UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF DIFFERENT VARIETIES OF GROUNDNUT *(Arachis hypogaea L)* HAULMS ON DIGESTIBILITY AND GROWTH PERFORMANCE OF *DJALLONKÉ* SHEEP

BY

ASARE-AGYAPONG, EMMANUEL (BSc. AGRICULTURE TECHNOLOGY)

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DECLARATION

I, **Emmanuel Asare-Agyapong**, declare that this dissertation has not been presented in any previous institution for a degree other than University for Development Studies and that it is my original work conducted under the supervision of Prof. Addah Weseh. All assistance towards the production of this work and all the references contained herein have been duly acknowledged.

Candidate's Signature…… Date……..

Asare-Agyapong, Emmanuel

Principal Supervisor's Signature…… Date……

Prof. Addah Weseh

DEDICATION

This study is dedicated to my family and friends.

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ABSTRACT

Seasonal factors affect the availability and nutritive value of groundnut haulms. Hence some farmers prefer early-maturing varieties while others prefer late-maturing varieties. This study determined the effects of bale temperature on spontaneous heating of groundnut haulm bales, digestibility and growth performance of sheep fed early- or late- maturing varieties of groundnut haulms. Early-maturing varieties (90 days) included Chinese, Yenyawoso and Sumnut 23 whereas late-maturing varieties (110−120 days) were Sumnut 22, Azivivi and Manipinta. Split plot design was employed to cultivate each variety on 4 different replicate plots of 2.4 × 4.0 m^2, 3.6 × 4.0 m^2, 4.8 × 4.0 m^2 and 6.0 × 4.0 m^2. At maturity, all the varieties were harvested. The pods were separated from the haulms (leaves and twigs) and equal portions of the haulms were combined into early- or late-maturing varieties. In experiment I, the groundnut haulms were baled and shade dried. During the shade drying, core bale temperatures and room temperatures were recorded at the same hour (3:03:00 PM) Greenwich Mean Time (GMT) in the consecutive days as it was done for the first day. Each of the combined haulms were then dried to a DM of 92% and chopped to a theoretical length of 3–4 cm before being used to formulate two diets that were fed to West African Dwarf growing rams (14.75 ± 2.52 kg) every morning (07:00 am GMT) and every evening (05:00pm GMT). in experiment II. In experiment III, two fistulated Nungua Black Head sheep were used to determine the *in situ* digestibility of early- or late- maturing groundnut haulms. The concentrations of ADF and ADL were greater ($P < 0.05$) in the early- compared to late- maturing haulms whereas the extent of digestibility of the late-maturing varieties was higher than the early-maturing variety. The intake and growth performance of sheep did not however differ ($P = 0.69$). This study suggests that duration to maturity has no effect on the nutrient quality of groundnut haulms and on the growth performance of sheep.

Keywords: Bale, Early-maturing, groundnut haulm, late-maturing, in situ digestibility, in vitro digestibility, sheep.

CHAPTER ONE

1.0. Introduction

Groundnut (*Arachis hypogaea* L.) is a member of the Fabaceae family and is cultivated in most tropical and subtropical nations, including Ghana (FAOSTAT, 2013). Groundnut, also referred to as peanut, is Ghana's most vital grain legume in terms of land farmed (MoFA-SRID, 2014). More than 70% of the total amount of groundnut produced in Ghana is traced to the Guinea savanna ecology (MoFA-SRID, 2014), which makes it the country's largest groundnut yielding region. Because the groundnut crop is under larger area of cultivation in Ghana, hence the need for the forage/haulms to be conserved after the farming season for future use. The haulms are therefore supposed to be reduced to favourable moisture content and baled. Even though baling is not a common practice in Ghana, the few farmers who practice it in Ghana are faced with many challenges among which poor drying is a major challenge. As a result, farmers do not wait for the hay to attain the favourable moisture content before baling. The maximum moisture content suitable for storing small (45kg) rectangular bale is about 20% (Collins *et al*., 1987). Once the moisture exceeds the recommended 20% for small rectangular bale, microorganisms will cause deterioration of bale. These microorganisms convert plant sugars into carbon dioxide, water and heat causing the phenomenon of spontaneous heating (Rotz and Muck, 1994). The spontaneous heating phenomenon is linked with mould growth (Roberts, 1995). Coblentz and Hoffman (2009) reported that spontaneous heating reduces the digestibility of forages. There are losses associated with the hay making process and there is a need for more information on such losses. Specifically, more information is needed on the changes in both quantity and quality as the crop advances from mowing to ingestion by the animal (Rotz and Abrams, 1988). Hence, groundnut haulms, which

are extra palatable and protein-rich compared to cereal stovers with low nitrogen, high fibre, and low digestibility and are used as supplementary feed (Singh *et al*., 2011), must be evaluated for the effects of chemical reactions and microbial growth caused by spontaneous heating.

In the sub humid zone of West Africa, groundnut is an essential plant in the production of fodder and seed in smallholder crop-livestock farming systems (ICRISAT, 1991; Njie and Reed, 1995; Olorunju *et al*., 1996). Groundnut haulms in Ghana is often utilized as supplementary feed in ruminants production (Konlan *et al*., 2012) by small-scale farmers who rely mostly on natural grassland. Groundnut haulms are utilized as fodder for livestock, particularly during the lean seasons (Brandenburg *et al*., 2003). Groundnut haulm is the most vital of its by-products that maybe supplied as feed to livestock and its fodder providing additional financial gain to smallholder farmers (Arslan, 2005).

The cake is used as a protein supplement in livestock feed after extracting oil from seed for human consumption. Groundnut haulms are mainly fed to ruminants after pods are harvested, mainly in the lean season (Njie and Reed, 1995; Olorunju *et al*., 1996). Small-scale crop-livestock farmers consider forage yield and quality and seed yield of groundnut as joint products with equal value and significance (Olorunju *et al*., 1996). Late-maturing groundnut varieties are preferred to the early-maturing varieties by the Small-scale crop-livestock farmers in subtropical zone of West Africa (Olorunju *et al*., 1996), since the late-maturing varieties yields more forage for livestock and seeds in addition. An on-farm trial, using three improved varieties of groundnut and a local variety showed that the improved varieties were superior to the local variety in terms of forage yield and quality, CP, NDF and rumen dry matter degradability characteristics (Dung *et al*., 1999). Omokanye *et al*. (2002) also reported that there was sufficient concentration of CP and NDF to sustain livestock production in the critical periods of the farming season in groundnut forage, with

the improved cultivars out-performing the local cultivars. Feeding trials on groundnut haulms in the past is centered on supplementary diets with few studies on sole feeding or cultivar effects (Ikhatua and Adu, 1984; Durga *et al*., 1986).

Crop residues degradation characteristics in the rumen are the main determining factors of residue quality, since they are top predictors of animal performance (Orskov, 1991). The varieties of groundnut which vary in seed yield and forage yield have been developed by plant breeders to meet particular production target (Ntare and Waliyar, 1998). However, the value of crop residue is hardly a primacy as programmes improving groundnut varieties focuses primarily on seed yield, resistance to pests and diseases and drought-tolerant (Parthasarathy and Hall, 2003; Pande *et al*., 2003).

Considerable attention has been drawn to the problems in feeding ruminants in the tropics and subtropics (Tesfayohannes, 2003). Poor quality, unavailability and insufficient forage crops and farm waste in most developing countries puts ruminants in constant harm from under feeding chiefly in the dry seasons (Nyako, 2015). The quantity and quality of feed in the dry season is the major challenge amidst the numerous limitations of livestock production in Ghana (Oppong-Anane, 2013). This is because human population has increased and the cost and demand for conventional feedstuffs like soya bean meal and groundnut cake is on the increase, it is quintessential to use other feed ingredients to reduce the competition between humans and livestock (Iyeghe-Erakpotobor *et al*., 2002). One attainable practice to lessen this drawback and retain production is to feed crop residue and browse plants to ruminants as alternative feed during the lean seasons in the tropics (Okafor *et al*., 2012). Adamu *et al*. (2013) noted that native forage resources of the savannah zones of the country will meet requirement of the animals for

maintenance and low levels of production for about only 2 to 3 months of the year. However, rangeland is declining because of increase in land use for crop production (Lamidi, 2005).

The obtainable crop residues like cereal straw, maize husk, corn cob and maize stovers do not meet ruminants' nutritional requirements (Ibrahim and Yashim, 2014). This has led to a cyclical body weight gain in the rainy season and weight loss during the lean seasons (Annor *et al*., 2007). Brand *et al*. (1991) suggested that urea-ammoniated diets like barley, maize stovers, oat, wheat straw and oat hay might not be adequate for production functions like growth, gestation and lactation.

This is because of the very fact that legume based diets are more digestible and so more volatile fatty acid (VFA) are produced per unit weight than from grass counterparts (Orskov and Ryle, 1990). Van Soest (1994) reported higher CP and lower fibre in tropical legumes than in grasses and so can serve as a valuable supplements to straw based rations.

Groundnut haulms represent a nutritious fodder for livestock. The haulms of groundnut contains (38%–45%) carbohydrate, (8% -15%) CP, (1%–3%) lipids, (9%–17%) minerals and at quantities higher than cereal straws. Nutrients degradability in groundnut haulms is estimated at 53% with that of CP at 88% once fed to cattle. Equivalent energy of 2,337cal/kg of dry matter is released by the haulms (Janila *et al*., 2013). Groundnut haulms contains 47%, 36.5% and 6.3% of NDF, ADF and lignin respectively (Ayantunde *et al*., 2008). Digestibility of groundnut haulms ranges from 74% to 88% in ruminants and maintain animals' growth performance even when fed as sole feed (Karbo *et al*., 1997). Nigam and Blummel (2010) reported an In vitro degradability range of 52% to 61%. Kamstra *et al.* (1958). Van Soest (1967) reported that poor degradability is associated with the level of lignification of the cell wall components.

The aim of this study therefore was to assess the effects of internal bale temperature on spontaneous heating, nutritive value, in vitro (48 h) DM disappearance and in situ ruminal

disappearance kinetics of six groundnut varieties and the growth performance of West African Dwarf (Djallonké) growing rams. The different varieties of groundnut was selected for this study because it is a cash crop commonly cultivated in the sub-tropical countries including Ghana; its seeds are sold with haulms serving as a good source of feed for ruminants during the lean season.

1.1. Study Objectives

1. To assess the effects of bale temperature on spontaneous heating within groundnut haulm hay during storage.
2. To evaluate the nutrient composition of early- or late- maturing varieties of groundnut haulms and their effects on digestibility and growth performance of West African Dwarf (Djallonké) growing rams.

CHAPTER TWO

2.0. Literature Review

2.1. Ruminant Production in Ghana

The predominant livestock kept in Ghana are cattle, sheep and goats. This is because, ruminant animals are capable of transforming unsuitable plant material into high-quality food products for human consumption. Such animals may be owned by individual members of the household, including men and women (Dossa *et al*., 2008), it could be housed next to houses and herded by younger members of the family (Asafu-Adjei and Dankwatah, 2001). Ghana's ruminants are produced primarily in the extensive system of production (Oppong-Anane, 2011).

Marginalized and landless farmers rear sheep and goats, not for meat only but as a vital source for savings and wealth as well as insurance for crop failure (Otchere 1986; Dossa *et al*., 2008). Because such farmers are poor and rely solely on low input and production technologies (Turkson and Naandam, 2006), such insurance policies and wealth and savings might fail as well.

Roughly 25% of Ghana's 13.3 million small ruminants are raised by peri-urban and urban residents (Oppong-Anane, 2011). Ghana also imports most of its live animals (most of them ruminants) and meat products from neighbouring countries such as Togo, Benin, Niger and Burkina Faso and sometimes from European countries.

Table 1: Importation of live animals into Ghana (2007-2016; MoFA, 2017).

Year	Cattle	Sheep	Goats	Total
2007	8,891	6,594	4,498	19,983
2008	1,081	1,401	1,514	3,996
2009	10,119	4,987	6,098	21,204
2010	11,389	4,843	3,711	19,943
2011	9,384	2,835	2,495	14,714
2012	23,622	9,840	10,008	43,470
2013	21,131	16,738	16,953	54,822
2014	20,948	22,188	32,012	75,148
2015	17,968	15,763	20,004	53,735
2016	23,575	13,854	16,900	54,329

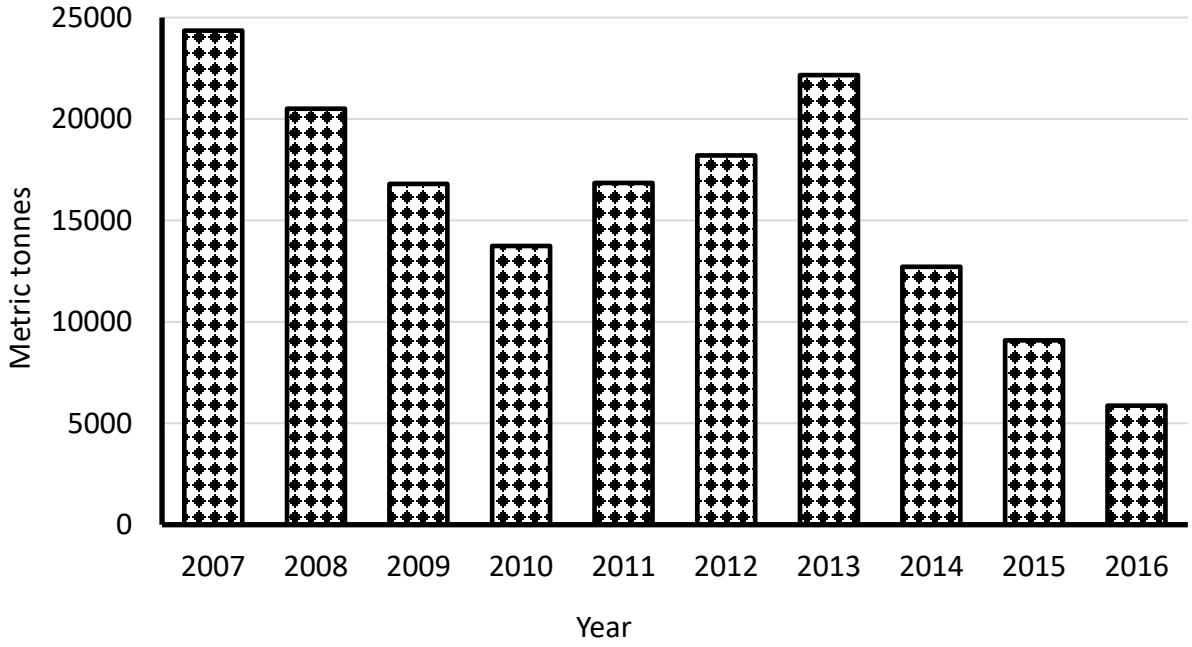

Figure 1: Importation of bovine (beef and buffalo) products (Metric tonnes) into Ghana (2007-2016; MoFA, 2017).

