concentration of 3-4%, and a crude fiber content of 35-48%. Cattle are fed leftovers of grain sorghum, maize, soybean, sugarcane bagasse, vegetables, and wheat daily (Gertenbach and Dugmore, 2004). Leguminous and grain residues are most often used as agricultural leftovers by livestock producers inthe Yendidistrict, according to Ansah *et al*. (2006). The primary ruminant sources of feed discovered in Ghana in the northernregion, according to Konlan *et al*. (2015) were cowpea haulms, groundnut haulms, and pigeon pea residues. Each year, developing nations create over one billion tonnes of agricultural waste, according to FAO (1999). Crop leftovers are predicted to reach 136 million metric tonnes in the West African sub-region, with national feed resources ranging from 1% to 82% depending on the country, and ranging from (0.07-70.57) per million tonnes (Fleischer, 1991). Ghana produces 9.38 million metric tonnes of agricultural leftovers each year reported by Ampadu-Agyei *et al*. (1994). Oppong-Anane (2010) reported that Ghana produces 8,000,000 tonnes of grain stalks and 3,500,000 tonnes of residual roots and tubers per year, all of which may be used as animal feed.

The yearly agricultural residue output in Northern Ghana is predicted to exceed 5 million tonnes dry matter according to Agyare and Karbo (2002) and MoFA (2011). Konlan *et al*. (2017) reported that sorghum straw output would be 8.5 tonnes DM/ha, which is more than the total agricultural waste in Northern Ghana. According to Ansah *et al*. (2006) in Ghana's Yendi district around 94% of agricultural leftovers were utilized as a supplement for ruminant cattle. Groundnut haulms accounted for 40% of crop residues discovered in Northern Ghana's animal feed markets sorghum straw was the least popular in the feed market (Konlan *et al*., 2015).

During the dry season, appropriate utilization of Ghana's 2.3 million tonnes of agricultural waste might save 186 million kg of cattle weight (Amaning-Kwarteng, 1991).

2.7 Silage

The forage composition during the ensiling process and the employment of suitable silage-making techniques are the main determinants of the production ofhigh-quality, and well-preserved silages. Maintaining anaerobic conditions while swiftly lowering pH through lactic acid fermentation is the key to silage preservation (Pahlow*et al*., 2003). For the ensiling process to be successful, lactic acid bacteria are essential. They can swiftly convert fermentable carbohydrates from forage crops into lactic acid and, to a lesser extent, acetic acid. Biological and chemical silage additives can enhance a well-preserved silage by boosting rapid pH lowering, and reducing aerobic decomposition (Kung *et al*., 2003; Muck *et al*., 2018). Silage that has been created and handled properly is a great feed that neither endangers human or animal health. According to Weinberg *et al*. (2003) the microorganisms included in these silages may have probiotic benefits on animals. Silage, however, can support the growth of severalunfavorable bacteria when the pH is not adequately lowered or when there is a presence of oxygen. *Clostridium botulinum*, Molds, *Listeria monocytogenes*, *Bacillus cereus*, *Escherichia coli*, and other Enterobacteriaceae species, can be harmful to animal health or the safety of milk or other animal food products are among the undesirable microorganisms. A health danger may come from the microbe itself or a metabolite it produces, such as the mycotoxins some molds create. In addition to microbial health risks, silages may include harmful chemicals arising from the ensiling of the forage crop or other pollutants (Driehuis*et al*., 2018).

2.7.1 Silage fermentation processes and their manipulation

2.7.1.1 The ensiling process

Ensiling may preserve fresh fodder plants including wheat, alfalfa, grasses, legumes, and maize. To produce silage of the highest quality, a successful microbial fermentation process is required. A successful fermentation process depends on the forage's kind and quality as well as the harvesting and ensiling methods. Five different species of bacteria have reportedly been linked to outbreaks including anything from human sickness and death to dairy products, according to Michael*et al*. (1995)

2.7.1.1.1 Phase 1: Aerobic phase.

During this phase, the ambient oxygen present between the plant particles is diminished owing to plant respiration andfacultative aerobic and aerobic microorganisms such as enterobacteria and yeasts. Plant enzymes includingcarbohydrases and proteases are active during this phase as long as the pH is within the typical range for fresh forage juice (pH 6.5-6.0) (Syomiti and Bauni, 2010).

2.7.1.1.2 Phase 2: Fermentation phase.

This phase begins when the silage becomes anaerobic and lasts a few days to a few weeks, depending on the properties of the silaged forage crop and the ensiling conditions. If the fermentation is successful, lactic acid bacteria will proliferate and become the majority population at this point. The pH falls between 3.8 and 5.0 due to the production of lactic and other acids (Syomiti and Bauni, 2010).

2.7.1.1.3 Phase 3: Stable phase.

As long as the silo is locked off from the outside world, little happens. The population of the majority of microorganisms progressively decreases in phase 2. Clostridia and bacilli are two acid-tolerant bacteria that can exist inactively throughout this period. As spores, other acid-tolerant microbes can thrive. Few specialized bacteria, such as *Lactobacillus buchneri*, as well as acid-tolerant proteases and carbohydrases, remain active at low levels (Syomiti and Bauni, 2010).

2.7.1.1.4 Phase 4: The feed-out phase or aerobic spoilage phase.

This phase begins as soon as the silage is exposed to air. Although it may begin earlier due to silage covering damage (caused by rodents or birds, for example), it is unavoidable during feedout. The decaying process is divided into two stages. Yeasts and, in rare situations, acetic acid bacteria degrade preserving organic acids and initiating the degradation process. As a result, the pH rises, signaling the onset of the second stage of rotting, which is characterized by rising temperatures and the activity of spoilage microorganisms such as bacilli. In the final phase of the ensiling process, molds, enterobacteria, and various other facultative aerobic microorganisms become active. When silage is exposed to air upon opening, it undergoes aerobic degradation. The presence and activity of spoilage organisms within the silage significantly impact the rate of deterioration. In certain instances, locations have reported spoilage rates leading to dry matter losses of 1.5-4.5% per day, comparable to losses that may occur over several months in airtight silos (Syomiti and Bauni, 2010).

To prevent failures, close monitoring, and adjustments are necessary at each stage of the ensiling process. Proper silo-filling practices can help minimize oxygen availability between plant particles during the initial phase. By employing suitable harvesting techniques and effective silo-filling procedures, losses of water-soluble carbohydrates (WSC) in both the field and silo can be reduced, ensuring more WSC are available for lactic acid fermentation in the subsequent phase.

While farmers have limited direct control over phases 2 and 3 of ensiling, enhancements in these stages can be achieved through the utilization of silage additives that have been proven effective throughout the ensiling process. Once oxygen exposure occurs, Phase 4 commences. Maintaining an airtight silo is crucial to prevent spoilage losses during storage, and any damage to the silo cover should be promptly addressed. A rapid feed-out rate can help minimize spoilage due to air exposure during feed-out. Furthermore, the use of silage additives that aid in reducing spoilage losses can be beneficial during ensiling (Syomiti and Bauni, 2010).2.7.2 Silage fermentation in tropical silages

Although it has not yet been extensively used, ensiling fodder crops or industrial wastes might considerably improve tropical and subtropical animal production systems. This is brought on by a lack of ensiling experience in addition to low levels of automation, low pricing of animal products, and expensive silo-sealing materials. To address the unique problems related to tropical silages, more research is needed. Tropical legumes and grasses contain a comparatively high concentration of cell wall components compared to temperate forage crops, but a low concentration of fermentable carbohydrates. Bacilli also have an advantage over lactic acid bacteria since storage temperatures in tropical areas are often greater than those in temperate settings. Additionally, certain silo-sealing materials are not able to survive prolonged sun exposure, which might reduce the silage's aerobic stability. The ability of temperate climate ensiling technologies to adapt to tropical circumstances, however, seems feasible (Stefanie*et al.*, 2000).

2.8 Supplementation in ruminant nutrition

Supplements are feedstuffs given to ruminants in trace amounts to deliver essential nutrients. They are used to boost the nutritional content of basal diets. Supplements are required to compensate for soluble nitrogen and mineral deficiencies, as well as to increase base food intake and animal production. They can also be employed as protein or energy sources. Protein concentrates (groundnut cake and soybean meal), energy concentrates (rice bran and cereal), urea, molasses, and minerals are the most common types of supplements (Gatenby, 2002). Forage legumes and leaves are rich in nitrogen and can be used as supplements. To increase microbial nitrogen in the rumen, concentrate supplementation is necessary for feed having less than 6% crude protein. If its meal comprises CP of (6–7%), DM intake of (1.7%), and digestibility of (50–55%) of body weight, an adult ruminant may maintain its body (Devendra, 1985). Crop residues generally fall well short of these requirements. To guarantee a healthy rumen environment, meet animal demands, and enhance the use of agricultural leftovers (B vitamins, bypass protein and energy, roughage), nutritional supplements are necessary to supply fermentable energy, nitrogen, and micronutrients. Due to the rumen's physiological adaptability, ruminants may eat low-quality feed to satisfy their demands for upkeep, development, and reproduction. The digestion of ingested fibrous and soluble plant material is primarily the responsibility of the ruminant forestomach and microbial communities. The majority of forages are heavy in fiber and low in nitrogen; adding nitrogen will benefit the rumen ecology and make it easier for animals to digest the fibrous parts (Agolisi, 2019). Sheep and goats performed well when given sorghum stover, rice straw, and wheat straw supplemented with oil palm, urea, and molasses (Agolisi, 2019). Tolera and Sundstøl (2000) also found that sheep fed a basal diet containing maize stover supplemented with desmodium interim hay at different graded levels (0, 150, 300, 450 g/h/d) had higher crude protein intakes (12.1, 29.8, 47.2, 62.4 g/head/day), dry matter intake (43.2, 53.8, 63.1, 66.1g/kgW0.75/day) and as well as body weight gains. Konlan *et al*. (2012) discovered that supplementing with concentrate enhanced total dry matter consumption while not affecting basal meal intake. Teye *et al*. (2011) found that feeding Djallonké sheep with whole cotton seed (200 g) as a supplement resulted in the best nutritional eating muscle quality.

Ndemanisho *et al*. (2007) found that goats fed supplemented maize stovers with varied browse leaf meal-based concentrates and cotton seed-based concentrates consumed (334.25 g) of dry matter per day. Marsetyo *et al*. (2017) observed that Mulato grass fed to Kacang goats supplemented with *Leucaena leucocephala, Desmantus pernambucanus,* and *Gliricidia sepium*, and grew faster than goats fed only Mulato grass. Goats given bean supplements grew faster because they devoured more dry matter, protein, and metabolizable energy. According to Dessie *et al*. (2010) the nutritional digestibilityandfinal body weight of sheep given hay alone, hay+150, hay+250, and hay+350 g/DM of concentrate diet were greater than those of sheep on the control diet.

2.9 Digestion in ruminants

Ruminants may ingest fibrous plant materials due to the form and operation of their digestive tracts (Van Soest, 1994). The digestive system's distinctive qualities are due to the microbial fermentation, gastric, and intestine digesting processes (Niwiska, 2012). The rumen is the site where feed initiates microbial fermentation. According to McDonald et al. (2002), the rumen harbors a diverse and densely populated microbial community. The rumen microorganisms consist of over 20 species of protozoa and 200 types of bacteria (Czerkawski, 1986; McDonald et al., 2002). Protozoa within the rumen can sequester protein, preventing the host animal from accessing it (McDonald et al., 2002). Rumen bacteria play a crucial role in all stages of ruminal fermentation (Kamra, 2005). Optimal conditions for rumen bacteria to thrive without oxygen are at a temperature of 39 to 40°C and a moderate fermentation product concentration, maintaining acidity levels between pH 5.5 and 7.0 (Hungate, 1966). The strained rumen fluid typically contains 1 billion bacteria per milliliter, but this count can vary due to the presence of bacteria and protozoa associated with solid digesta (McDonald et al., 2002). Hungate (1966) estimated a range of 16.2 to 40.8 billion rumen bacteria per milliliter. Bryant (1970) noted that rumen microbe concentrations can vary from 4 to 88 billion per milliliter based on factors such as the meal composition, feeding regimen, time elapsed after feeding, and individual animal differences. Coleman (1980) explained that certain protozoa consume and digest food particles, bacteria, and even small protozoa, resulting in the conversion of bacterial protein into a higher-quality protein with approximately 80% greater biological value. This transformation is a notable advantage of rumen digesta as a protein source in cattle production. The abomasum functions as a true enzymatic stomach, while the reticulum and omasum act as filters (Niwiska, 2012). In the rumen, an animal's diet undergoes fermentative processes that generate microbial cells, methane gases, volatile fatty acids, and carbon dioxide (McDonald et al., 2011). Rumen microorganisms form biofilms on feed particles, breaking down plant components. The rumen environment, comprising bacteria, ciliate protozoa, bacteriophages, and anaerobic fungi, plays a significant role in the animal's ability to digest food (Hobson, 1989). While gases are expelled through eructation (belching), volatile fatty acids are primarily absorbed through the rumen wall. Undigested feed components and microbial cells proceed to the small intestine and abomasum for further breakdown by the animal's enzymes before absorption. In the large intestine, there is a secondary phase of microbial digestion (McDonald et al., 2011). Following enzymatic digestion, undigested dietary protein enters the lower tract and is typically absorbed as amino acids. The remaining rumen degradable protein component is absorbed as ammonia, with a portion utilized as a nitrogen source by rumen microbes for protein synthesis. Most of the absorbed ammonia is excreted in the urine, with a small fraction recycled back to the rumen as urea through saliva (Mayank et al., 2008).

2.10 Protein metabolism in ruminant

Metabolizable protein is the real protein absorbed by the gut and provided by both microbial protein and protein that does not disintegrate in the rumen and is accessible to the animal for development, fetal growth during gestation, maintenance, and milk production (Das *et al*., 2014). McDonald *et al*. (2011) identified three key protein sources for ruminant maintenance: dietary, microbial, and endogenous. A portion of the ingested dietary protein is broken down in the rumen to give peptides, amino acids, and ammonia for microbial protein synthesis. Bacteria that grew on non-structural carbohydrates got 65% of their nitrogen from amino acids and peptides, with a little help from ammonia (McDonald *et al*., 2011). Bacteria rely on ammonia in their feed to degrade structural carbohydrate components. During ruminal fermentation, proteins and carbohydrates are converted into sugars and amino acids (Niwiska, 2012). Through metabolism, the early breakdown products are transformed into volatile fatty acids, microbial mass, carbon dioxide, ammonia, and methane. McDonald *et al*. (2011) reported that, the microbial protein was absorbed in the small intestine for the supply of amino acids after passing through the host animal's rumen wall. The amount of microbial protein that reaches the intestines has a significant impact on the pace and degree of microbial breakdown of dietary protein, as well as the efficiency with which the degraded material is converted into microbial protein. The quantity of proteins, vitamins, and short-chain organic acids consumed by the animal influences the rate and scope of the fermentation parameters (Koenig *et al*., 2003). Digested proteins, volatile fatty acids, lipids, and carbohydrates components of microorganisms, as well as food wastes, entered the small intestine as nutrients for growth, reproduction and maintenance. The simplest technique for controlling the amount and pace of protein breakdown in the rumen is to choose the right protein source (Grubić*et al*., 1992).

2.11 Source of protein for ruminants

Protein sources for ruminants in the tropics include oilseeds, residual food from food production, pasture, and legumes (Crawshaw, 2001). Additionally, significant sources of protein for the development of ruminants include brewery by-products (Ruzic-Muslic *et al*., 2014; Fernandez, 2017). Brewers' grain has 240 g/kg of crude protein, according to Crawshaw (2001). With a crude protein level of 600–700 g/kg, maize gluten is a superior source of protein for ruminant animals. Animal by-products and oilseeds are used as protein sources after oil extraction. The high protein content of the cakes and meals makes them perfect for cattle diets. The crude protein content of groundnut cake ranges from 40 to 48%, soybean meal from (48% to 50%), sunflower (35%), cottonseed cake from (45% to 35%), oil rape seed meal 40%, palm kernel expeller (18%), and copra meal (23%) as reported by Sindhu *et al*. (2002) and Fernandez (2017). Zagorakis *et al*. (2018) stated that soybean meal has surpassed corn as the primary source of protein for animal feed. Sunflower meal (SFM), according to NRC, (2001) and Ruzic-Muslic *et al*. (2014) may be an excellent supplement to meals containing slow-degradable proteins. Mulrooney *et al*. (2009) reported rapeseed meal (RSM) a common protein source in animal feed, has been employed successfully in the diets of dairy cows. Due to their high crude protein content, pea seeds and faba bean seeds are protein sources (Larsen *et al*., 2009). Furthermore, as compared to pea seeds, lupin seeds (LS) are a superior protein source for dairy cow diets. Lupin seeds offer good ruminant feed due to their greater quantities of nitrogen (N) and EE (Froidmont and Bartiaux-Thill, 2004). Groundnuts have a protein level equal to soybean meal (Weiss, 2000).

Forage legumes and other plant leaves, such as groundnut haulms and cassava leaves, are used as a source of protein for ruminant animals due to their greater protein content than cereal (Ruzic-Muslic *et al*., 2014; Fernandez, 2017). Protein sources for animal feed include *Desmodium, Aeschynomene, Macroptilium, Centrosema, Arachis, Leucaena,* and *Stylosanthes* (Quesenberry and Wofford, 2001).

2.12 Challenges of accessing protein feed

The absence of a protein-rich diet is the fundamental obstacle to ruminant production. For smallholder farmers, access to animal feeds is limited and, when it is, it is excessively expensive (Ruzic-Muslic *et al*., 2014). Protein rations cost for livestock production has increased due to competition between humans and animals for limited available protein feed ingredients, the price of imported protein feeds, and the uncertainty surrounding the production and distribution of protein feedstuffs, which limits livestock farmers access to them (Ruzic-Muslic *et al*., 2014). Merry *et al*., (2001), reported that farmer's reliance on protein feed ingredients that are imported has exposed them to irregular pricing, inflation, and supply constraints. These difficulties have hampered access to protein for cattle production by farmers. Some of the locally accessible shrubs and browses used as a source of protein have anti-nutrients that prevent the consumption and use of these legumes, which support the activities of rumen microorganisms (Yacout, 2016).

