UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECT OF REPLACING SOYBEAN MEAL WITH DRIED RUMEN DIGESTA ON DIGESTIBILITY AND GROWTH PERFORMANCE OF DJALLONKÉ SHEEP

BY

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DECLARATION

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.

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ABSTRACT

This study was conducted to assess the effect of replacing soybean meal in concentrate with dried rumen digesta (DRD) on digestibility and growth performance of Djallonké sheep. Sixteen (16) Djallonké rams with an initial average body weight of 12.4±2.4kg of 10-12 months old were randomly assigned to four treatment diets and replicated four times over a 63 day period in a completely randomized design (CRD). The treatments were T0 (0% DRD), T1 (4% DRD), T2 (8% DRD) and T3 (12% DRD). The animals were fed 30% of the concentrate diet and 70% of rice straw at 3% live body weight. The crude protein (CP) of the concentrate diet ranged between 22.6% and 26.8% in T2 (8% DRD) and T3 (12% DRD). The neutral detergent fibre (NDF) was highest (65.40%) in T1 and lowest (58.8%) in T0. The highest acid detergent fibre (ADF) was obtained in T3 with the least in T0. The *in vitro* organic matter digestibility (IVOMD) was higher ($P<0.05$) in T0 than the DRD based concentrate diets. The total viable count and lactic acid bacteria count showed no significant difference among the DRD based concentrate diets. Total dry matter intake (DMI), organic matter intake (OMI) and Metabolizable energy intake (MEI) were not significantly ($P>0.05$) affected by the inclusion of DRD. However crude protein intake (CP) was significantly ($P=0.030$) higher in T3 more than the other treatments. The inclusion of DRD in the rams' diet did not affect digestibility negatively. The average daily weight gain (ADWG) of the rams were 56.6g, 51.8g, 48.8g and 47.9g for T0, T1, T2 and T3 respectively and they were not significantly ($P>0.05$) different when compared to the control diet. Final live weight, carcass weight, dressed weight and dressing percentages were not significantly different across the treatments. The primal cuts (the shoulder, thigh and neck) expressed as percentage of dressed weight of experimental rams were not significantly affected by the dietary treatments. The haematological and serum parameters of the studied animals showed no significant difference between the control diet and DRD based concentrate diets at all the inclusion levels. Feeding rams with concentrate diet containing dried rumen digesta (DRD) did not have any adverse effect on growth performance, health of animals and nutrient digestibility. Farmers can replace soybean meal with dried rumen digesta up to 12% to rams to reduce cost of production and to maximize their income. Keywords: Dried Rumen Digesta, Concentrate diet, Digestibility, Growth and Djallonké rams

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In memoriam to my co-supervisor Mr. Benjamin Alenyorege who participated in the planning of the research, but could not live to see its final completion. May His Soul rest in the bosom of the Lord.

DEDICATION

This thesis is dedicated to my beloved daughter Favour Awinsum Agolisi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

ADF: Acid detergent fibre

ANOVA: Analysis of variance

AOAC: Association of Analytical Chemists

ADG: Average daily gain

CP: Crude protein

DM: Dry matter

DMD: Dry Matter Digestibility

DMI: Dry Matter Intake

DRD: Dried Rumen Digesta

ME: Metabolizable Energy

MEI: Metabolizable Energy Intake

NDF: Neutral Detergent Fibre

IVOMD: In vitro Organic Matter Digestibility

OMI: Organic Matter Intake

SBM: Soybean meal

CHAPTER ONE

1.0 INTRODUCTION

Protein is very important in ruminant nutrition, it is absolutely necessary for growth, body maintenance, reproduction and output of products such as milk, meat and wool (Yacout, 2016), biological processes such as enzymatic catalysis, transport, storage, motion, mechanical support immunology and control of metabolism (vander Walt, 1988). However, protein feeds are the most expensive in animals' diet (Esonu *et al.,* 2005; Fernandez, 2017). Majority of these protein rations consist mainly of soybean meal as a source of protein (Rufino *et al.*, 2013). However, its use is becoming difficult due to high cost and fluctuation in production in recent time (Cherdthong *et al.*, 2011).

For the past twenty years, prices of animal products have increased because of high prices of protein feedstuff used in livestock feed formulation (Adeniji, 2002; Esonu *et al.*, 2005). Livestock, human beings and industries are in contest for the available protein feedstuffs. Ghana as a developing country is not left out of this situation and this demands the pursuit for locally accessible wastes or by-products to be reprocessed as livestock feed in order to stop the situation. This has placed emphasis on the search for cheaper local alternative sources of protein that can effectively replace soybean meal (SBM) (Cherdthong *et al*., 2011; Rufino *et al.*, 2013; Fernandez, 2017)

Dried rumen digesta (DRD) is one of the potential sources of protein for ruminant livestock (Adeniji and Balogun, 2002; Dairo *et al*., 2005). Rumen digesta is generated in slaughterhouses and usually discarded as waste (Agbabiaka *et al.*, 2011). In 2011, slaughterhouses in Thailand produced about 41,000 tonnes dry matter of rumen digesta

from 1.2 million ruminant animals (FAO, 2012). Fearon *et al*. (2014) estimated 5,760,300 kilograms of rumen digesta generated from 2005 to 2013 with an estimated 527.5 kilograms daily being discharged into the environment as waste in the Tamale Metropolis of Ghana. Until now, rumen digesta was discarded or only used as organic fertilizer on farms (Ristianto *et al*., 2016). It is currently used as feed ingredient for both ruminants and monogastric animals in some countries (Okere, 2016). There is no report of its use in ruminant feed in Ghana as at the time of this study.

Al-Wazeer (2016) recommended feeding ruminants with DRD to replace part of barley grain and soybean meal because of its lower cost over conventional feed ingredients in order to increase economic returns. Several research works have shown the potential of DRD from ruminants as protein supplement in livestock nutrition. Rumen digesta has both semi-fermented and unfermented dietary feed, microbes and end products of metabolic activities of the rumen (Cherdthong *et al.*, 2015; Elfaki and Abdelatti, 2015). The crude protein of DRD ranges from 9-20% of dry matter which makes it an alternative source of protein for animal nutrition if it is well processed (Adeniji and Balogun, 2002; Esonu *et al*, 2006; Agbabiaka *et al.*, 2011). Sundried rumen digesta has a moisture content of 5.83 (Sakaba *et al.*, 2017). The lower moisture content is an indication that it could be stored for a long period of time without deterioration. The protein quality of rumen digesta could vary due to the quality and diversity of the herbage material consumed by the animal, population and action of the microorganisms in the rumen and the length of time the animal takes before slaughter after ingesting the forage material (Sakaba *et al.*, 2017).

Most experiments have shown the effectiveness of DRD as diet in fish, poultry and rabbit (Odunsi, 2003; Esonu *et al*., 2006; Okpanachi *et al.*, 2010; Agbabiaka *et al.*, 2011). The

inclusion of 10% Dried Rumen Digesta (DRD) fed to Awassi lambs showed no hostile effect on health and nutrient digestibility of the animals (Al-Wazeer, 2016). Feeding buffalo with DRD as part of concentrate diet improved organic matter and dry matter digestibility (Cherdthong and Wanapat, 2013).

Increase demand for meat has led to increased slaughter of ruminant animals; this has raised the amount of rumen digesta waste generated at slaughterhouses causing pollution problems in urban areas (Ristianto *et al*., 2016). Rumen digesta is usually thrown away as waste to rot causing environmental problems to residences nearby (Agbabiaka *et al.*, 2011). Indiscriminate disposal of rumen digesta causes environmental pollution by entering into rivers, streams and local free water bodies and imitate methane and carbon dioxide in the air (Uddin *et al*., 2018). Improper disposal of slaughterhouse wastes causes a severe health challenge to people and the environment (Fearon *et al*., 2014). There is a growing concern about the current situation.

The use of rumen digesta as a protein source may minimize cost, maximize profit and serve as environmentally friendly way of disposing abattoir waste (Sakaba *et al.*, 2017). Feeding livestock with dried rumen digesta will result in minimizing cost of feeding and also reduce environmental pollution. It could also, minimize the competition that exist between livestock, human beings and industries for available feedstuffs. The relevance of rumen digesta as protein supplement can be realized after conducting proximate analysis to evaluate biochemically the individual components of the feedstuff (FAO, 2003).

It is against this background, that this study was undertaken to investigate the nutritive value of dried rumen digesta in the diet of Djallonké sheep in Northern Savanna zone of Ghana.

1.1 Objective of the Study

The objective of this experiment was to assess the effect of DRD on growth performance of Djallonké rams

1.2 Specific objectives

1. To determine the effect of DRD and rice straw on *in vitro* rumen fermentation and organic matter digestibility.
2. To determine the microbial quality (lactic acid bacteria, *Salmonella* and *E. coli*) of DRD based concentrate diet.
3. To determine effect of DRD on nutrient intake and apparent digestibility of rams
4. To examine the effect of DRD on growth performance of Djallonké rams
5. To examine the effect of DRD on haematology, blood biochemistry and carcass characteristics of Djallonké rams

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sheep production in Ghana

The ruminant (sheep, goat and cattle) livestock subsector is mostly dominated by smallholder enterprises and generally widespread in Ghana. The southern coastal grassland and the Northern savanna zones of Ghana were formerly noted for sheep production (Koney, 2004). Sheep production is widespread and universally distributed across Ghana but greater portion of the national livestock population is in the Northern sector (Koney, 2004). Uncertainties in weather patterns and increasing demand for meat to feed the growing human population has led to the development of livestock such as sheep production providing farmers opportunities to diversify and add value (FAO, 1995; Koney, 2004).

2.1.1 Importance of Sheep Production

The livestock subsector plays a critical role in meeting the nutritional needs of people (meat and milk) however the demand for livestock products is still at greater rate especially in the cities due to higher incomes and lifestyle of consumers (Osei, 2012). The livestock subdivision is a vital constituent of Ghana's agriculture, and it adds about 9.3% to agriculture Gross Domestic Product (GDP) with a yearly growth rate of 5.4% (MoFA, 2017). According to Oppong (1965) in almost all villages in West Africa, sheep are kept and are of economic importance to the communities. Sheep are a characteristic feature of smallholder farms in Northern Ghana (Tuah, 1990). According to Avornyo *et al.* (2007)

households in the Northern Region of Ghana are estimated to keep between 10 and 20 small ruminants.

Keeping sheep comes with various benefits for the resource-poor farmers (Adogla-Bessa *et al.*, 2005). Sheep make considerable contribution to the well-being of the African through the supply of meat, milk, skins, wool/hair, manure and cash (Gatenby, 2002; Zygoyiannis, 2006). Meat production is the main function for keeping sheep. However, in temperate countries milk and skins have become valuable product especially in countries with large sheep population (Gatenby, 2002). Small ruminant production adds averagely 18% to total meat consumed in Sub Saharan Africa. Their contribution to food security is very crucial (Ibrahim, 1998). Sheep are kept as an insurance against uncertainties and investment by pastoralists and agricultural subsistence societies (Davendra and Mcleroy, 1987). Sheep rearing is a vital capital asset for family needs, school fees, medical bills and other emergencies situation and making an indirect contribution to rural poverty reduction (MoFA, 1997; Annor, 2002). According to Attoh-Kotoku (2003) sheep are processors of forage, agro-industrial by-products and residues which cannot be utilized by human as food into products (milk, meat, skin and leather) for human consumption and clothing. They are very productive and have shorter pregnancy period to increase the flock sizes within a short period after disasters (Robert and Ralph, 1988). There is no religious or cultural barriers on keeping sheep and eating mutton (Attoh-Kotoku, 2003).

2.1.2 Systems of sheep production in Ghana

In Ghana, sheep production systems include the extensive, intensive, semi-intensive and tethering. The extensive system of sheep production is the most practices system in Ghana

(Gatenby, 1985). Ansah and Issaka (2018) reported that about 78% of farmers in Kumbungu District in the Northern Region of Ghana kept their ruminants livestock under the extensive system of management. With this system, animals are allowed to find their own food, search all over near the house and feed on uncultivated land and/or kitchen waste left for them (Gatenby, 1985). Owners have to provide the animals with food and water to protect their crops during the main cropping season (Charray *et al.*, 1992). The lack of control over pastures in this system leads to low productivity. However, this system is easy to manage.

Large numbers of animals are kept on limited land in confinement in the intensive system. The use of cultivated pastures is divided into paddocks. Animals are grazed from one paddock to another. Shade trees are used as shelter. There is zero grazing or "cut and carry" where forage is cut and fed to sheep in their stall or pens. This system, according to Gatenby (1985), is used for fattening rams for festivals like Eid-ul-Fitr among Muslim communities in Ghana. The constraint in this system is that, the animals may be underfed and it is capital and labor-intensive as time taken to collect and carry fodder is considerable.

The third system is the semi-intensive a practice between the extensive and intensive systems. The system is branded by a mixture of limited stall feeding and grazing. The animals are housed at night in simple structures and released during the day to graze. Tethering is practice in small communities. In this system, sheep are tied by a rope to pegs, poles or trees during grazing. The length of the rope determines the area available for grazing. This restricts the movement of the animal (Addo, 2007). This requires moderate labour but sheep should be tethered on areas of good quality fodder and should be moved two or three times each day so they can eat enough vegetation (Gatenby, 1991).

2.1.3 Breed of Sheep in Ghana

The West African Dwarf (WAD) or Djallonké (indigenous sheep) is the major sheep breed which is distributed throughout Ghana. This breed of sheep is widely spread throughout West and Central Africa and is tolerant to the dry Savannah and humid, tsetse fly-infested areas (Epstein, 1971). It is small in size, with matured weight of 25-30 kg and 20-25 kg for males and females, respectively. Gbangboche *et al.* (2008) and Koney (2004) also described this breed of sheep as a compact breed that have a height of 40 to 60cm and a weight range of 20 to 30kg (females) and 25 to 35kg (males). The typical colours of this breed are white, black, brown or a motley mixture of white and black, where the black colour is confined to the headquarters and hindquarters, with the white colour dominating the middle portion (Wilson, 1991; Payne and Wilson, 1999; Animut *et al*., 2002). The rams are usually horned but mane and a throat ruff. Ewes are usually polled. The Djallonké has a thin and medium-length tail. It is known for its hardiness, trypanotolerance, prolificacy and suitability for year round breeding (Animut *et al.*, 2002).

The Sahelian sheep is a larger and long-legged cross between the Djallonké and Sahelian sheep are mostly found in the northern part of Ghana and in peri-urban areas. Several attempts to cross indigenous breeds with exotic breeds to improve the indigenous breeds have not been successful because of failure to sustain initial efforts and lack of harmonization. The Nungua Blackhead sheep developed in Ghana (a cross between the Persian and Djallonké) is an example of breed of sheep in Ghana (Animut *et al*., 2002). The Local breeds are tolerant to the unpredictable weather conditions.

2.2 Nutrient requirements of sheep

Protein, energy, minerals and vitamins are the major nutrients required by sheep for body maintenance, growth, reproduction and production (Schoenian, 2003). When activities of animals increase it directly increases the maintenance requirements of the animal. Cold and severe weather condition raise maintenance level of sheep, therefore, more forage will be required to maintain constant body temperature. Nutrient levels for maintenance also increases during pregnancy, lactation and further growth. Sheep will consume 2-4% of their body weight in g/kgDM of feed. The precise ratio differs based on the size (weight) of the animal (Schoenian, 2003; Rayburn, 2013). The nutrient requirement of animals on pasture can increase up to 25% because of increased activity (Rayburn, 2013). It is extremely difficult to present data collected from all over the world on the nutrient requirements of sheep. For this reason, recommended minimum requirements of sheep are suggested.

Table 1: Suggested nutrient level in diet (based on 100% dry matter)

	Maintenance	Breeding	Late pregnancy	Lactation
Energy TDN	9.0	9.4	10-12	13-14
Calcium	55	59	60-65	65
Phosphorus	0.20	0.32	0.40	0.40

Adapted from (Saskatchewan Agriculture Council, 2008)

The energy requirements of sheep according to NRC (1981) for dry, non-pregnant sheep the maintenance requirements is 0.42 MJME/kg$W^{0.75}$. Hofmeyr (1972) reported energy requirement of 79 kcal ME/kg$W^{0.75}$ for sheep. Steyn (1974) also reported less than 97 kcal ME/kg$W^{0.75}$. Similar result (98 kcal ME/kg$W^{0.75}$) was reported by Ranjhan (1980) and several figures have been reported, 88 kcal ME/kg$W^{0.75}$ (Benjamin *et al*., 1977); 102 kcal

ME/kgW$^{0.75}$ (Agricultural Research Institute, 1977); 110 kcal ME/kgW$^{0.75}$ (Olatunji *et al.*, 1976); 101 kcal ME/kgW$^{0.75}$ (NRC, 1981); 71 kcal ME/kgW$^{0.75}$ (van der Merwe *et al.*, 1962); and 92 kcal ME/kgW$^{0.75}$ (Boshoff and Vosloo, 1976). These nine values average 93 kcal ME/kgW$^{0.75}$. This value is less than the 98 kcal ME/kgW$^{0.75}$ recommended by NRC (1975). Engels (1972) reported 166 kcal ME/kgW$^{0.75}$ as the energy requirement for young sheep grazing on pasture. Benjamin *et al.* (1977) reported energy requirements of 153 kcal ME/kgW$^{0.75}$ for grazing sheep compared to sheep grazed on confined pasture.

Kearl (1982) also reported average body weight of sheep at 32 kg recorded ME requirement of 7.8 kcal ME/kgW$^{0.75}$ gain/kgW$^{0.75}$ and 0.83 kcal ME/g gain/kgW$^{0.75}$. The following were also reported from different authors, 7.9 and 0.6; 11.2 and 0.85; 1.3 and 0.86; 10.5 and 0.8 (vander Nerwe *et al*. 1962); 7.9 and 0.91 (Oyenuga and Akinsoyinu, 1976); 7.9 and 0.91 (Olatunji *et al.* 1976); and 11.5 and 0.9 (Engels, 1972) kcal ME/g gain or kcal ME/g gain/kgW$^{0.75}$.

According to Gatenby (1991) the energy obtained from food is usually used for critical body operations (maintenance) and growth, lactation and pregnancy (production). To properly care for ruminants when confined attention must be paid to their feeding behaviors (Okello, 1993). For sheep to maintain body weight they require at least 8 to 10 MJ/KgDM of energy. Surplus energy is achieved for production when the energy density in the diet exceeded the least level for maintenance for the sheep (Gatenby, 1991).

2.3 Feed resource for ruminant production

2.3.1 Pasture

Addo (2007) defined pasture as an area of land covered with forage crops usually grasses and legumes, used for grazing. In animal production, good pasture management is critical for animal performance, milk production, conception rates (Arseneau, 2010). According to Addo (2007) good pasture plant should be highly productive with a high forage yield per hectare; perform well under different environmental conditions (withstand drought); withstand grazing and recover after grazing; easy to propagate and establish (fast growing); highly palatable and nutritious and must have a good ability to associate and be able to mix well with other pasture species.