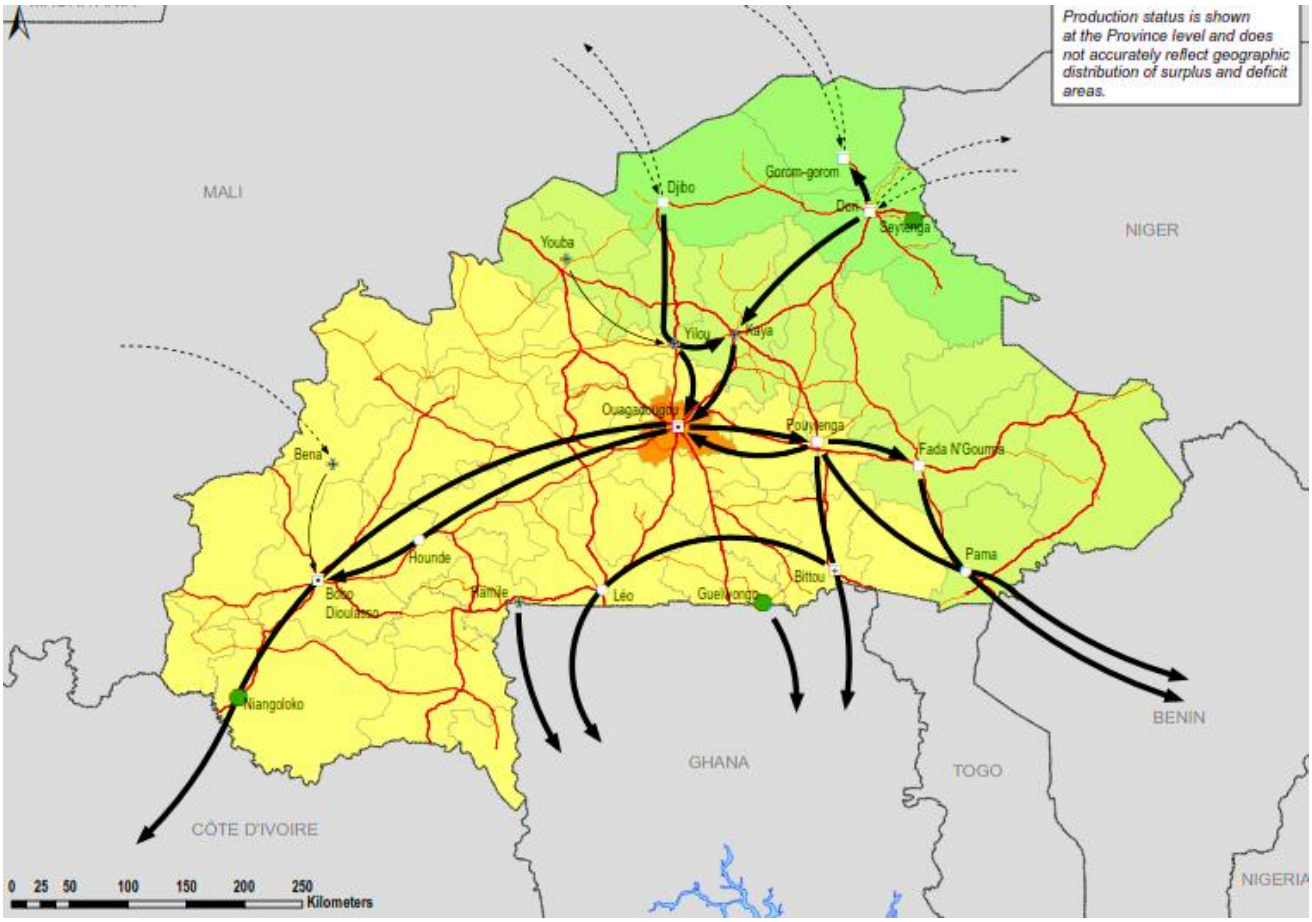

Figure 2: Importation of livestock from Burkina Faso to Ghana through major livestock markets (Guelwongo, Léo, Hamile, Bittou) in Burkina Faso into Ghana and Cote d'viore and Benin (source: http://fews.net/west-africa/burkina-faso/production-and-trade-flow-map/october-2017-0)

2.2. The West Africa Dwarf (Djallonké) Sheep

The West African Dwarf (djallonké) sheep does not certainly display traits of dwarfism (World Bank, 1992). The djallonké sheep is the commonest breed reared in Ghana, and are used in breeding programmes by parastatal farms or individual farmers (Karbo *et al*., 1997; Oppong-Anane, 2006). It is well-known for its stress and disease resistance and tolerance to harsh weather conditions and trypanosomiasis, prolific and able to lamb all year round. The production of small ruminants is thus dependent on breeds that tolerate trypanosomiasis (Mahama *et al*., 2003; Oppong-Anane 2011). This is because breeding of animals which are trypano-tolerant (e.g. Western African Dwarf) is economical and more sustainable than combatting trypanosomosis and worm disease (Mawuena, 1986; Mawuena, 1987; Osaer *et al*., 1994).

The djallonké has an average matured weight of 25kg-30kg for male and between 20kg to 25kg for females (Oppong-Anane, 2006) with 40cm - 60cm of height at the withers (Koney, 2004; Gbangboche *et al*., 2008). It has fine hair and are usually black and white in colour, with the white colour dominating (Suleman, 2006). The djallonké is a thin-tailed sheep from West Africa Dwarf breed (Traore *et al*., 2008). Its reproductive performance on the average is 1.28 lambs/ewe/year and mortality between birth and weaning is 0.3 (Mourad *et al*., 2001). Generally, the mortality rate is about 21% and off-take rate (proportion of animal sold or consumed per annum) stands at 38% for the djallonké sheep managed under the traditional production system (World Bank, 1992).

In Ghana, the total value for sheep is US$ 75,485,000.00, or 14.2% of the total livestock output, according to GLSS (2008). The northern regions of Ghana (Savana Zone), where about 60% of sheep are reared by rural households, are homes to a large population of these sheep. The remainder are divided among rural forest regions (22%), urban centers (12%) and coastal savannah (6%); (Sadat, 2015).

2.2.1. Growth Performance of West Africa Dwarf (Djallonké) Sheep

The quantity and quality of the available forages and natural pastures during the dry season are low in the necessary nutrients needed for increased rumen microbial fermentation. This results in weight losses, low birth weight, reduced disease resistance, poor digestibility and overall poor animal performance (Jiwuba *et al*., 2016).

Feeding level, genotype, sex, health and management are the main determinants of growth (Mike, 1996). The rate of growth of lambs depends on sex, birth year and month (Tuah and Abu, 1988). Because of these whether diet is restricted or not, ram lambs grow faster than ewe lambs (Ansaayiri, 1996).

The live weight of djallonké sheep is 40-50g/day from birth to 5 months of age (Rombant and Van Vaenderen, 1976) but may be up to 80g/day if the diet is sufficiently supplemented (Berger, 1983). Karbo *et al*. (1997) reported an average daily weight gains of 130g and 87.9g in Sahelian and Djallonké crosses fed cassava peels and pigeon pea waste basal diets respectively.

Ngwa and Tawah (1991) reported that, for rice straw, groundnut haulms, cotton seed, and cowpea vines, Djallonké sheep with average live weight of 22kg at age 15 months recorded a daily increase in weight of 29.0 g, 48.9 g, 52.4 g and 49.2 g respectively. Etela and Dung (2011) noted even more difference in daily live weight changes from -6 to 46g/day when six different cultivars of groundnut haulms were fed as sole diet to Djallonke.

2.3. The Nutrient requirement of sheep

The major sources of energy for sheep are Crop residues, Natural pastures, silage, grains and agricultural industrial by-products.

The more the distance a sheep covers for food and water, the greater their nutritional requirements, therefore sheep kept under the intensive system of production have lower nutritional requirements

than free ranging sheep (NRC, 2007). For every kilometer traveled, sheep need 2.6 kg of feed/kg of body weight (McDonald, 1991). McDonald *et al*. (1995) reported that 0.46 kg/d of DM intake, 4.8MJ/kg of metabolizable energy is required to grow a 20 kg body weight lambs with a daily average weight gain of 0 to 50 g. As microbes in the rumen can produce protein from amino acids, the protein in a sheep's diet is more significant than the protein quality (NRC, 2007). In addition, there are higher protein requirements for young lambs that build up muscle and lactating ewes that synthesize milk protein (NRC, 2007).

2.4. The potentials and constraints of ruminant production in developing countries

The production of Farm animals in the sphere of sub-Saharan Africa (SSA), contributes up to 35% to agricultural GDP according to Pritchard *et al*. (1992). In promoting sustainable livelihoods in arid regions of sub-Saharan Africa, like Northern Ghana, small ruminant make a particular economic contribution to the livelihoods of the poor (ADF, 2001; IFAD, 2004; Otte *et al*., 2010). The production of livestock contributes to food security through direct food production (animal products) and non-food functions (Sanon, 1999). In terms of the food function, ruminant animals are capable of transforming unsuitable plant material into high-quality food products for human consumption.

The inaccessibility to modern supplies, for example tractors and fertilizers, and the maintenance of the viability and environment sustainability of production, by most smallholder farmers is compensated for by their animal draught power and nutrient cycling through manure (Sanon, 2007). Work carried out annually by draught animals, if carried out by motorized machinery, would require 20 million tons of petroleum worth US$ 6 billion as projected by Steinfeld *et al*. (1997). In the times of crop shortages, livestock also represents a means of savings, a food reserve and a key investment and insurance asset (Sanon, 2007). The use of livestock as gifts, for dowry

and for traditional festivals or for religious ceremonies strengthens the relationship between families and society.

The production of livestock in SSA is, nevertheless, subject to numerous limitations, most of which is feed scarcity. Producing farm animals in Northern Ghana is inhibited by several factors of which quantity and quality feed in the lean season contributes most to the challenge (Oppong-Anane, 2013). This has led to a cyclical body weight gain in the rainy season and weight loss during the lean seasons (Annor *et al*., 2007). The main feed resource for livestock is the natural pastures. The productivity of these pastures depends heavily on rainfall and seasons over the years.

2.5. Degradation of Forages

The low protein concentration of tropical grasses and crop residues has been reported as a key limitation to animal production (Minson, 1990; Egan, 1997). Ruminant diets need to contain sufficient amounts of protein that would be digested in the rumen to energize microbes in the rumen to the maximum magnitude for fermentation, to guarantee adequate amount of microbial nitrogen move to the intestine to fulfil amino acids requirements of the animal (Siddons *et al*., 1985; Hvelplund and Madsen, 1990). The composition of diets hangs on the actual amount of CP within the feed ingredients which are degraded in the rumen (Broderick *et al*., 1988; Tamminga *et al*., 1991). Ruminants with high productivity provided with certain specific amino acids under certain conditions met their requirements (Schwab *et al*., 2007). Digestion of protein within the rumen by *protozoa lapidate* produces amino acids and ammonia and peptides, major sources of nitrogen to the animal. Rumen bacteria are important in this process (Orskov, 1982; Stern *et al*., 1994). The bacteria also have the capacity to degrade cellulose (Lindberg, 1985; Wallace and Cotta, 1988). On the other hand, protozoa has the ability to decompose the protein also (Russell and Hespell, 1981).

Nature and counts of microbes influence the rate of protein degradation in the rumen. It is essential to supply sufficient quantity of protein to be degraded in the rumen to meet the requirements of the bacteria, to generate enormous amount of microbial protein with essential amino acids (Stern *et al*., 1994; Klopfenstein *et al*., 2001). Crude protein in the feed is important as a nitrogen source in the rumen (Orskov, 1982) and in the feed which suffers from lack of protein degraded in the rumen like most grain, will limit the fermentation by microbes, which has a negative impact on digestion of fibre in the rumen (Martin-Orou *et al*., 2000). There is little benefit in raising the level of protein degraded or undegraded when formulating diets with higher levels of protein (Sloan *et al*., 1988). Foods containing low rumen degradable protein are particularly important for ruminants that need high protein level in their diets (Broderick *et al*., 1991).

Furthermore, feed crude protein can be grouped into potentially digestible fraction, fraction not digested and rapidly digestible fraction (NRC, 2001). Digestibility of a feed crude protein is determined by the fraction not digested, while digestion of crude protein is determined by the relationship between fractional rate of digestion and the passage rate out of the rumen (Van Straalen and Tamminga, 1990; Broderick *et al*., 1991), with the latter influenced mainly by dry matter intake. National Research Council applies a discount factor to decrease energy value and ruminal crude protein digestion at higher intakes (NRC, 2001). For instance, when dry matter intake increases from 25kg/day to 30kg/day, the metabolisable energy value of the feed is discounted by 4% and the diet crude protein digestibility is decreased by about 3% (NRC, 2001). Factors affecting the amount of crude protein digested in the rumen include the amount of crude protein consumed, solubility of crude protein in rumen fluid and the residence time of the crude protein in the rumen (Netemeyer *et al*., 1980).

Differences in digestibility can be caused by differences in the rumen environment and by the differences in resistance to proteolytic enzymes (Orskov, 1992). Digestibility of crude protein varies among feeds, and within feed due to chemical or physical treatment of the feed (Lindberg, 1985; Madsen and Hvelplund, 1985; Orskov, 1992). Hence, degradation of crude protein in a mixed diet can be influenced by choosing ingredients with high or low degradability (Tamminga, 1979; Van Straalen and Tamminga, 1990). When diets are balanced for rumen degradable protein (RDP) and rumen undegradable crude protein (RUP), average or book values for these fractions of individual feeds are used (Stallings *et al*., 1991; Aldrich *et al*., 1996). The degradability of a diet can be predicted using crude protein degradability values of individual ingredients (Stallings *et al*., 1991; Aldrich *et al*., 1996).

2.5.1. Forage Evaluation Techniques

The kinetics of forage digestion is essential, since the extent and rate of digestion of feed in the rumen determines to a large extent voluntary intake (Hovell *et al*., 1986; Orskov *et al*., 1988).

A multifaceted process with complex interactions between microorganisms present (bacteria, protozoa and fungi) as well as between the microbial population and the host occur during microbial degradation of forages in the rumen (Czerkawski, 1986).

In order to estimate the extent of forage digestibility, several indirect methods have been used. The Tilley and Terry (1963), two-stage in vitro procedure has been employed extensively to predict digestibility of forages for ruminants and to screen large numbers of forages in plant nursery programs. But the method does not provide data on kinetics of digestion, and determines only an end point of digestion after 48 hours. Grant and Mertens (1992) demonstrated that the method could be modified by using only the first incubation phase to measure the (IVDM) degradation pattern over time.

The bag procedure, where the nylon bags are suspended in the rumen of fistulated animals and chronologically removed for determination of DM may provide data on the extent and rate of the dry matter degradability of feed (Orskov and McDonald, 1979). The accuracy of the bag technique is impelled by several technical features such as amount of sample in relation to bag size, pore size of the nylon bag, particle size of sample, method of washing after removal from the rumen and the basal diet of the fistulated animals (Uden *et al*., 1974; Noeck, 1985; Van der Koelen *et al*., 1992). McBee (1953) and Hungate (1966) first developed the principle of determination of the fermentability of feed or potential rumen degradability by means of quantifying gases generated from a batch culture.