2.13 Feed intake and growth of sheep

The kind of feed that is available, how much is ingested, and the energy density of the diet can affect nutrient absorption. Since sheep prefer fine feeds to coarse feeds, straw is frequently chopped before being given to them. Roughage dry matter intake ranges from 1.5 to 3.0%of body weight for poor and high-quality diets, respectively. The key factors influencing ruminant feed consumption include physiological, digestibility, nutritional deficit, processing, feed bulkiness, ambient temperature, pregnancy, health status, production level, herbage density, age, and animal type. A lamb's size, body composition, and growth all vary as it ages. After the age of five months, lambs normally develop swiftly, and the animal's growth rate decreases until it reaches adulthood. Lamb growth rates can range from 20 to 200g/d, with management, feeding level, genotype, sex, and health all having an influence, when given a bad diet, sheep develop slowly, but when given a better diet, they grow swiftly. this is referred to as compensatory growth according to Agolisi, (2019).

2.14 Animal waste and its use in agriculture

The cattle and poultry industries produce enormous volumes of potentially hazardous waste, including liquid waste, H_2S and CH_4, odour, and solid waste (manure and organic compounds) (Leha, 1998; Obi *et al*., 2016). Animal waste varies by species in terms of quantity and quality, and animal performance, food composition, feed conversion, and the kind of housing system employed can all affect the amount of manure generated (Ketelaars and Van Der Meer,2000; Ryser *et al*., 2001). According to Ketelaars and Van Der Meer (2000) turkey (5.4-45.3 kg), rabbit (5.1-11.3 kg), sheep (0.08-0.14 kg), cattle (0.13-0.34 kg), swine (0.71 kg), chicken (2.8 kg), and horse (28 kg) generated, on average of manure per day. Animal waste items may be useful resources if handled appropriately. Large quantities of inorganic fertilizer might be replaced by it (Leha, 1998). For crop productivity and soil nutrition, animal waste manure is a useful supply of nutrients and organic matter (Bell, 2002). Feces and urine contribute (55-90 %) of the phosphate and nitrogen content in animal feed (Ryser *et al*., 2001). These wastes come from the production of ruminant animals and include protein, energy, and mineral nutrients (Daghir, 1995; Bell, 2002). When these wastes are treated properly, they may be utilized as a protein source for animals, lowering production costs, the price of animal goods on the market, and competitiveness between animals and humans (EL-Boushy and Vander Poel, 2000; Bell, 2002).

Bell (2002) discovered that feeding pig and chicken manure to cattle and sheep had no negative effects on ruminant health or product quality.

2.15 Abattoir waste and its effect on the environment

The slaughterhouse's primary role is to produce edible components of the slaughtered animals for human consumption. A substantial amount of waste is produced, primarily comprising organic materials such as blood, bone, meal, manure, and by-products of rumen digestion (Coker et al., 2001; Nafarnda et al., 2006). Coker et al. (2001) approximated that for every 1000 kg of carcass processed, 6 kg of manure and 100 kg of partially digested feed are generated. The waste generated per slaughtered animal is approximately 35% of its weight. In 2011, Thailand generated about 41,000 tonnes of dry rumen digesta from 1.2 million bovine deaths (FAO, 2012). Fearon et al. (2014) calculated that the Tamale metropolitan area in Ghana produces and disposes of 636.5 tons of tissue waste annually, along with 1,159.7 tonnes of blood. Workers at slaughterhouses often dispose of waste irresponsibly, posing risks to nearby communities, animals, and water sources. Unfortunately, some slaughterhouses draw water from the same contaminated sources (Weobong, 2001; Adelegan, 2002; Osibanjo and Adie, 2007). Workers in Nigeria and Ghana frequently discard waste near slaughterhouses or into adjacent water bodies.

According to Adeyemo et al. (2009), slaughterhouse activities are a major contributor to air pollution, adversely affecting the health of residents living in proximity to these facilities, as well as contaminating surface and groundwater (Odoemelan and Ajunwa, 2008). A study conducted at the main abattoir in the Tamale metropolis revealed that all measured parameters exceeded the standards set by the Ghana Environmental Protection Agency (EPA), indicating severe pollution of the facility's wastewater (Weobong and Adinyira, 2011; Fearon et al., 2014). Improper disposal of animal feces into water bodies can lead to reduced oxygen levels and nutrient overenrichment, accelerating the accumulation of toxins (Nwachukwu et al., 2011). Aina and Adedipe (1991) highlighted that waste from abattoirs in water bodies could potentially decrease fish productivity. There is a risk of human infections with respiratory and waterborne diseases (Mohammed and Musa, 2012).

2.16 Rumen digesta and its current use

Rumen digesta, a by-product of ruminant animal slaughter (cows, sheep, and goats), is now a challenge in the majority of developing nations. Rumen digesta is typically present in the rumens of ruminants and is a kind of partly digested fodder (Okere, 2016). Awodun (2008) explained that the rumen digesta consists of gases, fluid, and feed particles with diverse sizes and physical characteristics. Bacteria, protozoa, and fungi play a role in affecting the composition of the rumen digesta (Awodun, 2008). Each slaughtered cow produces approximately 24.5 kg of fresh rumen digesta or 3.8 kg of dry matter, as reported by Witherow and Lammers (1976). In Owerri, Nigeria, an estimated 2,952,720 kg of rumen digesta is generated annually (Okere, 2016). Fearon et al. (2014) noted that the Tamale abattoir produces 822,900 tonnes of rumen digesta each year. Okere (2016) conducted a study on the financial benefits of rumen digesta from slaughterhouses in Owerri, Nigeria, revealing a profit of N29,527,240.00 per year, which could potentially create job opportunities for 681 graduates for a month, 49 graduates for a year, and 123 secondary school graduates.

Despite the potential benefits, a significant amount of rumen digesta produced in slaughterhouses worldwide is discarded as waste (Ristianto et al., 2016). To address soil nutrient deficiencies, rumen digesta is commonly utilized as organic manure on farms (Schobery, 2002; Ristianto et al., 2016). Dried rumen digesta is used as a fuel in thermal power plants (Arvanitoyannis and Ladas, 2008). While abattoir rumen digesta is employed to power cyclonic combustors (Virmond et al., 2011), cattle rumen digesta is also utilized for electricity and biogas generation (Ur-Rahman et al., 2014). Rumen digesta serves as a feed ingredient for both ruminant and non-ruminant livestock in various countries (Okere, 2016).

Researchers are actively exploring the appropriate processing of rumen digesta from slaughterhouses as an alternative nutrient source to address feed shortages in the cattle industry (Adedipe et al., 2005; Amata, 2014) and to enhance its economic value (Amata, 2014). Studies on dried rumen digesta have been conducted in several countries, including Cameroon, Ethiopia, Nigeria, Egypt, Sudan, Saudi Arabia, India, and Thailand, where animals were fed dried rumen digesta as a protein source at different inclusion levels (Ra and Iliyasu, 2017).

2.17 Nutritive importance of rumen digesta as feed to livestock

Rumen digesta, a by-product of cattle, can be added to fodder to increase its protein content (Ristianto *et al*., 2016). The quantity of amino acids and other chemicals that can be obtained depends on how much heat is utilized during processing (Makinde and Sonaiya, 2007). Dried rumen digesta has no detrimental effects on growth performance, hence utilizing it as a supplement in animal feed is advantageous, claim Yitbareket *et al*. (2016).

Nutritionists have highlighted the significant nutritional value of dried rumen digesta in the livestock feed industry as an economical feed ingredient (Togun et al., 2010; Elfaki et al., 2014; Osman and Elimam, 2015). Studies by Dairo et al. (2005), Mishra et al. (2015), and Osman and Elimam (2015) demonstrated no adverse effects when various animals (such as catfish, poultry, sheep, quail, cattle, and goats) were fed dried rumen digesta along with a blood mixture. The quality of the pasture consumed by the animals influences the chemical composition of dried rumen digesta (Togun et al., 2010).

Furthermore, dried rumen digesta is rich in beneficial yeasts, bacteria, and fungi, and it contains a substantial amount of crude protein (18.5) (Dairo et al., 2005; Esonu et al., 2006; Agbabiaka et al., 2011). According to Agbabiaka et al. (2011), dried rumen digesta comprises 34.44% crude fiber, 3.77% crude fat, 18.58% crude protein, 5.41% moisture, and 24.81% nitrogen-free extract (NFE).

Integrating rumen digesta into animal feed formulations can lead to cost savings in feeding practices and help mitigate environmental risks associated with slaughterhouse waste.

2.18 Rumen digesta as feed for Sheep

Agolisi (2019) observed an average daily gain ranging from 48.21g/kg to 56.47g/kg when djallonké rams were supplemented with graded levels of DRD-based concentrate (0%, 4%, 8%, and 12%) with rice straw as a basal diet fed in a ratio of 70:30 (concentrate and rice straw). In contrast, Agolisi and Ansah (2023) reported a lower average daily weight gain of 28.8g/kg to 48.9g/kg when djallonké rams were fed a diet of urea-treated DRD pellet concentrate (0%, 5%, 10%, and 15%).When dried rumen digesta were fed to sheep at (0, 5, and 10%) of their usual diet, Osmanand Elimam (2015) recorded improvements in feed efficiency, feed intake, and weight gain. After initially gaining 26.0 kg, 26.5 kg, and 31.75 kg, respectively, their ultimate weights were 30.27 kg, 31.25 kg, and 31.75 kg. Similar results were reported by Abouheif *et al*. (1999) for Najdi lambs fed a 4:1 blend of rumen digesta and barley, which did significantly influence carcass weight, growth performance, or dressing percentage. However, compared to lambs fed the control diet, lambs fed the 25 and 50 percent DRD, and barley-based diets put on less weight.DRD was fed to lambs by Al-Wazeer (2016) who observed no appreciable differences in ultimate body weight or nutritional digestibility.

Mondal *et al*. (2013) and Osman *et al*. (2015) fed DRD doses of 0%, 5%, and 10% to lambs, and neither research found any deleterious effects on daily weight growth or final weight. Osman and Abass (2015) observed a similar effect in Sudan desert lambs fed concentrate diets containing 0, 10, and 20% DRD. DRD feeding to Pelibuy Dorper lambs had no impact on daily growth or feed efficiency (Salinas-Chavira *et al*., 2007). Olafadeha *et al*. (2014) graded the quantities of DRD-based food given to Yankasa lambs at (0, 40, and 60%) DRD and found a rise in average daily weight gain and body weight gain at 0 and 40% DRD but a decrease at 60% DRD. Fajemisin *et al*. (2010) fed DRD to Djallonké sheep instead of cassava peels and observed that feed conversion efficiency and average daily weight gain did not change across the treatment.

Osman *et al*. (2015) discovered that increasing the quantity of dried rumen digesta (DRD) in the meal enhanced sheep feed intake and feed conversion efficiency. Weight gain was greatest in the sheep fed 10% DRD and lowest in the animals fed no dry rumen material. Animals administered 0.5% and 10% DRD had end body weights of 30.27, 31.25, and 31.75 g/kg, respectively, with no noticeable changes in weight. According to Babatunde *et al*. (2017) there was no noticeable difference in carcass weight, growth performance, or dressing percentage between lambs fed a 4:1 diet mixture of barley and rumen contents and the control group. Abbator *et al*. (2016) reported that when wheat bran was introduced to the rumen digesta in varied amounts in goat feed, increased intake of dry matter owing to the palatability of the diet. Goats given 25% dried tripe digesta with 75% wheat offal gained the most weight per day due to low DRD percentage, a greater feed conversion ratio, and high metabolizable energy.

2.19 Growth performance of ruminants fed silage

Er & Keles (2021) reported that feeding buckwheat silage to dairy cows with low (10%, 5) or high (46%, 6) showed no effects on DMI and milk yield within a short period. Massaro Junior *et* *al*. (2021) reported inclusion levels of grape pomace silage (0, 10, 20 and 30%) of the dry basis maintaining the mass concentration ratio of 55:45 inclusion of 10% GPS increased the final body weight of lambs by 3.6% Chikwanha *et al*. (2018) also observed a positive linear relationship between the intake of EE and the degree of GPS inclusion in the diet of lambs, total feed intake and weight gain of (840 g/d and 46.07 g/d) maximum for sheep-fed silage feeds with 60% cassava husk + 25% A. lebbeck + 15% P. Maximum silage mixes also leads to effective silage degradability leading to higher nutrient uptake and good performance as reported by Festus and Sunday (2018).

2.20 Blood indices

An animal's blood profile study offers a clear picture of the impact of nutrition on its metabolic needs. Dietary modifications have a sizable impact on blood component levels, which may be utilized to infer information about an animal's nutritional value. The standard for evaluating the nutritional content of a meal is the change in the concentration of blood components as an indication of metabolic disruption or toxicity (Agolisi, 2019).

2.20.1 Haematological indices

Red blood cells from both vertebrates and certain invertebrates contain hemoglobin (Hb), an iron-containing metalloprotein (Maton *et al*., 1993). According to Maton *et al*. (1993) hemoglobin transfers oxygen from the respiratory organ to the remainder of the body, where it is released to burn foods to sustain the physiological processes of the organism. Low hemoglobin levels suggest anemia; a healthy sheep should have a range of 8 to 16 g/dl. The proportion of red blood cells to the volume of white blood cells in capillary, venous, or arterial blood is known as hemocrit (HCT), sometimes known as packed cell volume. Bull *et al*. (2000) indicated that packed cell volume is a crucial indicator for identifying anemia or polycythemia and evaluating differences in hemodilution and hemoconcentration. For healthy sheep, the ideal packed cell volume range is 27–45% (Agolisi, 2019). Invertebrate circulatory systems depend on red blood cells (RBC) to transport oxygen to bodily tissues. Haemoglobin, an iron-containing biomolecule that carries oxygen and gives blood its color, is abundant in the cytoplasm of red blood cells (Fadiyimu *et al*., 2010). The cells in the body that fight illnesses and foreign objects are called white blood cells (WBC). A WBC count that is higher above the physiological range denotes illness. Fadiyimu *et al*. (2010) stated that sheep with normal physiological parameters have white blood cell counts between 755.37 to 1379.94/L.

2.20.2 Biochemical indices

An essential component of the health and function of mammalian cell membranes, cholesterol is a waxy steroid of fat that is necessary for the formation of bile acid, steroid hormone, and vitamin D as well as optimal membrane fluidity and permeability. Hyperthyroidism is brought on by malnutrition's reduction of serum cholesterol (Lewington *et al*., 2007; Sadava *et al*., 2011). According to Cox-anser *et al*. (1994) a healthy sheep has total cholesterol levels between 1.33 and 1.95 mmol/l. The quantity of soluble proteins present in extracellular and intracellular fluids is measured as total protein. It keeps the blood pressure, substance distribution, and plasma pressure stable. Serum protein concentration was negatively impacted by malnutrition. Total protein levels in a healthy sheep should vary from 60 to 93 g/l (Borjesson *et al*., 2000; WebMD, 2009).

2. 20. 4 Hematological characteristics of ruminants fed with silage

A normal healthy sheep fed on silage has mean range values for serum protein of (45-51 mg/dl), mean albumin value of (2.70-4.55 g/dl), serum urea level of (23.63-34.54 mg/dl), serum cholesterol and glucose levels of 50.00 - 140.00 mg/dl and 55 .0 - 131.00 mg/dl, creatinine (1.1–1.9 mg/dl) reported by Amuda and Okunlola (2018). Alabi and Ososanya (2017) also reported that, a normal healthy sheep fed on silage has serum cholesterol (48.00-120.00 mg/dL), Serum creatinine (0.5-2.00 mg/dL), HDL levels (30.50-45.70 mg/dl), and LDL levels (10.20-10.85 mg/dl)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at the Livestock Unit of the Animal Science Department of the University for Development Studies (UDS)-Nyankplala Campus from October to December, 2022. The chemical, and the *in vitro* gas analysis were carried out at the Forage Evaluation Unit of the Agricultural Sub-Sector Improvement Project (AgSSIP), and the Spanish Laboratory at the University for Development Studies Nyankpala Campus. Nyankpala is located at longitude 0^0 58' 42.11" W and latitude 9^0 25' 41.11" N in the dry Savanna Region of Ghana is approximately 183 meters above sea level (SARI, 2007). Nyankpala experiences a seasonal rainfall period from April to the end to October receiving an annual rainfall of 1,043mm. The yearly average temperature ranges from 15˚C-42˚C with a median annual mean temperature of 28.5˚C, and an annual daily relative humidity of 54% (SARI, 2007).

3.2 Experiment 1: chemical composition and in vitro digestibility of experimental diet.

3.2.1 Chemical Analysis

AOAC (2000) procedures were used to analyze dry matter (DM), crude protein (CP), and ash content of the feed sample.

3.2.1.1 Dry matter

Dry matter results were obtained by weighing 2 grams of the feed sample into a crucible and placed in an air oven at 60˚C for 48 hours. After drying, the weight of each treatment was measured and used to determine the dry matter percentage according to AOAC (2000) procedure. The dry matter percentage was determined using the formula:

$$Dry\ matter\ (\%)\ = \frac{\text{sample dry weight}}{\text{sample weight}} \times 100$$

3.2.1.2 Ash

After dry matter content determination, the remaining samples were used to determine the Ash content using the AOAC (2000) procedure. The crucible containing the samples were placed in a muffle furnace at 550˚C to burn all the organic components leaving only the non-volatile mineral components. The crucible was then removed and placed in a desiccator to cool before weighing. The Ash concentration was then calculated using the formula:

$$Ash\ (\%) = \frac{ash\ weight}{dry\ sample\ weight} \times 100$$

3.2.1.3 Crude protein

AOAC (2000) procedure were us to determine the crude protein content of the feed sample. Each 1 gram of dried feed sample were weighed, and placed in Kjeldahl digestion tubes with a blank determination conducted by digesting filter paper in each round of digestion. 15 ml of concentrated sulphuric acid (H_2SO_4) and two Kjeldahl tablets were added to each content in the digestion tube. The Kjeldahl tablets contains copper sulphate ($CuSO_4$) and potassium sulphate (K_2SO_4) which enhance the boiling point and acts as a catalyst. The digestion tubes were then heated on Kjeldahl digesting block with a fume exhaust system (J.P. Selecta RAT2 Spain) gradually to 420˚C and maintained for 3 hours. After removing the digestion tubes and allowed to cool to room temperature, the tubes were distilled using an automated Kjeldahl distillation apparatus (J.P. Selecta, s.a., Pro-Nitro II Spain) which drew 50 mls of 35% sodium hydroxide

(NaOH) into the digesting tubes, and 25 ml of 4% Boric acid (H_3BO_3) into a 25 ml Erlenmeyer flask to capture thereleased ammonia during the 9-minute distillation phase. The average titre readings were recorded, and nitrogen (%N), and crude protein (%CP) percentage were calculated using the formula:

$$\%\ Nitrogen = \frac{(T-B)\times N\times 1.4}{sample\ weight\ (g)} \times 6.25 \text{ for } \%\ CP$$

Where:

T= sample titre value, N= HCL concentration, and B= blank titre value.