Pasture is divided into two types, namely natural pasture and man-made or cultivated pasture. Natural pastures are the rangelands that are covered with forage crops planted by nobody and it could be annual or perennial. Rangelands occupy about 54% of land-dwelling ecosystem and sustains nearly 30% of the world's inhabitants (Estell *et al*., 2012). Natural pastures are mostly unimproved or low in terms of nutritive value and can be enhanced by the application of manure or the introduction of legumes to improve the nitrogen status of the soil. The forage species are adapted to the local environment and tolerate to bush fires. Examples in Ghana are the Coastal savanna, Guinea savanna and Derived savanna (Addo, 2007). According to Ansah *et al*. (2014) natural pastures are the major source of forage for ruminant livestock in Northern Ghana.

Man-made pasture is established and managed by man through weed control, fertilizer application, irrigation, reseeding, rotational grazing and using the correct stocking rate during grazing are adopted. Type of pasture species that is used here could be annual,

perennial pastures, irrigated pastures and ley/rotational pastures (Addo, 2007). Guinea grass (*Panicum maximum*), Bahama grass (*Andropogon gayanus*), elephant grass (*Pennisetum purpureum*), giant star grass (*Cynodon plectostachyus*) and carpet grass (*Axonopus compressus*) are the major grasses used for establishing pasture in Ghana (Arseneau, 2010).

2.3.2 Browse plants

Browse refers to twigs and leaves from trees and shrubs including flowers, fruits and pods available as feed to ruminants (Sanon, 2007). Browses are rich in protein and minerals and could be used to supplement ruminant feed during the dry season (Le Houérou, 1980). In Ghana, it has been estimated that 16% of the land is occupied by different tree crops. Centrosema (*Centrosema pubescens*), stylo (*Stylosanthes graccilis*), tropical Kudzu (*Pueraria phaseoloide*s) and pigeon pea (*Cajanus cajan*) are the proper browse plants for pastures in Ghana (Addo, 2007). Some farming communities in Northern Ghana used browse plant to supplement ruminant diet. Thirty-one trees and shrubs have been identified for feeding and medication of livestock in the Talensi-Nabdam district in the Upper East Region of Ghana (Ansah and Nagbila, 2011). *Khaya senegalensis, Afzelia africana* and *Pterocarpus erinaceus* are major sources of fodder for cattle farmers in Benin during the dry season (Brisso *et al.*, 2007). According to Konlan *et al.* (2015), local browse leaves of *Ficus sp., Afzelia sp and Pterocarpus evinaceus* were some of the ruminant feeds found in Northern Ghana. Ansah and Issaka (2018) also reported that *Faidherbia albida, Afzelia africana, Pterocarpus erinaceus, Ficus gnaphalocarpa and Leucaena leucocephala* were

among the local browse plants used by farmers to supplement livestock feed in the Kumbungu District of Ghana.

2.3.3 Agro-industrial by-products (AIBP)

Agro-industrial by-product (AIBP) are products obtained from industries as a result of processing the main products (Aguilera, 1989). They have low fibre, mostly concentrated, very nutritious and less expensive compared to crop residues. In developing countries, feeding AIBP to animals will help reduce the cost of feeding (Aguilera, 1989). Rice bran, pineapple waste, maize bran, molasses, coconut cake and palm oil mill effluent are good examples of AIBP (Devendra, 1987). According to Aregheore (2000), agro-industrial by-products are listed as energy, protein and combined protein/energy sources. Protein sources are derived from animal by-products and oilseeds after oil extraction (Sindhu *et al.*, 2002). The cakes and meals are valuable sources of protein in livestock diets. Examples are fish meal (55% CP), meat meal (50-55% CP), blood meal (80% CP), soybean meal (48% crude protein), groundnut cake (protein 40- 48%), palm kernel meal (18.0 % CP) and copra meal (18.8 % CP). Energy sources are rich in fermentable carbohydrates and low in protein. Examples are cassava peels (Sekondi, 1991) and molasses, a by-product of the sugar industry, (75% DM, 4.1% CP and 12.7 MJ/kg DM of gross energy). The combined energy/protein are cereal by-products such as brewers' spent grains and bran from wheat, rice and maize (Cheeke, 1991). While some of these can be fed directly, others have to undergo processing to make their nutrients available to livestock.

2.3.3.1 Maize bran

Maize bran is a by-product obtained from maize processing industries, production of ethanol, starch and maize based food. Maize bran is defined as a product of highly variable composition due to the mixture of coasts, bran fraction and other products (Kalscheur *et al.*, 2012). During milling maize bran is mixed with fractions of germ, broken kernels, pericarp and endosperm to produce hominy food (Stock *et al.*, 1999). Maize bran is traded worldwide as livestock feed. It has become a major commodity for human and livestock consumption in developing countries which could limit its availability to smallholder livestock farms (Mulumpwa and Kang'ombe 2009).s

2.3.3.2 Soybean meal

The use of soybean meal (SBM) as a source of protein in animal nutrition has boosted its production. About 18.6% of soybean is oil and 78.7% is meal while 2.7% is discarded as waste (FEFAC, 2007). These products differ in terms of nutritional composition. Their protein contents are high with good balance of amino acid and high in energy when processed well, however, they are low in methionine and fibre content (Grieshop *et al.*, 2003; FEFAC, 2007). According to INRA (2004) the amino acid content of SBM is similar to fishmeal excluding methionine. Soybean meal has more crude protein content, total digestible amino acid content than other vegetable protein sources. The digestibility of SBM protein in poultry is approximately 85% and for amino acid digestibility it ranges from 82% to 94% (Woodworth *et al.*, 2001).

Soybean is mostly used in livestock and poultry nutrition as a source of protein to meet their nutritional requirement due to the limiting amino acid in vegetable protein and cereal based sources (Stein *et al.,* 2008). Some of the products derive from soybean include: soy protein isolate, soybean hulls, full-fat soybeans and soy protein concentrate. These products are used in vary degree in animals diets due to their distinctive nutrient characteristics (Stein *et al.,* 2008). However, soybean meal has detrimental features such as trypsin and flatulence-causing oligosaccharides (Grieshop and Fahey, 2000).

2.3.3.2.1 Soybeans in diets of ruminants

Soybean meal provides good quality protein, degradable, undegradable, soluble protein, energy, fat and fibre to ruminant animals (Ruzic-Muslic *et al.,* 2014). Satter *et al*. (1991) studied 13 commercial roasted soybean and observed CP range of 36% to 58% with and an average of 48% for ruminal undegradable protein. Dairy cows at their first week of lactation were fed soybean meal, raw soybean or roasted soybean for 17 weeks. Cows fed roasted soybean produced 3.5% of fat corrected milk yield (38.0 kg/d) more than the soybean meal (33.4 kg/d) and untreated soybean (34.7 kg/d) (Faldet and Satter, 1991). Grummer *et al.* (1994) and McNiven *et al*. (1994) replaced soybean meal with heat treated soybean in diets of lactating cows and they observed 3.5% increase in fat corrected milk by 1.4 and 1.6 kg/d, respectively. Chouinard *et al.* (1997) fed early lactating dairy cows with extruded soybean, roasted soybean or raw soybean and observed cows fed treated soybean diets had higher solid corrected milk yield than those fed untreated soybean diets (33.5 against 31.2 kg/d). Scott *et al.* (1991) fed cows roasted or extruded soybean and observed similar yield of milk in both diets. Bernard *et al.* (1995) carried out a two-year

study on dairy cows fed roasted soybean diet and raw soybean and observed no improvement in dairy cow performance compared to raw soybean diet. This was attributed to the lack of response to less optimum heated soybean in a similar trend as reported by Satter *et al.* (1994) who compared roasted soybean heated at various temperature namely 123 ºC, 135 ºC, 146 ºC and 153 ºC and steeped for 0 or 30 minutes in dairy cows performance; the roasted soybean diet prepared at 146 ºC for 30 minutes milk yield was better than the untreated soybean diets (38.4 vs 36.4 kg/d). Amentano *et al.* (1997) fed dairy cows with mixed ration based and alfalfa silage and heat treated soybean and observed that cows were limited in methionine content. Broderick *et al.* (1990) offered expeller soybean meal or untreated soybean to early lactating cows and observed that expeller soybean meal produced 3.5% more fat corrected milk (FCM) than the untreated soybean meal (34.5 against 33.9 kg/d). Socha (1991) reviewed published works on heat treated soybean meal and concluded that heat treated soybean meal fed lactating cows increased milk production compared to untreated soybean meal. Santos and Huber (1996) also studied 15 published experiments where soybean meal was replaced with heat treated soybean diets and observed that 12 out of 15 comparisons milk yield did not change.

Fairbrother and Brink (1991) also supplemented expeller or solvent soybean meal at a rate of 0.25% body weight to steer (250 kg) grazing burmuda grass pastures. They observed that steers fed expeller SBM supplement gained 5.4% more than solvent soybean meal supplement. Njwe and Godwe (1988) reported live weights gained of 41 g/d, 77 g/d and 79 g/d when West African Dwarf sheep were fed fresh napier grass without soybean supplement, fresh napier grass supplemented with soybean meal and NaOH-treated soybean pods with soybean meal, respectively. Schwulst (1988) observed daily gains that

ranged from 0.776 to 0.674 pound when lambs were fed with corn and soybean meal ration. Thomas *et al*. (1992) recorded 1.46 vs 1.35 kg/d weight gain when 67% of lignosulfonate soybean meal was substituted in corn diets fed calves weighting 75 kg.

Di Francia *et al*. (2007) replaced part of soybean cake with pigeon pea in lactating dairy cows and observed improvement in weight gain and milk yield. Lanza *et al.* (2003) used 39% of soybean meal and 18% of peas to fatten Barbaresa lambs and observed sufficient protein fraction to meet lambs amino acids requirements. Al-Wazeer (2016) studied the effect of replacing part of soybean meal with DRD at 0, 5 and 10% inclusion levels and showed no adverse effect on nutrient digestibility and growth performance or health of Awassi lambs. Mekuriaw and Asmare (2018) fed lambs graded levels of *Ficus thonningii* dried leaves (FTL) as a replacement for concentrate mixture and observed that the FTL supplement increased organic and dry matter intake significantly.

Rufino *et al.* (2013) replaced 45% of SBM with IDY (inactive dry yeast) in lambs' diet and observed that SBM with IDY in diet of lambs reduced the cost of feeding and maximized nutrient digestibility of lambs. According to Zagorakis *et al*. (2018) rapeseed meal (RSM), pea seeds, flaxseeds and lupin seed diets can replace soybean meal diets without adverse effect on energy value and nutrient digestibility coefficients in sheep diets. Additionally, lupin seeds (LS) can effectively replace SBM in dairy cow diets (Froidmont and Bartiaux-Thill, 2004). The chickpea seed could replace soybean meal (SBM) in lamb fattening diets (Hadjipanayiotou, 2002). Flaxseeds (FS) inclusion in cow diets to replace soybean meal did not affect nutrient digestibility and milk yield (Martin *et al.*, 2016). According to Schroeder *et al.* (2014), feeding steers with FS did not affect total CP digestibility. Cherdthong *et al.* (2014) observed improvement in straw intake and aNDF digestibility

when parts of soybean meal were replaced with dried rumen digesta in concentrate diet for cattle. They recommended 100% DRD inclusion level to reduced cost of feeding. Dietary inclusion of dried rumen digesta reduced cost of producing 1 kg of feed and this reflected in the cost of meat (kg) produced (Esonu *et al*., 2006). Uddin *et al*. (2018) fed Black Bengal (BB) goats with dried rumen digesta and observed reduction in the feeding cost and improved growth performance of goat. According to Olafadehan *et al*. (2014) lambs fed DRD saved 36% cost of producing 1 kg of meat per weight gain.

2.3.3.3 Cassava peels

The main parts of a mature cassava plant possess 6% leaves, 44% stem and 50% of storage roots. The nutritional parts of cassava are the leaves and roots which serve as potential feed source. The age, variety and processing technology determine the chemical composition of the leaves and roots of cassava (Smith, 1988). Cassava peel is a good source of energy for ruminants either as supplement or basal diet. Due to the high levels of cyanogenic glycoside found in cassava it is uncommon to be fed fresh. To reduce glycoside to appreciable levels, ensiling, fermentation and sun drying are used to solve this problem (Smith, 1988). Heuzé *et al.* (2012) reported 78% and 81% for DM and OM digestibility value for cassava peels.

2.3.3.4 Rice bran

Rice bran is an important by-product obtained from rice processing and often adulterated with rice hulls. It contains 14-18% oil and crude fibre range of 10-15% with B vitamin and fairly palatable to livestock (Göhl, 1982). Milled rice bran contains approximately 60% hulls, 35% bran and 5% polishing. Supplementing basal diets with full fat rice bran

in sheep seems to have positive effects, however, its inclusion levels vary from less than 20% to more than 40% depending on the basal diet (Nega and Melaku, 2009).

2.3.3.5 Shea nut by-products

The shea tree (*Vitellaria paradoxa*) is a wild plant that grows naturally in West Africa around the dry savannah belt (Hatskevich *et al*., 2011; FAO, 2014). In Ghana, the guinea savannah zone is where shea nut production mostly occurs. The area covers about 77,670 km^2 (Hatskevich *et al.*, 2011) with 73,500 metric tonnes of nuts produced annually in Ghana (FAOSTAT, 2013).

The method of extraction results in various by-products; solvent extraction method gives shea nut meal (SNM) and mechanical extraction also gives shea nut cake (Oddoye *et al.*, 2012; FAO, 2014). About 55% of the by-products derived from butter production areas are discarded as waste without monetary value (Heuze´ and Tran, 2011). Shea nut by-products may differ in nutritional composition due to the method used to extract the oil and also how the nuts were handled before processing (Dei *et al*., 2007). The nutritional composition of by-products obtained from shea nut ranges from 53-138 g/kgDM crude fibre, 33-76 g/kgDM ash, 80-250 g/kgDM for crude protein, 17-362 g/kgDM ether extract and 318-675 g/kgDM nitrogen-free extracts and the estimated true metabolizable energy corrected for nitrogen balance to be 12.6 $MJkg^{-1}$ to 15.1 MJ kg^{-1} for different SNC samples.

Studies have shown that, by-products derived from shea nuts contain significant quantity of nutrients (Atuahene *et al*., 1998; Dei *et al*., 2008; Oddoye *et al.*, 2012; Agbo and Prah, 2014). Various authors have reported poor performance of animals after the feeding trials

with shea nut by-products (SNPs) inclusion in pig (Okai and Bonsi, 1989; Rhule, 1999) poultry; (Atuahene *et al*., 1998; Dei *et al.,* 2008; Zanu *et al.,* 2012) sheep (Konlan *et al*., 2012) and rabbit (Ansah *et al.*, 2011) due to anti nutritional factors and poor palatability. Various authors have suggested maximum recommended inclusion levels of 25 g/kg for poultry, 50 g/kg for pig and 100g/kg for sheep (Adeogun, 1989; Okai, 1990; Osei-Amaning, 1993; Rhule, 1995; Atuahene *et al*., 1998 and Olorede and Longe, 1999). Sheep fed SNC based supplement improved weight gain, feed intake, haematology and serum biochemical properties (Ansah *et al*., 2012; Konlan *et al.*, 2012).

2.3.4 Crop residues

Crop residues are useful feed source for animals and offering them to animals is an effective way of returning plant nutrients to the soil. Cattle and pigs are often used to crop residues in USA, whereas sheep and cattle or solely sheep or cattle are generally used to graze crop residues in South Africa. The most appropriate way to utilize crop residues, is to feed to sheep (Gertenbach and Dugmore, 2004). Crop residues are left over materials after harvesting crops (cassava tops, maize stover, maize cobs, rice straw, etc.). Crop residues are known to be high in fibre, low in nitrogen and low in digestibility due to lignin and low nutritional value to meet the requirements of livestock (Sundstol *et al*., 1978). According to Devendra (1997) most of the crop residues have high biomass, low crude content of approximately 3-4% and crude fibre of 35-48%. However, livestock are regularly fed residues of maize, grain sorghum, sugar cane, soybean, wheat and vegetables (Gertenbach and Dugmore, 2004). Ansah *et al*. (2006) reported that cereal residues and leguminous residues were the most used crop residues by livestock farmers in the Yendi

District of Ghana. According to Konlan *et al.* (2015) the major ruminant feeds found in the Northern Region of Ghana were mainly residues of groundnut haulms, cowpea haulms and pigeon pea residues.

According to FAO (1999), over 1000 million tonnes of crop residues are produced yearly in developing countries. Kossila (1984) reported that Africa produced 236 million tonnes of crop residues in 1981. In West African sub-region an estimated 136 million metric tonnes of crop residues ranging from 0.07 to 70.57 per million tonnes depending on the country and it may constitute about 1% to 82% of the available national feed resources (Fleischer, 1991). According to Ampadu-Agyei, *et al*. (1994) an estimated 9.38 million metric tonnes of crop residues are produced annually in Ghana. Oppong-Anane (2010) estimated 8,000,000 tonnes of cereal stalks and 3,500,000 tonnes of roots and tubers residues per DM are generated annually and available as animal feed in Ghana. In Northern Ghana, over 5 million tonnes DM of crop residue is estimated to be generated annually (Karbo and Agyare, 2002; MoFA, 2011). Konlan *et al*. (2017) estimated 8.5 tonnes DM/ha of sorghum straw yield which was higher than all the crop residues in Northern Ghana. Ansah *et al.* (2006) observed that about 94% of crop residues were used as supplement for ruminant livestock in the Yendi District of Ghana. Konlan *et al.* (2015) also reported that groundnut haulms constituted 40% of the crop residues found in the livestock feed markets in Northern Ghana; cereal straws such as sorghum straw were the least sold in the feed markets. If the 2.3 million tonnes of crop residues produced in Ghana are effectively utilized, it could save 186 million kg of livestock weight lost during the dry season (Amaning-Kwarteng, 1991).

2.4.1 Rice straw

Rice straw is the vegetative part of the rice plant cut at harvest or after. It may be burned or left on the field and ploughed down to improve the soil or used as feed for livestock (Kadam *et al.*, 2000). According to Komar (1984) about 36-62% of rice straw is usually burned or returned to the soil as compost, livestock ranges use 31-39% as feed while industrial purpose use 7 to 16%. One of the crop residues often fed to ruminants is rice straw due to its abundance however, some farmers do not use it due to its low nutritional quality to livestock.

According to Devendra and Thomas (2002), over 90% of the ruminants livestock in South East Asia are fed with rice straw. About 30-40% of the rice straw produced in China and Mongolia are used in feeding animals (Devendra, 1997). When other feed sources are insufficient, then rice straw utilization becomes very important. In general, the maximum rice straw intake by ruminants ranged from 1.0-1.2 kg/100kg live weight (Devendra, 1997). Cattle and swamp buffaloes with live weight of 200 and 350 kg, respectively are usually fed rice straw in Southeast Asia (Devendra, 1997).

According to Shen *et al*. (1998) the nutritional composition of rice straw differs depending on the variety and growing season. Ansah *et al.* (2017) reported crude protein content of 45.9, 47.3, 65.7, 53.4 and 45.1 g/kgDM for Hybrid, Exbaika, Jasmine 85, IR841 and Long grain ordinary 2 varieties of rice respectively. Rice straw consists of cellulose, hemicellulose, lignin and cell walls. These components affect the nutritive quality (Schiere and Ibrahim, 1989).