Czerkawski and Breckenridge (1975) developed the direct displacement of a plunger through fermentation of feedstuffs in a glass syringe and was the foundation of the 'Hohenheim gas test' later engineered by Menke *et al*. (1979). Blummel and Orskov (1993) modified the method by incubating the syringes in water bath, instead of a rotary incubator. Measuring the rate of gas production during In vitro fermentation of forages with microbial rumen inoculum has been shown to be used to assess kinetics of fermentation (Theodorou *et al*., 1991; Beuvink and Kogut, 1993; Blummel and Orskov, 1993; Khazaal *et al*., 1993). For the measure of In vitro gas produced from forages, Theodorou *et al*. (1991, 1994) developed the pressure transducer technique (PTT). Factors that can affect the kinetics of gas production such as inoculum, atmospheric pressure changes, sample size effects and preparation must be investigated to determine the exactness of the results achieved (Ansah *et al*., 2016).

2.5.2. Kinetics of Rumen Degradation

Digestion site or location and the ratio of VFA's and lactic acid are largely determined by kinetics of degradation characteristics of fermentation of feed in the rumen (Yu *et al*., 2004).

In past times, researchers examined the association between kinetics of fermentation attained by In sacco procedure and the In vitro gas production method (Blummel and Orskov, 1993; Lopez *et al*., 1999; Cone *et al*., 1999, 2002). These techniques include feed incubation in rumen or using rumen fluid to assess kinetics of rumen digestion (Fonseca *et al*., 1998). For each substrate, the time-course disappearance curve is used to assess the kinetics of rumen feed degradation, by assuming that the disappearance from the bag equals rumen degradation (López *et al*., 1999). Kamalak *et al*. (2005) reported higher dry matter degradability associated with incubation time increment. Dry matter degradability at all incubation times for Lucerne haulms and silage of maize was significantly greater than those of barley and wheat stovers. The degree of fill in the reticulo-rumen has also been suggested as the dominant factor limiting voluntary intake of poor quality roughage diets because they have longer rumen retention time (Grovum and Williams, 1979). Decreasing the retention time however, tends to increase passage rate and decrease the extent of fiber degradation in the rumen (Van Soest, 1982).

2.6. Agro by-product and agro-industrial by-product used as feed for ruminants

Agro by-products derived in mixed farming systems (Thornton *et al*., 2002), have been referred to by El-Nouby (1991) as those materials gotten other than the main products for which the crop was cultivated. They comprise on-farm by-product or crop residues such as stovers, leaves, tops and stubbles (El-Nouby, 1991). Approximately 8,000,000 metric tons of cereal stems and 3,500,000 metric tons of root and tuber residues are produced annually in Ghana (Oppong-Anane, 2006).

Agro-industrial by-product (AIBPs) are obtained from the processing of cassava peels, yam peels, cocoyam peels, rice bran, rice husk, cowpea husk, maize husk, pineapple peels and banana peels (El-Nouby, 1991). After harvesting and processing agricultural products, agricultural waste is the remaining residue. It may be categorized as crop residue and agro-industrial by-products (Tripathi *et al*., 1998; Sindhu *et al*., 2002). They may be low or high in fibre (sugarcane bagasse, palm press

fibre), rich in nitrogen (oilseed cakes, brewery), more concentrated (molasses), highly nutritious and less costly compared to crop residues (Smith, 1988; Aguilera, 1989). The demanding nature of humans for several food types has led to an increase in the availability of agro-industrial by-products (AIBPs), which are not fully used in livestock feeding (Amata, 2014). As more land is grown to meet a growing population's needs, crop residues have become an important source of animal feed (Harris, 2002). They account for 40% to 60% of the total DM intake of cattle in the Sahelian regions, especially during dry seasons (de Leeuw, 1997). The difficulty in the use of AIBPs as fresh material for long periods and the lack of efficient ways for their incorporation in feeding regimes may be the reason for their underutilization (Chadhokar, 1984). The use of AIBPs as a part of feed for livestock reduces the cost of production, improve feed quality, guarantee regular feed supply even during the lean season and finally increase the profit margin of livestock farmers (Sindhu *et al*., 2002). Different agro-industrial by-products like soya bean cake (Obese, 1998), groundnut haulms (Weseh, 1999), cotton seed (Avornyo *et al*., 2001) and rice straw (Karbo *et al*., 2002) used to feed ruminants have been stated as a good supplementary feed for ruminants. Agro-industrial by-products are generally classified as protein, energy and or combined protein-energy sources (Aregheore, 1998). The energy sources are rich in fermentable carbohydrates and lack protein. Examples are cassava peels and molasses, a by-product of the sugar industry (75%DM, 4.1%CP and MJ/kg DM). 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), blood meal (80% CP), soya meal (48% CP), groundnut cake (40%-48%CP) and copra meal (18.8% CP). The combined protein-energy is from cereal by-products such as brewers' spent grain and bran from wheat, rice and maize (Cheeke, 1991). Whilst some of these can be fed directly, others are processed to make its

nutrients available to livestock. Other AIBPs such as oyster shell and bone meal are rich sources of minerals and remains the most reliable source of calcium and phosphorus to various kinds of animals in developing countries (Verma, 1997). They are essential in diets of young animals which require large amounts of calcium and phosphorus for bone development. Poultry excreta have been found to be a rich source of protein, calcium, phosphorus and can be used as a source of nitrogen in ruminant ration (Ranjhan, 1993).

The major limitations on the use of agro-industrial by-products and crop residues include bulkiness, low nutritive value and the inappropriateness of some for direct utilization by animals (Aregheore, 2000). A wide range of anti-nutritional factors including various compounds, which are harmful to animal health and performance are found in AIBPs but a number of technologies and methods have been developed to help detoxify or at any rate minimize the adverse effects of these toxins/anti-nutritional factors (Sindhu *et al*., 2002). For example, the high lignin content of untreated sugarcane bagasse (Bhatti and Khan, 1996) which makes it less digestible has reportedly been enhanced by high pressure treatment. This treatment improved both palatability and digestibility of sugarcane bagasse (Morrison and Brice, 1984). The level of phosphorus and high crude fibre (38%), are the main limiting factor of groundnut haulm, which may in warm periods of the year, inhibit feed intake has been found to be overcome by sprinkling a mixture of molasses and di-ammonium phosphate or preferably a balanced liquid supplement on chopped peanut haulms (Maglad *et al*., 1986). The inhibitors and toxins in feedstuffs and the deactivation processes or methods of some of the inhibitors and toxins are shown in table: 2.

Table 2: Some inhibitors/toxins factors in agro-industrial by product (adapted from Benerjee, 1993; Bhatti and Khan, 1996).

Feedstuffs	**Inhibitor(s)**	**Deactivation process**
Linseed meal	Crystalline water soluble substance	Water treatment
Groundnut meal	Aflatoxin, goitrogen, protease inhibitors, saponins	Treatment with ammonia or ammonium hydroxide
Soybean meal	Hemagglutinins, goitrin, trypsin and protease inhibitors, saponins	Heat (autoclaving), toasting
Cottenseed meal	Gossypol eyclopropene fatty acids	Adding iron salt, rupturing pigment gland
Raw fish	Thiamin	heat treatment
Sheanut cake	Saponins, tannins	Polyethylene glycol addition
Lucerne meal	Saponins, pectin methyl esterase	Limit quantity fed
Cassava peels	Hydrogen cyanide	Sun drying, ensiling, cooking, addition of methionine

2.7. Groundnut production in Ghana

Ghana is 4th in Africa and 10th in the world with 530,887 metric tonnes of in shell groundnut production (FAOSTAT, 2011). In terms of total production and value, groundnut is highly an essential legume plant cultivated in Ghana (Tsibey *et al*., 2003). The agricultural production figures for 2010 show the Northern region (227,650 MT) and Upper West region (196,676 MT) combined produces about 80% of Ghana's groundnut (MOFA, 2011). Groundnut is a valuable cash crop and a staple food for millions of Ghanaians, just like in all other sub-Saharan African countries (MoFA, 2011). Groundnut is high in edible oil, protein, essential vitamins and minerals. The groundnut grains are also transformed into paste and widely used in the preparation of soups, strew and cereal mixtures by Ghanaians (Asibuo *et al*., 2008; Masters *et al*., 2013). Groundnut cake from industrial oil manufacturers is used primarily in feeding poultry and livestock, particularly in southern Ghana, where most of the commercial poultry and livestock enterprises are situated (Awuah *et al*., 2009).

2.7.1. The groundnut plant

As one of the world's major oil seed crops, Groundnut (*Arachis hypogeal L*) is the 4th largest oils seed crop (FAO, 2011). Atotal of about25 million tons of unshelled nuts are produced worldwide each year, 70% of which are contributed by India, China and the USA (El Naim *et al*., 2010).

Farmer's groundnut pod yields have an average of about 800 kg/ha, less than one - third of the possible yield (Norman *et al*., 1995; Dalley *et al*., 2004; Konlan, 2013a and b). The wide interval between actual and possible yields is due to a range of factors including seeds of improved variet ies not being available for particular ecology, inefficient soil fertility, inadequate crop manageme nt, pests and disease (Norman *et al*., 1995; Dalley *et al*., 2004; Konlan *et al*., 2013a and b). The key problems with retaining the production of groundnut, however, are poor cultural/manage

ment practices, particularly weed management practices (Mubarak, 2004). The oil content of groundnut varies in quantity, the relative amount of fatty acids, terrestrial location, seasons and growing conditions (Holaday and Pearson, 1974; Young *et al*., 1974; Brown et al., 1975). The groundnut seeds are rich in minerals (phosphors, magnesium, potassium and calcium) and in vitamins (Group K, E and B) and contain 44% to 56% oil and 22% to 30% protein on dry seed basis (Savage and Keenan, 1994). The total carbohydrates content reported as both soluble and insoluble carbohydrate in groundnut seed ranges from 9.5% to 19.0% (Crocker and Barton 1957; Rao *et al*., 1965; Oke, 1967; Abdel Rahman, 1982; Woodroof, 1983).

2.8. Haying Systems

There is a background to Hay production and storage to conserve forage over 2000 years ago (Robertson, 1983).

The pH in mouldy hay remains nearly neutral (Wittenberg, 1997), unless the moisture content in the storage is more than 40%, pH may increase to 7.0 or higher. The majority of fungi multiply terrestrial easily across a broad pH range, but will strive poorly with bacteria at pH 7.0 or above when there is enough moisture. Wittenberg (1997) did very few research on stored hay to determine oxygen levels. Lower oxygen and high carbon dioxide levels could probably occur if the plant or microbial respiration occurs. Whilst the fungi bring about spoilage in hay are regard as obligate aerobes, many are able to grow in low oxygen levels.

2.9. Implications of spontaneous heating on bale

When hay is very moist at baling, microorganisms' respiratory activities causes hay to heat instantaneously (Rotz, 2003). The degree and period of the increase in hay temperature depends on its moisture content. In the first 2 to 3 weeks after baling, all hay with moisture levels from 15% to 20% will be subjected to increase in temperature. Such undesirable storage characteristics

can most often occur if alfalfa and other hays are baled at moisture content greater than 20% and in small rectangular packages (approximately 45kg) (Collins *et al*., 1987).

This heat accumulation is called "sweating" and is as a result of plant respiration and microbial activity (Lemus, 2009). Measurable losses of 4% to 5% in hay DM can be recorded during "sweating." When stored hay reaches the moisture content balance, for each 1% loss in the original baling moisture content will result in 1% DM loss (Lemus, 2009). For example, in case of hay being baled at 20% moisture content and reduces to 12% moisture content after 3 weeks, an 8% DM loss should be reported.

During respiration of plants and epiphytic organisms, plant cells and diverse organisms utilize plant sugars in the presence of oxygen to produce carbon dioxide, water and heat:

Plant sugars + oxygen → carbon dioxide + water + heat.

This increase in temperature lasts up to 10 days. A bale can maintain a high temperature for up to 40 days at moisture levels of approximately 30 percent regardless of the forage species or the shape of the bale (Lemus, 2009). Spontaneous heating, triggers the core temperature of bale to rise, thus enabling drying by encouraging vaporization of water, and eventually reducing the energy content and degradability of the forage (Coblentz *et al*., 2004). The moisture content of forage before baling, bale weight, bale type, environmental factors, storage site and preservative usage are influences that add up to spontaneous heating of hay bales. The degree of heating that takes place in bales is a reliable marker of unfavorable changes in terms of nutritive value that may be observed after storage. Oxidation of non - structural carbohydrates, mould growth and related production of toxins, and increased concentration fibre and heat – damaged nitrogen are well - known results of spontaneous heating in bale (Coblentz and Hoffman, 2008). Related studies shows that spontaneous heating causes dry matter losses and wide range of adverse changes in forage nutritive

value (Collins *et al*., 1987; Coblentz *et al*., 1996, 2000; Turner *et al*., 2002), changes in rumen degradability kinetics of nitrogen, fibre and dry matter (Coblentz *et al*., 1997b; McBeth *et al*., 2003; Turner *et al*., 2004), and less desirable measures of in vitro and in vivo degradability (Montgomery et al., 1986; Coblentz *et al*., 2000; McBeth *et al*., 2001; Turner *et al*., 2004). Few studies (McBeth *et al*., 2003; Turner *et al*., 2004) have endeavored towards linking rumen degradability to spontaneous heating. In small rectangular bale with moisture content greater than 20%, typical measures of nutritive value of forages, including fibre portion and NDF or ADIN, have been related to measures of spontaneous heating, primarily in linear patterns (Coblentz *et al*., 1996, 2000) that frequently display comparatively high coefficients of determination (r2). But, the cost and availability of labour in modern days have obliged many hay or livestock producers to package their hay in large-rectangular or large-round bales (Coblentz and Hoffman, 2009). In general, the moisture threshold for these bigger hay packages is less than the 20% threshold moisture recommended for small rectangular bales (Collins, 1995). But certain principles often change with the bale type, bale size, storage location, and other factors. Usually hay baled at moisture content lesser or equal to 15% are said to be reasonably stable and typically shows little microbial activities (Rotz and Muck, 1994); but for large bale types this has not been thoroughly investigated.

2.9.1. Relationships and features of spontaneous heating

2.9.1.1 Patterns of Heating

Soon after baling, the core bale temperature rises as a product of respiration by both plant cells and microbes associated with the plant in the field (Roberts, 1995). Spontaneous heating often lasts less than five days. Following a short period in which core bale temperatures may decline (at 4 to 5 days post-baling), a long period of heating begins that can last for numerous weeks. This heating happens mainly as a result of respiration by microorganisms that multiply during bale

storage. Also, it should be well-known that bales packaged at 30% moisture content kept a larger core bale temperature than the drier hay for about 25 days. Figure 3 below illustrates the typical patterns of spontaneous heating that occur over storage time for conventional rectangular bales of alfalfa hay made at 20% and 30% moisture.