3.2.1.4 Neutral detergent fiber and acid detergent fiber

According to Van Soest *et al.* (1991) the Ankom 200 fibre analyzer (Method 5 for Acid detergent fibre, and Method 6 for Neutral detergent fibre) were used in the determination of acid detergent fibre (ADF), and neutral detergent fibre (NDF) excluding residual ash using sodium sulphite and alpha-amylase. Each sample weighing between 0.45-0.55g were placed directly into ANKOM F57 filter bags and labelled. Each ANKOM F57 bags were then sealed within 4mm from the top using an electric heat sealer. A blank filter bag was included in each run to determine the blank bag adjustment. The sample filled bags were then suspended on a bag suspender and inserted into ANKOM fibre analyzer vessel with a bag suspender weight placed on top to keep them submerged. Subsequently NDF, and ADF solutions were prepared by dissolving specific quantities of 30g Sodium dodecyl sulphate, USP; 18.61g Ethylene diamine tetra disodium salt, dehydrate; 6.81 sodium borate; 4.56 g Sodium phosphate dibasic, anhydrous, and 10 ml Triethylene glycol in 1 litre distilled water and 20 g Cetyl trmethylammonium bromide (CTAB) into 1 litres of 1 N H_2SO_4 respectively. Two litres of NDF solution were added to the fibre analyzer vessel for every 12 sample bags along with Sodium sulphite and alpha-amylase. Twenty grams (0.5g/50 ml) of Sodium sulphite and 4 ml of alpha-amylase were added to the solution in the fibre analyzer vessel. The fibre analyzer was operated for 75 minutes after which the solution was drained, and the content were washed with two litres of hot water (70-90˚C). The samples underwent rinsing for about 5 minutes repeatedly for about 3 times with 4.0 ml alpha-amylase added to the first and second rinses. Following rinsing the samples were immersed in acetone for 3-5 minutes then oven-dried at 102˚C for 2 hours, and weighed. The ADF procedure mirrored the NDF protocol except the fibre analyzer operated for 60 minutes, and sodium sulphite, and alpha-amylase were not icluded.

3.2.1.5 *In vitro* digestibility procedure

The *in vitro* digestibility analysis was determined at the Forage Evaluation Unit of the Animal Science Department of the University for Development Studies Nyankpala Campus. The batch *in vitro* gas production technique developed by Theodorou *et al*. (1994) was utilized with modifications in the rumen fluid source as described by Ansah *et al.* (2016). The experiment was laid in CRD and replicated three times. The rumen fluid was obtained from four slaughtered Sanga cattle (300 ± 15 kg) at the Tamale abattoir which were raised on indigenous pasture fields. The rumen fluid was filtered through a double-layer cheesecloth under a continuous supply of carbon dioxide. McDougall salivary buffer solution was prepared from solution A, and B consisting of specific amounts of $NaHCO_3$, $Na_2HPO_4 \cdot 2H_2O$, KCl, NaCl, and $MgCl \cdot 6H_2O$ dissolved in distilled water, and maintained at 39˚C in a water bath. Treatment samples weighing between 0.45-0.55g per bag were placed in fibre filter bags sealed, and placed in 50 ml digestion tubes. Approximately 30 ml of the warm anaerobic incubation media (rumen + buffer) was added to the digestion tubes, and then incubated for 48 hours at 39˚C in a water bath. After the incubation period the samples were washed in distilled water oven-dried at 102˚C for 3-4 hours. The residual neutral detergent fibre in the incubated samples was determined using an Ankom

200 fibre analyzer (Method 6). The *in vitro* dry matter true digestibility (IVDMTD), Indigestible NDF, Digestible NDF, and NDF digestibility were calculated using the equation (Mertens 2002);

$$IVDMTD\ (\%DM) = \frac{dry\ matter\ weight - neutal\ detergent\ fibre\ residues}{dry\ matter\ weight} \times 100$$

Indigestible NDF (iNDF) was obtained using the equation; iNDF (%DM) = 100 – IVDMTD

Digestible NDF (dNDF %DM) = NDF – iNDF

$$NDF\ digestibility\ (NDFD\ \%DM)\ = \frac{digestible\ neutral\ detergent\ fibre}{neutal\ detergent\ fibre} \times 100$$

Where;

IVDMTD = *In vitro* dry matter true digestibility, NDF = neutral detergent fibre, DM = dry matter, DMwt = dry matter weight, NDFres = neutral detergent fibre residues, iNDF = Indigestible neutral detergent fibre, dNDF = digestible neutral detergent fibre, NDFD = neutral detergent fibre digestibility.

3.3 Experiment 2: Effect of feeding graded levels of DRD-based concentrate and a basal diet ensiled elephant grass on feed intake, nutrient digestibility, serum biochemistry, and growth performance of djallonké sheep.

3.3.1 Planting of elephant grass for silage preparation

The planting of elephant grass for silage preparation began by acquiring land from the experimental field at the University for Development Studies-Nyankpala Campus. The land was plowed to a depth of about 6-8 inches to create a fine seedbed. Stem cuttings of elephant grass were sourced from the plant house of the University for Development Studies and propagated without specific attention to planting distances between rows and plants. Upon sprouting at 4 and

7 weeks old, organic fertilizer (urea) was applied to supply the necessary nutrients for the elephant grass growth. Weed management was carried out manually.

3.3.2 Source of Experimental Animals

Nine djallonké rams aged between 8 and 12 months were purchased from the Navrongo market. Before commencing the trial, all animals received treatments of albendazole 2.5%, antibiotic 20%, and multivitamins. The animals were then ear-tagged for easy identification.

3.3.3 Experimental design

9 djallonké sheep were used for the experiment with an initial average weight of (8.4±0.385kg) and were assigned to 3 treatments with 3 replicates in a Completely Randomized Design (CRD). The 3 treatments included T_0 (free range), T_1 (12.5% concentrate + 37.5% silage), and T_2 (25% concentrate + 75% silage). The experiment lasted for 56 days following a 14-day adaptation period, taking place between October 2022 and December 2023.

3.3.4 Experimental dietary preparation

Fresh elephant grass was harvested at 70 days at the optimal stage of growth for higher nutrient content. It was then chopped into small pieces, around 1.5-2cm in length with a mechanical chopper to facilitate compaction and fermentation. The chopped elephant grass was ensiled for 8 weeks in a clean and airtight anaerobic container and compacted tightly to remove air as much as possible. The containers were covered tightly and sealed to prevent air from entering the silage to create an anaerobic environment that promotes fermentation. The silage was stored for 3-5 weeks to achieve a pH of 3.80–4.0. The basal diet was ensiled elephant grass and the concentrated meal composed of DRD, shea nut cake, rice bran, maize bran, and cassava peels. In the other diets (T_1 and T_2), the dried rumen digesta was added at a rate of 12.5% (T_1) and T_2 (25%) to 37.5% and 75% ensilage.

Rumen digesta processing procedure

1. Collection of rumen digesta from abattoir to exclude blood to plastic containers.

2. On arrival, the digesta was place in a sack, tied and heavy object place on it for 3 hours to press the liquid out before spread on polyethylene sheet to sun dry for 4 days

3. The dried rumen digesta and the other ingredients are now thoroughly mixed before using a mechanical pelleting machine to pellet it to a concentrate for the feeding trials.

Table3. 4:Composition of Rumen digesta-based concentrate

Ingredients	Inclusion level (%)
Maize bran	55
Cassava peels	13.5
Rice bran	15
Shea nut cake	5
DRD	10
Mineral premix	0.5
Salt	1
TOTAL	100

DRD=dry rumen digesta.

3.3.5 Experimental Animal Management

The animals were housed individually in cages with concrete floors. Wooden troughs containing the experimental diet and plastic bowls containing water were attached to the cages. Before introducing the animals, the cages underwent thorough cleaning. The feed weight was measured before feeding. The concentrate and the silage were mixed and given at 7:00 am every morning with water available ad libitum. Every morning the remaining feed for each animal was measured, and the difference between the amount provided and the amount remaining indicated the feed consumption.

The experimental diet was weighed each morning and distributed equally to all animals. The leftovers were weighed to calculate the consumption. Samples of the experimental diets offered and leftovers were collected daily and stored in a refrigerator until the conclusion of the experiment. During the experiment, the collected diet samples were combined for each treatment replicate, and a subsample was extracted for drying in the oven. Each duplicate of the sub-sampled treatments was weighed and subjected to oven drying at 60ºC for 48 hours. The dry matter (DM) percentage was then calculated to estimate the total DM intake of the supplemented diet for each treatment group.

Weekly weighing of all animals was conducted before their morning feeding. The weekly feed allocation was determined by calculating 4% of the ram's body weight which was divided between 75:25 (75% silage and 25% concentrate).

Dry matter intake of free-range rams was obtained by using the total collection method. The rams in the control were attached with a faecal bag for small ruminants to their hindquarters in a way that allowed for easy collection without causing discomfort to the rams for 24-hour faecal matter collection (Arnold, 1960; Karbo*et al*., 2008). The total dry matter intake of the rams was determined using the ratio method described in the equation below (Lippke, 2002; Stuth*et al*., 2009; Cottle, 2013).

$$\text{Dry matter intake (kg DM/d)} = \frac{\text{Total faeces voided (kg DM/d)}}{1 - \text{coefficient of digestibility}}$$

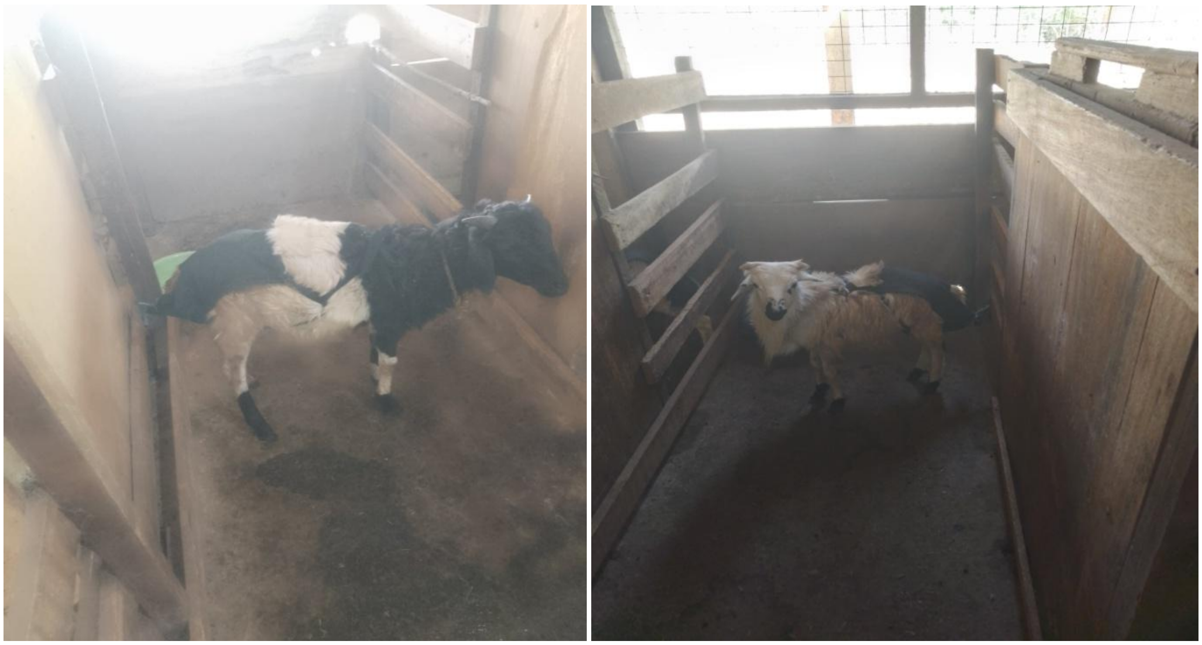

Plate 3. 1:Experimental rams in experimental cages

3.3.6 Feed intake

The daily feed portions were carefully weighed using a scale before being given to the animals. Feed intake was closely monitored and documented each day by determining the difference between the quantity of feed offered and the amount refused. The average daily feed intake was computed by dividing the total feed consumed by the number of days the experiment spanned.

3.3.7 Live body weight gain

The weight of the experimental ram was assessed weekly utilizing a digital scale (Jadever JPS-1050). Weight gain was determined by subtracting the initial live weight of each animal from its final live weight after the experiment. The average daily gain was calculated by dividing the total weight gained by the duration of the experimentwhich was 56 days, as illustrated in the formula below.

$$\text{ADG (g)} = \frac{\text{final weight (kg)} - \text{intial weight (kg)}}{\text{number of days}}$$

3.3.8 Nutrient digestibility

During the 8-week duration of the experiment, feed digestibility was evaluated. Faecal collection bags were affixed to the rams to collect faeces for the digestibility assessment. Daily faecal output was gathered, weighed, and recorded, with samples stored in a refrigerator until the end of the experiment. The accumulated faecal samples were pooled for each treatment replicate, and a sub-sample was taken for oven-drying post-experiment. Each sub-sample was duplicated, weighed, and subjected to oven-drying at 60ºC for 48 hours. The dry matter percentage was calculated and used to estimate the total dry matter digestibility for each treatment group. The digestibility coefficient was calculated by subtracting the daily matter output from the daily dry matter intake and dividing it by the daily dry matter intake of each animal.

$$\text{Digestibility coefficient} = \frac{\text{Dry matter intake} - \text{dry matter output}}{\text{dry matter intake}}$$

3.3.9 Blood sampling

Blood samples were collected in the morning before feeding. Approximately 10 ml of blood was extracted via a syringe from the jugular vein and transferred to sterile test tubes without any anticoagulant. Subsequently, the samples were dispatched to the laboratory at Tamale Central Hospital for analysis of hematological and biochemical parameters. The variables evaluated included Urea, albumin, total protein, glucose, globulin, creatinine, cholesterol, triglycerides, LDL cholesterol, VLDL cholesterol, and coronary risk.

3.3.10 Glucose

Using the BT 3000 Random Access Chemistry analyzer and Amidu *et al*. (2013) technique, the isolated serum was examined for glucose. Hydrogen peroxide (H_2O_2) and gluconic acid are produced when glucose is oxidized by the glucose oxidase.

3.3.11 Total protein and urea

This research modified Gornall *et al*. (1949) to base their calculation of total protein. When a protein in serum reacts with cupric ions in an alkaline solution, a blue-colored complex results. Using the methods used by Fawcett and Scott (1960) and Chaney and Marbach (1962) blood urea nitrogen levels were examined.

3.4 Data analysis

Chemical composition, in vitro digestibility and growth trial parameters, and serum biochemistry, were subjected to one-way analysis of variance using GenStat Statistical Package, 12th edition, and a significant difference was tested at P = 0.05 and means separated using Tukey's honestly significant difference (THSD).

CHAPTER FOUR

4.0 RESULT

4.1 Chemical composition of the experimental diets

The results of the chemical composition of the experimental diet are presented in Table 4.1. From Table 4.1 dry matter composition did not record any significant difference among the various treatments, however, T0 (960.0 g/kg) recorded the highest dry matter composition among the various treatments. The organic matter composition recorded no significant difference ($p>0.05$) between the DRD inclusion levels but a significant difference ($p<0.05$) was recorded between the supplemented rams. The crude protein also recorded some level of significant difference ($p<0.05$) with T_1 (109.8 g/kgDM) being the highest. The Ash content for DRD inclusion levels was the same but significantly different ($p<0.05$) from the control. T_2 (485.6 g/kgDM) recorded the highest NDF. There was no significant difference ($p>0.05$) recorded for the ADF among the various treatments. Additionally, T_2 (232.6 kgDM) recorded the highest HM among the various treatments.

Table 4.1: Chemical composition of the concentrate fed to Rams.

	DRD inclusion levels (%)				
Parameters	T_0	T_1	T_2	SED	P-value
Dry matter (g/kg)	960.0	947.5	947.5	5.00	0.073
Organic matter (g/kgDM)	856.4^{b}	813.0^{a}	823.2^{a}	7.45	0.003
Crude protein (g/kgDM)	105.3^{a}	105.4^{a}	102.4^{a}	2.72	0.493
Ash (g/kgDM)	143.6^{a}	187.0^{b}	176.8^{b}	7.45	0.003
NDF (g/kgDM)	435.6^{a}	460.1^{b}	461.1^{b}	6.34	0.011
ADF (g/kgDM)	212.2^{a}	256.8^{a}	253.0^{a}	14.87	0.141
HM	223.4^{a}	208.1^{a}	207.1^{a}	7.80	0.144

NDF = Neutral detergent fiber, ADF = Acid detergent fiber DRD = Dried rumen digest, HM= hemicellulose, SEM= standard error of means, T_0 (free range), T_1 (12.5% concentrate + 37.5% silage), T_2 (25% concentrate + 75% silage). Dry matter intake was calculated using the ratio method of Lippke (2002); Stuth *et al*. (2009); Cottle (2013).