Rice straw has low nutritional quality therefore, has to be supplemented with protein and more readily energy sources to enhance rumen function to maximizing straw intake. Protein supplement is required in the rumen for effective degradation of straw or cell walls (Kadam *et al.*, 2000). Concentrate, molasses, green leaves and by-products from food processing are used as supplements to improve straw intake in animals. According to Akter *et al.* (2004) supplementation can improve rice straw the utilization. Table 2 below shows the mean of nutritional composition of rice straw obtained from five varieties.

Table 2: Nutritional composition of rice straw

Constituent	Unit	Value
Dry matter	% DM	91.08
Crude protein	%DM	5.034
NDF	%DM	68.96
ADF	%DM	46.8
Ash	%DM	14.81

(Ansah *et al.*, 2017).

2.5 Quality of crop residues

The factors that affect crop yield are similar to the factors that affect the quantity and availability of crop residues. Trampling accounts for losses of palatable materials when grazing crop residues. According to Mclntire *et al.* (1989) smallholder farms in Sub-Saharan African graze cereal crop residues on the field, apart from densely populated highlands. Animals do selective grazing of parts when turned onto harvested fields leading to wastage due to trampling. This can lead to 40 and 50% (Chandler, 1984) or as high as 70 to 75% losses on grazing days (Ward, 1978). According to Said and Wanyoike (1987) when stovers are fed without chopping it leads to low feed intake and wastage. When crop residues are left on the field for long period, they lose their nutritive quality. The top and

the leaves are the nutritive parts of stalk but often lost due to exposure to wind damage and over drying.

2.5.1 Improving the feeding value of residues

Milling can improve acceptability of residue ingested by animals, but reduced animal performance is one of the problems associated with crop residues because animals are forced to consume material poor in nutritional value. Feed intake and quality can be enhanced by applying molasses and urea to the residues to stimulate the rumen (Gertenbach and Dugmore, 2004). According to McDowell (1988) the adaptation of simple methods such as chopping, topping after maturity, stripping and storage by farmers can improve the quality and intake of crop residues. However, this has not been fully implemented due to lower returns and labour requirement. Limited access to feed supplement, cost of transportation and handling have affected efficient utilization of crop residues by farmers (Scarr, 1987).

The quality of crop residues can be improved if enhanced methods of storing is maintained however this will largely depend on the physical form of the crop residue. Additional labour is required to transport crop residues to their storage place (Dzowela, 1987).

Several techniques have been employed to enhance utilization of crop residues in ruminant animals. These techniques include chemical, biological, supplementation and physical approaches which are used to help break down the cellulose-lignin complex to release the available structural carbohydrates accessible to rumen microbes. Dzowela (1987) reported that oil seed cake, brans, legumes, urea and fodder can be used to supplement crop residues.

The digestibility, intake and metabolizable energy (ME) of the material can be improved by processing.

2.5.1.1 Physical methods of Processing Crop Residues

This includes processes like soaking, chopping, grinding and pelleting, boiling, gamma irradiation and high pressure steaming. Physical treatment has been found to increase intake of crop residues (Chaturvedi *et al.*, 1973; Adu and Lakpini, 1983). Chopping and grinding of straw has been found to help increase the daily intake of straws by animals (Smith, 1987). This is partly due to the reduction in chewing time required to reduce ingested feed material to a particle size suitable for digestion by rumen micro-organisms. Pelleting has been found to improve intake, probably because it reduces dustiness due to grinding (Chaturvedi *et al.,* 1973). After soaking straw in water Chaturvedi *et al.* (1973) reported an increase in digestible organic matter and intake of straw. Nitrogen retention was however variable. Soaking also increased DM intake of the treated material.

2.5.1.2 Chemical method of Processing Crop Residues

Alkalis, acids or oxidizing agents are able to soften cell wall of complex components and improve the swelling ability of cell wall to facilitate the entry of microbial enzyme (Smith, 1987). Sodium hydroxide is an alkali generally used for its effective improvement of the digestibility of crop residues. Amaning-Kwarteng (1991) reported that NaOH increased the *in vitro* digestibility of treated straw (up to 38%) as well as *in vivo* digestibility (24-30%) and also increased intake of about 30%. Urea is another alkali generally used to treat crop

residues. Response parameters used to assess the effect of urea ammonization on animal performance include intake, live-weight gain and digestibility. Mosi and Lamboume (1982) found that intake and digestibility of straw, oat straw and mixed legume haulms were nearly doubled when the straws were ensiled with 4% (wt/vol.) urea for 3 to 6 weeks. Sheep fed ensiled straw gained 80 g/day during 21 day feeding period as compared to a gain of 20 g/day in animals fed untreated straw. Studies by Egyir (1994) have showed that ensiling straw with urea (3 to 5%) increased digestibility by 10 to 12%. Chemical treatment of residues has not caught up with the smallholder in Africa due to lack of availability, cost and handling (Reed and Goe, 1989).

2.5.1.3 Biological method of processing crop residues

The metabolic cellulases are used to treat straw to improve its nutritional value (Jalc, 2002). Lack of required technology and difficulties to produce enzymes and fungi in large quantities limit the application of this method in developing countries. Other challenges include the fact that toxic substances could be produced from the fungi, difficulties in controlling temperature, pH, O_2 and CO_2 concentration to maintain optimal growth of the fungi (Schiere and Ibrahim, 1989). Shetty and Krishnamurthy (1980) cultivated rice with *Pleurotus sajorcaju* and observed 50% improvement in nitrogen and protein of straw. Langar *et al.* (1980), cell soluble, lignin and crude protein content of straw increased when *Agaricus bisporus* and *Volvariella displasia* were used on wheat and paddy straw. Zafar *et al*. (1981) observed 43% improvement in paddy straw digestibility when *Pleurotus sajorcaju* was used to degrade paddy straw than the untreated rice straw. Paddy straw

treated with Cellulomonas species successfully upgraded the nutritional degradability as feed (Thanikachalam and Rangarajan, 1986).

2.5.1.4 Supplementation in ruminant nutrition

Supplements refer to feedstuffs that are used to improve the value of basal diets. They are fed to ruminants in small quantities to supply essential nutrients. Supplement is required to rectify deficiencies of soluble nitrogen and minerals, as sources of protein or energy to increase basal diet intake and enhance animal production. The most common types of supplement are: energy concentrates (cereal and rice bran), protein concentrates (soybean meal and groundnut cake), molasses, non-protein nitrogen (urea) and minerals (Gatenby, 2002). Forage legumes and leaves high in nitrogen can be used as supplements (FAO, 1994).

Bondi (1987), feed that contain crude protein less than 6% needs concentrate supplementation to enhance microbial nitrogen in the rumen. According to Devendra (1985) an adult ruminant can maintain its body if its feed contains CP of 6 -7%, DM intake 1.7% and digestibility of 50-55% of body weight. Most crop residues hardly meet these requirements. Preston and Leng (1981) suggested that to ensure an adequate rumen ecosystem and complement the needs of the animal as well as maximize the use of crop residues, nutritional supplement is needed to provide the fermentable energy, nitrogen and micronutrients (B vitamins, roughage, bypass protein and bypass energy). Ruminants can utilize low quality forage to meet their maintenance, growth and reproduction requirements because of the rumen physiological adaptation. The microbial population in the fore-stomach of ruminants is solely responsible for the digestion of fibrous and soluble fraction

of plant material consumed. Most forages are low in nitrogen and high in fibre; nitrogen supplementation will help improve the rumen's ecosystem to enhance the animals' ability to digest the fibrous portions (Preston and Leng, 1987).

Sheep and goats fed sorghum stover and wheat straw supplement with urea molasses and rice straw supplemented with oil palm slurry produced satisfactory performance (Alhassan and Akorfur, 1982; Sudana and Leng, 1986; Olayiwole and Olorunju, 1987). Tolera and Sundstøl (2000) also observed increases in dry matter intake (43.2, 53.8, 63.1 and 66.1g/kg$W^{0.75}$/day) and crude protein intakes (12.1, 29.8, 47.2 and 62.4 g/head/day) as well as body weight gains (-32, 9, 34 and 44g/day) of sheep fed a basal diet of maize stover supplemented with graded levels (0, 150, 300, 450 g/h/d) of *Desmodium intortum* hay. According to Konlan *et al.* (2012) concentrate supplementation did not improve the basal diet intake even though total dry matter intake was improved by it. Djallonké sheep fed 200 g of whole cotton seed as supplement produced the most desirable nutritional eating quality muscles (Teye *et al.*, 2011).

Adequate supplement is required for efficient utilization of crop residues by animals. Njwe and Godwe (1988) studied three treatment diets (fresh napier grass with no supplement), (fresh napier grass supplemented with soybean meal) and (NaOH treated soybean pods with soybean meal) and observed dry matter intake of 590.20 g/d, 699.53 g/d and 701.38 g/d for West African Dwarf sheep, respectively. Njwe and Olubajo (1992) fed Djallonké goats with fresh Guatemala grass and supplemented with cassava flour or groundnut cake and reported digestibility values of 69.90, 71.99 and 68.49% for dry matter, crude protein and energy respectively for groundnut cake supplementation and 69.90, 69.44 and 67.78%, respectively, for cassava flour supplementation. Ndemanisho *et al.* (2007) reported dry

matter intake of 334.25 g and 337.00 g for growing goats when fed maize stovers supplemented with different browse leaf meal-based concentrate and cotton seed based concentrate, respectively.

According to Marsetyo *et al*. (2017) Kacang goats fed Mulato grass supplemented with *Desmantus pernambucanus*, *Gliricidia sepium* and *Leucaena leucocephala* grew faster compared to goats fed Mulato grass only. Increased dry matter, protein and metabolizable energy intake accounted for the higher growth performance of legume supplemented goats. According to Dessie *et al.* (2010) sheep fed dietary treatments of hay only, hay+150, hay+250, and hay+350 g/DM observed that sheep fed high level of concentrate diet had the highest final body weight and nutrient digestibility than the control diet. Cherdthong *et al.* (2014) observed improved in straw intake and aNDF digestibility when beef cattle diet was supplemented with dried rumen digesta to replace parts of soybean meal.

2.6 Protein nutrition of ruminant animals

In ruminant nutrition, protein is needed for three basic purpose: meeting the ammonia, amino acids and peptides needs of rumen for optimal carbohydrates degradation and synthesis of microbial protein; meeting the metabolizable protein requirement for reproduction, maintenance and growth of the host animal and to meet the amino acid and metabolizable protein needs of the animal (Das *et al.*, 2014). In ruminant animals, protein is in two divisions, the rumen degradable and undegradable dietary protein that is the small but essential amount of dietary protein that bypasses rumen degradation. The host animal gets its amino acids requirement from microbial protein and undegradable dietary protein, both moving to the lower tract. Although in the case of low yielder, the microbial protein

synthesized in the rumen is sufficient. In some cases microbial protein and undegradable dietary protein is enough to meet animal's requirement (Mayank *et al*., 2008).

2.6.1 Digestion in ruminants

The structural and functional nature of ruminants' digestive system enable them utilize plant materials that are fibrous (Van Soest, 1994).The microbial fermentation gastric and intestinal digestion activity give the digestive tract the unique characteristics (Niwiska, 2012).

The rumen is the first chamber of the four compartments; this is where microbial fermentation of feed starts. The rumen contains various microbial populations which are dense in nature (McDonald *et al.*, 2002). The microbes in the rumen are made up of protozoa and bacteria with more than 20 species of protozoa and 200 species of bacteria (Czerkawski, 1986; McDonald *et al*,. 2002). McDonald *et al.* (2002) stated that protozoa have the characteristic of being retained in the rumen, where they may hold protein and stop its use by the host animal. Kamra (2005), the bacteria in rumen play an important role in all aspects of the ruminal fermentation.

Acidity between pH 5.5 and 7.0 is suitable for the rumen microbes to live without oxygen at a temperature of 39-40 ºC with moderate products fermentation concentration (Hungate, 1966). The strained rumen fluid contains 1 billion bacteria per millilitre but usually not uniform due to the number of protozoa and bacteria that are associated with solid digesta (McDonald *et al.*, 2002). Hungate (1966) gave the value of rumen bacteria in a range of 16.2 to 40.8 billion per milliliter. Bryant (1970) suggested a range of 4 to 88 billion per milliliter of rumen digesta which vary due to diet, feeding regime, sampling time after

feeding and individual animal difference. This according to Coleman (1980) is because some protozoa ingest and digest food particles, bacteria and even small protozoa and in effect remodeling bacterial protein into a better quality protein of about 80% biological value. This is a distinct advantage of using rumen digesta as a source of protein in livestock production. The reticulum and omasum act as a filter and the abomasum is the true enzymatic stomach (Niwiska, 2012). The feedstuffs ingested by the animal first come into contact with the fermentative activities in the rumen where microbial fermentation of dietary to produce microbial cells, methane gases, volatile fatty acids and carbon dioxide (McDonald *et al*., 2011). The rumen microbes hook on to the feed particles to form biofilms to degrade plant materials. The ability of the animal to digest feed is mainly because of the rumen ecosystem containing ciliate protozoa, bacteria, anaerobic fungi and bacteriophage (Hobson, 1989). Through the rumen wall volatile fatty acids are mainly absorbed and gases are lost by belching (eructation), undegraded feed components and microbial cells pass to the abomasum and small intestine; they are then digested by enzymes secreted in the animal and the products of the digestion are absorbed. In the large intestine there is a second phase microbial digestion (McDonald *et al*., 2011). Undegradable dietary protein that moved into the lower tract is regularly absorbed as amino acids following enzymatic digestion. The part of rumen degradable protein fraction is utilized as nitrogen source for rumen microbes for protein synthesis while the rest is absorbed as ammonia. Only part of absorbed ammonia is recycled back to rumen as urea through saliva, the rest are passed out through the urine (Mayank *et al*., 2008).

2.6.2 Protein metabolism in ruminant

Metabolizable protein (MP) is the true protein which is absorbed by the intestine and supplied by both microbial protein and protein which escapes degradation in the rumen; the protein which is available to the animal for maintenance, growth, fetal growth during gestation and milk production (Das *et al*., 2014). Protein required for maintenance, production in ruminants is obtained from three major sources dietary, microbial and endogenous (McDonald *et al*., 2011). In rumen, a portion of the ingested dietary protein is degraded to release amino acids, peptides and ammonia for microbial protein synthesis. Bacteria rely on ammonia available to them to act on the diet to degrade structural carbohydrate portion and the bacteria acting on the non-structural carbohydrate obtained 65% of their nitrogen from amino acids and peptides some from ammonia (McDonald *et al*., 2011). Ruminal fermentation leads to the breakdown of carbohydrates and protein to sugars and amino acids (Niwiska, 2012). The products of the initial degradation are metabolized to microbial mass, carbon dioxide, ammonia, methane, and volatile fatty acids. According to McDonald et al. (2011) the microbial protein synthesized passed the rumen wall of the host animal and absorbed in the small intestine for amino acid supply. The speed and extent of microbial degradation of dietary protein and efficiency of the transformation of the degraded material into microbial protein mostly depends on the amount of microbial protein entering the intestines.

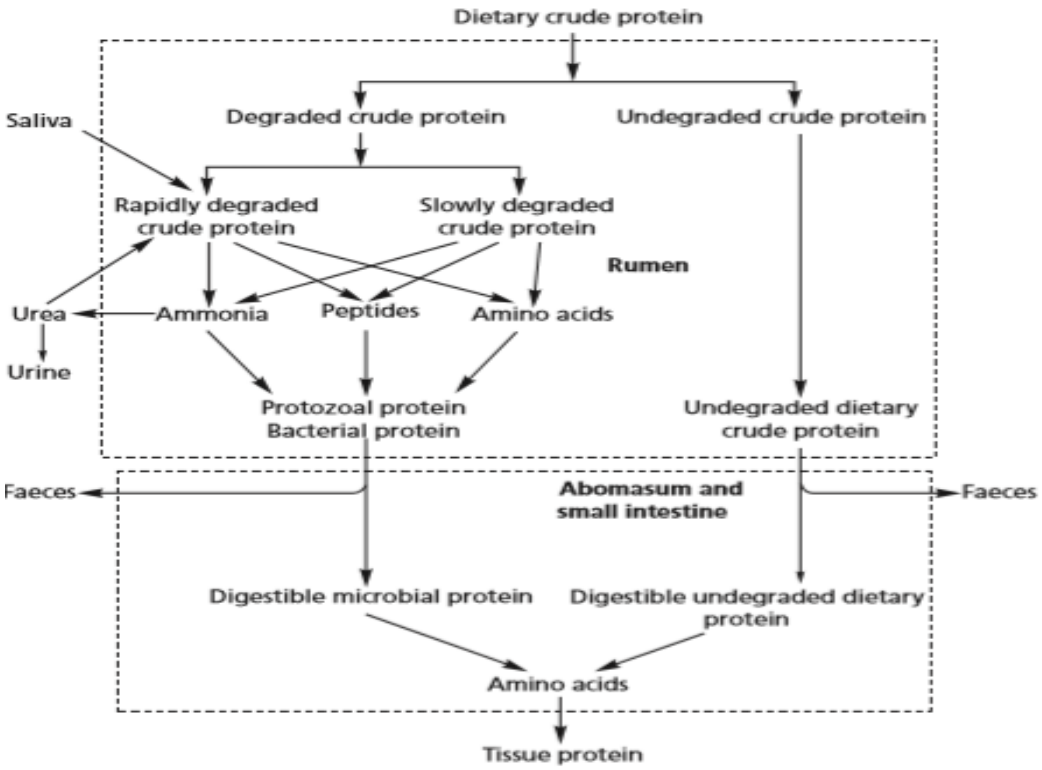

Figure 1: Fate of dietary CP in the ruminant animal (McDonald *et al*., 2011)

The supply of vitamins, protein and short chain organic acids to the animal determines the rate and extent of fermentation parameters (Koenig *et al.*, 2003). Volatile fatty acids, digested proteins, carbohydrates and lipids constituents of microbes and feed residues entered into the small intestine to supply the requirement for production, maintenance and reproduction. The simplest method to influence the extent and rate of degradation of protein in rumen mostly depends on selecting the correct source of protein (Grubić *et al.*, 1992).