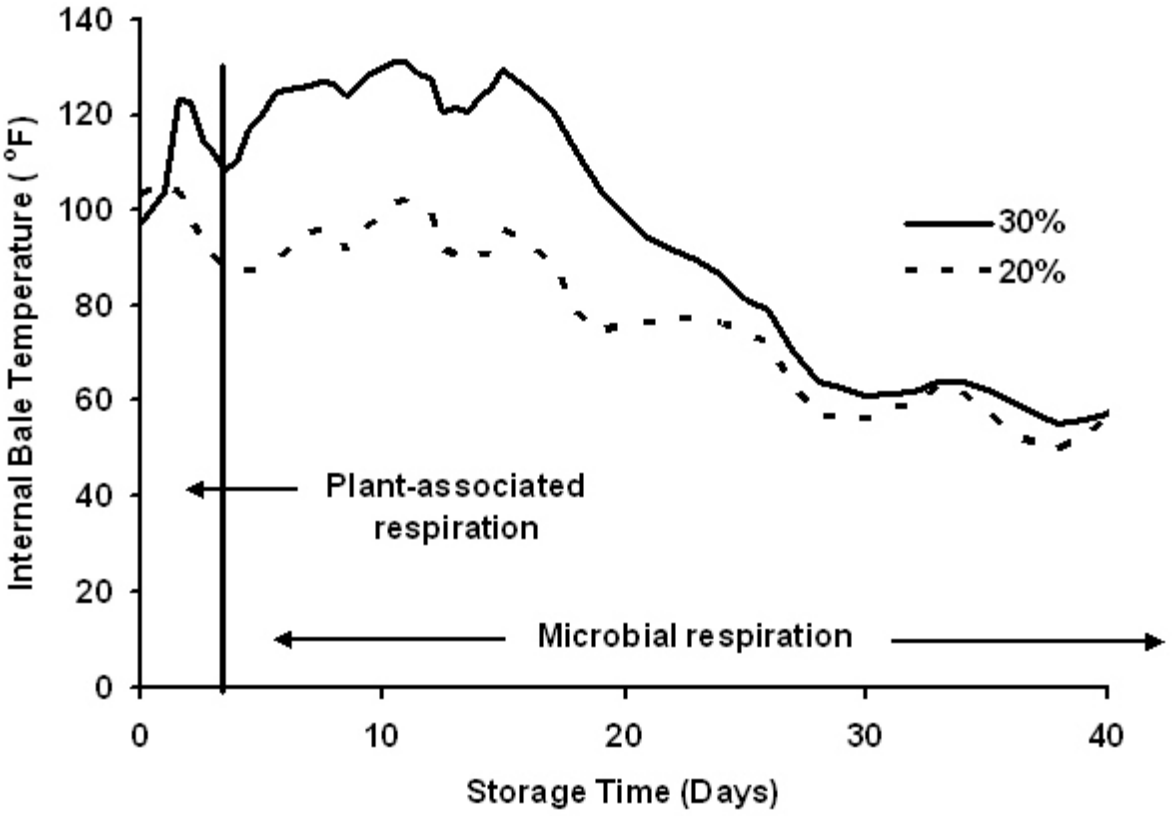

Figure 3: Internal bale temperature versus storage time curves for conventional rectangular bales of alfalfa hay packaged at 20 and 30% moisture (adapted from Coblentz *et al*., 1996).

2.9.1.2. Moisture Content

Moisture content during baling is by far the most crucial of all factors which influence spontaneous heating (Coblentz *et al*., 2004). Figure 4 summarizes several alfalfa hay experiments conducted in Kansas. A heating degree day (HDD) concept often has been applied to combine the magnitude and duration of heating in hay bales, and often it is used as a response variable in hay conservation studies. The positive linear correlation between moisture content and HDD is unusually close (r^2 = 0.902) for a biological system. All bales within this summary are included in conventional rectangular bales. The synopsis contains studies conducted at different times with different densities of bales, including studies that have been mishandled to produce a negative reaction. The above clearly establishes that the moisture content in any particular type of bale is the main variable that drives spontaneous heating. While it is widely said that in broad round or other large bales types, comparable relationships exist between moisture content and spontaneous heating. There is inadequate documented research that supports this, since bale size and density also influence spontaneous heating, the close linear relationship between spontaneous heating and moisture content observed in Figure 4 would likely worsen if data from different bale types were used within the same linear regression.

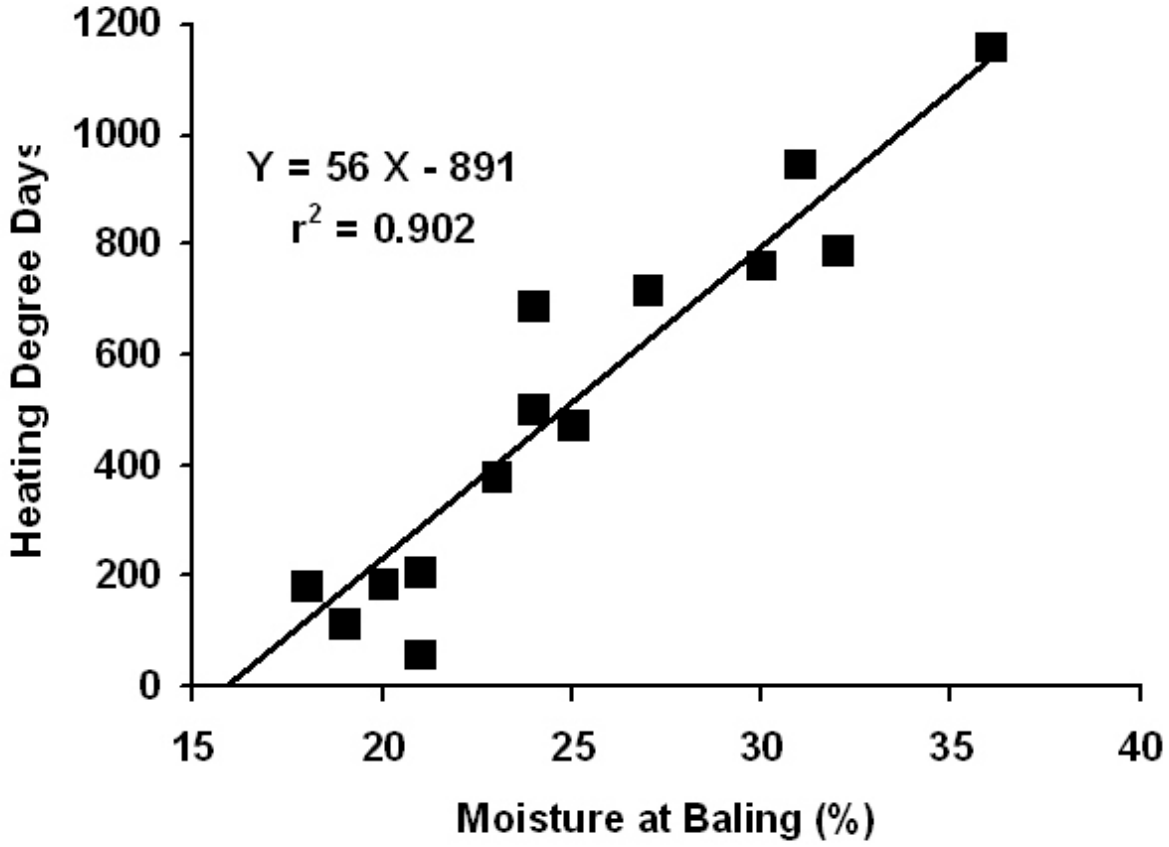

Figure 4: Relationship between heating degree days > 86°F (a numerical index that integrates the magnitude and duration of heating) and moisture content at baling (adapted from Coblentz *et al*., 2004).

2.9.1.3. Combustion

Combustion and fire may also occur, as oxidative reactions due to the breakdown of protein causes the core temperatures to exceed 175 ºF. This type of oxidative reaction tends to take place after 30 to 35 days (Lemus, 2009). Festenstein (1971) proposed the possibility that core bale temperatures above 158˚F were caused not by microbial and plant respiration but rather by oxidative reactions, mainly by denaturing the enzymes and rendering their systems inactive at high temperatures. High temperatures (> 158˚F) may occur more than 30 days after baling, caused by oxidative chemical reaction. Of course, large round bales are more likely to heat spontaneously, and the risk of spontaneous combustion is higher especially when core bale temperatures reach 340˚F (Collins, 1995). This does not usually happen in the center of the stack because lower oxygen levels can control temperature increases and reduce the likelihood of the combustion. Spontaneous combustion occurs more commonly near the outside of the stack, where there is more oxygen.

2.9.1.4. Bale Size and Density

The size and density of the bales influences spontaneous heating in the hay packs. Density simply boosts spontaneous heat by adding more DM into the bales, but it does not cause heat changes per unit of forage DM (Nelson, 1966; Rotz and Muck, 1994). A difference in the mean density of 1.4lbs./ft^3 was not detectable in the characteristics of heating in conventional rectangular bales of Bermuda grass hay with five moisture levels ranging from 18% to 30% (Coblentz *et al*., 2000). Large and denser packages also have higher core bale temperatures since it is harder to dissipate the heat produced. This was shown to be the case by Montgomery *et al*. (1986) who reported a peak core bale temperatures of around 190˚F contrasted to only 104˚F with 25 bale stacks of conventional rectangular, bales at 23% moisture in a round bale with weight 1,375 lbs. Though, the highest core bale temperatures for both of these bale types transpired at about the same time

chronologically (after 11 to 12 days of storage). The tall fescue hay bales were relatively small (783 lbs.) compared to other large hay packages, and they would be expected to heat less severely than larger bales of the same forage. Normally, the recommended moisture content at baling for larger, round hay bales is lower than is necessary for conventional rectangular bales. A good rule of thumb for maintaining acceptable storage in conventional rectangular hay packages is to bale hay at 20% moisture or less; however, this guideline is often reduced to 16% moisture or less for large-round or other large hay packages. This chronological resemblance was observed generally for heating characteristics within 4 x 3½-foot round bales of tall fescue hay baled at 39% moisture (see Figure 5) packaged in conventional rectangular bales.

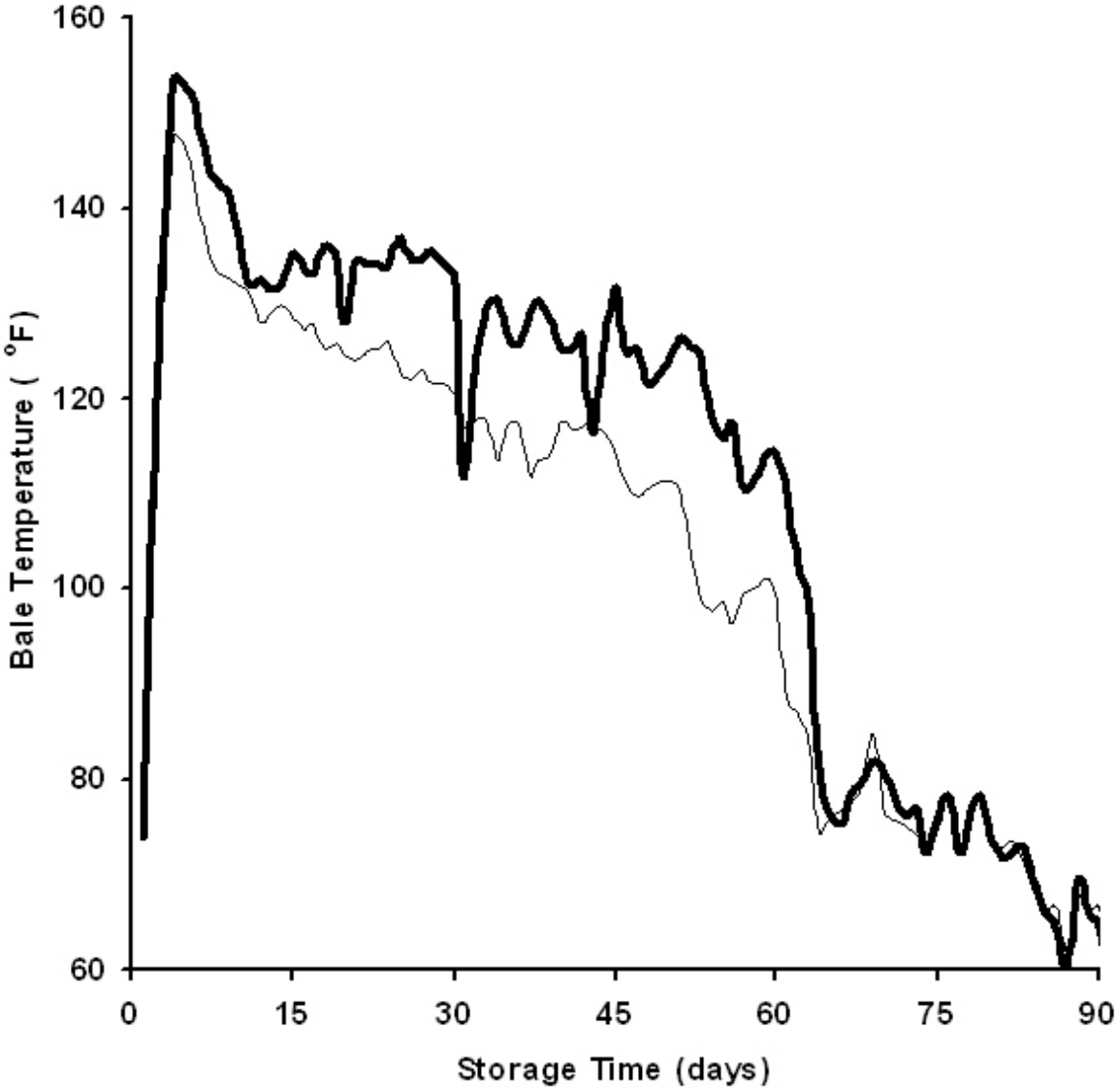

Figure 5: Surface (thin line) and core (heavy line) temperatures for large round bales of tall fescue made at 39% moisture at Fayetteville, AR. Bales were 4 x 3½ feet, and the mean initial bale weight was 783 lbs. (Adapted from Coblentz *et al*., 2004).

2.9.1.5. Techniques for reducing hay dry matter and quality losses

- Make sure hay is dried properly (less than 15% moisture).
- Shield the bales against rain and other elements of weather.
- Allocate space for proper aeration and air flow.
- Raise the hay from the floor, and
- Inspect hay for mould and increasing heat.

2.9.2. Hay Preservatives

Hay preservatives work by inhibiting or killing microorganisms that can damage hay at over 20% moisture content. Salt (sodium di - acetate) has previously been a common practice for preventing mould growth and spontaneous heating, but for a high-moisture hay, the quantities of salt required may be large and costly. In some cases, large quantities of salt might reduce palatability of forage. Urea, anhydrous ammonia, and other chemicals are branded to be efficient in preserving moist hay if applied in appropriate quantities. Organic acids such as propionic-acetic acid, ammonium propionate, and pure Propionic acid have been used to trim down dry matter losses and preserve forage quality. Checking moisture content of hay is important because application rates of preservatives depend on bale moisture content (Lemus, 2009).

2.9.3. Nutritional features of heated hays

2.9.3.1. Total non-structural carbohydrate (TNC)

The concentrations of non-structural carbohydrates in alfalfa as standing crop can exceed 20% of the total plant DM and usually reach a maximum in the late afternoon or in the early evening (Holt and Hilst, 1969; Lechtenberg *et al*., 1971). Photosynthate accumulate during daylight hours due to the fact that energy from the sun is converted into sugars at a faster rate than they can oxidize to meet the immediate energy demands of forage plants or stored for subsequent use. Still when alfalfa is drying tremendously, non-structural carbohydrate concentrations can be reduced to under

8% DM when the baling is carried out. This happens during the wilting process because of the inevitable plant respiration. Despite losses of TNC during wilting, hay cuts in the sunset and dried in good wilting conditions should be higher than hay cuts in the sunrise. Fisher *et al*. (2002) reported that this concentration difference is about 1% when averaged over 3 mid-bud harvests from alfalfa cultivated in Idaho.