4.2 In vitro neutral detergent fiber digestibility.

From Table 4.2 T_1 recorded the highest IVNDMTD while T_0 and T_2 were comparable. NDFD and dNDF digestibility increased slightly as the inclusion level of the ensiled elephant grasses increased with T_2 recording the highest NDFD and dNDF. iNDF digestibility did not record any significant difference ($p>0.05$) among the various treatments.

Table 4.2: Effect of feeding rumen digester-based concentrate with a basal diet of ensiled elephant grass on in vitro nutrient digestibility.

	DRD inclusion levels (%)				
Parameters	T_0	T_1	T_2	SEM	P-value
IVDMTD	82.75	83.52	82.26	0.987	0.673
NDFD	62.25	61.88	63.48	2.590	0.902
dNDF	28.58	26.90	30.84	1.474	0.220
iNDF	17.25	16.48	17.74	0.987	0.673

IVDMTD= in vitro dry matter true digestibility, NDFD=neutral detergent fiber digestibility, dNDF= digestible neutral detergent fiber, iNDF= insoluble neutral detergent fiber, SEM= standard error of means, T_0 (free range), T_1 (12.5% concentrate + 37.5% silage), T_2 (25% concentrate + 75% silage).

4.3 Growth performance and dry matter intake of experimental rams.

From the data presented in Table 4.3, it can be observed that there is a significant difference ($p<0.05$) between rams fed the control diet and rams supplemented with DRD concentrate diet with ensiled elephant grass as a basal diet, with the control recording the highest daily weight gain. Generally, weekly weight gain, final, and total weight gain also follow the same trend as the daily weight gain.

Table 4.3: Effect of feeding rumen digester-based concentrate with basal diet of ensiled elephant grass and free-range feeding on growth performance of djallonké sheep.

Parameters (g/kg)	T_0	T_1	T_2	SED	P-Value
Feed intake (g/day)	114.1	62.80	182.3	4.750	<.001
Daily weight gain (kg)	0.10	0.069	0.05357	0.014	0.023
Weekly weight gain (kg)	0.75	0.479	0.3750	0.099	0.023
Final weight gain (kg)	14.0	11.50	10.67	0.720	0.009
Total weight gain (kg)	6.00	3.833	3.000	0.793	0.023

T_0 (free range), T_1 (12.5% concentrate + 37.5% silage), T_2 (25% concentrate + 75% silage), SED = standard error of deviation, P = probability.

4.4 Blood biochemical indices

Table 4.4 shows the results of the effects of feeding rumen digester-based concentrate with a basal diet of ensiled elephant grass and free-range feeding on blood hematology and serum of djallonké sheep. The serum urea concentration recorded a significant difference ($p<0.05$) between the control and DRD concentrate diet, with the control being the highest (6.337 mmol/l). Additionally, a similar trend is also observed between the albumin and total serum protein. The creatinine and globulin concentration recorded a highly significant difference ($P<0.05$) between the control rams and DRD concentrate-supplemented rams. The cholesterol levels were highly significant ($p<0.05$) between the control and DRD concentrate diet with the control (0.986mmol/l) recording the highest cholesterol levels. LDL and VLDL cholesterol levels recorded no significant difference ($p>0.05$) between the control and DRD concentrate diets. HDL and triglyceride levels are comparable across the treatment. T_2 recorded the highest coronary ratio (0.466), followed by T_O (0.300) with T_1 (0.160) being the least.

Table 4.5: Effect of feeding rumen digester-based concentrate with a basal diet of ensiled elephant grass and free-range feeding on serum biochemistry of djallonké sheep.

Parameters	T_0	T_1	T_2	SED	p-value
Urea (mmol/l)	6.337^b	3.957^a	4.187^a	0.620	0.016
Creatinine (µmol/l)	57.13^a	74.17^b	75.57^b	0.881	<.001
Albumin (g/l)	18.33^b	13.43^a	14.93^a	0.997	0.007
Globulins (g/l)	13.55^c	9.50^a	11.06^b	0.440	<.001
Cholesterol (mmol/l)	0.986^b	0.626^a	0.940^b	0.056	<0.001
HDL cholesterol (mmol/l)	0.293^{ab}	0.223^a	0.406^b	0.058	0.053
Triglycerides (mmol/l)	0.2400^b	0.1200^a	0.1833^{ab}	0.0310	0.023

LDL cholesterol (mmol/l)	0.573[a]	0.350[a]	0.543[a]	0.132	0.264
VLDL cholesterol (mmol/l)	0.1133[a]	0.0533[a]	0.0766[a]	0.0291	0.196
Coronary risk	0.300[a]	0.160[a]	0.466[b]	0.0635	0.009
Total protein (g/l)	4.803[b]	4.233[a]	3.903[a]	0.2120	0.015

T0 (free range), T1 (12.5% concentrate + 37.5% silage), T2 (25% concentrate + 75% silage), SED = standard error of deviation, P = probability.

CHAPTER FIVE

5.0 Discussion

The inclusion of ensiled elephant grasses with DRD concentrate diet did not influence the dry matter composition of the diet as compared to the control as the inclusion levels of the ensiled elephant grasses increased and this trend agrees with Agolisi and Ansah (2023). The lack of significant difference between the ensiled elephant grass with DRD concentrate diet could be attributed to the dietary composition and the ensiling processing method used. The ensiling treatment method used in processing the elephant grass could have caused the leaching of water-soluble nutrients of the elephant grasses leading to a decrease in the overall dry matter content.

Additionally, prolonged ensiling time beyond the optimal time can also lead to excessive fermentation leading to a decrease in dry matter content of the ensiled feed material. However, the high dry matter content recorded in T_0 as compared to ensiled elephant grass with a DRD concentrate diet is an excellent source of energy for rumen microbes. High DM content is a potential source of dietary energy which is beneficial for rumen microbial protein synthesis. Oni *et al*. (2008) reported that DM content is a good source for ruminant rumen functions as it acts as a substrate for fermentative microbial function.

The DRD concentrate diet inclusion decreased the OM content of the diet. The range of OM recorded in this experiment is higher than 85.5-90.69% reported by Agolisi (2019). The variation in the OM can be attributed to the various treatment methods used and the dietary composition. The decreasing trend of OM recorded in this experiment does not agree with the findings of Agolisi (2019) who recorded an increased trend of OM when rams were fed with urea urea-treated rice straw DRD concentrate. However, the higher OM content recorded for the control in this experiment agrees with Olafadehan *et al*. (2014) and Cherdthong *et al*. (2014) when higher OM content was recorded for the control with DRD incorporation in the diet of sheep and steer.

The CP value recorded in this experiment is within the range (105-126 g/kgDM) reported by Victoria *et al*. (2018) but lower than the range (22.6-26.8%) reported by Agolisi (2019). The low CP value recorded for T_2 is an indication that the ensiled elephant grass might have been low in CP value as its inclusion level was higher. The CP level recorded in this experiment is lower than the NRC (2007) recommendation. NRC (2007) reported that 12% CP of total DMI is recommended for the maintenance and growth of sheep. Low dietary CP can compromise the efficient utilization of nutrients, which can subsequently lead to reduced overall metabolic efficiency and affect the growth and development of experimental animals. The variation in CP value reported in this experiment and that of Agolisi (2019) can be attributed to the species of forage and the maturity stage at the time of harvesting. Mtenga*et al*. (1992) reported that CP variation can be attributed to the difference in the stages of growth or physiological fractions of the plant.

The inclusion of the DRD concentrate diet increased NDF concentration in this experiment and this agrees with Agolisi (2019). The NDF recorded in this experiment is; however, lower than the range (480-580 g/kgDM) reported by Victoria *et al*. (2018) when African dwarf sheep were fed Guinea grass. The improved NDF content with the DRD concentrate diet inclusion is essential for nutrient absorption, digestive tract health, prevention of metabolic disorders, and gut microbiota. Oni *et al*. (2008) reported that high NDF is beneficial for the proper functioning of the rumen.

Nutrient digestibility indicates the extent of degradation of the feed material by rumen microbes in a fermentation system and the ease of utilization and digestion by animals (Xue *et al*., 2007). Digestible nutrients are the nutrients needed for the development and growth of animals. Dietary energy intake levels directly correlate with growth rate of animals. Research indicates that animals can adjust their intake of feed according to the dietary energy levels within a certain range and increasing energy levels of the diet can enhance the growth rate and feed rewards in sheep (Sayed, 2011; Kabir *et al*., 2014; Yerradoddi *et al*., 2015). The in vitro dry matter true digestibility (IVDMTD) and neutral detergent fiber digestibility (NDFD) were not significantly different across the various treatments. The extent of nutrient digestibility recorded indicates that the ADF and NDF composition of the diet did not compromise the digestibility of the feed material negatively. The higher IVDMTD recorded in T_1 can be attributed to the low quantity of in-soluble neutral detergent fiber in the dietary composition as indicated by the nutrient digestibility. Novotny *et al*. (2017) reported that forages that contain a high amount of ADF and NDF are low in energy digestibility which implies that as the ADF concentration increases, the concentration of energy digestibility also decreases. The ensiled elephant grass with DRD concentrate diet improved nutrient digestibility. Bestari *et al*. (1998) reported that silage enhances dry matter digestibility as a result of higher nutritional content. Pramata *et al*. (2021) reported that the ensiling of elephant grasses improves feed intake and digestibility of nutrients.

DRD concentrate diet inclusion positively influenced the fraction of ADF in the diet. However, the ADF recorded in this experiment is lower than the range reported by Victoria *et al*. (2018), and Agolisi (2019) in terms of the control but the DRD inclusion levels fall within the range. ADF-rich diets tend to be more filling and satiating for animals and can also act as a physical stimulus for the gut, promoting the proper movement of the gut. McDonald *et al*. (2002) reported that ADF is a major factor that affects forage intake because of its rumen fill which is directly connected with rumination and chewing time.

Ensiling of elephant grass increased voluntary feed intake by the experimental rams. Higher feed intake was recorded in T_2 as the inclusion level of the ensiled elephant grass was higher. The ensiling treatment method has been demonstrated to enhance feed intake and this could be attributed to the palatability of the silage, the particle size of the silage, silage fermentation characteristics such as pH, lactic acid content, volatile fatty acid production, and the environmental factors within the experiment unit. Bureenok *et al*. (2012) reported that ensiled elephant grass with molasses was addictive and resulted in 1.4 times higher feed intake than ensilation without any additive. The chopping of the elephant grasses before ensiling could have also contributed to the improved DMI by the rams supplemented with ensiled elephant grasses as the particle size was reduced. Pratama *et al*. (2021) reported that particle size reduction in the rumen of ruminants enhances the rate of passage of the feed through the digestive tract thus improving appetite. McDonald *et al*. (2011) reported that chopping treatment resulting in smaller forage particle sizes will enhance the surface area of the feed material to facilitate digestion by digestive enzymes.

DRD supplementation did not have a significant effect on the daily weight and final weight gain. The DRD supplementation resulted in a decreasing trend of weight gain as recorded in this experiment. The lack of significant difference observed between treatments supplemented with DRD concentrate in this experiment agrees with several research findings such as Fajemisin *et al*. (2010) who recorded no significant difference in daily weight gain of djallonke sheep fed 25% DRD and poultry droppings. Agolisi (2019) also recorded no significant difference when djallonke rams were fed DRD with urea-treated rice straw. Osman *et al*. (2015) also reported no significant difference in final weight and daily weight gain in lambs fed with DRD at different inclusion levels (0, 5, and 10%). However, Olafadehan *et al*. (2014) reported an increase in daily weight gain and final weight gain in Yankasa lambs when fed with DRD as the inclusion levels increased from 0-40% but at 60%, final weight gain and daily weight gain was compromised. The trend of decreasing weight gain recorded in this experiment and the previous findings and between that of Olafadehan *et al*. (2014) could be attributed to genetic variation of the sheep type used, feeding management and duration, the dietary composition of the DRD, and the prevailing environmental conditions within the experimental unit. The improved CP levels recorded in T_1 did not significantly result in the improvement of the daily weight and final weight gain and this suggests that CP digestibility might have been compromised despite its improvement.

Blood biochemical indices are essential parameters that reflect the nutritional composition of a diet. The serum urea nitrogen levels in this study were within the range (6.18-6.97mmol/l) reported by Su *et al*. (2022). However, it is greater than the range (4.72-8.44mg/dl) reported by Agolisi and Ansah (2023). The difference in serum urea nitrogen levels in this study and that of Agolisi and Ansah (2023) can be attributed to dietary composition, age, and genetic variation among the experimental rams used. There was a sharp decrease in serum urea nitrogen levels as the rams were supplemented with an ensiled elephant grass DRD diet. Agolisi and Ansah (2023) observed that serum urea nitrogen and albumin levels are influenced by dietary treatment. Additionally, the serum urea nitrogen levels recorded in this experiment are greater than the normal range (23.63-34.54 mg/dl) reported by Amuda and Okunlola (2018) for a healthy sheep-fed silage. Chen *et al*. (2016) reported that a reduction in serum urea nitrogen levels is an indication of enhanced nitrogen utilization efficiency, which also provides adequate amino acids and other essential elements for protein deposition. In this study, it is discovered that rams fed ensiled elephant grasses and DRD concentrate diet did not record any significant difference between the two inclusion levels of ensiled elephant grasses and this finding agrees with Wang *et al*. (2020) when male Hu lambs were fed corn silage at difference inclusion levels.

The serum total protein is lower than the range (5.71-6.22 g/l) and (59.22-63.76 g/l) reported by Mako *et al*. (2021) and Wang *et al*. (2020) respectively. The difference in serum total protein can be attributed to the breed type of rams used, environmental factors, and dietary composition as well. Akinmoladun *et al*. (2020) observed that an increased serum total protein can be attributed to dehydration, higher environmental temperatures, and kidney or liver diseases. The decreasing trend of serum total protein in this study contradicts Wang *et al*. (2008) who reported that alfalfa hay supplementation increased serum total protein and decreased urea nitrogen levels of small-tailed Han lambs.

Serum total protein decreased as the inclusion levels of ensiled elephant grasses in the diet increased. Li *et al*. (2020) reported that an increase in serum total protein is essential for the growth promotion, development of animals, and improvement of feed conversion ratio. The gradual decrease in serum total protein can be attributed to reduced nutrient supply or impaired immune function. Also, a decrease in serum total protein can be an indication that the intake of protein, its absorption, and utilization were compromised and this can be attributed to the dietary composition. Su *et al*. (2022) reported that supplementation of alfalfa powder increased the immunity of experimental animals and disease resistance by regulating the metabolism of protein and also enhanced nutrient deposition in animal products.

Albumin and globulin levels decreased considerably. The decrease in albumin and globulin levels in this study is an indication that protein metabolism was affected by ensiled elephant grasses supplementation. The albumin levels recorded are far below the range (29.36-32.26 g/l) reported by Wang *et al*. (2020). Similarly, the globulin levels follow the same trend as albumin which is also lower than (33.32-38.58 g/l) as reported by Su *et al*. (2022). Mako *et al*. (2021) reported that low serum albumen levels are an indication of poor health. The decreased levels of albumin and globulin in the serum in this study might have been caused by inadequate protein intake, genetic variation, and the ages of the rams used. Hormonal imbalance, stress, and physiological changes could have adversely affected the production and regulation of globulins and albumin levels in the rams. Li *et al*. (2020) reported that albumin is a nutrient carrier that stabilizes plasma osmotic pressure, provides energy, and repairs tissues.

The serum creatinine concentration increased rapidly as indicated by the analysed result. This rapid increase in serum creatinine concentration can be attributed to the ensiled elephant grasses DRD concentrate dietary intake. However, the creatinine concentration is comparable to the range (0.82-0.95 mg/dl) reported by Mako *et al*. (2021) when West African dwarf sheep were fed Alternanthera brasiliana-based diet at different inclusion levels. However, the serum creatinine concentration recorded in this study is within the range (0.5-2.0 mg/dl) reported by Amuda and Okunlola (2018) as a normal range for sheep-fed silage. These findings are an indication that the kidneys of the experimental rams were functioning normally and efficiently in eliminating waste products from the system of the animal.

Lipid metabolism-associated products reflect the body's lipid metabolism function and are closely associated with the growth of the animal, development, and health of the body. Triglyceride is the component of fat decomposition which serves as an energy source for various body tissues of the animal body. Total cholesterol, on the other hand, is the sum of cholesterol contained in all lipoproteins in the blood of the animal and its concentration indicates the absorption and metabolism of lipids (Chen *et al*., 2016; Su *et al*., 2022). The triglyceride and cholesterol concentrations show a gradually decreasing trend in this experiment as the rams were fed an ensiled elephant grasses DRD concentrates diet. This trend is an indication that the dietary composition did not have much impact on triglyceride metabolism and cholesterol deposition. Li *et al*. (2020) reported that alfalfa saponin can reduce triglyceride and cholesterol concentration in the plasma of Hu sheep and subsequently prevent atherosclerosis and liver injury. The low concentration of serum triglyceride and cholesterol recorded in this study might have been caused by the nutritional composition of the diet, the processing and preservation method of the silage, and the fibre content of the diet which can affect digestion and absorption of nutrients. Saxena *et al*. (2013) attributed decreased cholesterol levels in the serum to the presence of phytochemicals in forages which affects the synthesis and absorption of cholesterol. Additionally, low energy intake and prolonged feeding of silage with low-fat content may result in lower triglyceride and cholesterol concentrations in the serum. Cerci *et al*. (2011) reported that alfalfa intake reduces cholesterol levels in lambs significantly. Mpenduo *et al*. (2020) reported that higher levels of serum cholesterol are a sign of dehydration.

HDL and LDL cholesterol are the main carrier forms of lipids (Chen *et al*., 2016). The nutritional composition of ensiled elephant grasses and DRD concentrate diet did not have any significant effect on HDL and LDL cholesterol concentration in the serum of the experimental rams. The HDL and LDL cholesterol recorded in this experiment is lower than (0.99-1.14 mmol/l) and (0.50-0.68 mmol/l) reported by Wang *et al*. (2020) when Hu lambs diet was supplemented with corn silage at different inclusion levels. This difference in the concentration of HDL and LDL cholesterol can be associated with dietary composition, genetic variation, and experimental conditions. Kwiecien *et al*. (2021) observed that alfalfa protein concentrate decreased the concentration of triglyceride, cholesterol, and LDL cholesterol and increased HDL cholesterol in broiler chicken serum indicating that alfalfa protein concentrate can be used as a potential substitute for inorganic feed additives to produce meat that is healthier for consumption.