2.6.3 Source of protein for ruminants

The oilseeds, by-products of food production, forage and legumes are some of the protein sources available for ruminants in the tropics (Crawshaw, 2001). By-products from

breweries are also essential sources of protein for ruminant production (Ruzic-Muslic *et al.*, 2014; Fernandez, 2017). Crawshaw (2001) observed crude protein of 240 g/kg in brewers' grain. Maize gluten has a crude protein range between 600 and 700 g/kg making it a good source of protein for ruminant animals. Protein sources are derived from animal by-products and oilseeds after oil extraction. The cakes and meals are excellent sources of protein in livestock diets. Groundnut cake has a crude protein range of 40 to 48%, soymeal meal 48 to 50%, cottonseed cake 45%, sunflower 35%, oil palm kernel expeller 18%, rape seed meal 40% and copra meal 23% (Sindhu *et al.*, 2002; Fernandez, 2017). Soybean meal (SBM) has been established as the main protein source for animal nutrition (Zagorakis *et al.*, 2018). Sunflower meal (SFM) could be a good supplement to slow degradable protein feedstuffs (NRC, 2001; Ruzic-Muslic *et al.*, 2014). Rapeseed meal (RSM) is one of the main protein sources used in animal feeding and has been used successfully as a protein in dairy cow diets (Mulrooney *et al.*, 2009). The pea seeds (PS) and fababean seeds (FBS) are protein sources owing to their relatively high crude protein levels (Larsen *et al.*, 2009). Additionally, lupin seeds (LS) is a good source of protein for dairy cow diets compared to pea seeds. Lupin seeds contains more nitrogen (N) and EE, and therefore qualifies as a high-quality feedstuff for ruminants (Froidmont and Bartiaux-Thill, 2004).

The quality of groundnut protein is equivalent to soybean meal (Weiss, 2000). Forage legumes and other plant leaves such as cassava leaves and groundnut haulms are used as protein source for ruminant animals due to their high protein levels than cereal (Ruzic-Muslic *et al.*, 2014; Fernandez, 2017). *Aeschynomene, Arachis, Centosema, Desmodium, Leucaena, Macroptilium* and *Stylosanthes* are examples of tropical legumes available as potential protein feed sources (Quesenberry and Wofford, 2001).

2.6.4 Challenges of accessing protein feed

The main challenge to ruminant production is access to protein feed. Animal feeds are not readily available and where they are, affordability to the smallholder farms is a challenge (Ruzic-Muslic *et al.,* 2014). The cost of protein rations for livestock production has increased due to competition between human and animals for available protein feeds, import prices of protein feeds, instability in production and distribution of protein feedstuffs limiting its access to livestock farmers (Ruzic-Muslic *et al.,* 2014). According to Merry *et al.* (2001) the overreliance on imported proteins has exposed farmers to unstable price, currency fluctuation and supply shortages. These factors have limited farmers' access to protein for livestock production. Some of the browses and shrubs locally available as protein sources contain anti-nutritional factors which inhibit intake and utilization of these legumes that promote rumen microbes' functions (Yacout, 2016).

2.7 Feed intake and growth of sheep

Sheep are allowed to consume as much feed as they desire however, they are often not fed the feed they like most. Nutrient intake depends on the kind of feed available, the quantity consumed and the energy density in the feed (Gatenby, 1991). Straw are often chopped before offering to sheep because they prefer fine feeds to coarse feeds. According to Gatenby (1991) dry matter intake of a roughage ranges from 1.5 to 3.0% of body weight for poor quality diet and high quality diet, respectively. Physiological, nutrient deficit, digestibility, feed bulkiness, processing, pregnancy, production level, environmental temperature, health status, herbage density and type and age of animal are the major factors that influence feed intake of ruminants (Chesworth, 1992).

As a lamb gets older, it increases in size and body composition changes as well as growth. Normally, lamb grows rapidly when they are about 5 months old. However growth rate reduces after 5 months until the animal attains its adult weight. Growth rate of lambs ranges from 20 to 200g/d and mostly influenced by feeding level, genotype, sex, health and management (Gatenby, 1991). Sheep grow slowly during times of low quality diet but grow rapidly when fed improved diet. And this is known as compensatory growth (Gatenby, 1991).

2.8 Constraints to sheep production in Ghana

The major challenge to livestock production in Ghana is unavailability of feed resources, most especially, when the dry season sets in. There is availability of forage in the wet season but accessibility is often limited because during the cropping period, farmers have to tether or stall feed their animals (Awuma, 2012). The main feed resources available are the natural pastures and crop residues, with agro-industrial by-products contributing less (Amankwah *et al.*, 2012). The deteriorating natural pasture in the urban zones owing to infrastructural development has mounted pressure on urban farmers to search for alternative sources of feed such as crop residues.

According to MoFA (2011) and ADB (2014) the 2010 population census of Ghana shows that there is 51% increase in urbanization resulting in declining grazing lands for livestock. The lack of quality and shortage of feed resources during the dry season is a prime concern of livestock farmers in Sub Saharan Africa (Jutzi, 1993). The low ruminant livestock production in Ghana is attributed to the lack of adequate nutrition during the dry season

period. According to Jones and Wilson (1987) the lack of green and quality forage during the dry season are the major factors inhibiting livestock production.

In Ghana from November to April the Northern parts of the country' the weather becomes very dry and hot. This period comes with its challenges such as very poor feed quality low in nitrogen, scarce grazing material and shortage of drinking water for ruminant livestock on natural pasture. This results in loss of weight of animals (Alhassan and Karbo, 1993). Smallholders of livestock in the cities are restricted with grazing areas (Charray *et al*., 1992).

Karbo *et al.* (2002) reported that the northern region of Ghana holds bulk of the livestock species in the country. However, lack of improved breeds, lack of inexpensive quality feed, a weak livestock extension system, poor management, lack of suitable technology and weak livestock veterinary services remain the major constraints to livestock production. During wet season forages develop very vigorously but they become fibrous as the rainy season comes to an end. In the tropic lignification rate is very high and this accounts for the low nutritive value in most herbage. In most places the problem is further worsened by bush fires (Nour, 1986). Unfortunately, the abundant of crop residues used for supplementation have high fibre and lignin content hence the poor nutritional value (Nour, 1986).

2.9 Animal waste and its use in agriculture

The livestock and poultry industries generate huge amount of solid wastes (manure and organic materials), liquid waste, H_2S and CH_4 and odor which could be harmful to the environment (Leha, 1998; Obi *et al.*, 2016). The amount and quality of waste produced by

animals differ among species. Diet composition, feed conversion, animal performance and housing system practiced are the factors that have impact on amount of manure produced (Ketelaars *et al.,* 2000; Ryser *et al*., 2001). Averagely, the amount of manure generated per animal ranged from 5.4-45.3, 5.1-11.3, 0.08-0.14, 0.13-0.34, 0.71, 2.8 and 28 litre/day for cattle, swine, chicken, turkey, rabbit, sheep and horse, respectively (Ketelaars *et al.*, 2000). The waste materials produced from animals are useful resources if used properly. It could replace huge amounts of inorganic fertilizers (Leha, 1998). Manure from animal waste is valuable source of nutrient and organic matter for crop production and soil nutrition (Bell, 2002). Studies by Ryser *et al*. (2001) showed 55-90% of nitrogen and phosphorus content in the animal feed is excreted in faeces and urine. These wastes are of protein, energy and mineral nutrients in ruminant animal production (Daghir, 1995; Bell, 2002). When properly processed, they could serve as protein source for livestock which will partly reduce production cost, price of animal products in the livestock market and the competition between livestock and human (Daghir, 1995; Bell, 2002; EL-Boushy and Vander poel, 2000). According to Bell (2002) cattle and sheep fed poultry droppings and swine manure showed no adverse on ruminants health and their products quality.

2.9.1 Abattoir waste and its effect on the environment

The operations of abattoir is to obtain the edible portion of the slaughtered animals for human use. However, this process generates a significant amount of waste mostly organic matter containing grease, grit, manure, rumen digesta, blood and bones (Coker *et al*., 2001; Nafarnda *et al*., 2006). The total volume of waste generated per animal slaughtered is approximately 35% of its weight, every 1000 kg of carcass produced, generates 6 kg of

manure and 100 kg of partially digested feed (Coker *et al.*, 2001). Thailand in 2011 recorded about 41,000 tonnes of dried rumen digesta from 1.2 million of ruminants in slaughterhouses (FAO, 2012). Fearon *et al*. (2014) estimated 1,159.7 tonnes of blood and 636.5 tonnes of tissue waste as being generated annually in the Tamale metropolis of Ghana and being discharged into the environment.

Abattoir workers throw away waste materials with no regard to environmental safety practices, thus exposing human, animals and waterbodies nearby to harm. Abattoir workers in Nigeria and Ghana dispose waste materials around the slaughterhouses or into waterbodies nearby, regrettably, some of these abattoirs obtain water from the same waterbodies (Weobong, 2001; Adelegan, 2002; Osibanjo and Adie, 2007). Section of the population have attributed the indiscriminate disposal of abattoir wastes to inadequate waste recovery facilities (Adeyemo *et al.*, 2009). Some research works have tagged abattoir activities as the main cause of underground and surface waters and air pollution which affect the health of residents living around these facilities (Odoemelan and Ajunwa, 2008). A study on the activities of the main abattoir in the Tamale metropolis of Ghana revealed that effluent water from the facility was heavily polluted because all the parameters measured were above the Environmental Protection Agency (EPA) of Ghana acceptable levels (Weobong and Adinyira, 2011; Fearon *et al.*, 2014).

Wrongfully discharged blood and faeces of animals into waterbodies promotes oxygen depletion and nutrient over enrichment which could increase the rate of toxin accumulation (Nwachukwu et *al.*, 2011). These pollutants in waterbodies may destroy fish yield (Aina and Adedipe, 1991). Humans may be affected through outbreak of waterborne and respiratory diseases (Mohammed and Musa, 2012).

2.9.2 Rumen digesta and its current use

Rumen digesta is waste generated from ruminant animals in slaughterhouses (cattle, sheep and goats) which is currently a nuisance in most developing countries. Rumen digesta is partially digested forage mainly found in the rumen of ruminant animals (Okere, 2016). According to Awodun (2008), the digesta in the rumen contains gas, fluid, feed particles of various sizes and physical characteristics. Bacterial, protozoa and fungi act upon the digesta in the rumen (Awodun, 2008). Each cow slaughtered would produce about 24.5 kg of fresh rumen digesta or 3.8 kgDM (Witherow and Lammers, 1976). An estimated 2,952,720 kg rumen digesta is generated yearly in Owerri-Nigeria (Okere, 2016). Fearon *et al*. (2014) estimated that 822,900 tonnes of rumen digesta is produced annually in the Tamale metropolis of Ghana. Okere (2016) evaluated the economic benefits of rumen digesta generated in Owerri-Nigeria slaughterhouses and reported a profit of ₦29,527,240.00 per annum which could employ 681 graduates for a month, 49 graduates for a year and 123 secondary school leavers.

Majority of the rumen digesta generated in slaughterhouses across the globe are discarded as waste (Ristianto *et al*., 2016). Rumen digesta is mostly used as organic fertilizer on farms to alleviate soil nutrient problem (Schobery, 2002; Ristianto *et al*., 2016). Dried rumen digesta is use as fuel to power thermal plants (Arvanitoyannis and Ladas, 2008). Cattle rumen digesta is also used to generate electric power and biogas production (Ur-Rahman *et al.*, 2014) while rumen digesta generated from abattoirs is used as fuel in the cyclonic combustor (Virmond *et al.*, 2011).

Rumen digesta is used as feed ingredient for both ruminants and non-ruminant animals in some countries (Okere, 2016). Currently, researchers are making great efforts to properly process rumen digesta from slaughterhouse as alternative source of nutrient to support the shortage of feed sources (Adedipe *et al.,* 2005; Amata, 2014) and economic value for the livestock industry (Amata, 2014). According to Ra and Iliyasu (2017) several animals have been fed with dried rumen digesta as protein at different inclusion levels. The studies on dried rumen digesta have been conducted in countries such as Cameroon, Egypt, Sudan, Ethiopia, Nigeria, Saudi Arabia, Thailand and India.

2.9.3 Nutritive importance of rumen digesta as feed to livestock

Rumen digesta is among livestock waste that can be used to partially replace protein forage (Ristianto *et al*., 2016). The amount of heat applied during processing determines the quantity of amino acid and other compounds available (Makinde and Sonaiya, 2007). According to Yitbarek *et al.* (2016) the use of dried rumen digesta as supplement in animal feeding is good because it has no detrimental effect on their growth performance. The nutritional composition of dried rumen digesta has actually revealed its relevance in the feed industry by nutritionists as inexpensive feedstuff (Togun *et al.*, 2010; Elfaki *et al.*, 2014; Osman and Elimam, 2015). Additionally, Dairo *et al*. (2005) Osman and Elimam (2015), and Mishra *et al.* (2015) observed no adverse effect on animals (poultry, catfish, quail, sheep, goat and cattle) fed mixture of blood and dried rumen digesta.

The chemical composition of dried rumen digesta depends on the type of pastures consumed by the animal (Togun *et al.*, 2010). It is fairly rich in crude protein (18.5) and

other micro-flora such as bacteria, fungi and (Dairo *et al.*, 2005; Esonu *et al.*, 2006; Agbabiaka *et al.*, 2011).

Table 3: Chemical position of rumen digesta (cattle) from different countries (Ra and lliyasu, 2017)

Country	DM %	CP %	EE %	CF %	Ash %	NDF %	ADF %	Reference
Cameroon	92.4	15.2	7.8	41.8	9.3	-	-	(Colette *et al.*, 2013)
Egypt	91.3	18.5	7.8	28.3	9.3	-	-	(Said *et al.*, 2015)
India	92.6	18.3	3.6	24.9	14.5	-	-	(Mishra *et al*., 2015)
India	90.5	12.8	-	-	-	78.7	-54.5	(Froidmont, 2004)
Nigeria	91.8	11.4	6.1	24	8.1	-	-	(Togun *et al*., 2010)
Nigeria	81.8	18.5	8.8	15.3	7.6	-	-	(Uchegbu *et al*., 2006)
Saudi Arabia	13.4	14.2	1.7	-	11.6	59.2	36.7	(Abouheif *et al.*, 1999)

DM=dry matter, CP=crude protein, EE=ether extract, CF=crude fibre, NDF= neutral detergent fibre, ADF=Acid detergent fibre

The chemical composition of DRD ranged from 13.6 to 98.4% dry matter, 11.38-19.6% crude protein (CP) and 15.3-41.84% crude fibre (CF) (Wilson, 1992). According to Agbabiaka *et al*. (2011), dried rumen digesta had 5.41% moisture, 18.58% CP, 3.77% crude fat, 34.44% CF and 24.81% NFE. The use of rumen digesta in animal feed can reduce cost of feeding and reduce the environmental hazards associated with abattoir waste (Ørskov, 2007).

2.9.4 Rumen digesta as feed for ruminants

2.9.4.1 Sheep

Osman and Elimam (2015) reported improvement in feed intake, feed efficiency and weight gain when sheep were fed dried rumen digesta at 0, 5 and 10% compared to the normal diet. They recorded final weight of 30.27, 31.25 and 31.75 kg, respectively. Abouheif *et al.* (1999) reported similar trend of no significant effect on growth performance, weight of carcass and dressing percentage of Najdi lambs fed mixed rumen

digesta and barley in a ratio 4:1. However, lambs fed 25 and 50% DRD and barley based had lower average daily gain (ADG) relatively to those fed the control diet.

Al-Wazeer (2016) fed lambs with DRD and observed no significant difference in final body weight and nutrient digestibility of lambs. Mondal *et al.* (2013) and Osman *et al.* (2015) fed lambs graded levels of DRD at 0%, 5% and 10% and saw no adverse effect on final weight and daily weight gain. Osman and Abass (2015) observed a similar trend in Sudan desert lambs fed at 0, 10 and 20% of DRD based concentrate diets. Salinas-Chavira *et al*. (2007) reported no significant effect on daily gain and feed efficiency of Pelibuy×Dorper lambs fed DRD based diet. Olafadehan *et al*. (2014) fed Yankasa lambs graded levels of DRD based diet at 0, 40 and 60% and observed increase in body weight gain and ADG at the 0 and 40% but reduced at 60% DRD. Fajemisin *et al.* (2010) replaced cassava peels with DRD at 25% to Djallonké sheep and observed that the ADG and feed efficiency did not differ among the dietary treatments.

2.9.4.2 Cattle

Cherdthong *et al.* (2014) replaced part of soybean meal with DRD and rice straw as a basal diet and observed improvement in straw intake and nutrient digestibility coefficient in beef cattle without affecting rumen fermentation when soybean meal was replaced with DRD up to 100%. Ristianto *et al.* (2016) observed higher feed conversion ratio in silage rumen digesta when Ongole crossbred cattle were fed 100% Napier grass, 67% Napier grass + 33% rumen digesta silage, 33% Napier grass + 67% rumen digesta silage, 100% rumen digesta silage.

2.9.4.3 Goat

Uddin *et al*. (2018) fed Black Bengal (BB) goat dried rumen digesta and observed improved growth performance, similar daily growth rate of 48g/d for control diet and 47g/d digesta based diet, similar final live weight and reduced feeding cost. Abbator *et al.* (2016) supplemented DRD at different levels in goats diets and reported improvement in DM intake, feed efficiency and maximum weight gain in animals fed 25% DRD based diet. According to Khattab *et al*. (1996) there was no adverse effect on feed intake and health of goats fed DRD based diets. Similarly, Mondal *et al*. (2013) reported that, DRD did not pose any diseases to goats health due to absence of enterotoxin gene. Replacement of concentrate diets with rumen digesta based concentrate diets resulted in better feed conversion efficiency (Uddin *et al*., 2018).

2.9.5 Rumen digesta as feed for monogastric

2.9.5.1 Rabbit

Rabbits fed graded levels of DRD at 0, 12.5 and 25% to replace maize showed no adverse effect on blood hematology parameters implying that DRD based diet posed no health challenge to the experimental animals (Oluwafemi and Iliyasu, 2016). Mohammed *et al*. (2011) carried out similar experiment on rabbits fed graded levels of DRD mixed with bovine blood and observed increased feed intake but daily weight gain showed no significant effect. Dairo *et al.* (2005) reported significant reduction in feeding cost per kg of feed as the dietary level of rumen digesta increased. Rabbits fed 20% rumen digesta based diet recorded higher dry matter digestibility, reduced feed cost per kg and highest dressing percentage.

2.9.5.2 Poultry

Esonu *et al.* (2011) fed broiler chicken graded levels of DRD based diets mixed with dried bovine blood at 0, 5, 10, 15 and 20%; birds fed DRD based diet reported increase in feed intake, weight gain and nutrient digestibility than the control diet. Makinde *et al.* (2008) observed similar trend in broiler chicken fed DRD at different inclusions levels 0, 5 and 10%. The DRD based diets produced quality meat at a lower cost per weight gain than the control diet. Uchegbu *et al.* (2006) fed DRD as protein supplement to broiler chicken and observed improvement in feed intake, weight, carcass characteristics and reduced feeding cost per kg of carcass produced. Colette *et al.* (2013) reported improved juiciness when broiler chicken were fed 5 and 25% DRD with castor seed cake. Makinde *et al.* (2008) reported increased feed intake, no mortality and reduction in feeding cost per weight gain when broilers consumed DRD with blood meal at 0, 5 and 10% inclusion levels. Basher *et al*. (2002) reported that cockerels fed 20% rumen digesta based diet can suitably replace wheat offal as a source of fibre in the diets for cockerels.

2.10 Blood indices

The assessment of animal's blood profile gives a clear idea of dietary effect on its metabolic requirement. Dietary treatment have significant effects on blood constituent values which can be used to draw conclusion on nutritive value of a diet offered to an animal (Church *et al*., 1984). The criterion for assessing nutrient status of a diet is the change in the concentration of blood components (Russel and Wright, 1983) and index of metabolic disturbance or toxicity (Puoli *et al.*, 1992).