These rather small differences in sugar concentrations can have a positive effect on animal preference and on subsequent consumption of DM by ruminants as shown in several studies.

During storage, the levels of TNC decline in a curvilinear pattern with storage time, but final concentrations depend heavily on storage conditions (Table 3; Coblentz *et al*., 1997a). Recovery of TNC will be greater in no heated hays than in heated hays, and concentrations of TNC have been related to spontaneous heating in negative, linear relationships (Coblentz *et al*., 1997a).

The time interval in which TNC concentrations are reduced faster (0 to 12 days) corresponds to the occurrence of the heating of the most heated hay bales (see Figures 3). During this first period of intensive spontaneous heating the sugars of plants are oxidized throughout the hay as a source of fuel to rapidly spread microorganisms.

Table 3: Concentrations of total nonstructural carbohydrates (TNC) in alfalfa hays packaged in conventional rectangular bales at 20 and 30% moisture and sampled over time in storage (adapted from Coblentz et al., 1997a).

Storage time	Moisture content of hay at baling	
	30%	20%
Days	%TNC	
0	5.96	7.29
4	5.63	5.17
11	3.67	3.95
22	2.71	3.59
60	2.07	4.21

2.9.3.2. Fiber components

During bale storage, forage fiber components such as NDF, ADF, crude fiber and lignin remain relatively stable. These components makeup the cell wall of the forage and are the least digestible portions of the plant. DM loss is usually linked with respiration of TNC as a result of spontaneous heating; therefore, the fiber component concentrations are increased primarily by indirect mechanisms, not because additional plant fibers are synthesized. Fiber component concentrations generally increase linearly with spontaneous heating measures, such as maximum temperature, mean temperature or Heating Degree Day; and r^2 statistics for these linear regressions are usually quite high (> 0.7) for both bermuda grass (Coblentz *et al*., 2000; Turner *et al*., 2002) and alfalfa (Coblentz *et al*., 1996). Turner *et al*. (2002) also found that changes in fiber component concentrations (NDF, ADF and lignin) for heated bermuda grass hay have a strong connection with storage time; Speedy changes are generally observed during the first 12 days of storage, but later concentrations stabilizes.

2.9.3.3. Total digestible nutrients (TDN)

Quantities of the energy content in a forage, such as TDN or net energy, are often predicted from equations centered mostly on concentrations of fiber components (ADF and or NDF). Any process, such as spontaneous heating, which increases fiber concentrations within a drilling will likely have a negative effect on estimates of energy.

2.9.3.4. Digestibility

The degradability of forages is decreased in response to spontaneous heating, mainly due to the oxidation of TNC, which is extremely digestible, and the increased concentrations of fiber components, which are digested partly. The heating effect on forage degradability (quantified as IVDMD) in bermuda grass hay prepared in Fayetteville in 1998 was minimal when core bale temperatures were not above 120˚F. Nevertheless, when the core bale temperature was above

140˚F, digestibility reduced by approximately 14% units. Also, McBeth *et al*. (2001) reported that the DM, organic matter (OM), NDF and hemicellulose digestibility coefficients measured by lambs fed with heated bermuda grass hay decreased linearly with Heating Degree Day amassed during storage of bale (see Table 4), however, the voluntary consumption was generally not affected.

Table 4: Digestibility coefficients for DM, OM, NDF, ADF, and hemicellulose measured in lambs offered common Bermuda grass hays subjected to various levels of spontaneous heating (adapted from McBeth et al., 2001).

Heating Degree Day					
Item (%)	5	119	201	273	401
DM	58.3	59.4	56.6	51.0	54.4
OM	58.6	59.5	56.5	51.1	54.0
NDF	65.6	66.5	65.4	60.4	62.5
ADF	55.9	58.1	56.2	52.0	54.8
Hemicellulose	73.2	73.4	73.8	68.1	68.9

2.9.3.5. Crude Protein (CP)

In general CP concentration changes are somewhat time dependent from the time of baling. CP concentrations may increase in the short term (< 60 days) in fact due to the preferential oxidation of TNC (Rotz and Abrams, 1988; Coblentz *et al*., 2000). These increases represent linear function of the moisture concentration at the baling and measurements of spontaneous heating for conventional rectangular Bermuda grass bales (Coblentz *et al*., 2000; Turner *et al*., 2002). Spontaneous heating during bale storage has the long term effect of lowering the CP content. Rotz and Muck (1994) reported that the volatilization of ammonia and other nitrogen compounds may decrease crude protein to 0.25% unit per month in longer - term storage. It is unlikely, however, that this loss will continue forever.

2.9.3.6. Heat-Damaged Protein

The spontaneous heating in hays causes maillard or non-enzymatic browning reactions and can affect the apparent digestibility of N negatively than the simultaneous heating effects on the digestibility of the fiber components. Carbohydrates in maillard reactions are degraded to polymers, largely indigestible in ruminants, in the presence of amines or amino acids. The quantification of N remaining in forage residue after digestion in acid detergent (ADIN) will usually determine the heat damaged protein. Concretely, ADIN concentrations increases by direct mechanisms, unlike fibre components. The content of moistures, the extent and duration of spontaneous heating, and type of forage all affect the heat damage on forage proteins. Moisture plays a key role here in two separate ways. Foremost, the effect is catalytic and therefore, silages are more likely to be damaged by heat than forages kept as hay. The moisture in the bale intensifies spontaneous heating, which increases the likelihood of heat damage thereafter.

2.9.3.7. Ruminal Protein Degradability

Substantial research has been undertaken to evaluate ruminal degradability characteristics of forage proteins. Lots of this work has focused on efforts to improve the production of milk. High quality forages, like alfalfa, are often present with high concentrations of CP, however, this protein is quickly degraded in rumen, and thus dairy cows and other livestock can use it unproductively. Spontaneous heating reduces both the rate and amount of alfalfa forage protein degraded in the rumen. The rate of ruminal degradation is decreased by about 40% in a linear relationship with HDD as caused by spontaneous heating in alfalfa hay baled at 30% moisture content (Coblentz *et al*., 1997b). While this may offer some advantage regarding nitrogen retention and use, it should not be regarded as a rationale for the intentional heating of forages in the bale. Naturally, the ruminal degradation of protein from warm season grasses like Bermuda, is lower. Based on differences in plant anatomy associated with the C3 and C4 photosynthetic pathways, this natural resistance to ruminal degradation can be clarified. In contrast to alfalfa and other legumes, the rate of ruminal degradation of proteins found in hot - season forages cannot be essentially slowed. Rumen degradability estimates were linearly reduced through spontaneous heating for both alfalfa and Bermuda grass hays. Reductions of 0.15% units of total CP per degree of maximum core bale temperature were noted over harvests from two years for Bermuda grass hays (Coblentz *et al*., 2001). Comparably, a negative slope of 0.018% units of total CP per HDD > 30˚C (r^2 = 0.684) also was noted for alfalfa Coblentz *et al*. (1997b) using the in situ method of evaluation. The rumen bypass protein is said to be 80% digestible NRC (1996), however, the source, conditions of processing or handling may clearly vary and have variable digestibilities rumen bypass protein (NRC,2001). In the narrow context of alfalfa hay protein degradation, a very small amount of spontaneous heating can have some small benefit; heating however cannot be controlled effectively, and the negative results of inadequate desiccation prior to baling, such as mould

growth, increased concentrations of fibre components, reduced energy density, and reduced total and component digestibilities, are gigantic compared to any possible benefit by slowing ruminal protein degradation.

CHAPTER THREE

3.0. Materials and Methods

3.1. Study Area

The study was conducted during the dry season from 4TH October, 2017 to 29TH March, 2018.

The animal experimentation was conducted at the Livestock Unit of the Department of Animal Science, Faculty of Agriculture (FOA) of the University for Development Studies (UDS), located at Nyankpala. The chemical analyses were conducted at Livestock and Poultry Research Centre (LIPREC) – Legon. Nyankpala is situated on longitude 0º58'47.57" W and latitude 9º 23'45.53" N and at an altitude of 168m above sea level in the Guinea Savannah ecological zone of Ghana. Nyankpala has a unimodal rainfall pattern that begins in late April and reaches a peak in July to September; there is a sharp decline and absolutely no rain in November (SARI, 2004). The mean annual rainfall is 1200mm (SARI, 2004). Temperature generally fluctuates between 19º C minimum and 42º C maximum with a mean annual temperature of 28.5º C (SARI, 2015). The mean annual day time relative humidity is (27% – 40%); and sunshine (80% – 87%). The area experiences dry cold Harmattan winds from November to February and a period of warm dry conditions from March to Mid-April. Data on environmental conditions during this period were obtained from weather records of Savanna Agricultural Research Institute (SARI, 2004; SARI, 2015) situated 1.8km (22 minutes) walk from the location of the experiment.

Table 5: GPS coordinates for the agronomic trial fields of Africa Research in Sustainable Intensification for the Next Generation (RISING) project of the International Institute of Tropical Agriculture (IITA) in the Northern region of Ghana.

Communities	Latitudes (N)	Longitudes (W)
Cheyohi No. 2	9.44576^0	-0.99313^0

Cheyohi No. 2	9.44681^0	-0.99187^0
Tingoli	9.35937^0	-1.01673^0
Duko	9.56270^0	-0.82440^0
Duko	9.55907^0	-0.81787^0
Tibali	9.66808^0	-0.84657^0
Tibali	9.67097^0	-0.84540^0
Tibali	9.66683^0	-0.84688^0

3.2. Experimental animals, Housing and Feeding trials

A total of 22 intact West African Dwarf (Djallonké) growing rams with average initial live weight of (14.75 ± 2.52kg) were purchased from Council for Scientific and Industrial Research Animal Research Institute (CSIR-ARI) at Nyankpala in Ghana. Animals were given 16 days adaptation period to feed and experimental site. Animals were given prophylactic treatment, Oxykel 20 L.A. (KELA, Belgium) against bacterial infections was administered by deep intramuscular injection: 1ml per 10kg body weight per day while, ivermectin 1% (Hovione, Portugal) for treatment and

control of internal and external parasites was administered by subcutaneous injection: 1ml per 50kg body weight. Animals were randomly assigned to twenty-two wooden pens (2.44 m × 0.87 m) with concrete floors, each pen contained a ram, at the University for Development Studies, Tamale, Ghana.

The Groundnut haulms were obtained from 6 varieties of groundnut cultivated on the agronomic trial fields of Africa Research in Sustainable Intensification for the Next Generation (RISING) project of the International Institute of Tropical Agriculture (IITA) in Duko and Tibali communities in (Savelugu-Nanton District), Cheyohi community in (Kumbungu District) and Tingoli community in (Tolon District). The groundnut varieties were Chinese, ICGX SM 87057 (Yenyawoso), ICGV-IS 96894 (Sumnut 23), MS72.80 (Sumnut 22), RMP 12 (Azivivi), and Manipinta. Chinese, Yenyawoso and Sumnut 23 are classified as an early maturing varieties with 90-day maturity, Sumnut 22, Azivivi and Manipinta are late maturing varieties with maturity ranging from 110 to 120 days. Each variety was cultivated on 4 different replicate fields measuring (2.4×4 m^2), (3.6×4 m^2), (4.8×4 m^2) and (6.0×4 m^2). A pre-emergence herbicide (Stomp) was sprayed immediately after planting and (Sun phosphate) was sprayed post-emergence. Exactly 5 weeks after planting weeds were removed with hoes. At maturity, the groundnuts were harvested manually and the pods separated from the haulms. The haulms which was mainly leaves and twigs were baled in the various communities and transported to the livestock unit of the Animal Science Department of UDS for shade drying which lasted for 12 days. During the shade drying the bale temperatures and ambient temperatures were recorded.

The dried haulms were reduced to a theoretical length (3cm – 4cm) and used to formulate two diets (EMGH and LMGH).

Sheep were weighed on two consecutive days at the beginning of the experiment and every two weeks thereafter until the end of the experiment, when two consecutive weights were taken. The average of the consecutive weights at the beginning of the study and at the end were used as the initial and final weights, respectively.

Feed was mixed manually and delivered daily as a total mixed ration. The daily amount of feed offered was recorded and leftovers were collected daily, weighed and sampled before being discarded. Samples of feed that were collected daily were composited into biweekly samples, subsampled and stored (1^{o} c) for subsequent chemical analysis, *in situ* and *in vitro* digestibility trial. DM of leftovers were determined weekly. Animals were offered their feed every morning (07:00 am) and every evening (05:00pm). The quantities of feed offered daily were adjusted to meet appetites of animals and to ensure minimal feed leftovers without limiting intake. Fresh water was supplied *ad libitum* daily per pen. Dry matter intake of each pen was calculated as feed DM offered minus DM of the left-overs. The DMI, average daily gain (ADG), and feed conversion ratio (expressed as DMI/ADG) were estimated separately for the periods when the sheep were fed the EMGH diet and the LMGH diet, and for the whole 45-day experimental period. Feed offered sampled biweekly were used to determine DM. Dry matter was determined in a force-air oven at 60 °C for 48 hours instead of the conventional 105 °C for 24 hours because the diets contained Groundnut haulms and whole cotton seed. These ingredients contain oils, carotenes, vitamins and other volatile compounds. Determining DM at 105 °C for 24 hours usually leads to underestimation of DM concentration because all these compounds that volatilizes at higher temperature are erroneously calculated as moisture when DM of the feed is determined at 105 °C (Addah *et al*., 2012).

Feed samples composited into biweekly samples were subsampled for proximate analysis according to the official methods of analyses described by Association of Official Agricultural Chemists (AOAC, 1990). All analyses were done in duplicate with triplicate for In vitro digestibility trial. The protocol was used to determine the concentration of DM, CP calculated as total N × 6·25. All nutrient constituents were expressed on DM basis.

Biweekly sub-samples of each diet were also air-dried and ground through a 1-2 mm screen to analyze Neutral Detergent Fibre (NDF), Acid Detergent Lignin, cellulose, silica and Acid Detergent Fibre (ADF), using the Association of Official Agricultural Chemists, method (AOAC, 1990). The neutral detergent solution dissolves the easily digestible plant cell contents (proteins, sugars and lipids) and pectins, leaving a fibrous residue of NDF, which is primarily cell wall components (cellulose, hemicellulose and lignin). Sodium sulfite also helps remove some nitrogenous matter. The hemicellulose component of NDF is then dissolved by refluxing again with an acid detergent solution, leaving a residue of cellulose and lignin (ADF).

Plate 1: Variety and planting density

Plate 2: Manual harvesting

Plate 3: Separating pods from haulms

3.3. Baling and bale sampling procedures

At maturity, the groundnut crops were harvested manually and the pods separated from the haulms. The haulms which was mainly leaves and twigs were left on the various trial fields to wilt and baled in the various communities. Bales were transported to the livestock unit of the Animal Science Department of UDS for shade drying which lasted for 12 days. During which the internal bale temperature and ambient temperature were recorded.