CHAPTER SIX

6.0 Conclusion and Recommendation

6.1 Conclusion.

The effect of ensiled elephant grasses on the growth performance of djallonke sheep based on the results of this study suggested that;

- Ensiled elephant grasses and DRD concentrate diet contains a high amount of dry matter and improved CP value.
- Feeding of ensiled elephant grasses and DRD concentrate diet improved nutrient digestibility.
- Ensiled elephant grasses and DRD concentrate diet improved dry matter intake by the rams.
- Ensiled elephant grasses and DRD concentrate diet compromised weight gain of the experimental rams.
- Ensiled elephant grasses and DRD concentrate diet did not compromise the blood biochemical indices of the experimental rams.

6.2 Recommendation

It is recommended that;

- Further research should be carried out to establish an appropriate inclusion level of ensiled elephant grasses with DRD concentrate diet without compromising weight gain.
- Further research should be carried out on the ensiling process of elephant grass to improve the acceptability of all animals.

REFERENCE

Abbator, F. I., Kolo, U. M., Taimako, A. R. and Kwaghe, A. L. (2016). Performance of Goats Fed Bovine Rumen Content and Wheat Offal as Supplement to Groundnut Haulms. Global Journal of Agricultural Research, (4), 9–16.

Abdullah, A. A., Ismail, M. F. B., Balakrishnan, K. N., Bala, J. A., Hani, H., Abba, Y., Awang, M. K. I., Jesse, F. F. A., Arshad, S. S., Nazariah, Z. A., Abdullah, R., Noordin, M. M. and Mohd-Lila, M. A. (2015). Isolation and phylogenetic analysis of caprine orf virus in Malaysia. Virus Disease 26, 255–259.

Abouheif, M. A., Kraidees, M. S. and Al-Selbood, B. A. (1999). The utilization of rumen content-barley meal in diets of growing lambs. *Asian Journal Animal Science*, *8*(12), 1234-1240.

Adam, F. and Ohene-Yankyera, K. (2015). socio-economic analysis of small ruminant livestock production in northern Ghana. Journal of Veterinary Medicine and Animal Health. Vol. 7(5), pp. 193-204, DOI: 10.5897/JVMAH2015.0367uminant Res. http://dx.doi.org/10.1016/j.smallrumres.2015.09.010

Adams, F., Ohene-Yankyera, K., Robert, A. and Camillus, A. W. (2021). Economic benefits of livestock management in Ghana. Agricultural and Food Economics (2021) 9:17 https://doi.org/10.1186/s40100-021-00191-7

Addo, P. K. (2007). Animal Husbandry for Senior High School of West Africa. Akaddo.

Adedipe, N. O., Sridhar, M. K. C., Verma, M. and Wagner, A. (2005). Waste Management, Processing, and Detoxification. Ecosystem Human Well-Being Policy Responses, 3(94), 313–334.

Adelegan, J. (2002). Environmental Policy and Slaughterhouse Waste in Nigeria, In: 228th WEDC Conference Report, Calcutta, India.

Adeniji, A. A. and Balogun, O. O. (2002). Utilization of flavor treated blood- rumen content mixture in the diets of laying hens. *Nigerian Journal Animal Production*, *29*, 34–39.

Adeyemo, O., Adeyemi, I. and Awosanya, E. (2009). Cattle Cruelty and Risks of Meat Contamination at Akinyele Cattle Market and Slaughter Slab in Oyo State, Nigeria.

Adu, I. F., Fajemisin, B. A. and Adamu, A. M. (1992). The utilisation of sorghum fed to sheep as influenced by urea or graded levels of lablab supplementation, in: B. Rey, S.H. B. Lebbie, L. Reynolds (Eds.), Small ruminant research and development in Africa, Proceedings of the First Biennial Conference of ILRAD, pp. 367–374.

African Development Bank. (2014). The Bank's human capital strategy for Africa (2014– 2018). Tunisa, Tunisa

Agbabiaka, L. A., Anukam, K. U. and Nwachukwu, V. N. (2011). Nutritive value of dried rumen digesta as replacement for soybean in diets of Nile Tilapia (Oreochromis niloticus) fingerling. *Pakisan Journal Nutrition*, *10*, 568–571.

Agbabiaka, L. A., Anukam, K. U. and Nwachukwu, V. N. (2011). Nutritive value of dried rumen digesta as replacement for soybean in diets of Nile Tilapia (Oreochromis niloticus) fingerling. Pakisan Journal Nutrition, 10, 568–571.

Agbo, N. W. and Prah, C. D. (2014). Evaluation of fermentation period on the proximate composition and tannin concentration of sheanut (Vitellaria paradoxa) meal. *Journal of Microbiology and Biotechnology Research, 4*, 21-27.

Agolisi, H. M. (2019).Effect of replacing soybean meal with dried rumen digesta on digestibility and growth performance of djallonké sheep.*www.udsspace.uds.edu.gh.*

Agolisi, H. M. and Ansah, T. (2021). Effects of urea-treated rumen digesta pellet concentrate on digestibility, growth performance and blood profile of Djallonke sheep. Scientific African. https://doi.org/10.1016/j.sciaf.2023.e01864

Agolisi, H. M., & Ansah, T. (2023). Effects of urea-treated rumen digesta pellet concentrate on digestibility, growth performance and blood profile of Djallonké sheep. *Scientific African, 21*, e01864.

Agricultural and Food Research Council (AFRC). (1993). Energy and protein requirements of ruminants. An advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients. CAB International, Wallingford, UK.

Aguilera, J. F. (1989). Use of Agro by-products in the feeding of ruminants. *Revista Argentina de Production Animal*, *9*, 253–67.

Aina, E.O.A. & Adedipe, N.O. (1991). Water quality Monitoring and Environmental status in Nigeria, FEPA Monograph, Lagos, pp 12-59.

Akinmoladun, O. F., Fon, F. N., Mpendulo, C. T. and Okoh, O. (2020). Performance, heat tolerance and blood metabolites of water restricted Xhosa goat supplemented with vitamin C. *Translational Animal Science*, *4*(2), 1–15.

Alabi, B. O. and Ososanya, T. O. (2017). Haematology and Serum analysis of West African Dwarf (WAD) rams fed silage combinations of Maize Forage and Mucuna pruriens L. foliage. Nigerian J. Anim. Sci. :190 – 198

Alenyorege, B., Akansake, D. A. and Gustav. (2010). —An assessement of losses to rural livestock farmers due to accidents involving livestock on the Tamale-Navorongo portion of the Accra-Paga highway‖ in: Boa-Amposem, K., Obese, F.Y., Affedzie-Obresi,S., Botchway, A.V.,(Eds.), Proceedings of the 30th Ghana Animal Science Association (GASA) Conference 2010, Kumasi, Ghana.

Alhassan, W. S. and Karbo, N. (1993). In: K. Oppong –Anane, (ed). The effect of supplementing rice straw to lactating ewes in the dry season in Northern Ghana. In: *Proceedings of the 6th Annual Conference of Ghana Society of Animal Production(GSAP) (p. 18).*

Al-Wazeer, A. M. (2016). Effect of Different Levels of Dried Rumen Content on Nutrient Intake, Digestibility and Growth Performance of Awassi Lambs. *International Journal of Advanced Research*, *4*(9), 2106–2113.

Amaning-Kwarteng, K. (1991). Sustainable dry season feeding of ruminants in Ghana. The use of crop residues and leguminous shrubs as feed stuffs. In: The complementarity of feed resources for animal production in Africa. In *Proceedings of the Joint Feed Resources Networks workshop held in Gaborone, Botswana 4-8 March 1991*. 149–150.

Amankwah, K. Klerky, L. Oosting, S., J. Sakyi-Dawson, O. Van der Zijpp, A. and Millar, D. (2012). Diagnosing constraints to market participation of small ruminant producers in northern Ghana: An innovation systems analysis. NJAS-Wageningen Journal of Life Sciences., 60, 37–47.

Amata, I. A. (2014). The Use of Non-Conventional Feed Resources (NCFR) for Livestock Feeding in the Tropics. A Review. Journal Global Bioscience, (3), 604–613.

Amidu, N., Owiredu, W., Alidu, H., Sarpong, C., Gyasi-Sarpong, C. and Quaye, L. (2013). Association between metabolic syndrome and sexual dysfunction among men with clinically diagnosed diabetes. Diabetology and Metabolic Syndrome, 5(42), 1758–1996.

Amole, T., Ayantunde, A., Mulubrhan, B. and Adegbola, T. A. (2021). Livestock feed resources in the West African Sahel. Agronomy journal. DOI: 10.1002/agj2.20955.

Ampadu-Agyei, O., Manful, G. A., Fleischer, J. E., Opam, M. and Ameyaw, A. M. (1994). ‘'Climate and Africa Country Report, Ghana. In: African Conference on PolicyOptions and Responses to Climate change held at the United Nations Environment Programme (UNEP) Hq., Nairobi, Kenya, December 5-8, 1994. pp 23.

Amuda, A. J. and Okunlola, D. O. (2018). Haematological Parameters and Serum Biochemistry of West African Dwarf Sheep Fed Ensiled Maize Stover and Concentrate Supplements *Journal of Agriculture and Veterinary Science (IOSR-JAVS) e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 11, Issue 5 Ver. PP 57-63*

Andlar, M., Rezić, T., Marđetko, N., Kracher, D., Ludwig, R., & Šantek, B. (2018). Lignocellulose degradation: An overview of fungi and fungal enzymes involved in lignocellulose degradation. *Engineering in life sciences*, *18*(11), 768-778.

Animut, G., Merkel, R. C., Abebe, G., Sahlu, T. and Goestsch, A. L. (2002). Effects of level of broiler litter in diets containing wheat straw on performance of Alpine doelings. Small Ruminant Research, 44(2), 125-133.

Ansah, T, Dzoagbe, G. S. K., Yahuza, R. and Adzitey, F. (2006). Knowledge of Farmers in the Utilization of Crop Residues and Agricultural By-Products for Dry-Season Feeding of Ruminants. a Case Study in the Yendi District. *The Savanna Farmer, Publication of the Association of Church Development Projects (ACDEP)*, *7*(2), 1–17.

Ansah, T. and Nagbila, D. A. (2011). Utilization of local trees and shrubs for sustainable livestock production in the Talensi-Nabdam District of the Upper East Region of Ghana. Livestock Research for Rural Development 23, 1 - 4.

Ansah, T., Konlan, S. P., Ofori, D. K., & Awudza, H. A. (2012). Effect of Agro-Industrial By-Product Supplementation on the Growth Performance and Hematology of Djallonké Sheep. *Ghana Journal of Animal Science*, *6*(1), 96–100.

Ansah, T., Wilkinson, R. and Dei, H. K. (2016). Effects of tanniferous browse plant supplementation on the nutrient digestibility and growth of Djallonké rams. *International Journal of Livestock Production*, *7*(12), 122–127.

AOAC International. (2000). *Official methods of analysis of AOAC International* (Vol. 17, No. 1-2). AOAC international.

AOAC. (2000). Official methods of analysis. Association of Official Analytical Chemists. 17th ed. Arlington, VA, USA.

Aregheore, E. M. (2000). Crop Residues and Agro-industrial By-products in Four Pacific Island Countries: Availability, Utilisation and Potential Value in Ruminant Nutrition. Asian-Aus. Journal of Animal Science, 13, 266–269.

Arnold, G. W. (1960). Harness for the total collection of faeces from grazing sheep. Animal Production, 2: 169–173.

Arseneau, J. D. (2010). Pasture Management. University of Minnesota Extension Service – Carlton County.

Aruwayo, A. (2018). Use of Urea Treated Crop Residue in Ruminant Feed. International Journal of Advances in Scientific Research and Engineering (ijasre), Vol 4 (7), DOI: 10.31695/IJASRE.2018.32794

Arvanitoyannis, I. S. and Ladas, D. (2008). Meat Waste Treatment Methods and Potential Uses. International of Journal of Food Science and Technology, 43, 543–559.

Attoh-Kotoku, V. (2003). Stylosanthes Hamata Supplementation: effects on degradation characteristics, passage rate of rice straw and performance of lactating djallonke ewes and their lambs. (M.Sc.), Kwame Nkrumah University of Science and Technology Kumasi, Ghana. Retrieved from http://hdl.handle.net/123456789/2052.

Atuahene, C. C., Donkoh, A. and Asante, F. (1998). Value of sheanut cake as a dietary ingredient for broiler chickens. *Animal Feed Science and Technology*, *72*, 133–142.

Awodun, M. A. (2008). Effect of nitrogen generated from rumen digesta and cow dung on soil and leaf nutrient content of Gboma (Solanum macrocarpon L.). Journal on Applied Bioscience, 7, 202–206.

Awuma, K. S. (2012). Description and diagnosis of crop–livestock systems in Ghana. In Proceeding of Regional Workshop on Sustainable Intensification of Crop-Livestock Systems in Ghana for Increased Farm Productivity and Food/Nutrition Security. 34.

Baah, J., Tuah, A.K., Addah, W. and Tait, R.M. (2012). Small ruminant production characteristics in urban households in Ghana. *Livestock Research for Rural Development* 24(86). Accessed on July, 2013, available at: http://www.lrrd.org/lrrd24/5/baah24086.htm.

Babatunde, O. A., Andrew, B., Falowo, A. C. and Voster, M. (2017). The Potential of Animal By-Products in Food Systems: Production, Prospects and Challenges. Sustainability, 1089; doi:10.3390/su9071089.

Baiden, R.Y., Rhule, S.W.A., Otsyina, H.R., Sottie, E.T. and Ameleke, G. (2007). Performance of West African dwarf sheep and goats fed varying levels of cassava pulp as a replacement for cassava peels, Livest. Res. Rural 19.

Belesky, D.P., Walker, J.W., Cassida, K.A. and Muir, J.P. (2020). Forbs and browse species. Pages 347–366 in K.J. Moore, M. Collins, C.J. Nelson, and D.D. Redfearn, eds. Forages: The science of grassland agriculture, II. 7th ed. Blackwell, West Sussex, UK

Bell, D. (2002). Waste Management. In: Chicken and egg production, 5th edition (Bell, D.D. and Weaver, Jr., W.D., eds). Kluwer Academic publisher. Massachusetts. http://dx.doi.org/10.1007/978-1-4615-081, 1–3.

Bestari, J., Thalib, A., Hamid, H. and Suherman, D. (1998). Kecernaan in vivo ransum silase jerami padi dengan penambahan mikroba rumen kerbau pada sapi peranakan ongole Jurnal Ilmu Ternak dan Veteriner 4(4) 1-6

Bettencourt, E. M. V., Tilman, M., Narciso, V., Carvalho, M. L. S. and Henriques, P. D. S. (2015). The livestock roles in the wellbeing of rural communities of Timor-Leste. RESR, Piracicaba-SP 53(1): S063–S080. https://doi.org/10.1590/1234-56781806-94790053s01 005

Borjesson, D. L., Christopher, M. M., & Boyce, W. M. (2000). Biochemical and hematologic reference intervals for free-ranging desert bighorn sheep. *Journal of Wildlife Diseases*, *36*(2), 294-300.

Brisso, N. Houinato, M. Adandedjan, C. and Sinsin, B. (2007). Dry season woody fodder productivity in Savannas. Ghanaian Journal of Animal Science 2&3(1), 181–185.

Bryant, M. P. (1970). Normal flora-rumen bacteria. *Animal Journal of Clinical Nutrition*, *23*, 1440.

Bureenok, S., Yuangklang, C., Vasupen, K., Schonewille, J. T. and Kawamoto, Y. (2012). The effect of additives in Napier grass silages on chemical composition, feed intake, nutrient digestibility, and rumen fermentation Asian-Aust. J. Anim. Sci. 25(9) 1248-1254

Cardoso, D. B., Véras, R. M. L., de Carvalho, F. F. R., Magalhães, A. L. R., de Vasconcelos, G. A., Urbano, S. A., Fonsêca, G. M. and de Freitas, M. T. D. (2016). Carcass and non-carcass component characteristics of lambs fed with cassava wastewater dregs in replacement of corn. Ciências Agrárias, Londrina, 37, 2711 – 2724.

Cercı, I. H., Cıftcı, M., Bahsı, M. and Kılınc, U. (2011). Cholesterol and fatty acid composition of lamb serum and offal as affected by alfalfa and concentrate. *Veterinarski arhiv, 81*(5), 575–584.

Chaney, A. L. and Marbach, E. P. (1962). Modified reagents for determination of urea and ammonia. *Clinical Chemistry*, *8*, 130–132.

Charray, J., Humbert, J. M. and Levif, J. (1992). Manual of Sheep Production in the Humid Tropics of Africa. CAB International, Wallingford UK.

Cheeke, P. R. (1991). Cereal milling by-products. In: Applied Animal Nutrition: *Feeds and Feeding. Macmillan, New York.*

Chen, Y., Gong, X., Li, G., Lin, M., Huo, Y., Li, S. and Zhao, G. (2016). Effects of dietary alfalfa flavonoids extraction on growth performance, organ development and blood biochemical indexes of Yangzhou geese aged from 28 to 70 days. *Animal Nutrition*, *2* (4), 318–322.

Cherdthong, A., Wanapat, M., Saenkamsorn, A., Waraphila, N., Khota, W., Rakwongrit, D. and Gunun, P. (2014). Effects of replacing soybean meal with dried rumen digesta on feed intake, digestibility of nutrients, rumen fermentation and nitrogen use efficiency in Thai cattle fed on rice straw. Livestock Science, 169(C), 71–77.

Chikwanha, O. C., Raffrenato, E., Muchenje, V., Musarurwa, H. T. and Mapiye, C. (2018). Varietal differences in nutrient, amino acid and mineral composition and in vitro rumen digestibility of grape (*Vitis vinifera*) pomace from the Cape Winelands vineyards in South Africa and impact of preservation techniques. Industrial Crops and Products 118: 30-37.