2.10.1 Haematological indices

Haemoglobin (Hb) contains iron for oxygen transportation and metalloprotein in the red blood cells of vertebrate and some invertebrates as well (Maton *et al*., 1993). Haemoglobin transports oxygen from the respiratory organ to the rest of the body where it releases the oxygen to burn nutrients to supply energy support to physiological functions of the organism (Maton *et al*., 1993). Low Hb count is an indication of anemia, a range of 8–16g/dl according to Greenwood (1977) is normal for a healthy sheep. Haematocrit (HCT) or packed cell volume is the ratio of red blood cells to the volume of white blood cells in a capillary, venous or arterial blood. Packed cell volume is a very important index for detecting anemia or polycythemia and plays a critical role in assessing hemodilution and hemoconcentration variations (Bull *et al.*, 2000). According to Jain (1993), range of 27–45% packed cell volume is suitable for healthy sheep.

Red blood cells (RBC) play an essential role of oxygen delivery to the body tissues through flow to vertebrate organism's circulatory system. Red blood cell cytoplasm is rich in haemoglobin, an iron-containing biomolecule that holds oxygen and it is responsible for thered colour of blood (Fadiyimu *et al*., 2010). White blood cells (WBC) are the cells involved in fighting infections and foreign materials in the body. WBC count above the physiological range is an indication of disease. White blood cell range of 6.93–12.66 x 10^9/L is the normal physiological values for healthy sheep (Fadiyimu *et al.*, 2010).

2.10.2 Biochemical indices

Cholesterol is an organic substance classified as waxy steroid of fat that plays a critical role in the life of mammalian cell membrane and is required for proper membrane permeability, fluidity and manufacture of bile acid, steroid hormone and vitamin D. Malnutrition leads to lower serum cholesterol a condition known as hyperthyroidism (Lewington et al., 2007; Sadava *et al.,* 2011). The range of 1.33–1.95 mmol/l total cholesterol levels is considered as normal for a healthy sheep (Cox-anser *et al.,* 1994). Total protein is a measure of soluble proteins circulating in extracellular and intracellular fluids. It maintains plasma pressure and distribution of blood and substances. This has been used as a marker to help clinical diagnosis (Rastogi, 2008). Persistent malnutrition had negative impact on serum protein concentration. A range of 60-93 g/l is normal for a healthy sheep (Borjesson *et al*., 2000; WebMD, 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The chemical, microbial analyses and *in vitro* gas study were conducted at the Forage Evaluation Unit (FEU) of the Agricultural Sub-Sector Improvement Project (AgSIP) and the Spanish Laboratory both at the University for Development Studies (UDS), Nyankpala whilst the feeding trial was conducted at the Livestock unit of the Department of Animal Science, University for Development Studies and Animal Research Institute (ARI), Nyankpala, between December, 2018 and February, 2019. Nyankpala is found in the dry Savanna zone of Ghana on longitude 0^{o} 58^{1} 42^{11} W and latitude 9^{o} 25^{1} 41^{11} N at a height of 183 m above sea level (SARI, 2007). It has a single season of rainfall that starts from April to the end of October with 1043mm of rainfall per annum. The general temperature ranges from 15ºC to 42ºC with 28.5ºC of average temperature per annum and annual daily relative humidity of 54% (SARI, 2007).

3.2 Experiment 1: Chemical composition, *In Vitro* gas production and microbial analyses of the experimental diets.

3.2.1 Dietary preparation for laboratory analysis

The rumen digesta (mainly cattle) was obtained from the Tamale abattoir in the Northern Region of Ghana. All cattle were examined by veterinary staff to ensure that no infectious animals were slaughtered. The rumen digesta was carefully collected to exclude blood into plastic containers and transported to the experimental site. On arrival, the digesta was placed in a sack, tied and a heavy object placed on it for 3 hours to press the liquid out

(Plate 1). This reduced the moisture content in the rumen digesta before it was spread on polyethylene sheet to sun dry for 4 days (Plate 2). The dried rumen digesta (DRD) and the other samples were milled through 2 mm and then 1 mm sieve screens sequentially using a Hammer mill (Brabender, Germany) for chemical analysis and *in vitro* gas production (Goering and van Soest, 1970; AOAC, 1990). The DRD was incorporated in the diet at 0%, 4%, 8% and 12% (T0, T1, T2 and T3) respectively.

Plate 1: Draining moisture from rumen digesta

Plate 2: Drying of digesta on polyethylene sheet

Table 4: Composition of experimental diet

Ingredients %	T0	T1	T2	T3
Maize bran	40	40	40	40
Cassava peels	10.5	10.5	10.5	10.5
Rice bran	15	15	15	15
Shea nut cake	10	10	10	10
Soy bean meal	20	16	12	8
DRD	0	4	8	12
Mineral premix	1	1	1	1
Urea	3	3	3	3
Salt	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**

3.2.2 Chemical Analysis

The samples were analysed for dry matter (DM), ash and crude protein (CP) using the procedures of AOAC (2000). Micro-Kjeldahl technique was used to obtain the nitrogen and multiplied by 6.25 to get the crude protein.

3.2.2.1 Dry matter

This was determined by weighing 2 g of the sample into crucible and placed into forced air oven at 60 ^{0}C for 48 hours. The weight after oven drying was recorded and used for computing the dry matter percentage of each treatment (AOAC, 1988). The percentage dry matter was calculated as dry matter (DM) % = sample dry weight/sample weight × 100.

3.2.2.2 Ash

After determining dry matter, the remaining sample was used to determine the amount of ash according to the procedure of (AOAC, 2000). The crucibles and the samples were placed in a muffle furnace at 550 ^{0}C to burn all the organic constituents, leaving behind the non-volatile mineral elements. The ash crucible was removed from the oven and placed in desiccator, allowed to cool and weighed. The ash content was calculated as:

Ash (%) = weight of ash/net weight of the dry sample × 100.

3.2.2.3 Crude protein

The crude protein content of the samples was determined according to the method of (AOAC, 2000). A gram (1g) of each dried sample was weighed and placed into Kjeldahl digestion tubes and blank determination was done by digesting filter paper in each set of digestion. Approximately 15 ml of concentrated sulphuric acid (H_2SO_4) and two Kjeldahl tabs were added to the content of each digestion tubes. The Kjeldahl tabs contained potassium sulphate (K2SO4) and copper sulphate ($CuSO_4$) which increase the boiling point and acted catalysts respectively.

The tubes were mounted on Kjeldahl digestion block with fume exhaust set (J.P. Selecta RAT2 Spain) and heated gradually to 420^{o}C and maintained for 3h. The tubes were removed and allowed to cool to room temperature after which, 50mls of distilled water was added and distilled using an automated Kjeldahl distillation apparatus (J.P. Selecta, s.a, Pro-Nitro II Spain). The apparatus draws 50 mls of previously prepared 35% sodium hydroxide (35 % NaOH) into the digestion tubes and 25 mls of 4% Boric acid (4% H3BO3) into a 25 mls erlynmeyer flask to trap the liberated ammonia during the distillation period of 9 min per sample. The distillate was collected and titrated against 0.1N HCl (hydrochloric acid). The average titre values were recorded and the percentage nitrogen (% N) as well as the percentage crude protein (% CP) calculated using the formulae: % Nitrogen = (T− B) × N×1.4/ weight of sample (g) % Crude protein = % nitrogen × 6.25

Where:

T – Sample titre value,

B – Blank titre value

N – Concentration of HCl

3.2.2.4 Neutral detergent fibre and acid detergent fibre

Neutral detergent fibre and ADF were determined exclusive of residual ash by sodium sulphite and α- amylase following the procedure of Van Soest *et al.* (1991) and was run on the Ankom200 fibre analyser. About 0.45-0.55g of each sample was weighed directly into filter bags (ANKOM F57) and labelled. The filter bags were then sealed within 4mm of the top with an electronic heat sealer. One blank filter bag was included in each run to determine blank bag correction. The bags with samples were then placed on the bag suspender and inserted into the ANKOM fibre analyser vessel with a bag suspender weight on top to keep it submerged. Neutral Detergent Fibre and ADF solutions were then added respectively. Neutral detergent fibre solution was prepared by dissolving 30.0g Sodium dodecyl sulphate, USP; 18.61 g Ethylene di-amine tetra acetic disodium salt, dehydrate; 6.81g Sodium borate; 4.56g Sodium phosphate dibasic, anhydrous; and10.0ml Triethylene glycol, in 1L distilled water; Whilst that of ADF was prepared by dissolving 20.0g Cetyl trimethylammonium bromide (CTAB) into 1L of 1.00N H2SO4.

For NDF, two litres of NDF solution were added to every 12 sample bags in the fibre analyser vessel. 20 g (0.5 g/50 ml) of sodium sulphite and 4.0 ml of alpha-amylase was added to the solution in the vessel. The fibre analyser was then allowed to run for 75 minutes. After 75 minutes, the solution in the vessel was exhausted and the content rinsed with 2 L of hot water (70-90^{o}C). Rinsing was repeated three times for 5 minutes and 4.0 ml of alpha-amylase added to the first and second rinses. After rinsing, the samples were placed in acetone for 3-5 minutes after which they were oven dried at 102^{o}C for 2 h and weights recorded.

For ADF, the procedure was the same as that of the NDF except that for ADF the fibre analyser was allowed to run for only 60 minutes and also sodium sulphite and alpha - amylase was not added.

3.2.3 *In vitro* gas production experimental procedure

The *in vitro* gas production technique of Theodorou *et al.* (1994) was adopted where approximately 200 mg of oven dried samples from each treatment was weighed into 50 ml test tubes.

The McDougall's salivary buffer was prepared a day before the incubation. McDougall's salivary buffer solution was prepared from solutions A and B. Solution A was made by dissolving 19.60 g $NaHCO_3$, 9.28 g $Na_2HPO_4 \cdot 2H_2O$, 1.14 g KCl, 0.94 g NaCl and 0.26 g of $MgCl \cdot 6H_2O$ in 2 L of distilled water. Solution B was made by dissolving 2.65 g of $CaCl_2 \cdot 2H_2O$ in 50 ml of distilled water. Complete salivary buffer was prepared by adding 2 ml of solution B to solution A, which was then warmed to 39 ^oC with continuous stirring and flushing with carbon dioxide (CO_2) immediately before starting to incubate samples.

Rumen fluid was obtained from 3 different cows at the Tamale Abattoir. The rumen fluid was collected from the rumen into a thermos flask that had been pre-warmed to a temperature of 39 ^oC after the animals have been slaughtered and rumen taken out. The rumen fluid was squeezed through a four layer cheesecloth whilst being warmed at 39 ^oC and CO_2 dispensed into it. The strained rumen fluid was then mixed with McDougall's buffer in a ratio of 1:4 (1 part of rumen fluid, 4 parts of buffer). Approximately 30 ml of the buffer and rumen fluid was dispensed into the test tube containing the feed sample. Carbon dioxide was injected into

the test tube, sealed and gently swirled. They were then placed in a water bath (PRECIS TERM, Spain) set to a temperature of 39 ºC. The gas produced was recorded at 3, 6, 12, 24, 36, 48, 60 and 72 hours with the help of a digital manometer (Fisher Scientific model no. 06-664-21-Pittsburgh, PA).

The gas reading were then fitted to the exponential curve of Orskov and McDonald (1979) without an intercept using sigma Plot 10th edition (Systat Software Inc., 2006). The degradation parameters (b and c) were derived from the exponential model:

$Y= b (1-e^{-ct})$

Where Y= gas volume at time (ml)

b = asymptotic gas production or gas production from insoluble fraction (ml)

t= incubation time (h)

c= fractional rate of gas production (h^{-1}).

The *In vitro* digestible organic matter was computed from the 24 h gas production using the equation:

IVDOM (%) =16.4 + 0.9042 GP + 0.0492 CP + 0.0387 ash (Menke and Steingass, 1988).

The metabolizable energy (ME) was calculated using the equation:

ME (MJ/Kg DM) = 2.20 + 0.136 GP + 0.057 CP (Menke *et al*., 1979)

Where:

GP= *In vitro* gas production at 24 h

CP= Crude protein

Plate 3: Feed samples under incubation in a water bath

3.2.4 Microbial quality test

3.2.4.1 Chemical reagents

OXOID laboratories agar were used. These include plate count agar for total viable count, MacConkey agar for *Escherichi*a coli; peptone water and selenite broth for *Salmonella* isolation.

3.2.4.2 Feed Sample Preparation

Ten grams (10 g) of the processed DRD and the concentrate diets samples were weighed and aseptically taken into a sterile jar containing 90 ml sterile normal diluents and 1 ml aliquot of homogenate was transferred to a test tube containing 10 ml sterile distilled water to make 10^{-1} dilution and shaken well. Serial dilutions up to 10^{-5} were prepared for the microbiological analysis.

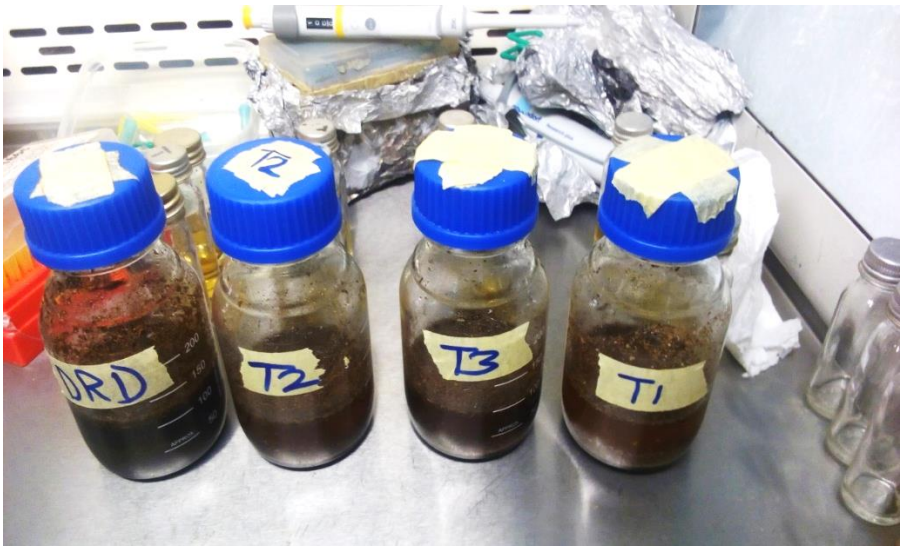

Plate 4: Sample preparation for microbial count

3.2.4.3 Total viable count (TVC)

Pour plate and on grown plate count agar method was adopted to isolate and enumerate the total viable count. Approximately 10 g of the feed samples were diluted in 90 ml of sterilized distilled water to prepare the serial dilution up to $10^{-5.}$

One millilitre (1 ml) aliquot from each feed dilution was inoculated into petri dishes containing the prepared plate count agar. The inoculum was evenly spread and incubated at 37 ^{0}C for 24 hours. All white spots were counted and recorded as total viable count using the colony counter after incubation.

3.2.4.4 Enumeration of lactic acid bacteria (LAB)

Man Rogosa Shape (MRS) agar was used to enumerate LAB count. About 1 ml aliquot of each feed were inoculated into petri dishes. Sterile bent rod was used to spread the

inoculum evenly on the petri dishes and allowed to dry at room temperature, the plates inverted and incubated at 37 ^{0}C for 24 hours.

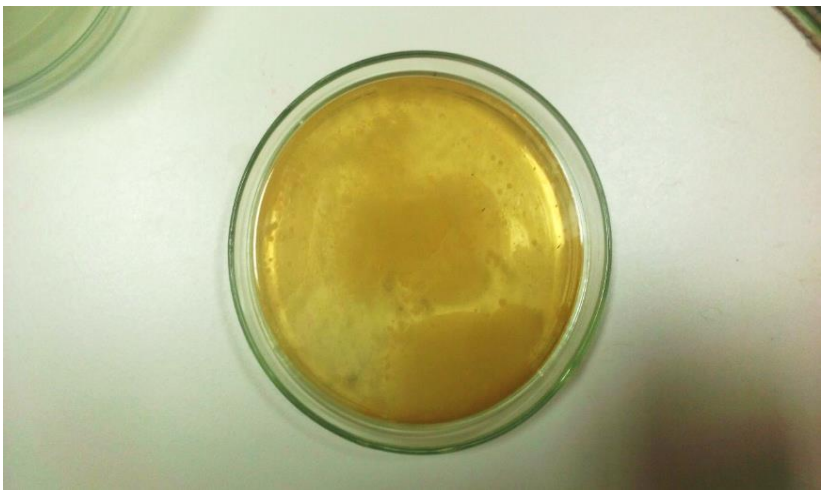

Plate 5: Lactic acid bacteria growth

3.2.4.5 Enumeration of *Escherichia* coli

Approximately, 10 g of the feed samples were diluted in 90 ml of sterilized distilled water to prepare the serial dilution up to 105. Millilitre (1 ml) aliquot from each feed dilution were inoculated into petri dishes containing the prepared MacConkey agar. The plates were then incubated at 37 ^{0}C for 24 hours. Pink colonies were recorded and counted as *E*. coli prevalence.

3.2.4.6 Enumeration of *Salmonella*

Buffer peptone water (BPW) was prepared according to the formula of Oxoid CM009 into universal bottle and serial dilution of sample added to it. It was incubated at 37 ^{0}C for 24 hours. Then 0.1 ml of the sample from the BPW was placed in a 10 ml serenite broth in

universal bottle and incubated at 42 ^{0}C for 48 hours. Cream colonies with black centre on the agar indicated the presence of *Salmonella.*

3.3 Experiment 2: Effect of Feeding Graded Levels of DRD Based Concentrate and a Basal Diet of Rice Straw on Intake, Nutrient Digestibility, Blood Profile, Growth and Carcass Characteristics of Djallonké Rams

3.3.1 Source of experimental animals

A total of 16 Djallonké rams (10-12 months old) were obtained from Animal Research Institute (ARI) Nyankpala. All animals received prophylactic treatment (Albendazole 2.5%, Antibiotic 20% and Multivit) before commencement of the experiment. The animals were fitted with ear tags for easy identification.

3.3.2 Experimental design

The animals (12.4±2.4kg) were assigned to 4 treatments with 4 replicates each in completely randomized deign (CRD). The treatments were T0 (0% DRD based concentrate), T1 (4% DRD based concentrate), T2 (8% DRD based concentrate) and T3 (12% DRD based concentrate diet). The experiment lasted for 63 days after an adaptation period of 7 days between the months of December 2018 to February, 2019.

3.3.3 Dietary preparation for feeding

Rice straw was obtained from the experimental sites of the Savanna Agricultural Research Institute (SARI) in Nyankpala, chopped into pieces (3-5 cm) and bagged for the feeding trial. The first diet was the preparation of the concentrate meal which included the use of cassava peels, rice bran, maize bran, soy bean meal, shea nut cake, urea and DRD. The dried rumen digesta was incorporated into the other diets at 0%, 4%, 8% and 12% (T0, T1, T2 and T3), respectively and fed to rams in the ratio of 70:30 (70% of rice straw and 30% concentrate). Approximately 500 g of iodated salt was dissolved in 10 L of tap water and sprinkled on 12 kg of rice straw before feeding to improve taste.