The baler used was locally manufactured by the Africa Research in Sustainable Intensification for the Next Generation (RISING) project of the International Institute of Tropical Agriculture (IITA) in Tamale.

First and foremost, the flat metallic plate was placed in the baler with the metallic bar already in the baler. The rectangular baler was lined with binding wire at both sides from the bottom of the rectangular baler. The groundnut haulms were then arranged uniformly (equal ratio of roots to forages) in the baler. The lid of the baler was closed and locked with a metallic rode. The hydraulic jack which acted as a compressor with the aid of the flat metallic plate and bar, pressed the haulms against the lid of the baler to reduce the air spaces between the haulms thereby reducing spoilage. Once there is oxygen, microorganisms will cause it to deteriorate faster. After compressing, the bale was left in the baler overnight and removed the next day with the aid of the binding wire, binding each side of the bale. The bales were air-dried under shade with individual bales suspending in the air. There should be free air circulation around the bales to cause both heat and moisture to dissipate. Avoid placing bale stack with other bales.

3.3.1. Temperature measurements

Each bale was probed from the sides (four corners) using K-thermocouple thermometer (HI 935005) and the bales were evaluated for average internal bale temperature and change in

temperature between the average internal bale temperature (AIBT) and the ambient temperature (=ambient temperature minus AIBT) during storage. The ambient temperature was between 30℃ to 35℃ for the period of storage.

3.3.2. Bale sampling procedures

At the end of the storage period, each bale was sampled for laboratory analysis. The samples were taken from 2 parts of the bale (surface layer and the core of the bale) and independently processed for analysis. All samples taken were handled similarly.

Plate 4: Binding wire and cutter

Plate 5: Hydraulic jack

Plate 6: Baler jacked overnight

Plate 7: Shade drying of bale

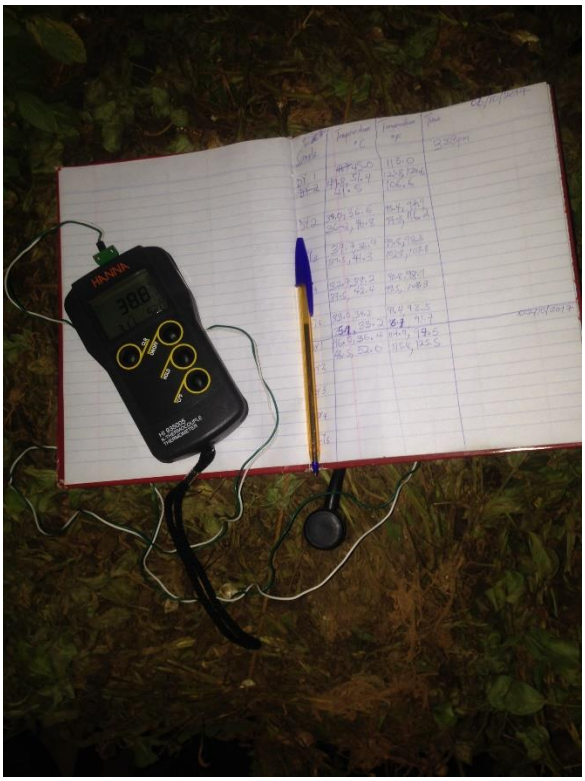

Plate 8: Recording bale temperature

3.4. Formulating the diet

The diets were formulated at the livestock unit of the Animal Science Department, of UDS for both EMGH and LMGH varieties with ingredients such as cracked corn, Whole cotton seed, Cassava peels and vitamin/mineral supplement having each in a specified quantity. This can be represented in (% *as fed*) of the diets. 45, 15, 15, 20 and 5 for groundnut haulm, Whole cotton seed, Cassava peels, and cracked corn and vitamin/mineral supplement respectively in the formulation of 100 kg of feed. The following steps were employed in formulating the diets. 20kg of the cracked corn was weighed and poured on the large polythene bag. 5kg of vitamin/mineral supplement was weighed and added to the cracked corn and mix thoroughly to assume an even mixture. After which 15kg of whole cotton seed was weighed and add to the mixture and mix thoroughly again. Thereafter, 15kg of cassava peels was weighed and added to mixture and mixed thoroughly. Finally, 45kg of the dried groundnut haulm (either EMGH or LMGH) was weigh and added to the mixture and mix thoroughly to assume an even distribution of the mixture. The final mixture was scooped into a large sack and indicate (either EMGH or LMGH) diet on it.

The Table below shows the various feed ingredients and their inclusion levels in batches of the simple rations formulated.

Table 6**:** Formulation of different batches of feed during the experimental period **(**% as fed basis).

	Batches of feed formulated	
Feed ingredients	50kg	100kg
EMGH	22.50	45.00
LMGH	22.50	45.00
Cracked corn	10.00	20.00
Cassava peels	7.50	15.00
Whole cotton seed	7.50	15.00
vitamin/mineral supplement	2.50	5.00

EMGH = early-maturing groundnut haulms; LMGH = late-maturing groundnut haulms.

The entire diet was prepared using early maturing groundnut haulm (EMGH) varieties in contrast to late maturing groundnut haulm (LMGH) varieties.

Table 7**:** Ingredient composition (% as fed) of the diets

Items	EMGH	LMGH
Groundnut haulm	45	45
Cassava peels	15	15
Whole cotton seed	15	15
Cracked corn	20	20
Supplement	5	5

Plate 9: Formulating the diet

Plate 10: Thorough mixing of diet

3.5. Assigning of sheep to their individual pens and treatments

The 22 growing rams (subjects) with average initial live weight of (14.75 ± 2.52kg) were randomly assigned to individual pen (experimental unit) with each pen numbered P_1, P_2, and P_3, to P_{22} accordingly. The 22 growing rams were each tagged with a number, ranging from 1 to 22 and assigned randomly to the pens (P_1, P_2, and P_3, to P_{22}) by the use of simple random sampling using ballot papers which had on each paper numbers corresponding to that of rams. Again with the help of simple random sampling using ballot papers, the experimental units were assigned to treatments (either EMGH or LMGH) diet. The sheep were allocated such that each received one and only one treatment throughout the entire experiment till the end.

Plate 11: A sheep assigned to individual pen and treatment

3.6. Feeding

Animals were offered their feed every morning (07:00 am GMT) and every evening (05:00pm GMT). The quantities of feed offered daily were adjusted to meet appetites of animals and to ensure minimal feed leftovers without limiting intake. Fresh water was supplied *ad libitum* daily per pen.

After the formulation, the feeds were administered to the sheep for the EMGH or LMGH diet equally as follows. All the rams were offered 0.5kg of the diet in the morning and 0.5kg in the evening according to their apportionments. The leftovers were weighed early in the morning of the next day before feeding the animals. When any is seen to have completely consumed the feed, feed quantity was increased until there is some leftover. Example if a ram eats all 1.0kg of feed in a day, give it 1.5 kg the next day. If it still eats all keep increasing till it is unable to eat all.

3.7. Measurement of growth parameters

Feed intake (DMI): Dry matter intake (DMI) of each pen was calculated as feed DM offered minus DM of the leftovers.

Average daily gain (ADG): The biweekly weights of animals were used to estimate average daily weight gain (ADG) by dividing total weight gain by 45 days.

Feed conversion ratio (FCR): The DMI of rams were used to estimate the feed conversion ratio, by dividing DMI by ADG of animals.

3.7.1. Feed Intake

Data was collected on daily basis for the feed intake where every morning, the quantity of feed leftover was collected, weighed and recorded as the leftover of the previous day. The feed intake was obtained from the difference between the quantity of feed offered to the animal and the quantity leftover. This can be done mathematically as: Feed intake = feed offered – feed leftover

The feed leftover also include the quantity of feed spilled onto the floor by the animal which was also collected and weighed in order to minimize error. The individual pens were swept in the morning and spilled feed content on the floor were collected. Feed leftover in the animal's feeding trough were added to the spilled feed collected on the floor and weighed. It was record as the leftover for the previous day. This procedure was repeated for each and every pen one after the other.

3.7.2. Weight Gain

Sheep were weighed on two consecutive days at the beginning of the experiment and every two weeks thereafter until the end of the experiment, when two consecutive weights were taken. The average of the consecutive weights at the beginning of the study and at the end were used as the initial and final weights, respectively. The weight gain was estimated as final weight minus initial weight.

Plate 12: Weighing sheep using Avery Tronix-weigh scale

3.8. Chemical Analyses

3.8.1. pH

Fifteen grams (15g) of the groundnut haulms samples were mixed with 135 mL of deionized water, blended (Moulinex Uno) for 45sec and the pH of the filtrate was measured with a Crison pH meter. The probe of the pH meter determines the pH and the temperature of the samples respectively.

Plate 13: Recording pH using Basic 20 Crison pH meter

3.8.2. Dry Matter

Twenty-five grams (25g) of the groundnut haulms samples were dried in an oven (J.R. Selecta) at a temperature of 60^0C for 48 hours. For feed samples, the air oven was regulated to 80^0C. Using aluminum dishes, 2g sample were approximately weighed into each dish. The dishes were placed in the oven as quickly as possible and samples were dried overnight. The dishes were transferred into the desiccator to cool. The dishes were weighed and loss in weight as moisture was calculated.

3.8.3. Ash (AOAC, 1990)

Two grams (2g) of feed samples were weighed into porcelain crucible and place in temperature controlled furnace preheated to 600^0C. It was held at this temperature for 2 hours. After which the porcelain crucible was transferred directly into the desiccator, cooled, and weighed immediately and %ash was reported to two decimal place.

3.8.4. In vitro digestibility procedure

Ruminal In vitro digestibility was determined on diets (EMGH and LMGH) using McDougall's artificial saliva (mix four parts of McDougall to one part of ruminal fluid). 9.8g of $NaHCO_3$ per litre, 7.0g $Na_2HPO{\cdot}7H_2O$ per litre, 0.57g KCL per litre, 0.47g NaCl per litre and 0.12g $MgSO_4{\cdot}7H_2O$ per litre were dissolved in 500ml of distilled water. The remaining (500ml) water was added to make up the 1 litre. Before use, 4% $CaCl_2$ solution was added (1ml of the 4% $CaCl_2$ solution per litre). The McDougall's solution was placed into the 39 ^{0}C water bath after the addition of the 4% $CaCl_2$ solution, and flushed with CO_2 gas until the pH of the McDougall's solution read 6.8 to 7.0. Pepsin solution (6.6g of 1: 3,000 pepsin in 100ml of 1 N Hcl).

Feeds were ground to pass through a 2mm screen (mesh). 0.5g of sample was weighed and place into a labeled 50ml centrifuge tube. To this tube, 28ml of McDougall's solution (pre-warm McDougall's solution in 39^{0}C water bath) was added. After which 7ml of ruminal fluid (4:1 ratio of buffer to ruminal fluid) was added. The rumen content was collected from 2 fistulated Nungua Black Head rams which was then strained through four layers of cheesecloth (with continues flushing with CO_2 gas) to obtain the rumen fluid. The ruminal fluid was placed on a stir plate to avoid settling of particles. The tubes were flushed with CO_2 gas (gently so sample is not blown out). The tubes were capped and inserted into the rack and the rack was implanted into the water bath (39 ^{0}C). The tubes were inverted several times to suspend the sample. At least four blanks (tubes containing NO sample except 35ml of the McDougall's solution to ruminal fluid mixture) were also implanted into the water bath. The incubation (triplicate) of the tubes lasted for 48 hours. The tubes were Inverted at 2,4,20, and 28 hours during incubation to suspend the sample. After 48 hour of incubation, the tubes were removed from the water bath, centrifuged for 15 minutes at 2,000 × g and suction off the liquid by vacuum. 35ml of pepsin solution was added to each tube

containing the filtrate. The tubes were again incubated for 48 hours in 39^{0}C water bath and inverted at 2, 4, and 6 hours after pepsin addition. After completion of the digestion, the contents of the tubes were filtered using the modified Buchner funnel and ash-less filter paper.

The filter paper containing the filtrate was inserted into an aluminum pan and oven dried for 48 hours. The dried filtrate was ash at 500^{0}C for 4 hours and calculations were completed. In vitro dry matter disappearance after 48h incubation data were fitted in the equation:

$$\%IVDMD = 1 - \frac{[(\text{Residue + filter paper}) - \text{filter paper}] - \text{blank}}{(\text{Sample weight})(\text{DM})}$$

Blank = (blank residue + filter paper) – filter paper

3.8.5. The nylon-bag technique/In Sacco (in situ) degradation.

Two rumen fistulated Nungua Black Head rams were used to measure the rate and extent of degradation of dry matter, of different diets. Sheep were allowed to graze the natural pastures with free access to water throughout the experiment. Approximately 2.0g of DM of test feeds was weighed into the artificial nylon bags (7cm × 14cm) with a pore size of 40µm. It was tightly sealed and placed in the rumen of the fistulated animals.

Degradability (or disappearance) of the substrate was determined by the weight loss in incubated bag and content after incubation. Feeds were ground to pass through a 2mm screen (mesh). The nylon bags (7cm x 14 cm) with a pore size of 40µm, were oven dry at 80^{0}C overnight and their empty weights were measured after allowed to cool to room temperature in a desiccator. The bags were tightly tied using nylon string which is resistant to rumen micro-organisms. The bags were anchored with about 25cm of nylon cord to the cannula top and placed deep into the rumen of a fistulated animal.

Bags were incubated (in duplicates) for 0, 6, 12, 24, 48, 72, 96 and 120 hours.

The 120-hour bags were placed in the rumen on the morning of day 1 of incubation in each fistulated animal. On the next morning (day 2), the 96-hour bags were incubated at the same hour as the day 1 bags. This activity was continued in the same manner until all bags were in the rumen except zero-hour bags. All the bags were taken out at the same time. This method is referred to as sequential addition. The advantage of sequential addition over sequential withdrawal is that there is less disturbance of the rumen environment. In addition, sequential removal is more prone to error.

Washing and drying

The bags were immediately washed (including the zero hour samples) with cold water for about 30 minutes under running tap water while rubbing gently between thumb and fingers until the water runs clear. The washed bags were dried in an oven at 80^0C for about 48 hours and allowed to cool down in a desiccator. The dry matter of the residue samples were estimated using the same method as with feed samples. Finally, the disappearance was calculated using the formula:

Disappearance = (SW1 - BW) × DM1 - (SW2 - BW) × DM2 / (SW1 - BW) × DM1

Where: SW1 = Weight of the original sample + nylon bag

BW = Weight of empty nylon bag

SW2 = Weight of the sample + nylon bag after incubation

DM1 = Dry matter of feed sample

DM2 = Dry matter of residue sample.

In sacco rumen DM disappearance data were fitted to the first order exponential model with discrete lag (Martens, 1977). Using the iterative Marquardt method and the NLIN procedure of 9.2 version of SAS (SAS Institute Inc., Cary, NC, USA). The model is of the form:

$R_{(t)} = a*(exp^{-k_d*(t-L)}) + r$, where $R_{(t)}$ = total indigested residue at any time t, a = insoluble potentially digestible fraction, k_d = fractional rate of digestion of a, t = time incubated in the rumen in hour, L = discrete lag time in hour, and r = fraction not digested after 120h of incubation. The wash fraction (A) was the percentage of substrate washed out of the nylon bag at 0h. Effective ruminal degradability (extent of digestion, ERD) was calculated using the model of Orskov and McDonald (1979): $ERD = A + \{B * [k_d/ (k_d + k_p)]\}$, where k_p = assumed ruminal passage rate of 0.05 per hour.