Coker, A., Olugasa, B. and Adeyemi, A. (2001). Abattoir Wastewater Quality in South Western Nigeria. In *Proceeding on the 27th WEDC Conference*, *Lusaka*, *Zambia*, 329–331.

Coleman, S. W. and Moore, J. E. (2003). Feed quality and animal performance Field Crops Res. 84 17-29.

Cook, S., Silici, L., Adolph, B. and Walker, S. (2015). Sustainable intensification revisited. International Institute for Environment and Development (IIED), Issue Paper. IIED, London https://pubs.iied.org/sites/default/files/pdfs/migrate/14651IIED.pdf

Cottle, D. J. (2013). The trials and tribulations of estimating the pasture intake of grazing animals. Animal Production Science, 53: 19–12.

Covarrubias, K., Nsiima, L. and Zezza, A. (2012). Livestock and rural livelihood in Tanzania. Joint paper of the World Bank, FAO, AUIBAR, ILRI, and Tanzania Ministry of Livestock and Fisheries. Available at: https://siteresources.worldbank.org/INTSURAGRI/ Resources/7420178 1294259038276/Livestock_Livelihoods_Tanzania.pdf. Accessed 16 Jan 2020.

Crawshaw, R. (2001). Co-product Feeds: Animal Feeds from the Food and Drinks Industries. Nottingham University Press, UK.

Czerkawski, J. W. (1986).*Introduction to Rumen studies. Pergamon Press*.

Daghir, N. J. (1995). Poultry production in hot climates. *CABI, Wallingford*.

Dairo, F. A. S., Aina, O. O. and Asafa, A. R. (2005). Performance Evaluation of Growing Rabbits Fed Varying Levels of Rumen Content and Blood Rumen Content Mixture. Nigerian Journal of Animal Production, 32, 67–72.

Dairo, F. A. S., Aina, O. O., and Asafa, A. R. (2005). Performance Evaluation of Growing Rabbits Fed Varying Levels of Rumen Content and Blood Rumen Content Mixture. *Nigerian Journal of Animal Production*, 32, 67–72.

Damen, B., Verspreet, J., Pollet, A., Broekaert, W. F., Delcour, J. A., and Courtin, C. M. (2011). Prebiotic effects and intestinal fermentation of cereal arabinoxylans and arabinoxylan oligosaccharides in rats depend strongly on their structural properties and joint presence. Mol. Nutr. Food Res. 55, 1862–1874. doi: 10.1002/mnfr.201100377

Darley-Usmar, V. M., Ball, L. E., & Chatham, J. C. (2012). Protein O-linked β-N-acetylglucosamine: a novel effector of cardiomyocyte metabolism and function. *Journal of molecular and cellular cardiology*, *52*(3), 538-549.

De Haan, N., C. Rich, K., M. and Wanyoike, F., N. (2015). Understanding the impact of ppr through the social and economic importance of small ruminants 1–30.

Dehouegnon, J., Agossou, T., Dominica, D. and Nazan, K. (2017). Recent Developments in Goat Farming and Perspectives for a Sustainable Production in Western Africa. International Journal of Environment, Agriculture and Biotechnology (IJEAB). ISSN: 2456-1878. http://dx.doi.org/10.22161/ijeab/2.4.62

Dei, H. K., Rose, S. P. and Mackenzie, A. M. (2007). Shea nut (Vitellaria paradoxa) as a feed ingredient for poultry. World's Poultry Science Journal, 63, 611–624.

Dei, H. K., Rose, S. P., Mackenzie, A. M. and Amarowicz, R. (2008). Growth performance of broiler chicken fed diets containing Shea nut (Vitellaria paradoxa, Gaertn.) meal fermented with Aspergillus niger. Poultry Science, 87, 1778-1780.

Deng, D., Xu, C., Sun, P., Wu, J., Yan, C., Hu, M., & Yan, N. (2014). Crystal structure of the human glucose transporter GLUT1. *Nature*, *510*(7503), 121-125.

Derero, A. and Kitaw, G. (2018). Nutritive values of seven high priority indigenous fodder tree species in pastoral and agro-pastoral areas in Eastern Ethiopia. *Agriculture and Food Security*, *7*(1), 1–9. https://doi.org/10.1186/s40066-018-0216-y

Devendra, C. (1985). Non-conventional feed resources in Asia and the Pacific. *FAO/APHCA publication; 6*.

Devendra, C. (1987). Expanding the utilisation of agro-industrial by-products and non-conventional feed resources in Asia, *CAB international; Wallingford, UK*, 24–29.

Devendra, C. (1997). Crop residues for feeding animals in Asia: Technology development and adoption in crop/livestock systems. In: Crop Residuals in Sustainable Mixed Crop/livestock Farming System (Ed. C. Renard). *CAB international; Wallingford, UK.*, 241–267.

Dierenfeld, E. S. and Fagbenro, O. A. (2014). Use of cassava in livestock and aquaculture feeding programs. ILRI Discussion Paper 25. Nairobi, Kenya: International Livestock Research Institute.

Dórea, J., R. R., Oliveira, J. S., Santos, E. M., Zanine, A. M., Silva, T. C., Danés, M. A. C., Franco, A. L. C., Gouvêa, V. N. and Mizubuti, I. Y. (2013). Cinética de degradação ruminal de silagem de capim-elefante com diferentes níveis de jaca e raspa de mandioca. *Semina: Ciências Agrárias*, Londrina, v. 34, n. 5, p. 2437-2446.

Driehuis, F., Wilkinson, J. M., Jiang, Y., Ogunade, I. and Adesogan, A. T. (2018). Silage review: Animal and human health risks from silage. *Journal of Dairy Science*, **101**, 4093–4110. **https://doi.org/10.3168/jds.2017-13836**

Duku, S. van der Zijpp, A., J. and Howard, P. (2010). Small ruminant feed systems: perceptions and practices in the transitional zone of Ghana. *Journal of Ethnobiology and Ethnomedicine*, *6*(1), 1-15.

Ebuehi, O. A. T., Babalola, O. and Ahmed, Z. (2005). Phytochemical, nutritive and anti-nutritive composition of cassava (Manihot esculenta L) tubers and leaves. Nigerian Food Journal 23, 40 - 46.

Ejlertsen, M., Poole, J. and Marshall, K. (2013). Traditional breeding objectives and practices of goat, sheep and cattle smallholders in the Gambia and implications in relation to the design of breeding interventions. Trop Anim Health Prod. 45(1):219–229. https://doi.org/10.1007/s11250-012-01941

Elfaki, M. O. A., Abdelatti, K. A. and Malik, H. E. E. (2014). Effect of Dietary Dried Rumen Content on Broiler Performance, Plasma Constituents and Carcass Characteristics. *Global Journal Animal Science Res.*, *3*, 264–270.

Er, M., & Keles, G. (2021). Buckwheat conservation as hay or silage: agronomic evaluation, nutritive value, conservation quality, and intake by lactating dairy goats. *Tropical Animal Health and Production*, *53*, 1-8.

Esonu, B. O., Ogbonna, U. D., Anyanwu, G. A. and Emenalom, O. O. (2006). Evaluation of Performance, Organ Characteristics and Economic Analysis of Broiler Finisher Fed Dried Rumen Digesta. *International Journal of Poultry Science*, *5*(12), 1116– 1118.

Esonu, B. O., Ogbonna, U. D., Anyanwu, G. A. and Emenalom, O. O. (2006). Evaluation of Performance, Organ Characteristics and Economic Analysis of Broiler Finisher Fed Dried Rumen Digesta. International Journal of Poultry Science, 5(12), 1116–1118.

Estefanos, T., Tegene, N. and Girma, A. (2015). Sheep production and marketing system in southern Ethiopia: the case of Awassazuria district. Trop Anim Health Prod 47:1417–1425. DOI 10.1007/s11250-015-0852-1.

Estell, R. F., Havstad, K. M. and Cibils, A. F. (2012). Increasing shrub use by livestock in a world with less grass. Rangeland Ecol Manag, 65, 553–62.

Fadiyimu, A. A., Alokan, J. A. and Fajemisin, A. N. (2010). Digestibility, Nitrogen balance and haematological profile of West African Dwarf sheep fed dietary levels of Moringa oleifera as supplement to Panicum maximum. Journal of American Science., 6(10).

Faizal, A., & Kwasi, O. Y. (2015). Determinants of small ruminant farmers decision to participate in veterinary services in Northern Ghana. *Journal of Veterinary Medicine and Animal Health*, *7*(5), 193-204.

Fajemisin, A. N., Fadiyimu, A. and Alokan, J. A. (2010). Dry matter, fiber consumption and body weight gain of West African Dwarf sheep fed sun-dried of fermented rumen digesta- poultry droppings mixed diets. Applied Tropical Agriculture, 15(1&2), 84–89.

FAO (Food and Agriculture Organization). (1999). “Yearbook of Fertilizers.” Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, (2002). Cattle and small ruminant production systems in Sub-Saharan Africa. A system reviews. 47–54.

FAO, (Food and Agricultural Organization). (1995). *Fao yearbook production.*

FAO. (2002). Protein source for animal feed industry. FAO Animal health and production paper 1. Expert consultation and workshop. Bangkok, 29 April-3 May 2002. Also available on: ftp://ftp.fao. org/docrep/fao/007/y5019e/y5019e00.pdf

FAO. (2012). FAO Statistics Divisions. Available at: Retrieved from /http://faostat3.fao. org/home/index.html#HOMES

FAO. (2014). profiles: Ghana. In FAO Fisheries and Aqua- culture Department (online). Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/ fishery/country sector/FI-CP_GH/3/en;

FAOSTAT. (2013). Food and Agriculture Organization of the United Nations Cropping Database. http://faostat3.fao.org/faostat- ga t ewa y / go / t o / home / E.

Fasuyi, A. O. and Aletor, V. A. (2005). Protein replacement value of cassava (Manihotesculenta, Crantz) leaf protein concentrate in broiler starter: effect on performance, muscle growth, haematology and serum metabolites. International Journal of Poultry Science, 4, 339 - 349.

Fawcett, J. K. and Scott, J. E. (1960). A rapid and precise method for the determination ofurea. *Journal of Clinical Pathology*, *13*(2), 156-159.

Fearon, J., Mensah, S. B. and Boateng, V. (2014). Abattoir operations, waste generation and management in the Tamale metropolis: Case study of the Tamale slaughterhouse. *Journal of Public Health and Epidemiology*, *6*(1), 14–19.

FEFAC, (European Feed Manufacturers Federation). (2007). Industrial compound feed production. *Asian journal of animal science, 7:56-63.*

Fernandez, M., L. and de la, P. (2017). Balanced diet – Part 3.

Festus, T. A. and Sunday, O. O. (2018). Potential of Albizia lebbeck-Cassava Peel Silage as Dry Season Feed for West African Dwarf Sheep. Pertanika J. Trop. Agric. Sc. 41 (3): 1151 – 1167

Fleischer, J. E. (1991). Feed Resources Availability and the Future of Livestock Production in the Ecowas. *West African Economic Journal. Sponsored by West African Economic Association, 6*, 101-107.

Francis, G., Makkar, H. P. S. and Becker, K. (2001). The antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 119, 197 - 227.

Franzel, S., Carsan, S., Lukuyu, B., Sinja, J. and Wambugu, C. (2014). Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. *Current Opinion in Environmental Sustainability, 6*(1), 98–103. https://doi.org/10.1016/j.cosust.2013.11.008

Freund, K., Jungers, J.M., Hegeman, A.D., Wyse, D.L. and Sheaffer, C.C. (2020). Cultivation of native plants for seed and biomass yield. Agron. J. 112: 1815–1827. doi:10.1002/agj2. 20195.

Froidmont, E. and Bartiaux-Thill, N. (2004). Suitability of lupin and pea seeds as a substitute for soybean meal in high-producing dairy cow feed. Animal Research, 53, 475-487.

Gatenby, R. M. (1985). Sheep Production in the Tropics and Subtropics. Longman Group Ltd. Longman House, Harlow Essex CM, England.

Gatenby, R. M. (2002). Sheep (Second Revised Edition). Macmillan Publishers Ltd. Oxford, UK.

Gertenbach, W. D. and Dugmore, T. J. (2004). Crop residues for animal feeding. SA-ANIM

Göhl, B. (1982). Les aliments du bétail sous les tropiques. FAO, Division de Production et Santé Animale, Roma, Italy. Retrieved from http://www.fastonline.org/CD3WD_40/JF/414/05-222.pdf

Gornall, A. U., Barde, W. L. J. and David, M. M. (1949). Determination of serum protein by means of Biuret reaction. *Journal of Biology Chemistry*, *177*, 751–766.

Grieshop, C. M. and Fahey, G. C. (2000). The role of soy in companion animal nutrition. Soy in Animal Nutrition; J.K. Drackley, Ed.; In Federation of Animal Science Societies: Savoy, IL (pp. 171–181).

Grieshop, C., M. Kadzere, C., T. Clapper, G., M. Flickinger, E., A. Bauer, L., L. Frazier, R., L. and Fa- hey, J., G., C. (2003). Chemical and nutritional characteristics of United States soybeans and soybean meal. J. Agric. Food Chem., 51, 7684–7691.

Grubić, G., Adamović, M. and Negovanović, D. (1992). Razgradivost proteina kaokriterijum za sastavljanje obroka u ishrani preživara. *Inovacije u Stočarstvu, X,* 125- 131.

Hatskevich, A., Jenicek, V. and Antwi, D. S. (2011). Shea industry – A means of poverty reduction in Northern Ghana. *Agri- Cultura Tropica et Subtropica*, *44*, 223-228.

Heuzé, V., Tran, G., Bastianelli, D., Archimède, H., Lebas, F. and C. R. (2012). Cassava tubers. Feedipedia.Org. A Programme by INRA, CIRAD, AFZ and FAO. Http://Www.Feedipedia.Org/Node/527.

Heuze´, V. and Tran, G. (2011). Shea nut (Vitellaria paradoxa). Feedipedia.org. A pro- gramme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/51

Hobson, P. N. (1989). The rumen microbial eco-system. *Elsevier Applied Science, London*.

Hungate, R. E. (1966).*The rumen and its microbes.* Academic Press Inc. (London) *LTD.*

INRA (Institut Scientifique de Recherche Agronomique). (2004). Tables of composition and nutritional value of feed materials, 2 ed. (Sauvant, D., Perez, J.M. and Tran, G., eds.). Wageningen Academic Publishers, Netherlands., 186.

Issaka, A. C. and Ansah, T. (2018). Ruminant Livestock Feed Resources in the Kumbungu District of Ghana. Ghanaian Journal of Animal Science, 9(1), 3245–1359.

Jeffrey, C., Mariner, B. A., Jones, K. M., Rich, S., Thevasagayam, J., Anderson, M. J., Yi Cai, A. Peters, R. and Peter, L. R. (2016). The Opportunity to Eradicate Peste des Petits Ruminants. The Journal of Immunology. *J Immunol* (2016) 196 (9): 3499–3506.

Jiwuba, P. C. and Ezenwaka, L. C. (2016). Growth performance and apparent nutrient digestibility of West African dwarf goats fed B-carotene cassava peel-Centrosema leaf meal-based diets. Case Studies Journal, 5, 204 - 210.

Jiwuba, P. C., Njoku, C., Azodo, N. L. and Akazue, R. C. (2021). Nutrient intake, body weight changes, apparent nutrient digestibility and nitrogen utilisation of West African Dwarf goats fed four phytogenic browse plant parts in their diets. *Nigerian Journal of Animal Science*, *23*(2), 257-268.

Jones, D. I. H. and Wilson, A. D. (1987).*Nutritive quality of forage.* In: J.B. Hacker and J.H. Ternouth (eds). The nutrition of herbivores. Academic Press, Sydney.

Jutzi, S. (1993). Animal feed research in Eastern and Southern Africa. Priorities and Trends. *Animal Research and Development*, *37,* 59–78.

Kabir, M., Sarker, M., Saha, B., Khandoker, M. and Moniruzzaman, M. (2014). Effect of different levels of dietary energy on growth and carcass traits of black Bengal goat. *Bangladesh Journal of Animal Science*, *43*(2), 159–165. https://doi.org/10.3329/bjas.v43i2.20719

Kalscheur, K. F., Garcia, A. D., Schingoethe, D. J., Diaz Royón, F. and Hippen, A. R. (2012). Feeding biofuel co-products to dairy cattle. In: Makkar, H. (Ed.), Biofuel coproducts as livestock feed: Opportunities and challenges, 115–154.

Kamra, D. N. (2005). Rumen microbial ecosystem. Current Science, 89, 124-135.

Karbo, N. and Agyare, W. A. (2002). Improving livestock systems in the dry Savannas of West and Central Africa. In: Tarawali, G. and Hiernaux, P (Eds). Crop-livestock systems in the dry Savannas of West and Central Africa, 022–027.

Karbo, N., & Agyare, W. (2002). Crop–livestock systems in northern Ghana. *Improving crop–livestock systems in the dry savannas of West and Central Africa. Ibadan: IITA*, 112-126.

Ketelaars, J. J. M. H. and Van Der Meer, H. G. (2000). Establishment of criteria for the assessment of the nitrogen content of animal manures, Final Report to DG XI of the European Commission, Report 14, 64 pp. + Annexes, Plant Research International, Wageningen, The Netherlands.

Koenig, K. M. Beauchemin, K. A. and Rode, L. M. (2003). Effect of grain processing and silage on microbial protein synthesis and nutrient digestibility in beef cattle fed barley-based diets. Journal of Animal Science, 81, 1057–1067.

Koney, E., B., M. (2004). Livestock Production and Health in Ghana. Advent press, Accra.

Konlan, S. P. Karikari, P. K. and Ansah, T. (2012). Productive and Blood Indices of Dwarf Rams Fed a Mixture of Rice Straw and Shea Nut Cake. Groundnut Haulms Alone or Supplemented with Concentrates Containing Different Levels of shea nut cake. Pakistan Journal of Nutrition, 11(6), 566-571.