3.3.4 Housing and feeding during experiment

The animals were individually housed in cages with concrete floor. Wooden troughs for the basal diet (rice straw) and two plastic bowls were fitted to the cages for the concentrate diet and water. The cages were carefully cleaned and disinfected before the animals were brought in. The weight of the feed was taken before feeding commenced.

The leftover feed was weighed every morning for each animal and the difference between quantity offered and quantity left was the amount of feed eaten. The rice straw as a basal diet was also weighed each morning and fed to each animal in an equal quantity. The leftovers were weighed to determine the amount eaten. Daily samples of the concentrate diets offered and leftover were taken and stored in a refrigerator until the experiment was over. After the experiment, the sampled diet was bulked for each treatment replicate and subsample taken for drying in the oven. Duplicates of each subsampled treatment were

weighed and oven dried at 60 ^{0}C for 48 hours. The DM percentage was computed and used to estimate the total DM intake of the supplement for each treatment group.

The concentrate diet was first offered at 7:00 am in the morning, 15 minutes before the basal diet. Water was also provided ad libitum. All animals were weighed weekly before they were fed in the morning. Weekly feed offered were determined by computing 3 % of the rams body weight (RBW) and it was shared between the chopped rice straw and the concentrate diet in a ratio of 70:30 (70% straw and 30% concentrate), respectively.

Plate 6: Experimental ram in cage.

3.3.5 Parameters measured

3.3.5.1 Feed intake

The feed was weighed daily with a weighing scale before offering to the animals. Feed intake was measured and recorded daily as the difference between feed offered and feed refused. Average feed intake per day was determined by dividing the total feed intake by the number of days of the experiment.

3.3.5.2 Live body weight gain

The weekly weight of the animals were taken using a digital scale (Jadever JPS-1050). Weight gain was determined by subtracting the initial live weight of each animal from the final live weight of each animal after the experiment. The average daily gain was determined by dividing the weight gained by the duration of the experiment (63 days) as shown in the formula below.

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

3.3.5.3 Feed conversion ratio (FCR)

Feed conversion ratio was estimated as the daily feed intake divided by the daily weight gain of each animal.

$$FCR = \frac{daily\ feed\ intake\ (g/day)}{daily\ weight\ gain\ (g/day)}$$

3.3.5.4 Feed digestibility

Feed digestibility was determined in the fifth (5) week of the experiment. Faecal collection bags were fitted to the lambs to collect faeces for digestibility trial. Daily faecal output was collected, weighed, recorded and samples taken and stored in a refrigerator until the end of the experiment. The sampled faeces were bulked for each treatment replicate and subsample taken for drying in the oven after the experiment. Duplicates of each subsampled were weighed and oven dried at 60 ^{0}C for 48 hours. The dry matter percentage

was computed and used to estimate the total DM digestibility for each treatment group. Digestibility coefficient was estimated as the daily dry matter intake – dry matter output divided by the daily dry matter intake of each animal.

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

3.3.6 Blood sampling

Blood was taken in the morning before feeding. Approximately 10 ml of blood was taken with a syringe from the jugular vein and transferred into clean test tubes without an anti-coagulant to the Tamale Central Hospital laboratory for haematological and biochemical analysis. The parameters analysed included: packed cell volume (PCV), haemoglobin concentration, total white blood cells (WBCs), total red blood cell, Albumin, Total Protein, urea, glucose, globulin and creatinine.

3.3.6.1 Packed Cell Volume (PCV)

Blood samples were placed in capillary tubes which were arranged in a capillary centrifuge. The samples were centrifuged at 10,000 rpm for five minutes. This separated the blood layers. The Packed Cell volume was determined by measuring the packed red cell column on a micro haematocrit ruler.

3.3.6.2 Haemoglobin (Hb)

The estimation of haemoglobin levels was done by adding 20µl of blood sample to 5 ml of Drabkins solution. Drabkins solution haemolyses the red blood cells, releasing

haemoglobin pigment into the solution. The spectrophotometer (CECIL, CE 1011) was used to estimate the haemoglobin content at wave length of 540 nm.

3.3.6.3 Total White Blood Cell (WBCs)

Blood sample was taken and diluted with the WBC diluting fluid (Turks solution). This solution destroyed all the RBCs and stained WBCs for easier identification during counting. The dilution factor was 1 in 20 and allowed at least 10 minutes for reaction. The solution was then transferred into an improved Neubauer counting chamber (Superior Marienfeld) and the WBCs counted using ×10 objective lens of a microscope and the total count was estimated by calculation.

3.3.6.4 Glucose

The extracted serum was analysed for glucose following the method of Amidu *et al.* (2013) using the BT 3000 Random Access Chemistry analyzer. Glucose oxidase catalyses the oxidation of glucose to give hydrogen peroxide (H_2O_2) and gluconic acid.

3.3.6.5 Total Protein and urea

The estimation of total protein in this study was based on the modification of Gornall *et al.* (1949). Protein in serum forms a blue coloured complex when reacted with cupric ions in an alkaline solution. Blood urea nitrogen was analysed using the procedures of Fawcett and Scott (1960) and Chaney and Marbach (1962).

3.3.7 Carcass Characteristics

At the end of the experiment two animals from each treatment group were selected for carcass evaluation at the Meat Unit of the University for Development Studies. The animals were slaughtered by cutting the jugular vein with a sharp knife. After slaughter, the head, feet and testis were removed and weighed. Evisceration of carcass was carried out and internal organs were removed carefully, separately weighed and their weights recorded. The dressed weight and dressing percentage were taken as carcass parameters. The external organs weighted were head, legs and skin. The internal organs measured were liver, kidney, lungs, heart, spleen and empty digestive tracts. The carcass was divided into half and then into quarters.

3.3.7.1 Carcass dressed weight and dressing percentage

This was the weight of the animals after sticking, bleeding, skinning and removal of head, feet, testis and viscera. Each carcass weight was taken using a digital scale (Jadever JPS-1050). This was the hot carcass weight.

The carcass dressing percentage was calculated as follow:

$$\text{Carcass dressing (\%)} = \frac{\text{Dressed Carcass weight}}{live\ weight} \times 100$$

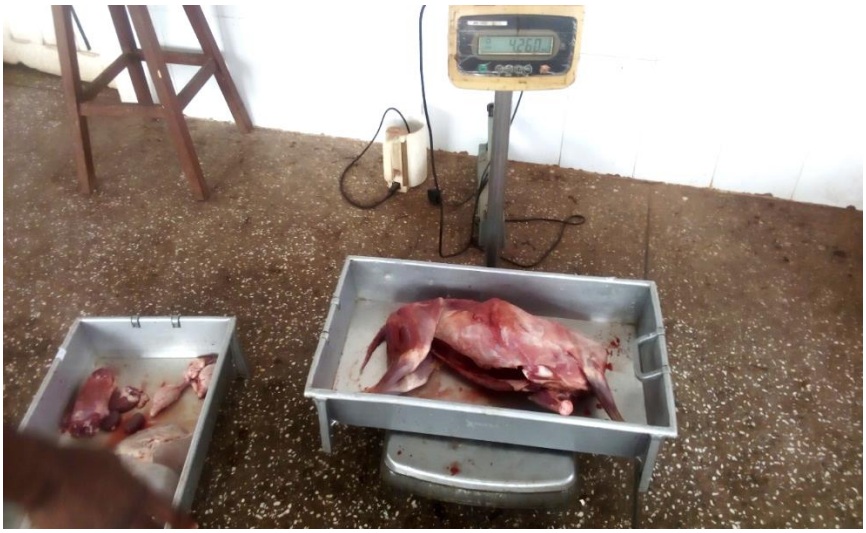

Plate 7: Weighing of carcass from various treatments

3.4 Statistical analysis

The data was subjected to statistical analysis of variance using GenStat 18.2 edition with the following model: Yij = μ + Ti + eij**,** where Yij: observed variation, μ: population means Ti: effect of treatments levels, i the diets and eij error. The initial weight of the animals was used as a covariate in the analysis of growth parameters. Significant difference among treatment means were tested by using Tukeys at 5%.

CHAPTER FOUR

4.0 RESULT

4.1 Chemical composition of the experimental diets

The result of the chemical composition of the dietary treatments, DRD and rice straw are presented in Table 6. The dry matter (DM) content ranged between 95 and 96.8% for T2 and T3 DRD based concentrate diets. The organic matter (OM) contents were fairly similar among treatments.

Table 5: Chemical composition of the dietary treatments fed to rams

Chemical composition (%DM)	DRD inclusion levels (%)					
	T0	T1	T2	T3	DRD	Straw
Dry matter	95.5	96	95	96.8	96.5	96
Organic matter	89.53	90.69	90.53	89.71	83.94	88.54
Crude protein	23.8	25.2	22.6	26.8	14.01	4.6
Ash	10.47	9.31	9.47	10.39	16.06	11.46
NDF	58.80	65.40	63.80	65.30	78.3	77.4
ADF	24.50	25.00	27.70	41.20	50	49.1

NDF = Neutral detergent fibre, ADF = Acid detergent fibre and DRD = Dried rumen digesta

The crude protein (CP) content ranged from 22.6 to 26.8%. The ash content was in the range of 9.31 to 10.47% with the highest recorded in T0. The NDF was lowest in T0 whilst the highest was recorded in T1. The ADF of the experimental diets ranged between 24.5 and 41.20% for T0 and T3 respectively

4.2 *In vitro* degradability parameters

The effect of DRD on *in vitro* gas production (IVGP) and fermentation characteristics is presented in Table 7. The lowest *in vitro* digestible organic matter (IVDOM) was recorded in T2 with significant (P = 0.048) difference between T0 and T2.

Table 6: Effects of dried rumen digesta on *in vitro* digestible organic matter (IVDOM), Kinetics and gas production

Parameters	DRD inclusion levels (%)				SED	P. value
	T0	T1	T2	T3		
IVDOM (%)	47.30^{a}	46.95^{a}	44.98^{b}	45.76^{ab}	0.687	0.048
ME (MJ/kgDM)	18.03^{c}	18.74^{b}	16.88^{d}	19.29^{a}	0.103	<.001
SCFA (mmol/l)	0.024^{a}	0.023^{a}	0.022^{a}	0.019^{b}	0.001	0.023
b (ml/gDM)	18.37	17.60	17.27	14.87	1.035	0.062
c (m/h)	0.10	0.11	0.10	0.10	0.009	0.861

IVDOM = *in vitro* digestible organic matter, ME = metabolizable energy, SCFA = short chain fatty acid, b = asymptotic gas production and c= rate of degradability.

The highest (P<.001) metabolizable energy content was recorded in T3 with the lowest in T2. The short chain fatty acid (SCFA) was relatively (P=0.023) low for T3 DRD based concentrate diet compared to the control. The asymptotic gas production (b) and rate of degradability (c) did not (P=0.062 and 0.861) differ among treatments, respectively. The asymptotic gas production recorded for the control diet (T0) was 19.0% more than the T3 DRD based concentrate diet. The rate of degradation (c) was in the range of 0.10% to 0.11% for T0 and T1, respectively. The cumulative *in vitro* gas production over 72 hours for the concentrate diet is shown in Figure 2.

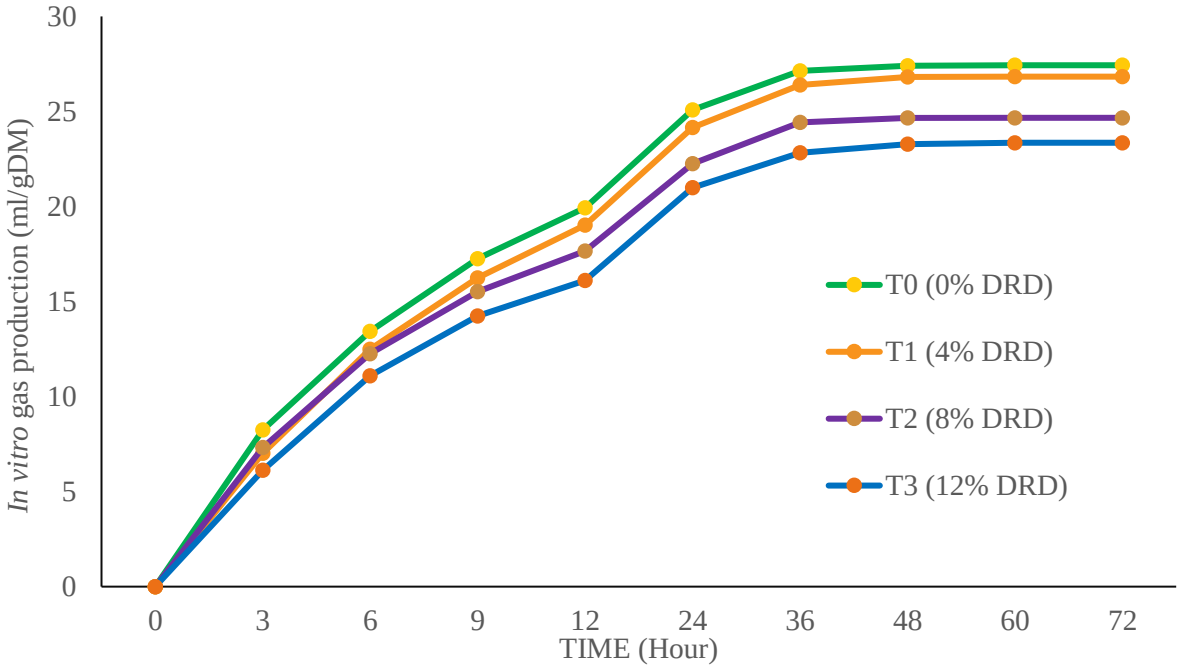

Figure 2: Cumulative gas production of dried rumen digesta based concentrate and control diets

4.2.1 Microbial quality of the DRD based concentrate and processed DRD

Table 8 shows the microbial count of the experimental diets. The total aerobic count did not differ (P=0.533) between the processed DRD and the DRD based concentrate diets.

Table 7: Microbial count of the dried rumen digesta (DRD) based concentrate and processed DRD

	DRD inclusion levels				P. value
Parameter (x10^5 cfu/g)	DRD	T1	T2	T3	
Total aerobic count	3.129	3.220	3.164	3.234	0.533
Lactic acid bacteria (LAB)	2.55^{a}	1.697^{b}	1.745^{b}	1.749^{b}	<.001
E. coli	1.000^{b}	0.000^{a}	0.667^{ab}	1.00^{b}	0.009
Salmonella sp.	1.000^{a}	0.000^{b}	0.000^{b}	0.000^{b}	<.001

Lactic acid bacteria (LAB) in the processed DRD was different (P<.001) from the DRD based concentrate. Even though there was no difference among the DRD based concentrate

diets, there was a marginal increase in LAB with an increase in DRD inclusion. *Escherichia coli* was found in the processed DRD, T2 and T3 but absent in T1. *Salmonella* sp. was also found in processed DRD but absent in the DRD based concentrate diet.

4.3 Nutrient intake

Table 9 shows the nutrient intake of rams. Concentrate dry matter intake was significantly (P=0.004) different among treatment groups. The control (T0) recorded the highest intake compared to the DRD based concentrate diets. However, these differences disappeared when expressed in metabolic weight ($W^{0.75}$). Basal diet (rice straw) intake was not significantly (P=0.944) affected by DRD supplementation. However, there was a marginal increase in intake of rice straw with DRD based concentrate relative to the control (T0). There was an increase (P=0.001) in organic matter intake of rams fed T1 DRD based concentrate compared to the control. Crude protein intake (CPI g/d) differed significantly (P=0.03) among the concentrate diets with T2 recording the least (109.95 g/d) however, the difference disappeared when expressed in metabolic weight. Metabolizable energy intake also showed no difference among the experimental diets. It ranged between 9.93 and 10.71 MJ/kg DM for T2 and T3 DRD based concentrate diets, respectively.

Table 8: Effect of feeding graded levels of dried rumen digesta (DRD) based concentrate and a basal diet of rice straw on nutrient intake in young Djallonké rams

Parameter	DRD inclusion level (%)				SED	P. value
	T0	T1	T2	T3		
Dry matter intake						
Concentrate intake (g/d)	123.20^{a}	112.77^{c}	119.67^{ab}	117.06^{bc}	2.26	0.004
Concentrate intake [g/(d kgW$^{0.75}$)]	19.05	17.29	18.34	18.52	2.07	0.857
Rice straw intake (g/d)	345.63	360.63	355.24	355.87	25.21	0.944
Rice straw intake [g/(d kgW$^{0.75}$)]	52.58	54.99	54.18	55.91	4.41	0.890
Total intake (g/d)	468.82	482.73	474.91	472.92	26.85	0.962
Total intake [g/(d kgW$^{0.75}$)]	71.62	73.72	72.51	74.42	6.24	0.970
Nutrient intake						
Concentrate OMI (g/kg)	69.40^{c}	77.18^{a}	72.06^{bc}	73.90^{ab}	1.42	0.001
Concentrate OMI intake [g/(d kgW$^{0.75}$)]	10.73	11.77	11.05	11.77	1.32	0.810
Straw OMI (g/day)	320.5	333.2	330.1	326.9	23.05	0.953
Straw OMI [g/(d kgW$^{0.75}$)]	48.7	50.8	50.4	51.3	4.05	0.926
Total OMI	439.7	456.8	451.2	440.2	25.23	0.878
Total OMI [g/(d kgW$^{0.75}$)]	67.1	69.7	69.0	69.3	5.85	0.972
CPI (g/d)	116.89^{ab}	127.0^{ab}	109.95^{b}	131.43^{a}	6.69	0.030
CPI [g/(d kgW$^{0.75}$)]	3.68	3.85	3.38	4.25	0.44	0.303
NDF (g/d)	275.62	315.71	302.96	308.89	16.82	0.143
ADF (g/d)	193.13^{a}	120.68^{b}	131.53^{b}	115.78^{b}	8.60	<.001
ME (MJ/kg DM)	10.26	10.66	9.93	10.71	0.69	0.647

DMI = dry matter intake, OMI = organic matter intake, CPI = crude protein intake, NDF = neutral detergent fibre, ADF = acid detergent fibre and ME = metabolizable energy

4.3.1 Nutrient digestibility

Table 10 shows the apparent digestibility of nutrients by rams fed graded levels of DRD based concentrate diets. The nutrient digestibility showed no significant difference between the control diet (T0) and DRD based concentrate diets.