3.9.6. Crude Protein

The Kjeldahl method was employed to determine the nitrogen and crude protein was calculated as 6.25×% nitrogen. The samples were digested in H_2SO_4, using $CuSO_4/TiO_2$ as catalysts, converting N to NH_3 which was distilled and titrated (AOAC, 2000).

One gram (1g) of ground feed samples were weighed into digestion flask. 16.7g K_2SO_4, 0.01g anhydrous $CuSO_4$, 0.6g TiO_2, 0.3g pumice, 0.5-1.0g Alundum granules, and 50ml H_2SO_4 were added. A standard sample (maize) of known nitrogen content was included and digested in a different flask. To digest samples, the digester was adjusted to 320^0C and samples were heated until dense white fumes clear bulb of flask, swirled gently, and continued heating for 2 hours. Reagents proportions, heat input, and digestion time are critical factors, do not change. Cooled, cautiously and about 50ml of distilled water was added, and cooled at room temperature. The distilled water was added as soon as possible to reduce caking. The titration beaker was prepared by adding 30ml of H_3BO_3 and the tip of the condenser was sufficiently immersed into the titration beaker to trap all NH3 evolved. 1-2 drops of indicator solution were added. The distillation apparatus adds required quantity of NaOH solution, such that mixture will be strongly alkaline. The flask was immediately connected to the distillation apparatus, mixed completely, and at about

7.5-minutes boil rate until distillate is collected in titration beaker. Excess standard acid was titrated into distillate with NaOH standard (0.098533N) solution.

Calculate % nitrogen: %N = {[(N_{acid}) (ml_{acid}) – (ml_{bk}) (N_{NaOH}) – (ml_{NaOH}) (N_{NaOH})] × 1400.67}/weight of sample.

Where ml_{NaOH} = ml standard base needed to titrate sample; ml_{acid} = ml standard acid used for that sample; ml_{bk} = ml standard base needed to titrate 1ml standard acid minus ml standard base needed to titrate reagent blank carried through method and distilled into 1 ml standard base. Calculate % crude protein, defined as 6.25×% nitrogen.

3.8.7. Determination of Neutral Detergent Fibre (NDF)

One gram (1g) of feed samples ground to pass 2mm screen were weighed into a beaker (Berzelius without spout, cap. 400ml) for refluxing. 100ml of Neutral Detergent Solution (Sodium lauryl sulphate 30g + EDTA disodium salt 18.61g + Sodium borate 6.81g + Disodium hydrogen phosphate anhydrous 4.56g + Ethyleneglycol 10ml) was added at room temperature. The content of the beaker was heated to boiling; heat was reduced to avoid foaming as boiling begins. It was reflux for 60 minutes from onset of boiling. After refluxing for 60 minutes, the beaker was removed from the hotplate, swirled, and filtered using suction (vacuum pump) through weighed sintered crucible (Yg). The content was washed in the sintered disc crucible with hot distilled water (80° C -100° C) at least 3-4 times. Then with acetone until no more colour is removed. The content of the crucible was dried in the oven at 100° C overnight and weigh (Xg). %NDF content was calculated as follows: %NDF = Wt. of crucible + Wt. of NDF - Wt. of empty crucible / Wt. of sample.

%NDF = (Xg-Yg) / Wt. of sample × 100

3.8.8. Determination of Acid Detergent Fibre (ADF)

One gram (1g) of feed samples ground to pass 2mm screen were weighed into a beaker (Berzelius without spout, cap. 400ml) for refluxing. 100ml of Acid Detergent Solution (dissolve 20g of n-Cetyl n-Trimethyl Ammonium Bromide (CTAB) in 1 litre sulphuric acid and check normality of sulphuric acid before use) was added at room temperature. It contained 2ml of dekalin. The content of the beaker was heated to boiling; heat was reduced to avoid foaming as boiling begins. It was reflux for 60 minutes from onset of boiling. After refluxing for 60 minutes, the beaker was removed from the hotplate, swirled, and filtered using suction (vacuum pump) through weighed sintered crucible (Yg). The content was washed in the sintered disc crucible with hot distilled water (80° c -100° c) at least 3-4 times. Then with acetone until no more colour is removed. The content of the crucible was dried in the oven at 100° c for 8 hours or overnight and weigh (Xg). %ADF content was calculated as follows: %ADF = Wt. of crucible + Wt. of ADF - Wt. of empty crucible / Wt. of sample.

%ADF = (Xg-Yg) / Wt. of sample X 100

3.8.9. Determination of Acid Detergent Lignin (ADL)

After determination of ADF, the residue in the sintered disc crucible was used for the determination of ADL. To the crucible containing ADF, 15ml of Sulphuric acid 72% (dilute 72ml of concentrated Sulphuric acid 72% A.R. to 100ml distilled water) was added and kept in a petridish for 3 hours. The content of the crucible was stirred with a glass rod at the interval of every half an hour and Sulphuric acid 72% was added when necessary. The content of the crucible was filtered and washed with hot distilled water until acid-free to pH paper. The content (residue) of the sintered disc crucible was transferred to a silica basin and dried in the oven at 105° c overnight. The silica basin was weighed after it was thoroughly dried and then it was ash in the furnace at 500° c for 3

hours. The silica basin was removed from the furnace, cooled at room temperature in the desiccator and weighed. The lignin (%ADL) was calculated as follows: % ADL = (Wt. of empty silica basin + residue before ash) - (Wt. of empty silica basin + residue after ash) / Wt. of sample × 100.

3.9. Statistical Analysis

The results from the chemical analysis and growth parameters of the EMGH and LMGH diets were subjected to analysis of variance (ANOVA) using Genstat Eighteenth Edition. Significant differences between means were separated using least significant difference (LSD). All data on bale were subjected to analysis of variance (ANOVA) using the MIXED procedure of the 9.2 version of SAS 2007 (SAS Institute Inc., Cary, NC, USA).

CHAPTER FOUR

4.0. Results

4.1. Spontaneous heating and pH of Bale

The peak and decline of bale temperature during storage varied between yenyawoso (EMGH) and sumnut22 (LMGH) in figure: 6. This is due to when conditions were made favourable for spoilage organisms to respire and convert plant sugars into carbon dioxide, water and heat. The peak temperatures recorded in both EMGH (44.15℃) and LMGH (43.95℃) bales were within normal limits to prevent bale fire.

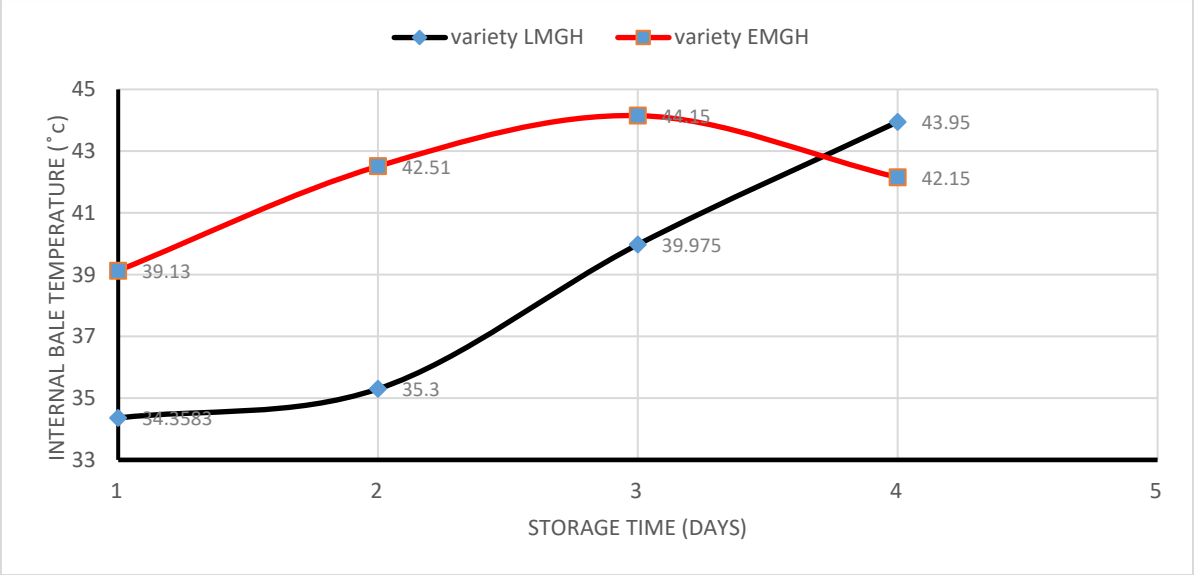

Figure 6: Internal bale temperature versus storage time curves for rectangular bales of groundnut hay.

The yenyawoso variety belonging to the early-maturing varieties (EMGH) recorded the lowest Temperature Difference (-9.13℃), suggesting a spontaneous heating "sweating" and a possible decaying of that bale (Table: 8).This is so because the internal bale temperature (42.15℃ - 47.15℃) for the yenyawoso variety was much higher than the ambient temperature (30℃ - 35℃) recorded over the period of experimentation.

Table 8**:** Temperature difference (T.D.) of varieties of groundnut haulm bales after 12 days of storage.

variety	T.D. (℃)	SEM	P - Value
MANIPINTA	-1.41	2.87	0.3262
SUMNUT22	1.86	1.08	0.5714
YENYAWOSO	-9.13	0.69	<.0001

T.D. = temperature difference (ambient temperature minus internal bale temperature)

The pH was lower (P=0.48) in EMGH (5.77) bale than in LMGH (7.00) see (Table: 9). The pH of the LMGH depicts that the bale was mouldy.

Table 9**:** pH of groundnut haulms obtained from early-maturing and late-maturing varieties bales after 12 days.

Item	EMGH	LMGH	SED	P-Value
pH	5.77	7.00	1.414	0.476

4.2. Chemical composition of forage

Table 10, below show results obtained from early-maturing groundnut haulm and late-maturing groundnut haulms.

The CP concentration did not differ (P = 0.97) in LMGH and EMGH (Table: 10). The highest CP concentration was observed in LMGH (13.75%) and the lowest in EMGH (13.69%). The Crude protein (CP) estimated in EMGH and LMGH were above the recommended 70g/kg DM (7%) minimum requirements for ruminants. Neutral detergent fibre (NDF) concentration was not significantly different (P = 0.08) between the EMGH and LMGH (Table: 10), however it was lower in LMGH than in EMGH. Acid detergent fibre (ADF) content was also significantly different (P = 0.01) between the EMGH and LMGH (Table: 10). The EMGH had the highest ADF content (28.71%) with LMGH having the lowest (26.35%). Estimates for lignin (ADL) were much lower and ranges from 6.65% to 7.63%.

Table 10**:** Chemical composition of groundnut haulms obtained from early-maturing and late-maturing varieties.

Item (% DM)	EMGH	LMGH	SED	P Value
DM	92.36	93.31	0.13	0.02
CP	13.69	13.75	1.09	0.97
NDF	33.19	30.34	0.87	0.08
ADF	28.71	26.35	0.27	0.01
ADL	7.63	6.65	0.13	0.02
Ash	8.87	8.24	0.16	0.06
Cellulose	19.24	17.09	0.53	0.06
Silica	1.83	2.61	0.24	0.08

DM= dry matter; EMGH= early maturing groundnut haulm; LMGH= late maturing groundnut haulm; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fibre; ADL= acid detergent lignin.

4.3. Nutrient intake and growth performance of animal

The daily DM intake did not differ significantly (P = 0.36) in LMGH and EMGH diets (Table: 11). The highest DM intake (0.72kg/d) was observed in LMGH which as well had the highest concentration of CP and the lowest daily DM intake was observed in EMGH (0.68kg/d). The daily CP intake, daily NDF intake, daily OM intake and daily Silica intake were highest for LMGH.

Table 11**:** Nutrient intake and growth performance of West African Dwarf (Djallonké) growing rams fed EMGH and LMGH.

Parameter	EMGH	LMGH	SED	P Value
Nutrient intake (DM basis)				
DMI (Kg/d)	0.68	0.72	0.04	0.36
Daily CP intake (g)	92.5	98.4	5.93	0.33
Daily OM intake (g)	615.0	657.0	39.5	0.31
Daily NDF intake (g)	228.5	258.7	15.32	0.06
Daily ADF intake (g)	196.2	193.4	0.78	<0.001
Daily cellulose intake (g)	129.9	122.3	7.66	0.33
Daily lignin intake (g)	51.6	47.6	3.00	0.20
Daily silica intake (g)	12.35	18.67	1.04	<0.001
Live weight and live weight gain				
Initial weight (Kg)	14.66	14.61	1.15	0.96
Final weight (Kg)	19.07	18.72	1.21	0.77
Weight gain (Kg)	4.41	4.11	0.74	0.69
ADG (Kg)	0.10	0.09	0.02	0.69
FCR (DMI/ADG)	7.41	7.74	0.97	0.74

DMI= dry matter intake; ADG= average daily weight gain; FCR= feed conversion Ratio; OM= organic matter.

4.4. In Sacco ruminal digestibility and IVDMD

Two rumen fistulated Nungua Black Head rams were used to measure the rate and extent of degradation of dry matter, of different diets. Sheep were allowed to graze the natural pastures with free access to water throughout the experiment. EMGH (43.98%) had the lowest effective ruminal degradability (ERD) compared to LMGH (52.14%).

Table 12**:** In Sacco DM disappearance kinetics (120h) and In vitro DM disappearance (48h) of EMGH and LMGH diets.

Item	EMGH	LMGH	SED	P Value
In Sacco DM disappearance kinetics				
Wash fraction (%)	0.935	0.936	0.054	0.99
Potentially degradable fraction (%)	55.7	70.6	8.84	0.24
Undegradable fraction (%)	33.2	29.7	2.11	0.24
Extent of digestion (%)	43.98	52.14	1.414	0.03
Lag time (h)	7.32	4.27	1.77	0.23
K_d (per h)	0.170	0.132	0.09	0.69
In vitro DM disappearance				
IVDMD (%)	70.2	63.1	8.07	0.43

K_d = fractional rate of digestion; IVDMD = In Vitro DM Disappearance after 48h incubation.

CHAPTER FIVE

5.0. Discussion

5.1. Bale pH and temperature responses

Bale production in Ghana and all other sub-Saharan African countries lacks popularity and technical advancement. However, the few farmers or producers engaged in bale production in Ghana do so to reduce the bulkiness of crop residues in order to transport more crop residues per unit price and per trip not to investigate how spontaneous heating and heating degree day affect the nutritional content of the bales.

The main constraints of bale production in the sub-Saharan African countries like Ghana are i) lack of machinery such as balers, racks, tedders ii) high cost of constructing hay barns iii) environmental factors such as ambient temperature, air movement and relative humidity.