Konlan, S. P., Ayantunde, A. A., Addah, W., Dei, H. K. and Panyan, E. K. (2017). Feed resource availability and fodder markets in northern Ghana. Poster prepared for the Africa RISING West Africa Review and Planning Meeting, Accra, 1-2 February 2017. Tamale, Ghana: Council for Scientific and Industrial Research.

Konlan, S. P., Ayantunde, A. A., Addah, W., Dei, H. K., & Karbo, N. (2018). Emerging feed markets for ruminant production in urban and peri-urban areas of Northern Ghana. *Tropical Animal Health Production*, *250*(1), 169–176. https://doi.org/10.1007/s11250-017-1418-1

Konlan, S. P., Ayantunde, A. A., Weseh, A., Dei, H. K. and Avornyo, F. K. (2015). Opportunities and challenges of emerging livestock feed markets in northern Ghana. *International Livestock Research Institute*, 1–31.

Konlan, S., P. Ayantunde, A., A. Weseh, A. Dei, H., K. and Avornyo, F., K. (2015). Opportunities and challenges of emerging livestock feed markets in northern Ghana. International Livestock Research Institute, 1–31.

Konlan, S.P., Ayantunde, A.A., Addah, W., Dei, H.K., Karbo, N. and Avarnyo, F.K. (2019). Effect of concentrate supplementation and season on apparent digestibility and growth performance of sheep in a smallholder production system, Ghana J. Sci. Technol. Dev. 6 (2019) 1–18.

Kosgey, I., S. Rowlands, G., J. van Arendonk, J., A. and Baker, R., L. (2008). Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research*, *77*(1), 11-24.

Kung, L. Jr., Stokes, M. R. and Lin, C. J. (2003). Silage additives. Pages 305–360 in Silage Science and Technology. D. R. Buxton, R. E. Muck, and J. H. Harrison, ed. Am. Soc. Agron., Madison, WI.

Kwiecien, M., Winiarska-Mieczan, A., Danek-Majewska, A., Kwiatkowska, K. and Krusinski, R. (2021). Effects of dietary alfalfa protein concentrate on lipid metabolism and antioxidative status of serum and composition and fatty acid profile and antioxidative status and dietetic value of muscles in broilers. *Poultry science*, *100* (4), Article 100974.

Larsen, M., Lund, P., Weisbjerg, M. R. and Hvelplund, T. (2009). Digestion site of starch from cereals and legumes in lactating dairy cows. Animal Feed Science and Technology, 153, 236-248.

Le Houérou, H. N. (1980). Browse in North Africa. In: Le Houérou H N (ed), Browse in Africa: The current state of knowledge. In *Papers presented at the International Symposium on Browse in*

Africa, Addis Ababa, April 8-12, 1980. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. (pp. 55–82).

Lebbie, S. H. B. (2004). Goats under household conditions. Small Ruminant Res. 15(2):131–136. https://doi.org/10.1016/j.sma llrumres.2003.08.015

Leha, C. (1998). Biodigester effluent versus manure, from pigs or cattle, as fertilizer for duckweed (Lemna spp.). *Livestock Research and Rural Development*, 5.

Lewington, S., Whitlock, G., Clarke, R., Sherliker, P., Emberson, J., Halsey, J. and Collins, R. (2007). Blood cholesterol and vascular mortality by age, sex and blood pressure. A meta-analysis of individual data from 61 prospective studies with 55,000 vascular deaths. Lancet, 370(9602), 1829-39.

Li, X., Xiong, X., Wu, X., Liu, G., Zhou, K. and Yin, Y. (2020). Effects of stocking density on growth performance, blood parameters and immunity of growing pigs. *Animal Nutrition, 6*(4), 529–534.

Lippke, H. (2002). Estimation of ruminants forage intake at pasture. Crop Science, 42: 869–872.

Lobo, B. S., Sales, E. C. J., Reis, S. T., Monção, F. P., Pereira, D. A., Rigueira, J. P. S., Oliveira, P. M., Mota, V. A. C. and Alves, D. D. (2014). Parâmetros morfogênicos e produtividade do capim-Pioneiro submetido a doses de nitrogênio. *Semina: Ciências Agrárias*, Londrina, v. 35, n. 6, p. 3305-3318.

Maciel, M. V., Carvaliho, F. F. R., Batista, G. A., Souza, E. J. O., Maciel, L. P. A., Pereira –Neto, J. D. and Lima–Junior, D. M. (2015). Carcass and non – carcass characteristics of sheep fed cassava (Manihotpseudoglaziovii Pax and Hoffm, K.) Chilean Journal of Agricultural Research. 75(3):307–312.

Makinde, O. A. and Sonaiya, E. B. (2007). Determination of Water, Blood and Rumen Fluid Absorbencies of Some Fibrous Feedstuffs. Livestock Research and Rural Development, 19, 156.

Mako, A. A., Ikusika, O. O. and Akinmoladun, O. F. (2021). Physiological response of WAD sheep fed different combinations of Guinea grass and ensiled A*lternanthera brasiliana* (L.) O. Kuntze based diets: Intake, haematology and serum biochemical indices. Veterinary and Animal Science. https://doi.org/10.1016/j.vas.2021.100220

Marsetyo, D. R. Yohan, R. and Suharno, H. S. (2017). The Effect of Supplementation of Different Legume Leaves on Feed Intake, Digestion and Growth of Kacang Goats Given Mulato Grass. Journal of Agricultural Science and Technology, 7(2), 117–122.

Massaro Junior, V., Fernando, L. H., Bumbieris. J., Elzânia, S., Pereira, E., Zanin, E., Henrique, H., Odimari, P., Prado, C., Eduardo, L., Terra, P., Sandra, G., Ivone, Y. and Mizubuti. (2021). Grape pomace silage on growth performance, carcass, and meat quality attributes of lambs. Sci. Agric. v.79, n.5, e20200343

Mayank, T., Tanuj, R. A. and Ambwani, S. (2008). Role of Bypass Proteins in Ruminant Production. Dairy Planner, 4(10), 11-14.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. and Morgan, C. A. (2002). Animal Nutrition. Pearson education Plc. Ltd Publishers. India 6th ed.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., Morgan, C. A. Sinclair, L. A. and Wilkinson, R. G. (2011). Animal Nutrition, Seventh edition. Pearson Education Limited, England.

Meissen, J.C., Galatowitsch, S.M. and Cornett, M.W. (2017). Meeting seed demand for landscape-scale restoration sustainably: The influence of seed harvest intensity and site management. Ecoscience, 24: 145–155. doi:10.1080/11956860.

Melaku, S. and Nega, A. (2009). Feed intake, digestibility and body weight change in Farta sheep fed hay supplemented with rice bran and/or noug seed (Guizotia abyssinica) meal. Tropical Animal Health Production, 41(4), 507–515.

Merry, R. J., Jones, R. and Theordorou, M. K. (2001). Alternative forages - back to the future. Biologist, 48, 30–34.

Micheal, S. G. (1995). *AM e AAAAA* (Doctoral dissertation, Virginia Polytechnic Institute and State University).

Mishra, J., Abraham, R. J., Rao, V. A., Rajini, R. A., Mishra, B. P. and Sarangi, N. R. (2015). Chemical Composition of Solar Dried Blood and the Ruminal Content and Its Effect on Performance of Japanese Quails. Veterinary World, 8, 82–87.

MoFA. (2011). Agriculture in Ghana. Facts and figures: Ministry of Food and Agriculture, statistical research and information directorate. Accra, Ghana.

Mohammed, S. and Musa, J. (2012). Impact of Abattoir Effluent on River Landzu, Bida.

Moll, H. A. J. (2003). Costs and benefits of livestock systems and the role of market and non-market relationships. Agric Econ 32(2):181–193. https://doi.org/10.1111/j.0169-5150.2005.00210.x

Mondal, S., Haldar, S., Samanta, I., Samanta, G. and Ghosh, T. K. (2013). Exploring Nutritive Potential of Undigested Rumen Contents as an Ingredient in Feeding of Goats. Animal Nutrition and Feed Technology, 13, 79–88.

Mourad, M., Gbanamou, G. and Balde, I. B. (2001). Performance of Djallonke sheep under an extensive system of production in Faranah, Guinea. Tropical Animal Health Production, 33, 13-22.

Mpendulo, C. T., Akinmoladun, O. F., Ikusika, O. O. and Chimonyo, M. (2020). Effect of hydric stress on intake, growth performance and nutritional status of Nguni goats. *Italian Journal Animal Science*, *19*(1), 1071–1078.

Mtenga, L. A., Komwihangilo, D. M. and Kifaro, G. C. (1992). Selectivity by sheep and goats fed Albizia, Gliricidia, Leucaena and Tamarind multipurpose trees. In: Proceedings of the Second Biennial Workshop of African Small Ruminant Network (SRNET). 7–11 December, 1992, Arusha, Tanzania. International Livestock Centre for Africa (ILCA) pp 151–155.

Muck, R. E. E. M. G., Nadeau, T. A., McAllister, F. E., Contreras Govea, M. Santos, C. and L. Kung, Jr. (2018). Silage review: Recent advances and future uses of silage additives. J. Dairy Sci. 101:3980–4000. https:// doi .org/ 10 .3168/ jds .2017 -13739.

Mulrooney, C. N., Schingoethe, D. J., Kalscheur, K. F. and Hippen, A. R. (2009). Canola meal replacing distillers grains with solubles for lactating dairy cows. Journal of Dairy Science, 92, 5669–5676.

Mulumpwa, M. and Kang'ombe, J. (2009). Effect of feeding soybean-based diets on the survival, growth and feed utilization of Tilapia rendalli in a semi-intensive pond culture system. Aquacultural Research, 40(9), 1099–1101.

Nafarnda, W., Yayi, A. and Kubkomawa, B. (2006). Impact of Abattoir Waste on Aquatic Life: A Case Study of Yola Abattoir. Global Journal Applied Science, 12, 31-33.

National Institute for Agricultural Research (INRA). (2018). Feeding system for ruminant. Wageningen Academic Publishers, Wageningen, Netherlands.

National Research Council (NRC). (2007). Nutrient requirements of small ruminants: sheep, goats, cervids and new words camelids. The National Academy Press, Washington, DC, USA.

Ndemanisho, E. E., Kimoro, B. N., Mtengeti, E. J. and Muhikambele, V. R. M. (2007). In vivo digestibility and performance of growing goats fed maize stover supplement with browse leaf meal and cotton seed cake-based concentrate. Livestock Research for Rural Development, 19(8).23-37.

Niwiska, B. (2012). Digestion in Ruminants. Carbohydrates - Comprehensive Studies on Glycobiology and Glycotechnology. https://doi.org/10.5772/51574

Nmoandor, F., Ziblim, A. I. and Timothy, K. A. (2020). Effects of cow dung, grasscutter droppings and NPK fertilizer on dry matter yield and nutritional value of elephant grass (*Pennisetum purpureum*).J Agric. Res., 2020, Vol. 58(1):01-07.

Novotny, L., Fahey, G., Layton, B. and Walter, M. (2017). Critical Factors in Determining Fiber in Feeds and Forages. *AAFCO's Laboratory Methods and Services Committee*, *1*(1), 1–14.

NRC. (2001). Nutrient Requirements of Dairy Cattle: Seventh Edition.

Nwachukwu, M., Akinde, S., Udujih, O. and Nwachukwu, I. (2011). Effect of Abattoir Wastes on the Population of Proteolytic and Lipolytic Bacteria in a Recipient Water Body (Otamiri River). Global Research Journal of Science, 1, 40–42.

Obi, F., Ugwuishiwu, B. and Nwakaire, J. (2016). Agricultural Waste Concept, Generation, Utilization and Management. Nigerian Journal of Technology, 35(4), 957.

Oddoye, E. O. K., Alemawor, F., Agyente-Badu, K. and Dzogbefia, V. P. (2012). Proximate analysis of shea nut kernel cake/meal samples from industry and cottage industry and some methods of removal of anti-nutritional factors. International Journal of Biochemistry and Biotechnology, 1, 239–242.

Odoemelan, S. and Ajunwa, O. (2008). Heavy Metal Status and Physicochemical Properties of Agricultural Soil Amended by Short term Application of Animal Manure. Journal of Chemistry Society Nigeria, 20, 60-63.

Ogunbosoye, D. O., Olurotimi, A. T., & Abayomi, A. (2022). Influence of Ensiled Guinea Grass-Cassava Peels Enriched With Soybean Waste on Performance of West African Dwarf (WAd) Goats. *Turkish Journal of Agriculture-Food Science and Technology*, *10*(12), 2397-2404.

Okere, S., E. (2016). Evaluating rumen digesta as a source of plant nutrient in Owerri Southeast, Nigeria. Academic Journal of Science, 5(1), 221–226.

Okunlola, D. O., Alao, A. J., Fasola, A. A., Olateju, B. O., Olaniyan, O. S., Ojoawo, O. T. and Olatunji, O. O. (2021). Growth Response, Carcass Yield and Meat Quality of West African Dwarf Sheep Fed Graded Level of Shea Cake Meal. *Journal of Advances in Biology & Biotechnology*, 57-62.

Olafadehan, O. A. (2011). Carcass quality and cost-benefit of rabbits fed cassava peel meal. Arch. Zootec, 60, 757 - 765.

Olafadehan, O. A. Okunade, S. A. and Njidda, A. A. (2014). Evaluation of bovine rumen contents as a feed for lambs. Tropical Animal Health and Production, 46(6), 939–945.

Oliveira, A.S., Weinberg, Z.G., Ogunade, I.M., Cervantes, A.A.P., Arriola, K.G., Jiang, Y., Kim, D., Li, X., Goncalves, M.C.M., and Vyas, D. (2017). Meta-analysis of effects of inoculation with homofermentative and facultative heterofermentative lactic acid bacteria on silage fermentation, aerobic stability, and the performance of dairy cows. *J. Dairy Sci. 100*, 4587–4603.

Olorede, B. and Longe, O. (1999). Growth, nutrient retention, haematology and serum chemistry of pullet chicks fed shea butter cake in the humid tropics. *Arch in Zootechnology, 49*, 441-444.

Oni, A., Onwuka, C., Oduguwa, O., Onifade, O. and Arigbede, O. (2008). Utilization of citrus pulpbased diets and Enterolobium cyclocarpum (JACQ. GRISEB) foliage by West African dwarf goats. Livestock Science, 117, 184–191.

Onyango, D., Oyoko, G., Too, R. and Masake, R. (2015). The contribution of livestock to the South Sudan economy. IGAD center for pastoral areas and livestock development (ICPLALD). Nairobi-Kenya. http://igad.int/attachments/714 The Contribution of Livestock to the Sudan 584Economy.pdf(igad.int). Accessed 27 Jan 2020.

Oppong-Anane, K. (2006). Country Pasture/forage resource profile. Ghana FAO.

Oppong-Anane, K. (2006). Country pasture/forage resource profiles. *Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extensions, FAO, Rome, Italy*.

Oppong-Anane, K. (2010). Ghana livestock sector. Review report, FAO, country report Accra.

Oppong-Anane, K. (2011). Ghana livestock review report. Food and Agriculture Organisation (FAO), Rome, Italy.

Osafo E.L.K., Attoh-Kotoku V., Oppong-Anane K. and Fynn K. (2008). Performance characteristics of lactating djallonké ewes fed rice straw basal diets supplemented with *Stylosanthes hamata*. *J. Sci. Technol.*, **28**(1), 57-64.

Osafo, E. L. K. Attoh-Kotoku, V. Oppong-Annane, K. and Fynn, K. (2008). Performance characteristics of lactating Djallonkè ewes fed rice straw basal diets supplemented with *stylosanthes hamata.* Journal of Science and Technology, 28: *0*57–064

Osei-Amaning, E. (1993). Shea nut expeller cake utilization: Integrated livestock shea nut farming experiment. Cocoa Research Institute of Ghana, Annual Report 1989/1990: 148.

Osibanjo, O. and Adie, G. (2007). Impact of Effluent from Bodija Abattoir on the Physicochemical Parameters of Oshunkaye Stream in Ibadan City, Nigeria. African Journal Biotechnology, 6, 1806-1811.

Osman, A. A. B. and Elimam, M. E. (2015). Processed Animal Waste as a Feed for Sudanese Desert Lamb. International Journal of Advance Multidiscipline Research, 2, 12–17.

Osman, A. A. B. Hamed, A. H. M. and Elimam, M. E. (2015). Effects of dried rumen contents level in rations on the performance of Shugor desert sheep in Halfa Elgadeda, Kassala state, Sudan. Animal Research., 2(4), 81–86.

Osman, A. A. M. O. and Abass, H. A. M. (2015). Processed animal waste as feed for Sudanese desert sheep. International Journal of Adv.Multidiscip. Res., 2(7), 12–17.

Osuga, I. M., Abdulrazak, S. A., Muleke, C. I. and Fujihara, T. (2011). Effect of supplementing Rhodes grass hay (*Chloris gayana*) with *Berchemia discolor* or *Zizyphus mucronata* on the performance of growing goats in Kenya. *Journal of Animal Physiology and Animal Nutrition*, *96*(4), 634–639.

Pahlow, G., Muck, R.E., Driehuis, F., Oude Elferink, S.J.W.H. and Spoelstra, S.F. (2003). Microbiology of ensiling. In: Buxton DR, Muck RE and Harrison HJ, editors. Silage science and technology (Agronomy Series No. 42). Madison, WI: American Society of Agronomy. p. 31–93.

Payne, W. J. A. and Wilson, R. T. (1999).*An Introduction to Animal Husbandry in the Tropics. 5th edition. Blackwell Science, Oxon.*

Peacock, C. (2005). Goats—A pathway out of poverty. *Small Ruminant Research*, 60(1), 179-186.

Pello, K., Okinda, C., Liu, A. and Njagi, T. (2021). Adaptation to climate change through Agroforestry in Kenya. *Land*, *10*(4), 1–16. https://doi.org/https://doi.org/ 10.3390/land10040371

Peterson, A.T. (2007). Why not Why Where: the need for more complex models of simpler environmental spaces. *Ecological Modelling*, **203**, 527–530.

Pica-Ciamarra, U., Nouala, S. and Kim, S. (2011). Livestock and Livelihoods in the IGAD Region: A Policy and Institutional Analysis. IGAD LPI Working Paper No. 01 - 11. FAO, Rome, Italy.