Table 9: Effect of feeding graded levels of dried rumen digesta (DRD) based concentrate and a basal diet of rice straw on nutrient digestibility of Djallonké rams

	DRD inclusion level (%)					
Parameter	T0	T1	T2	T3	SED	p. value
DM digestible	0.60	0.55	0.63	0.58	0.039	0.327
CP digestible	0.79	0.80	0.81	0.82	0.019	0.607
OM digestible	0.89	0.90	0.91	0.89	0.011	0.224
NDF digestible	0.43	0.42	0.49	0.46	0.058	0.598
FCR g DMI/g ADG	8.67	9.45	10.86	10.13	1.832	0.675

OM= organic matter, CP = crude protein, DM = dry matter, NDF = neutral detergent fibre and FCR = feed conversion ratio

The DM digestibility coefficient did not differ (P>0.05) between the control and the DRD based concentrate diets. Dry matter digestibility for T2 recorded a marginal increase of 0.03% more than the control. The CP digestibility did not differ (P=0.607) between the control and the DRD based concentrate diets. The lowest CP digestibility was obtained in the control diet. The trend was similar in the OM digestibility coefficient. It ranged between 0.89 and 0.91% for T0 and the T2. The NDF digestibility also lacked significant difference among the treatments. The lowest digestibility coefficient was recorded in T1. The feed conversion ratio (FCR) did not differ between the diets. It was in the range of 8.67 to 10.86 g DMI/g ADG.

4.4 Growth performance

The initial, final body weight, average daily gain (ADG), DWG/DM intake, DWG/ME intake and DWG/CP intake of the rams fed graded levels of DRD concentrate diets are shown in table 11.

Table 10: Effect of feeding graded levels of dried rumen digesta (DRD) based concentrate and a basal diet of rice straw on growth performance of Djallonké rams

	DRD of inclusion level (%)					
Body weight (g/kg)	T0	T1	T2	T3	SED	P. value
Initial (kg)	12.45	12.45	12.47	12.20	1.902	0.999
Final weight (kg)	15.96	15.67	15.47	15.42	0.580	0.786
Weight gain (kg)	3.56	3.28	3.07	3.03	0.580	0.786
ADG (g)	56.47	51.69	48.61	48.21	9.424	0.806
DWG/DM intake (g)	0.12	0.11	0.10	0.10	0.020	0.772
DWG/ME intake (g)	5.52	4.85	5.02	4.49	0.970	0.762
DWG/CP intake (g)	0.49	0.41	0.45	0.37	0.083	0.533

ADG= average daily gain DWG/DM= daily weight gain per dry matter, DWG/ME= Daily weight gain per metabolizable energy, DWG/CP= Daily weight gain per crude protein.

Weight of rams was not significantly (P=0.786) influenced by DRD based concentrate diets. There was a decrease in final weight and average daily gain with an increase in DRD inclusion compared to the control diet. The average daily weight gain did not differ compared to the control. It ranged from 48.21 to 56.47 g/d for T3 and T0, respectively.

4.5 Blood haematology and serum biochemical profile

Table 12 presents the results of the blood haematology and serum profile of rams fed graded levels of DRD based concentrate diets and a basal diet of rice straw. The

Haemoglobin (Hb) content showed no significant (P=0.918) difference with the highest Hb recorded in T2.

Table 11: Effect of feeding graded levels of died rumen digesta (DRD) based concentrate and a basal diet of rice straw on blood haematology and serum of Djallonké rams

Parameters	DRD inclusion levels (%)				SED	P. value	Normal range
	T0	T1	T2	T3			
Hb (g/dl)	8.8	8.95	9.5	8.50	1.484	0.918	8-16 g/l
PCV (%)	32.75	32.55	33.20	32.65	1.027	0.920	27-45%
WBC(10^9/µl)	7.34	7.7	6.87	5.78	1.151	0.463	4-11×10^7/µl
RBC ($10^{\wedge 12}$/ µl)	7.14	7.20	7.06	7.02	0.689	0.992	5-11×10^6/µl
MCV (fl)	58.35	58.05	57.55	56.85	2.108	0.896	-
Albumin (g/dl)	24.8	25.2	24	24.2	1.603	0.863	9.3 – 49 g/l
Glucose (g/dl)	1.06	0.83	1.16	0.77	0.69	0.931	0.4 – 4.84 g/l
Globulin (g/g)	41.35	42.15	40.35	39.35	1.412	0.347	11.6 – 55.8 g/l
Total Protein (g/l)	66.15	67.3	64.3	63.55	1.693	0.251	60-93 g/l
Creatinine (umol/l)	122	91	69	84	32.9	0.507	-
Urea nitrogen (mmol/l)	11.15	10.39	8.96	9.84	2.465	0.838	-

Hb= haemoglobin, PCV= packed cell volume, WBC= white blood cell, RBC= red blood cell and MCV= mean corpuscular volume

The packed cell volume (PCV) was not significantly different between the control diet (T0) and the DRD based concentrate diet. The highest PCV was recorded in T2. The WBC and RBC count were not adversely affected by the inclusion of DRD in the rams' diets. The highest WBC and RBC were recorded in T1. There was no significant (P=0.896) difference in the mean corpuscular volume (MCV). There was a trend of decreasing levels of MCV values as the levels of DRD was increased. The serum profile lacked significant difference among the treatment groups. The total protein was in the range of 63.55 to 67.3 g/l for T3

and T1, respectively. The blood urea nitrogen ranged from 8.96 to 11.15 mmol/l with the highest recorded in T0 and the least in T2.

4.6 Carcass characteristic of rams

The results of the carcass components for all the treatments are presented in Table 13. The dressed carcass weight and dressing percentage did not differ among the treatment groups.

Table 12: Effect of feeding graded levels of dried rumen digesta (DRD) concentrate and a basal diet of rice straw on carcass characteristics of Djallonké rams

Carcass parameter (%)	DRD inclusion levels (%)				SED	P. value
	T0	T1	T2	T3		
Live weight (kg)	14.53	15.87	15.87	14.54	1.698	0.794
Dressed weight (kg)	5.33	5.45	5.46	4.78	0.700	0.743
Dressing percentage %	36.72	34.89	34.25	32.87	1.337	0.167
Neck weight %	3.38	3.46	3.30	3.53	0.376	0.933
Shoulder weight %	17.15	13.57	16.18	14.58	1.018	0.079
Thigh weight %	15.98	13.96	14.50	14.50	0.534	0.064
Empty Digestive tract	10.99	12.55	11.01	10.97	1.499	0.680
Lung weight	1.51	1.45	1.79	1.46	0.385	0.793
Liver weight	1.72	1.54	1.70	1.74	0.119	0.414
Heart weight	0.48	0.51	0.44	0.42	0.087	0.727
Kidney weight	0.41	0.38	0.31	0.36	0.108	0.813
Spleen weight	0.17	0.16	0.16	0.16	0.034	0.978
Skin weight	7.07	6.80	6.47	7.12	0.488	0.572
Head weight	8.68	8.20	7.84	8.50	0.407	0.310
Leg (kg)	2.83	2.30	2.39	2.73	0.359	0.475
Testis weight	0.99	1.41	1.74	1.10	0.708	0.726

Rams fed DRD based concentrate diets had similar weight of primal cuts as compared to the control diet. External and internal organ expressed in percentages showed no significant difference among the treatments groups. The least (32.87%) dressing percentage was obtained in T3 and the highest in T0.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Chemical composition of the experimental diets

Crude protein, minerals and fibre component of a diet determines its nutritional quality. The quality of forage is more important in ruminant nutrition than its quantity (Mahmut *et al.*, 2010).

The dry matter content of the experimental diets compared favourably with earlier findings by Rios-Rincon *et al.* (2010), Cherdthong *et al*. (2014), and Olafadehan *et al.* (2014) where DRD was incorporated in the feed of steer and sheep. The highest dry matter content recorded in T3 DRD based concentrate is attributed to the high dry matter content in the processed DRD. The processed DRD dry matter was similar to 96.32% reported by Elfaki and Abdelatti (2015). However, it was slightly above the values observed by Froidmont (2004), Uchegbu *et al.* (2006), Togun *et al*. (2010), Colette *et al*. (2013), Said *et al.* (2015), Mishra *et al.* (2015) and Al-Wazeer (2016) and but slightly lower than the 98.4% reported by Cherdthong *et al.* (2014). The result confirms the report that DRD contains 13.36-98.4% dry matter (Abouheif *et al.*, 1999). The DM of the concentrate diet was sufficient to support a reasonable amount of DM intake. High dry matter content is good for rumen function of ruminants as they act as substrate for fermentative functions of the microbes (Oni *et al*., 2008). This is adequate for microbial activities in sheep, thus leading to high digestion and nutrient utilization (McDonald *et al*., 2011). The inclusion of DRD increases the organic matter content in the DRD based concentrate diets. Rios-Rincon *et al.* (2010), Cherdthong *et al.* (2014) and Olafadehan *et al*. (2014) recorded higher organic matter in the control diet when DRD was incorporated in the diets of steer and sheep.

The CP content of the concentrate used in this study was above the 7-8% requirement for satisfactory rumen function to enhance feed intake in ruminant animals (Van Soest, 1994). Gatenby (1991) reported a minimum of 8% crude protein level requirement for maintenance and 11% requirement for fast growth of lambs and lactating ewes. The partial replacement of soybean meal with dried rumen digesta increased the CP content of T3 DRD based concentrate diet in a similar trend as was reported by Cherdthong *et al*. (2014) and Al-Wazeer (2016). Dey *et al.* (1992) reported CP of 78.9 g/kg for sun dried rumen digesta mixed with molasses. The presence of dead microbes in the dried rumen digesta contributed to the higher crude protein in DRD based concentrate diet because microbes in the rumen are a source of protein. This implied that, replacing part of SBM with DRD as a source of protein supplement will meet the protein requirement of ruminants for proper rumen function.

The CP content of the processed DRD fell within the NRC (2007) recommended 12% CP of total DMI for sheep growth and maintenance. The processed DRD recorded CP value of 14.01% in the present study which was similar to 14.2% and 14.22% reported by Abouheif *et al.* (1999) and Al-Wazeer (2016), respectively and it also fell within the 13.3-16.4% reported for cattle rumen digesta by Abouheif *et al.*(1999), Rios-Rincon *et al*. (2010), Nasser *et al.* (2012), Olafadehan *et al*. (2014) and Talib *et al*. (2016). Patra and Ghosh (1990) recorded a CP of 154 g/kg for sun DRD. The 14.01% CP recorded in the study was higher than the 12.8%, 11.4% and 12.57% CP observed by Froidmont (2004), Togun *et al*. (2010) and Mondal *et al.* (2013), respectively. However, the 14.01% was lower than 16.4-19.56% reported by Uchegbu *et al*. (2006), Agbabika *et al.* (2012); Cherdthong and Wanapat (2013); Cherdthong *et al*. (2014); Elfaki and Abdelatti (2015);

Said *et al.* (2015); Mishra *et al.* (2015). However, Colette *et al.* (2013) reported 15.2% for cattle DRD. This confirms the report of Abouheif *et al.* (1999) that the CP of cattle DRD ranges from 11.38 to 19.6%. This conforms to the assertion that the chemical composition of DRD depends on the nutritive quality of the pastures consumed by the animal, population and action of the microorganisms in the rumen and the length of time the animal takes before slaughter after ingesting the forage material (Togun *et al.*, 2010; Sakaba *et al.*, 2017).

The inclusion of DRD in the concentrate diets accounted for the increase in NDF values in the DRD based concentrate diets. The higher ADF recorded in T3 was due to the fibrous nature of the DRD. Olafadehan *et al*. (2014) reported increase in ADF values when DRD was incorporated in the diets of cattle. The high fractions of cell wall in DRD based concentrate diets is an indication of lower feed intake and reduced nutrient digestibility. Acid detergent fibre is a major factor that affects forage intake because of its rumen fill which is directly associated with rumination and chewing time (McDonald *et al*. 2002). Diets with high fraction of ADF have lower nutrient availability due to its negative effect on feed digestibility (McDonald *et al.* 2002).

Various reports about the chemical composition of DRD suggests a high degree of variability. This variation is attributed to the type of forage ingested by the animal, the environment in which the experiment took place, health condition of the animal, season, microbial population present in the rumen and the time of forage ingestion before slaughter.

5.2 *In vitro* degradability of the experimental diet

In vitro gas technique has been used as a measurement of feed degradation; high gas production indicates high digestibility of substrates (Calabro' *et al.*, 2012).

In this study, there was significant difference among the dietary treatments in DOM, ME and SCFA. This was contrast with McDonald *et al.* (2002) and Novotny *et al.* (2017) that forages that contain high ADF values are low in energy digestibility this implies that as the concentration of ADF increases, concentration of energy digestibility also decreases. The differences in digestible organic matter (DOM), ME and SCFA among treatment diets may be partly due to the difference in NDF and ADF contents. The type of forage consumed by the animal before slaughter, time and maturity of forage affected the digestible organic matter content of the DRD based concentrate diets. Cell wall fractions of forage affect feed degradation in the rumen due to the indigestible nature of lignin that acts as a barrier limiting access of microbial enzymes to the structural polysaccharides of the wall. According to Mathison *et al*. (1999) and Agbagla-Dohnani *et al*. (2001), environmental, seasonal effects and proportion of morphological fractions namely stem, leaf and seed ratios have an effect on degradability.

The inclusion of DRD in the dietary treatment did not affect potential degradability and rate of degradability. The control diet (T0) produced more gas than the DRD based concentrate diets. Cherdthong and Wanapat (2013) reported higher gas production in the DRD based concentrate than the control. The reduction in gas production in the DRD based concentrate diets could be attributed to the partially digested nature of the processed DRD. The energy obtained from the *in vitro* gas production met the critical body requirement for maintenance, growth and production. According to Gatenby (1991) sheep do not lose

weight when the energy density is between 8 and 10 MJ/kgDM. Surplus energy is achieved for production when the energy density in the diet exceeded the least level for maintenance for the sheep.

5.2.1 Microbial quality of DRD based concentrate diets and processed DRD

Rumen microorganisms play different roles in feed digestion and fermentation of plant structure and nonstructural nutrient (Durand and Ossa, 2014). The microbial count for the processed DRD and DRD based concentrate diets were lower than the 17.8 cfu/g reported by Mondal *et al*. (2013) for DRD. They stated that drying the rumen digesta led to significant reduction of microbial population. The *E.* coli count in the DRD based concentrate diets showed no initial increase when compared to the processed DRD. The absence of *Salmonella* in the DRD based concentrate diets implies absence of enterotoxin gene in DRD. Therefore shows no detrimental effect when animals are fed DRD based concentrate diets. It can be concluded that the *E. coli* and the *Salmonella* presence in the DRD were non-pathogenic because none of the animals fell sick and was diagnosed with E. coli or *Salmonella* infection and hence its inclusion in animal diet would not lead to any pathogenicity. This result conforms to Khattab *et al*. (1996) and Mondal *et al*. (2013) who observed no negative effect on the safety of DRD in ruminant diets.

5.3 Nutrient intake and apparent digestibility

All the experimental rams voluntarily consumed the concentrate diets to the end of the experiment. None of the animals were detected to have any health problem such as diarrhoea and other related health issues associated with diet. Similar trends have been

reported in lambs by Salinas *et al.* (2007), Fajemisin *et al.* (2010), Olafadehan *et al*. (2014), Osman and Abass (2015) and in cattle by Cherdthong *et al.* (2014) when DRD was incorporated in the diets. Mondal *et al.* (2013) observed no adverse effect on goat health when fed DRD based diet. This also confirms the result of the microbial assessment that the microbes were not pathogenic.

Replacing part of SBM with DRD had an effect on concentrate dry matter intake. Similar result was reported by Al-Wazeer (2016) who partially replaced barley grain and soybean meal with DRD. Osman *et al.* (2015) reported differences in concentrate intake when Shugor desert lambs were fed different levels of DRD (0, 5 and 10%). This disagreed with Cherdthong *et al.* (2014) who reported no significant difference in the DRD based concentrate diet. The significant difference disappeared when expressed on metabolic weight ($W^{0.75}$). Cherdthong *et al*. (2014) observed no significant difference in DRD based diet when expressed on the metabolic weight. Mondal *et al.* (2013) also found no significant differences in DM intake when DRD was incorporated in Bengal goat diet at 10%.

There was a decrease in DRD concentrate dry matter intake relative to the control diet which was ascribed to the higher metabolizable energy in T3 which could have influenced the animals to meet their energy requirement earlier. Olafadehan *et al* (2014) found reduction in feed intake in Yankasa lambs fed diet containing 60% DRD based compared to the control diet. Abouheif *et al*. (1999) observed similar trend in Najdi lambs fed 100% DRD based diet. The reduction in concentrate intake is attributed to the inclusion of DRD that affected diet palatability. However, rams fed DRD based concentrate diets had the highest rice straw intake and total dry matter intake compared to the control diet (T0)

because the DRD based concentrate provided the needed rumen nitrogen required for the production of ammonia which is required for the synthesis of rumen microbes to degrade fibrous carbohydrates in the rice straw. Chopping of rice straw could have influenced daily intake of straws by animals. This is partly due to the reduction of the chewing time required to reduce ingested feed material to a particle size suitable for digestion by rumen microorganisms. This confirms several reports that sufficient supplementation and physical treatment is needed to enhance the utilization of crop residues by ruminant animals (Chaturvedi *et al*., 1973; Adu and Lakpini, 1983; Smith, 1987; Njwe and Godwe, 1988; Warly *et al.* 1992 and Akter *et al.* 2004).

Total DMI of the rams were not adversely affected by DRD based concentrate diets in the study. This result agreed with Al-Wazeer (2016) who reported no significant difference in total DM intake when parts of barley grain and soybean meal were replaced with DRD. Osman *et al.* (2015) fed Shugor desert lambs with 0, 5 and 10% DRD and observed no significant effect on DM intake. Mondal *et al*. (2013) noted that replacing wheat bran with DRD in Bengal goat diet at 10% did not affect DM intake. This was due to smaller inclusion levels of the DRD. Fajemisin *et al*. (2010) observed no significant effect on DM intake when Djallonké sheep were fed diet containing fermented rumen digesta mixed with poultry dropping.

Higher (P=0.001) OM intake was observed in T1 and T3 DRD based concentrate diets compared to the T0. The high OM observed in the chemical composition of the DRD based concentrate diets accounted for the higher OM intake. Similar trend was reported by Al-Wazeer (2016) when parts of barley grain and soybean meal were replaced with DRD.

Crude protein intake (g/day) was significantly different in the T3 compared to the T0. The difference in CP intake disappeared when expressed on the metabolic weight ($W^{0.75}$). Similar trends were observed in lambs by Abouheif *et al*. (1999) and Al-Wazeer (2016) and in goats by Mondal *et al.* (2013). The high CP content of the DRD based concentrate diet contributed to the high CP intake recorded in the T3. There was increased in NDF intake but showed no significant difference when compared to the control (T0) diet in the study. This can be explained by the higher NDF content of the concentrate diet which is attributed to the DRD inclusion levels. Olafadehan *et al.* (2014) observed increase in NDF intake when lambs were fed DRD based diets at 20% and 40% than the control diet. This is in contrast to Cherdthong *et al*. (2014) report that Thai cattle fed graded levels of DRD based diets did not affect NDF intake.

The dietary treatments were significantly affected by DRD inclusion levels for ADF intake. There was a decreased ADF intake in the DRD based concentrate diets compared to the control diet (T0). This agrees with Al-Wazeer (2016) who observed significant effect in ADF intake when lambs were fed DRD based diets at 10, 20 and 30%. Olafadehan *et al.* (2014) observed significant effect in ADF intake when lambs were fed graded levels (20% and 40%) of DRD based diets.