Pratama, A., Salundik. and Jayanegara, A. (2021). Nutrient digestibility of dairy cows fed with chopped and ensiled elephant grass. IOP Conf. Series: Earth and Environmental Science **756** 01206. doi:10.1088/1755-1315/756/1/012061.

Quesenberry, K. H. and Wofford, D. S. (2001). Tropical forage legume breeding. pg. 81105. In A. Sotomayor-Rios, A. & W.D. Pitman, W.D. (eds.). Tropical Forage Plants: Development and Uses. CRC Press, Boca Raton, USA, CRC Press., 81-105.

Ra, O. and Iliyasu, A. (2017). The potential of animal by-products in food systems: Production, prospects and challenges. Sustainability (Switzerland), 9(7), 1–18.

Rayburn, E. (2013). Nutrient Requirements of Sheep and Goats.

Rhule, S. (1995). Evaluation of sheanut cake as feedstuff for pigs in Ghana. 1. Growth rate and carcass characteristics of pigs fed diets containing varying levels of sheanut cake. *Legon Agriculyure Extension Journal*, *4*, 4-47.

Rhule, S. W. A. (1999). Performance of pigs on diets containing detoxified sheanut cake. *Tropical Animal Health and Production*, *31*, 45-53.

Rigueira, J. P. S., Monção, F. P., Sales, E. C. J., Brant, L. M. S., Pires, D. A. A., Matos, A. M., Leite, G. D. O., Silva, J. T., Fonseca, J. D. R., Moura, M. M. A. and Rocha Júnior, V. R. (2017).Níveis de glicerina bruta na ensilagem de capim Tifton 85 (*Cynodon dactylon*): perfil fermentativo e valor nutricional. *Revista de Ciências Agrárias*, Lisboa, v. 40, n. 3, p. 654-663.

Ristianto, U., Lies, M. Y., Cuk, T. N. and Aryogi, I. (2016). Rumen contents from slaughter house as alternative feed for replacing forage in ruminant diets. In The 17th Asian Australasian Association of Animal Production Societies Animal Science Congress 133-2.

Robert, E. T. and Ralph, B. (1988).*Scientific Farm Animal Production (3rd edition). Macmillan Publishing Company, New York*.

Rodrigues, R. T. S., Chizzotti, M. L., Martins, S. R., Silva, I. F., Queiroz, M. A. A., Silva, T. S., Busato, K. C. and Silva, A. M. A. (2016). Energy and protein requirements of non-descript breed hair lambs of different sex classes in the semiarid region of Brazil. Tropical Animal Health and Production 48, 87–94.

Rosly, S. M., Liang, J. B., Nordin, M. M., Somchit, N. and Jelan, Z. A. (2010). Tissues thiocyanate (SCN) concentration and liver pathology of sheep and goats fed on cassava forages. Pertanika Journal of Tropical Agricultural Science, 33, 127 – 133.

Rufino, L. D. A., Pereira, O. G., Ribeiro, K. G., Filho, S. C. V., Cavali, J., & Paulino, P. V. R. (2013). Effect of substitution of soybean meal for inactive dry yeast on diet digestibility, lamb' s growth and meat quality. *Small Ruminant Research*, *111*(1–3), 56–62.

Ruzic-Muslic, D., Petrovic, M. P., Petrovic, M. M., Bijelic, Z., Caro-Petrovic, V., Maksimovic, N. and Mandic, V. (2014). Protein source in diets for ruminant nutrition. Biotechnology in Animal Husbandry Biotehnologija Stocarstvu, 30(2), 175–184.

Ryser, J. P., Walther, U. and Flisch, R. (2001). Données de bases pour la fumure des grandes cultures et des herbages en Suisse,. *Engrais de Ferme Revue Suisse d'Agriculture.,33*, 1–80.

Sadava, D., Hillis, D. M., Heller, H. C. and Berenbaum, M. R. (2011). Life: The Science of Biology.9th edition. San Francisco: Freeman.

Sakaba, A. M., Hassan, A. U., Harande, I. S., Isgogo, M. S., Maiyama, F. A. and Danbare, B. M. (2017). Proximate composition of rumen digesta from sheep slaughtered in Zuru Abattoir, Kebbi State, Nigerian *Journal of Agricultural Science and Practice*, *2*(2536–7072), 86–89.

Salah, N., Sauvant, D. and Archimède, H. (2014). Nutritional requirements of sheep, goats and cattle in warm climates: a meta-analysis.Animal, 8:9, pp 1439–1447.doi:10.1017/S1751731114001153.

Salah, N., Sauvant, D. and Archimede, H. (2014). Nutritional requirements of sheep, goats and cattle in warm climates: A meta-analysis. Animal 8, 1439–1447.

Salinas-Chavira, J., Dominguez-Munoz, M., Bernal-Lorenzo, R., Garcia-Castillo, R. F., & Arzola-Alvarez, C. (2007). Growth performance and carcass characteristics of feedlot lambs fed diets with pig manure and rumen contents.

Salmon, G., Teufel, N., Baltenweck, I., van Wijk, M., Claessens, L. and Marshall, K. (2018). Trade-offs in livestock development at farm level: different actors with different objectives. Glob Food Security 17:103–112. https://doi.org/10.1016/j.gfs.2018.04.002

Sanon, H. O. (2007). The importance of sahelian browses species and feed for goats. PhD Dissertation, Faculty of Veterinary Medicine and Animal Science, Department of Animal Nutrition and Management, Uppsala.

Santos, V.L.F., Ferreira, M.A., Santos, G.T., Damasceno, J.C., Oliveira, K., Agostino, B.C., Olivo, P.M., Soares, L.F.P., Silva, J. L. (2015). Cassava peel as a replacement for corn in the diet of lactating cows. Trop. Anim. Health Pro. 47, 779–781.

SARI (Savanna Agricultural Research Institute). (2007). Meteorological department records. Annual Report. Nyankpala, Tamale, Ghana.

Saxena, M., Saxena, J., Nema, R., Singh, D. and Gupta, A. (2013). Phytochemistry of medicinal plants. *Journal of Pharmacology and Phytochemicals*, *1*, 168–182.

Sayed, A. B. N. (2011). Effect of different energy levels of diets on the performance, nutrient digestibilities and carcass characteristics of lambs. *International Journal for Agro Veterinary and Medical Sciences*, *5*(5), 472–476. https://doi.org/10.5455/ijavms.20110917083918

Schobery, J. (2002). Nitrogen stress effect on growth and nitrogen accumulation by field grown tomatoes. Agora. Journal, 92, 152-167.

Schoenian, S. (2003). An introduction to feeding small ruminants. University of Maryland Extension. SCI, 5, 49–51.

Sekondi, A. A. (1991). The effect of feeding graded levels of cassava peel meal on the performance of laying birds. *Paper Presented at NAPRI Seminar*.

Sindhu, A. A., Khan Mahr-Un-Nisa, M. A. and Sarwar, M. (2002). Agro-Industrial by- products as a potential source of livestock feed; Review. International Journal of Agriculture and Biology, 4(2), 307–310.

Smith, O. B. (1988). A review of ruminant responses to cassava-based diets Cassava as livestock feed in Africa. In Proceedings of the IITA/ILCA/University of Ibadan. Workshop on the Potential Utilization of Cassava as Livestock Feed in Africa. International Institute of Tropical Agriculture. Ibadan, Nigeria.

Smith, S. (2017). Regional native seed cooperatives: Working toward available, affordable, and appropriate native seed. Nativ. Plants J. 18: 126–134. doi:10.3368/npj.18.2.126.

Soundharrajan, I., Hyung, S. P., Sathya, R., Ravikumar, S. and Ki, C. C. (2021). Application and Future Prospective of Lactic Acid Bacteria as Natural Additives for Silage Production—A Review. *Appl. Sci.11*, 8127. https://doi.org/10.3390/app11178127

Stefanie J. W. H. Oude Elferink, Frank Driehuis, Jan C. Gottschal, and Sierk F. (2000). Silage making in the tropics with particular emphasis on smallholders, Mannetje, L.'t.- Rome (Italy): FAO Electronic Conference on Tropical Silage,FAO Electronic Conference on Tropical Silage,Internet,1 Sep - 15 Dec 1999.- ISBN 92-5-104500-3. p. 17-30

Stein, H. H., Berger, L. L., Drackley, J. K., Fahey, G. C., Hernot, D. C. and Parsons, C. M. (2008). Nutritional Properties and Feeding Values of Soybeans and Their Coproducts. Soybeans: Chemistry, Production, Processing, and Utilization, 613–660. https://doi.org/10.1016/B978-1-893997-64-6.50021-4

Stock, R. A., Lewis, J. M., Klopfenstein, T. J. and Milton, C. T. (1999). Review of new information on the use of wet and dry milling feed by-products in feedlot diets. *Am. Soc. Anim. Sc., Proceedings of the American Society of Animal Science*, 1–12.

Stuth, S., Hennig, M., & Allmendinger, J. (2009). *Die Bedeutung des Berufs für die Dauer von Erwerbsunterbrechungen* (No. P 2009-001). WZB Discussion Paper.

Su, Y., Xiao, S., Shumin, Z., Menglin, H., Defeng, L., Shengli, Q., Xilan, J. Yu, S., Chengzhang, W., Xiaoyan, Z. Z. and Yinghua Shi. (2022). Dietary alfalfa powder supplementation improves growth and development, body health, and meat quality of Tibetan sheep. Food Chemistry 396 133709.

Suleman, S. J. (2006). —Mortality in Small Ruminant and Implications for Livelihoods of their Keepers in the Savelugu-Nanton District of the Northern Region of Ghana‖. Master thesis. University of Cape Coast, Cape Coast, Ghana

Sunday, J. (2018). On the oscillation criteria and computation of third order oscillatory differential equations. *Communications in Mathematics and Applications*, *9*(4), 615-626.

Syomiti, M. and Bauni, M. (2010). Silage fermentation processes, manipulation and implications in thedairy sector. Kenya Agricultural Research Institute. “Driving livestock entrepreneurship towards attainment of food sufficiency and Kenya Vision 2030”

Teye, G. A., Adzitey, F., Alidu, O., Ansah, T., Addy, F., Alenyorege, B. and Dei, H. K. (2011). Effects of Whole Cotton Seed Supplementation on Carcass and Meat Qualities of the Djallonke Sheep Raised on Station. Journal of Animal and Feed Research, 1(2), 47–51.

Theodorou, M. K., Barbara, A. W., Dhanoa, M. S., McAllan, A. B. and France, J. (1994). A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. Animal Feed Science Technology, 48, 185–197.

Tion, M. A. and Adeka, I. (2000). Evaluation of cassava root meal as a replacement for maize in broiler diets. pp: 19 –23. In: Ukachukwu, S.N., Ibeawuchi, J.A., Ibe, S.N., Ezekwe A.G., Abasiekong, S.F. (Eds.) Proceedingsof25th Nigerian Society for Animal Production Annual Conference. Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Togun, V. A., Farinu, G. O., Ojebiyi, O. O. and Awotunde, A. I. (2010). Effect of Replacing Maize with a Mixture of Rumen Content and Blood Meal on the Performances of Growing Rabbits: Initial Study with Mash Feed. World Rabbit Sci., 17, 21–26.

Tolera, A. and Sundstøl, F. (2000). Supplementation of graded levels of Desmodium intortum hay to sheep feeding on basal diets of maize stover harvested at three stages of maturity 1. Feed intake, digestibility and body weight change. *Feed Science and Technology*, *85*, 239–257.

Traore, S. G., Fokou, G., Ndour, A. P. N., Yougbare, B., Kone, P., Alonso, S., Roesel, K., Bakou, S. N., Dao, D., Grace, D. and Bonfoh, B. (2017). Assessing knowledge, beliefs and practices related to the consumption of sheep and goat meat in Senegal. Glob Food Security 19:64–70. https://doi.org/10.1016/j.gfs.2018.10.001

Turkson, P., K. and Naandam, J. (2006). Constraints to ruminant production in East Mamprusi Districts of Ghana. Ghana Journal of Agriculture Science, 39, 155- 164.

Unigwe, C. R., Raji, A. M., Popoola, A. M., Balogun, F. A., Adekunle, F. O. and Nwokwu, G. N. (2017). Effect of different processing methods on the proximate composition of cassava peels. Journal of Plant and Animal Sciences, 2, 019 - 025.

Ur-Rahman, U., Sahar, A. and Khan, M. A. (2014). Recovery and Utilization of Effluents from Meat Processing Industries. Food Research International, 65, 322–328.

Van Soest, P. J. (1994). Nutritional ecology of the ruminant. 2nd. ed. Cornell University Press.

Victoria, O., Ojo, A., Damilola, K. O., Ayotunde, O., Ogunsakin, R., Yemisi, A., Oludotun, O., Adelusi, F. and Seidat, O. (2018). Effects of supplementing herbaceous forage legume pellets on growth indices and blood profile of West African dwarf sheep fed Guinea grass.Tropical Animal Health and Production https://doi.org/10.1007/s11250-018-1767-4

Virmond, E., Schacker, R. L., Albrecht, W., Althoff, C. A., De Souza, M., Moreira, R. F. and José, H. J. (2011). Organic Solid Waste Originating from the Meat Processing Industry as an Alternative Energy Source. Journal of Energy, 36, 3897–3906.

Wachiebene, S.K. (2021). Assessment of feed resources for ruminant production in northern region of Ghana. MSc thesis in Animal Science (Animal Nutrition). Tamale, Ghana: University of Development Studies

Wanapat, M. (2000). Role of cassava hay as animal feed in the tropics. In *Proceedings International Workshop on Current Research and Development in Use of Cassava as Animal Feed, Khon Kaen University, Thailand, 23–24 July 2001*, pp. 13–19. University, Khon Kaen, Thailand.

Wang, D., Fang, J., Xing, F. and Yang, L. (2008). Alfalfa as a supplement of dried cornstalk diets: Associative effects on intake, digestibility, nitrogen metabolization, rumen environment and hematological parameters in sheep. *Livestock Science, 113*(1), 87–97.

Wang, Q., Wang, Y. and Hussain, T. (2020). Effects of dietary energy level on growth performance, blood parameters and meat quality in fattening male Hu lambs. *J Anim Physiol Anim Nutr*. 00:1–13. https://doi. org/10.1111/jpn.13278.

WebMD. (2009). Total Serum Protein. Healthwise Incorporated.

Weinberg, Z. G., Muck, R. E. and Weimer, P. J. (2003). The survival of silage inoculant lactic acid bacteria in rumen fluid. J. Appl. Microbiol. 94:1066–1071.

Weiss, E. A. (2000). Oilseed Crops. 2nd edition. Blackwell Science, *Oxford, UK, Blackwell Science.*

Weobong, C. (2001). Distribution and Seasonality of Microbial Indicators of Pollution in Subin, an Urban River in Kumasi, Ghana, *Msc Thesis. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*

Weobong, C. and Adinyira, E. (2011). Operational Impacts of the Tamale Abattoir on the Environment. Journal of Public Health Epidemiology, 3(9), 386–393.

Weyori, A. E., Liebenehm, S. and Hermann, W. (2018). Returns to livestock disease control-a panel data analysis in Togo. Eur Rev Agric Econ 47(2):1–30. https://doi.org/10.1093/erae/jbz031

Wilson, R. T. (1991). Small ruminant production and the small ruminant genetic resource in tropical Africa. *FAO Animal Production and Health Paper.*, P 231.

Witherow, J. L. and Lammers, S. (1976). Paunch and Viscera Handling. Pp.37-66 in Workshop (1973) On in-Plant Waste Reduction In The Meat Industry. Compiled by: J.L.Witherow On J.F.Sci. Environ. *Protection Technology Ser. EPA, 600*(2), 76-214.

Wodajo, H., D. Gemeda, B., A. Kinati, W. Mulema, A., A. van Eerdewijk, A. and Wieland, B. (2020). Contribution of small ruminants to food security for Ethiopian smallholder farmers. Small Ruminant Research 184 (February). https://doi. org/10.1016/j.smallrumres.2020.106064.

Woodworth, J. C., Tokach, M. D., Goodband, R. D., Nelssen, J. L., O'Quinn, P. R., Knabe, D. A. and Said, N. W. (2001). Apparent ileal digestibility of amino acids and digestible and metabolizable energy content of dry extruded-expelled soybean meal and its effect on growth performance of pigs. Journal of Animal Science, 79, 1280-1287.

Xue, H. F. and Meng, Q. X. (2007). Recent Nutritional Advances of Neutral Detergent Fiber in Dairy Cow. *Chin. J. Anim. Nutr.19*, 454–458. Available online: http://en.cnki.com.cn/Article_en/CJFDTOTAL-DWYX2007S1007.htm

Yacout, M. (2016). Anti-Nutritional Factors & Its Roles in Animal Nutrition. Journal of Dairy, Veterinary & Animal Research, 4(1), 239–241.

Yerradoddi, R. R., Khan, A. A., Mallampalli, S. R., Devulapalli, R., Kodukula, P. and Blümmel, M. (2015). Effect of protein and energy levels in sweet sorghum bagasse leaf residue-based diets on the performance of growing Deccani lambs. *Tropical Animal Health and Production*, *47*(4), 743–749. https://doi.org/10.1007/s11250-015-0788-5

Yitbarek, M. B., Mersso, B. T. and Wosen, A. M. (2016). Effect of Dried Blood-Rumen Content Mixture (DBRCM) on Feed Intake, Body Weight Gain, Feed Conversion Ratio and Mortality Rate of SASSO C44 Broiler Chicks. *Journal of Livestock Science*, 7, 139–149.

Zagorakis, K., Liamadis, D., Milis, C., Dotas, V. and Dotas, D. (2018). Effects of replacing soybean meal with alternative sources of protein on nutrient digestibility and energy value of sheep diets. South African Journal of Animal Science, 48(3), 489.

Zanu, H. K., Adom, S. O. and Appiah-Adu, P. (2012). Response of cockerels to diets containing different levels of sheanut cake. *Agriculture Science Research Journal*, *2*, 420– 423.