According to Lee (2008) forage with DM digestibility of 60 to 69% is considered as high quality forage in terms of energy supply. About 70% of the energy in these kinds of forage is degraded in the rumen by microorganisms and 30% escape to small intestines and digested by enzymes for absorption. The lack of significant difference in DM digestibility between the control and the DRD based concentrate diets could be due to the smaller DRD inclusion levels used in this study. Several other researchers did not find significant

difference in DM digestibility when DRD based diets were fed to ruminants. Al-Wazeer (2016) recorded no significant difference in DM digestibility coefficient when fattening lambs on diets containing DRD up to 10%. Similar result was reported by Mondal *et al.* (2013) who found no significant effect on DM digestibility with the increasing levels (0, 5 and 10%) of DRD in Black Bengal goats' diets. Cherdthong *et al.* (2014) also found similar trend in cattle when parts of soybean meal was replaced with DRD. The result conforms to Kamstra *et al*. (1959) who reported that DRD inclusion in lambs' diet did not affect DM digestibility. However, Fajemisin *et al.* (2010) found significant increase in DM digestibility when Djallonké sheep were fed DRD based diet at 25%.

For all feedstuffs, ruminant animals need about 65 to 68% of the protein to be rumen degradable for adequate rumen function and the synthesis of microbial protein (McDonald *et al.,* 1995). The inclusion of DRD in the diet of sheep did not affect CP digestibility. However, the DRD based concentrate diets appeared to record higher CP digestibility compared to the control diet. The higher digestibility coefficients in the DRD based concentrate diet was due to the partially digested nature of the dietary material. This confirms reports by other researchers who found similar trends in CP digestibility of diets containing DRD fed to ruminants. Abouheif *et al*. (1999) observed higher CP digestibility in Najdi lambs fed 25% of rumen digesta-barley meal than lambs fed 0% DRD based diet. Olafadehan *et al*. (2014) fed graded levels of DRD at 0%, 20% and 40% to lambs and observed increase in CP digestibility in the 20% and 40% DRD based diets than the 0% DRD diet. Al-Wazeer (2016) also observed no significant effect in CP digestibility coefficient. Similar trends were reported by Mondal *et al.* (2013) and Cherdthong *et al.*

(2014). However, Fajemisin *et al.* (2010) found significant increase in CP digestibility when Djallonké sheep were fed 25% DRD based diet. They attributed the difference to enhanced microbial activity that eventually improved the digestibility of the diets due to supplementation.

The lack of difference in OM and NDF digestibility between the control and DRD based concentrate diets implies that there was no adverse effect of DRD on OM and NDF digestibility. This agrees with several authors who observed no significant difference in OM and NDF digestibility when graded levels of DRD were fed to sheep (Mondal *et al.*, 2013; Olafadehan *et al*., 2014; Al-Wazeer, 2016). Zagorakis *et al*. (2018) replaced soybean meal with rapeseed meal (RSM), pea seeds, flaxseeds and lupin seed diets and observed no adverse effect on nutrient digestibility coefficients in sheep diets. Rufino *et al.* (2013) replaced 45% soybean meal (SBM) with inactive dry yeast (IDY) in lambs' diet and observed that replacing SBM with IDY in lamb diets maximized nutrient digestibility due to its fermentation ability.

The numerical increase in nutrient digestibility of the experimental diets is attributed to the superior nutritive values. This implies that the processed DRD was of good quality that resulted in high nutrient digestibility in the DRD based concentrate diets.

Rams fed control diet (T0) had better feed FCR but lacked significant difference in the study. Salinas-Chavira *et al.* (2007) observed no significant difference in FCR of lambs fed DRD based diets. Fajemisin *et al.* (2010) recorded similar result when 25% of DRD was included in Djallonké sheep diet. Abouheif *et al.* (1999) observed that Najdi sheep fed mixed rumen digesta-barley meal at 25% and 50% had lower FCR. Mondal *et al.* (2013) in Black Bengal goats showed higher FCR in the control diet than the 5% and 10% DRD

based diets. Contrary to the present study, Olafadehan *et al*. (2014) observed higher FCR in lambs fed 40% DRD based diet than those fed 0% and 20% DRD based diets but a decrease in the 60% DRD based diet. Al-Wazeer (2016) noted that lambs fed 10% DRD based diet had higher FCR than the control diets. Similar observation was reported by Osman *et al.* (2015) when DRD was incorporated in lambs diet at 0%, 5% and 10%; lambs fed 10% DRD based recorded higher FCR than the 0% and 5% DRD based diet. Osman and Abass, (2015) also reported similar trend in 10 and 20% DRD based diets fed Sudan desert lambs. Ristianto *et al.* (2016) reported higher FCR in silage rumen digesta (SRD) when Ongole crossbred cattle were fed 100% Napier grass, 67% Napier grass + 33% SRD, 33% Napier grass + 67% SRD, 100% SRD.

5.4 Growth performance

Feed has great effect on animals' growth and their products quality (Okoli *et al.*, 2003). Sheep grow slowly on low quality diet but grow rapidly on improved diet. This faster than normal growth is known as compensatory growth (Gatenby, 1991).

The inclusion of DRD in the diet of Djallonké young rams had no adverse effect on final weight and daily gain. There was improvement in the final live weight of rams. However, these improvement were not statistically significant between treatments. The present daily weight gains compared closely with the 16-48 g/d observed by Adu *et al.* (1992) but they were lower compared to the 79-91 g/d observed by Baiden *et al.* (2007) due to age and differences in diet quality. The final body weight of the experimental rams conform to several studies that showed no significant difference in animals fed DRD based diets at various levels. Fajemisin *et al.* (2010) observed no significant effect on daily gain of

Djallonké sheep offered 25% DRD and poultry dropping. Al-Wazeer (2016) partially replaced soybean meal and barley grain meal with DRD in diet of Awassi lambs and observed that fattening lambs on 10% DRD based diets improved growth performance with no significant difference in the final weight and daily gain of lambs. Fajemisen *et al*. (2010) replaced cassava peels with DRD at 25% fed to Djallonké sheep showed no significant effect on final and daily weight gain as compared to the control. Mondal *et al*. (2013) and Osman *et al.*(2015) fed lambs graded levels of DRD based diet at 0%, 5% and 10% and observed no significant effect on final weight and daily weight gain. Osman and Abass (2015) fed Sudan desert lambs DRD based diet at 0, 10 and 20% and showed no significant difference on weight gain. Salinas *et al.* (2007) also observed no significant difference on daily gain of lambs fed DRD based diet. Uddin *et al*. (2018) fed Black Bengal (BB) goats with DRD and observed similar final live weight and daily growth rate of 48 g/d for control diet and 47 g/d for DRD based diet.

There was a trend of decreasing rate in final weight and daily weight gain of rams with increasing levels of DRD in the present study. The control diet T0 gained 14.9% live body weight more than T3. The high CP observed in T3 did not translate to higher weight gain which could be attributed to low intake of the concentrate diet, undegradable dietary protein, age and difference in body physiology. Abouheif *et al*. (1999) recorded lower ADG in Najdi lambs fed 25 and 50% DRD-barley diet compared to the 0% DRD-barley diet. However, Olafadehan *et al.* (2014) found increase in final weight and daily weight gain in Yankasa lambs as levels of DRD increased from 0% to 40% but decreased at 60%. Osman and Elimam (2015) also recorded final weight of 30.27, 31.25, and 31.75 kg in

lambs fed graded levels of DRD based diet at 0%, 5% and 10%, respectively; however, these weight gains were not significantly different.

The similarity in weight gain implies that, the DRD based concentrate diets met the nutrient requirement of the experimental rams. Therefore processed rumen digesta would be a valuable source of protein to the ruminant livestock industry in Ghana.

5.5 Blood haematology and serum profile

Dietary treatments have significant effects on blood constituent values which can be used to draw conclusion on nutritive value of a diet offered to an animal (Church *et al*., 1984).

The haematological and serum parameters measured for all the treatment groups in this study did not differ from the control diet. The haemoglobin levels in this experiment were similar among the treatment groups. The values recorded in the study were lower than the values reported by Konlan *et al*. (2012) for Djallonké sheep on supplementation. However, the values for Hb fell within the range of 8-16 g/dl reported for normal sheep (Pampori, 2003). This means that the inclusion of DRD in the rams' diet was good enough to maintain the health of the rams. The packed cell volume (PCV) was similar among the treatments groups. Similar result was observed by Konlan *et al*. (2012) for Djallonké rams. Packed cell volume values recorded in the study was line with Jain (1993) and within 27-45% normal physiological range for healthy sheep.

The RBC and WBC counts were similar among the treatments groups. White blood cells are responsible for fighting infections and foreign materials entering the body. The similarity in WBC count implies that the ability of the rams to fight infection was not

compromised with the inclusion of DRD in the concentrate diet up to 12%. The values recorded were lower than the values recorded by Konlan *et al*. (2012) for Djallonké rams. However, they all fell within the normal range of 5 x 10^7/dl-11 x10^7/dl for healthy sheep (Scott *et al*., 2006). Ansah *et al.* (2011) found significant effect on Hb, PCV, WBC and RBC values between Djallonké young rams fed sole rice straw and whole cotton seed supplement. They attributed the difference to supplementation which promoted rumen microbial function.

The serum metabolites of the experimental animals did not indicate any significant differences among the dietary treatments. Ansah *et al*. (2015) recorded no significant effect on haematology and serum metabolites among rams fed rice straw supplemented with browse plants. The serum metabolite values obtained in this experiment met the normal values for sheep (Pampori, 2003) and they compared favourably with values observed by Ansah *et al.* (2016) and Konlan *et al*. (2012). Albumin levels were similar to what Ansah *et al.* (2016) and Konlan *et al*. (2012) obtained for Djallonké young rams on supplementation. The glucose levels were above the figures recorded by Ansah *et al.* (2016) but lower than what Konlan *et al*. (2012) reported for Djallonké sheep. Serum total protein was similar to what Ansah *et al.* (2016) reported but higher than that of Konlan *et al*. (2012). Serum total protein values were within the normal range of 60-93 g/l. The result conforms to Aruwayo *et al*. (2007) who observed no significant effect in the serum total protein of lambs fed rumen digesta and poultry dropping based diets. Dried rumen digesta based concentrate diets did not have any negative effect on the health of the experimental animals in the current study. Khattab *et al.* (2011) fed goats with untreated DRD and enzyme treated DRD and observed no significant effect on serum total protein. Aruwayo

et al. (2007) observed normal haematological indices and serum metabolite values in lambs fed DRD based diets. Oluwafemi and Iliyasu (2016) reported no adverse effect in serum total protein of rabbit fed with DRD with or without enzyme. The blood urea nitrogen levels were above what Ansah *et al.* (2016) reported for Djallonké rams on supplementation. The DRD based concentrate diets at 8% and 12% recorded lower serum total protein, globulin, creatinine and blood urea nitrogen levels compared to T0 and T1. The normal levels of haematological indices and serum parameters values suggest that the immune systems of the rams were not impaired by DRD based concentrate diet.

5.6 Carcass characteristics of rams

Feeding rams with DRD based concentrate diet had no significant effect on carcass characteristics. However, the T0 gained 3.85% more than T3 in dressing percentage. There was no significant effect of dietary treatments on primal cuts (the shoulder, thigh and neck) expressed as percentage of dressed weight. Rams fed DRD based concentrate diet had similar weight of primal cuts compared to the T0. Ledger (1965) reported that as animals grow their organs increase in weight but in proportion to their live weight. The internal and external organs did not differ among the treatments groups. The high CP intake in T3 did not influence the dressing percentage of the experimental rams. The internal organs showed no abnormalities or pathological lesions. Similar trend was observed by Abouheif *et al.* (1999) when lambs were fed DRD and barley mixture in a ratio of 4:1 showed no statistical difference on carcass characteristics expressed as dressing percentage and per kg bases compared to the control diet. The lack of differences observed in both carcass and non-

carcass characteristics might be due to similar effect on weight gain of the experimental rams.

CHAPTER SIX

6.0 Conclusions and recommendations

6.1 Conclusions

Based on the results obtained from the study, it can be concluded that:

- The CP levels of the concentrate diets and DRD meet the requirement for ruminant supplementation.
- Dried rumen digesta had effect on *in vitro* degradability organic matter digestibility and metabolizable energy.
- The inclusion of dried rumen digesta in the diet of rams had an effect on daily concentrate intake.
- The growth performance of rams was not adversely affected by DRD based concentrates.
- The inclusion of dried rumen digesta in the diet of Djallonké sheep did not affect blood haematology and serum profile.
- The carcass and non-carcass characteristics were not affected by DRD based concentrate diets.
- Dried rumen digesta could be used as protein supplement to partially replace soybean meal (SBM) in sheep diet to help address the shortage of quality forage during dry season and also help to reduce waste pollution in slaughterhouses in the Northern Savanna zone of Ghana.

6.2 Recommendations

- Farmers can replace soybean meal with dried rumen digesta up to 12% to rams to reduce cost of production and to maximize their income.
- Similar research should be carried out on goats and poultry to determine the quality of DRD on their growth performance.
- Further study should be carried out using different drying methods. This will provide information on the best and most cost effective method to adopt to process rumen digesta while retaining its nutritional quality and the best method that extends shelf life when stored after processing.
- Further study should be carried out to determine the nutritional quality of cattle, goat and sheep rumen digesta in terms of season to find their average nutrient compositions.
- Finally, the inclusion levels of the DRD should be increased or the soybean meal replaced totally with rumen digesta in order to determine dried rumen digesta full potential in the livestock industry in Ghana.

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APPENDIX

Analysis of variance
In intro gas production

Variate: IVOMD					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.5076	0.2538	0.36	
Treatment	3	10.3093	3.4364	4.86	0.048
Residual	6	4.2420	0.7070		
Total	11	15.0588			

Variate: ME					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.01148	0.00574	0.36	
Treatment	3	9.79233	3.26411	204.08	<.001
Residual	6	0.09597	0.01599		
Total	11	9.89978			

Variate: SCFA					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.281E-06	6.404E-07	0.36	
Treatment	3	3.645E-05	1.215E-05	6.81	0.023
Residual	6	1.070E-05	1.784E-06		
Total	11	4.844E-05			

Variate: b					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.748	0.374	0.23	
Treatment	3	20.495	6.832	4.25	0.062
Residual	6	9.640	1.607		
Total	11	30.883			

Variate: c					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.0001389	0.0000694	0.61	
Treatment	3	0.0000836	0.0000279	0.25	0.861
Residual	6	0.0006787	0.0001131		
Total	11	0.0009012			

Variate: half_life					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.7248	0.3624	0.86	
Treatment	3	0.1586	0.0529	0.12	0.942
Residual	6	2.5431	0.4238		
Total	11	3.4265			

Feed intake

Variate: concentrate diet intake					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	231.64	77.21	7.52	0.004
Residual	12	123.24	10.27		
Total	15	354.88			

Variate: total_intake_g_kg_WB					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	18.61	6.20	0.08	0.970
Residual	12	935.81	77.98		
Total	15	954.41			

Variate: daily_Gain_CP_intake_g					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.03161	0.01054	0.77	0.533
Residual	12	0.16432	0.01369		
Total	15	0.19593			

Variate: ME_intake					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	1.6255	0.5418	0.57	0.647
Residual	12	11.4764	0.9564		
Total	15	13.1019			

Variate: NDF_Coefficent					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.013263	0.004421	0.65	0.598
Residual	12	0.081554	0.006796		
Total	15	0.094816			

Variate: NDF intake					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	3744.4	1248.1	2.10	0.154
Residual	12	7129.4	594.1		
Total	15	10873.8			

Variate: OMI					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	446.1	148.7	0.40	0.755
Residual	12	4459.3	371.6		
Total	15	4905.4			

Variate: Total_DMI					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	409.	136.	0.09	0.962
Residual	12	17310.	1442.		
Total	15	17718.			

Variate: con_g_kgBW0_75					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	6.529	2.176	0.25	0.857
Residual	12	102.850	8.571		
Total	15	109.380			

Variate: concentrate Intake					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	291.98	97.33	9.65	0.004
Residual	12	121.08	10.09		
Total	15	413.06			

Variate: cp_g_kgWB$^{0.75}$					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	1.5889	0.5296	1.36	0.303
Residual	12	4.6860	0.3905		
Total	15	6.2750			

Growth performance

Variate: INITIAL_WEIGHT					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.202	0.067	0.01	0.999
Residual	12	86.808	7.234		
Total	15	87.009			

Variate: Final_weight_kg						
Covariate: INITIAL_WEIGHT						
Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
TREATMENT	3	0.7164	0.2388	0.36	1.00	0.786
Covariate	1	68.9613	68.9613	102.70		<.001
Residual	11	7.3861	0.6715		9.48	
Total	15	77.5641				

Variate: Daily_gain_g						
Covariate: INITIAL_WEIGHT						
Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
TREATMENT	3	184.4	61.5	0.36	1.00	0.783
Covariate	1	255.5	255.5	1.50		0.247
Residual	11	1876.1	170.6		1.04	
Total	15	2306.0				

Variate: daily_straw_intake					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	475.	158.	0.12	0.944
Residual	12	15260.	1272.		
Total	15	15734.			

Blood profile

Variate: MCV_f_l					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2.580	0.860	0.19	0.896
Residual	4	17.780	4.445		
Total	7	20.360			

Variate: PCV_%					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	1.4138	0.4713	2.64	0.186
Residual	4	0.7150	0.1787		
Total	7	2.1287			

Variate: RBC_10_12_l					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0415	0.0138	0.03	0.992
Residual	4	1.9015	0.4754		
Total	7	1.9430			

Variate: WBC_x_10_9_l					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	4.165	1.388	1.05	0.463
Residual	4	5.296	1.324		
Total	7	9.462			

Variate: albumin					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	1.820	0.607	0.24	0.867
Residual	4	10.280	2.570		
Total	7	12.100			

Variate: calcium					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.16494	0.05498	2.58	0.191
Residual	4	0.08515	0.02129		
Total	7	0.25009			

Variate: creatinine					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2981.	994.	0.92	0.507
Residual	4	4320.	1080.		
Total	7	7301.			

Variate: globulin					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	8.860	2.953	1.48	0.347
Residual	4	7.980	1.995		
Total	7	16.840			

Variate: glucose					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.1996	0.0665	0.14	0.931
Residual	4	1.9039	0.4760		
Total	7	2.1035			

Variate: urea					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	5.112	1.704	0.28	0.838
Residual	4	24.298	6.075		
Total	7	29.410			

Dressing percentage

ssVariate: Dressing percentage					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	15.492	5.164	2.89	0.166
Residual	4	7.152	1.788		
Total	7	22.644			

Variate: %half					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	4.5854	1.5285	1.80	0.286
Residual	4	3.3941	0.8485		
Total	7	7.9794			

Variate: shoulder_%					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	15.230	5.077	4.90	0.079
Residual	4	4.147	1.037		
Total	7	19.377			

Variate: thigh %					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	6.3433	2.1144	5.62	0.064
Residual	4	1.5040	0.3760		
Total	7	7.8473			

Variate: Live WT					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	3.003	1.001	0.35	0.794
Residual	4	11.535	2.884		
Total	7	14.538			