The United States, Puerto Rico amid other western lands have seen increase in the popularity and technical advancements in bale production. There have been a lot of studies on alfalfa, Bermuda grass, tall fescue, Bahia grass and orchard grass with limited or no documented research on peanut/groundnut hay bale. For the sake of this study, I will compare findings on alfalfa hay bale to groundnut hay bale since they are both from the fabaceae botanical family and are comparable in nutritional composition (Yang, 2005).

Robert (1995) and Coblentz *et al*. (1996) reported that spontaneous heating often lasts for less than 5 days with another 4-5 days to decline. This is evident in figure 6, where the EMGH had its peak temperature (44.15˚C) on day 3 and started declining (42.15˚C) on day 4 whilst the LMGH its peak temperature (43.95˚C) on day 4. This heating occurs mainly as a result of epiphytic organisms and other spoilage organism that respire and convert plant sugars into carbon dioxide, water and heat during bale storage (Coblentz *et al*., 2004). Montgomery *et al*. (1986) reported a maximum

internal bale temperature of 104˚F for 25Ibs of alfalfa rectangular bales and a 190˚F for 1,375Ibs alfalfa large round bales. This is fairly comparable to EMGH (44.15˚C) and LMGH (43.95˚C) with weight range (19 – 25kg). This shows that bale shape and weight has effect on spontaneous heating. Since the larger and heavier bales recorded the highest internal bale temperatures. The peak temperatures recorded in both EMGH (44.15˚C) and LMGH (43.95˚C) bales were within normal limits to prevent bale fire as reported by Overhults (2004) who reported that internal bale temperature ranging from 100˚F – 130˚F (37.8˚C – 54.4˚C) to be usual. However there may be some losses in hay quality.

Table: 8 shows that yenyawoso variety belonging to the early-maturing varieties (EMGH) recorded the lowest Temperature Difference (-9.13˚ C), suggesting a spontaneous heating "sweating" and a possible decaying of that bale. This is so because the internal bale temperature (42.15˚˚C - 47.15˚C) for the yenyawoso variety was much higher than the ambient temperature (30˚C - 35˚C) recorded over the period of experimentation. This is illustrated by Coblentz and Hoffman (2009) who recorded cessation of heating in bales as a result of cold ambient temperatures (mean = -3.6℃). This phenomenon is best explained by a report by Cothren (2015) who observed that at a temperature range of 130˚F to 140˚F (54.4℃ to 60.48℃) mesophilic bacteria die and internal bale temperature starts to decline.

The pH of the LMGH depicts that the bale was mouldy and is in accordance with report by Wittenberg (1997) that the pH of mouldy hay remains nearly neutral unless hay moisture level at storage is higher than 40%, pH may increase to 7.0 or more but may strive poorly with bacteria at such pH. However, the pH of EMGH is fairly comparable to the (5.18) reported by Foster *et al*. (2011) in annual peanut but much higher than (4.60) in perennial peanut haylages. A pH range of 4.6 to 5.2 is recommended for legume haylage with DM content greater than 350g/kg

(Heinrichs and Ishler, 2000). Therefore, EMGH and LMGH bales had higher pH values than preferred.

5.2. Chemical composition, nutrient intake and animal growth performance

The dry matter (DM) content of EMGH (92.36%) and LMGH (93.31%) is fairly comparable to the (91.6%) reported by Nyako (2015) and the (94.5%) reported by Yahaya *et al*. (2001) in groundnut haulms.

The ash content for EMGH (8.87%) and LMGH (8.24%) is higher than the 2.5 % recorded by Yahaya *et al.* (2001) and the (5.0%) reported by Nyako (2015) for groundnut haulm but fairly comparable to the 8.1% reported by Ansah *et al.* (2017).

The CP concentration did not differ in LMGH and EMGH. The highest value (13.75%) was observed in LMGH and the lowest in EMGH (13.69%). Nevertheless the CP content in EMGH and LMGH was higher than what was reported by (Etela and Dung, 2011; Khan *et al*., 2013; Ansah *et al*., 2017) but comparable to those reported earlier by Oteng-Frimpong et al. (2017). However, they were lower than values reported by Foster *et al*. (2011). Blümmel *et al*. (2005) reported a CP range of (10%–18%) in peanut hay. The disparity between the CP of EMGH and LMGH, and other authors may be attributed to the genetic advancement of the varieties and or inherent genetic traits. Antwi *et al*. (2014) noted similar genetic variability in estimating the haulm quality of cowpea varieties. The Crude protein (CP) estimated in EMGH and LMGH were 13.69% and 13.75% respectively and is above the recommended 7% minimum requirements for ruminants (Van Soest, 1982; NRC, 2007). This is to say that EMGH and LMGH can supply enough rumen nitrogen for microbial activities just as Van Soest (1982) reported.

The CP content of EMGH and LMGH fell within the stated range of 8 to 15% (Nigamand and Blummel, 2010; Ozyigit and Bilgen, 2013). Crude protein (CP) content is a vital indication of

nutritional quality since the varieties are used as supplements for ruminants grazing poor quality natural pasture and crop residues (Antwi *et al*., 2014).

Neutral detergent fibre (NDF) concentration was not significantly different among the EMGH and LMGH, however it was lower than in earlier reports on groundnut fodder by Etela and Dung (2011); Foster *et al*. (2011); Khan *et al*. (2013); Ansah *et al*. (2017); Oteng-Frimpong *et al*. (2017). Acid detergent fibre (ADF) content was also significantly different among the EMGH and LMGH. The EMGH (28.71%) had the highest ADF content with LMGH (26.35%) having the lowest in an opposite form of the CP content. However they were lower than values reported by other authors (Nigamand and Blummel, 2010; Ozyigit and Bilgen, 2013; Oteng-Frimpong *et al*., 2017). But fairly comparable to the 28.1% reported by Foster *et al*. (2011) and 338 g/kg DM reported by Khan *et al*. (2013). Usually, forage with high ADF indicates that it is of poor nutritional quality, has poor digestibility, and decreases animal growth when fed over a long period of time without supplementation (Owen, 1994).

Estimates for lignin (ADL) were much lower and ranges from 6.65% (66.5g/kg) to 7.63% (76.3g/kg) and possibly contain protein contamination, as well as ADF soluble. The lignin content reported in this study however is lower than the 105g/kg to 135g/kg reported by Etela and Dung (2011), but comparable to the 7.2 % to 8.0% reported in alfalfa hays by Van Soest (1965). The observed differences in lignin and cellulose are likely to influence intake and digestibility of the EMGH and LMGH varieties. Cellulose contents of EMGH and LMGH are about equal, but is lower than was reported in alfalfa hay (Van Soest, 1965). Lignin is regarded an anti-quality factor in forages for its adverse effects on the nutritional availability of plant fiber (Moore and Jung, 2001). The major role of lignin is to give strength and rigidity to the cell wall as a structural component and reduction of water loss by decreasing cell wall permeability and preventing disease

organisms is also essential (Zeikus, 1980; Dean and Eriksson 1992). Even though all of these mechanisms are desirable from the angle of plant function and survival, it reduces the nutritional quality of the plant hence unfavourable for herbivores.

The fact that the lignin level of forages is negatively associated with digestibility is well established by Jung and Deetz (1993). While this relationship has been reported for both dry matter (DM) and cell-wall digestibility by Van Soest (1964); Smith *et al*. (1972). And only has significance for cell-wall digestion as lignin does not directly impact digestibility of plant cell soluble. Moore and Jung, (2001) attributed the reason for negative correlation between DM digestibility and lignin content to increase in lignin as cell-wall concentration rises and forage cell walls are always less digestible than cell soluble. Regardless of the technique of lignin analysis used, the negative correlation between lignin concentration and cell-wall digestibility is valid and has been seen by in vivo and in vitro digestibility measures (Jung *et al*., 1997). Usually, the slope of this negative relationship is less for legumes than grasses, indicating that lignin is more inhibiting in grasses digestion (Van Soest, 1964; Buxton and Russell, 1988). This finding has mainly been taken from studies in which lignin has been measured as ADL and should be deemed suspicious because it underestimates the lignin concentration in grasses more significantly than legumes (Moore and Jung, 2001). But the opposite conclusion may in fact be true. A number of microscopic studies indicate that lignin may be more inhibiting in legumes than grasses as lignified legume tissues are virtually indigestible whereas thick-walled, lignified grass tissues can be digested to leave only thin- walled indigestible residues (Engels 1989; Engels and Jung, 1998).

A number of mechanisms have been proposed for how lignin may inhibit cell-wall digestion, though, it is agreed that lignin basically acts as a physical barrier to the microbial enzymes reaching their target polysaccharides (Chesson, 1993; Jung and Deetz 1993).

This is possibly best shown by the fact that while the negative relationship of lignin concentration is always noticed when tested across forage samples of different maturities, when plant maturity is similar (i.e. forages from breeding studies, corn silage, etc.) large differences in lignin concentration and cell-wall digestibility are observed but lignin and digestibility are often not correlated (Jung and Vogel 1992, Jung and Buxton 1994, Jung *et al*., 1994). Clearly there must be modifying factors which influence the inhibiting effect of lignin on cell-wall digestion.

The silica content in EMGH and LMGH was not significant. Although LMGH had the highest concentration of silica 2.61% as compared to 1.83% in EMGH, they were lower than the 13% reported in rice straw (Van Soest, 2006). Silica is a complex structure in diatoms and a cell wall constituent in rice and many other grasses but also present in small quantities in vegetative tissues (Van Soest, 2006). Jones and Handreck (1967) allocated plants into three categories: plants that amass huge quantities, like rice, others intermediate with lower levels, including many grasses, and those that appear to reduce silica, including legumes and other dicots, while these plants also react to sufficient degrees of silica (Epstein, 1999).

Soni *et al*. (1972); Soni and Parry (1973); Balasta *et al*. (1989); Ha *et al*. (1994a, b); Shen *et al*. (1999); Agbagla-Dohnani *et al*. (2003) reported on the way by which silica concentration in a forage inhibits digestibility with the aid of a silicified waxy cuticular layer in leaf blades, a barrier to digestion of unsilicified tissue below.

Nevertheless, Agbagla-Dohnani *et al*. (2003) stated that silica appeared to inhibit parenchyma degradation, that microscopy did not prove and might be due to inhibition of cellulolytic enzymes. Treatment with ammonia does not remove silica, but damages the cuticular layer, which allows access by rumen bacteria (Ha *et al*., 1994a, b). Nothing like lignin, which protects cell wall carbohydrates via bonding and sets an ultimate limit to digestion, silica appears to operate by

coating (Van Soest, 2006). Long-term fermentations were not performed to determine the restriction of silica on the ultimate extent of digestion. Unlike lignin, silica is a nutrient element and likely functions in more than one way in plant metabolism (Van Soest, 2006). The plant organisms that accumulate silica do so through active transport and spend one ATP per silicon atom. The cost of synthesizing an equivalent amount of lignin is about 27 ATP (Raven, 1983). Silicon deficiency in animals promotes failure of normal collagen and results in impaired bone formation (Carlisle, 1978).

The daily DM intake did not differ significantly in LMGH and EMGH diets. Dry matter intake is influenced to a large extent by dietary CP content (Rogosic *et al*., 2006). The highest concentration of daily DM intake was observed in LMGH (0.72kg/d) which as well had the highest concentration of CP and the lowest daily DM intake was observed in EMGH (0.68kg/d). Nevertheless the daily DM intake content in EMGH and LMGH was lower than the (1,383g/d) reported by Khan *et al*. (2013) and (893.0g/d – 903.4g/d) reported by Ansah *et al*. (2017). But comparable to the 766.70g/h/d recorded by Nyako (2015). The daily CP intake, daily NDF intake, daily OM intake and daily Silica intake were highest for LMGH and could be attributed to its noted highest Dry matter intake.

The average daily live weight gain (ADG) of Djallonké rams fed EMGH and LMGH variety diets are shown in (Table: 10). The average daily live weight gain (ADG) for EMGH and LMGH did not differ significantly. The highest ADG was recorded in Djallonké rams fed EMGH (0.10kg) with the least for Djallonké rams fed LMGH (0.09kg). They are however comparable to (96.40g) recorded in rams fed groundnut haulms supplemented with cotton seed cake and (94.60g), observed in rams fed groundnut hay + Maize Bran by Nyako (2015). However, higher than the (10.7g – 52.7g) range obtained by Ansah *et al*. (2017) and the (66.07g) recorded by Nyako (2015)

in groundnut haulms as a sole diet. This enormous average daily live weight gain observed in this study shows that Djallonké rams fed LMGH and EMGH variety diets, were able to take up adequate nutrients and use it to increase total live weight gain (Okoruwa *et al*., 2013). This increase in total live weight gain suggests that there was enough nutrients in EMGH and LMGH variety diets to support growth performance and can be employed in the fattening of Djallonké rams. The performance of the Djallonké rams on the EMGH and LMGH diets coincide with the claim of Vazquez and Smith (2000) that the balance between energy and protein in a ration augments live weights gain.

Although LMGH had the highest nutritive value due to its high CP concentration and low ADF content. It as well had the highest Feed Conversion Ratio (7.74) compared to (7.41) for EMGH. Since a low Feed Conversion Ratio is a good indication of high quality feed and how efficient the Djallonké rams converted ingested feed into body mass. By this definition of FCR, even though LMGH had the highest CP content and low ADF (a characteristic of a top-quality groundnut haulm as a feed for ruminants), it is of low FCR compared to EMGH, using the weight gain as an indicator. EMGH had a weight gain of compared to (4.11kg) for LMGH. The FCR range of values (14.06-45.68) reported by Ososanya (2013) when sheep were fed with diets containing graded levels of corn cob and (22.0) by Ansah *et al*. (2014) for sheep fed groundnut chaff is higher than the (7.41 and 7.74) FCR reported by this study. However, it is fairly comparable to the range of (6.84-10.84) reported by Hossain *et al*. (2003) for goats under grazing conditions.

5.3. In Sacco ruminal digestibility and IVDMD

Among EMGH and LMGH diets, the wash DM fraction was slightly greater for LMGH (0.936) than EMGH (0.935) see (Table: 11). However, they are lower than ranges 181g/kg-347g/kg (18.1% - 34.7%) and 126g/kg-242g/kg (12.6% - 24.2%) reported by Larbi *et al*. (1999) in leaf and stem of groundnut respectively; 197g/kg-351g/kg (19.7% - 35.1%) by Etela and Dung (2011) in groundnut stover; 37.2% and 31.6% by Foster *et al*. (2011) in annual peanut and perennial peanut respectively. The potentially degradable DM fraction was highest in LMGH (70.6%) and lowest in EMGH (55.7%). The potentially degradable DM fractions were both above the recommended 50% digestibility for maintenance in ruminants (Elgunaid, 1994). They are comparable to range 584g/kg-687g/kg (58.4% - 68.7%) obtained by Etela and Dung (2011) but higher than 43.7% and 48.3% observed by Foster *et al*. (2011). The undegradable DM fraction was greatest in EMGH (33.2%) and lowest in LMGH (29.7%). Foster *et al*. (2011) reported a lower undegradable fractions (19.0% and 20.2%) compared to the current study. EMGH (43.98%) had the lowest effective ruminal degradability (ERD) compared to LMGH (52.14%). Digestibility of groundnut haulms ranges from 74% to 88% in ruminants and support animals' growth performance even when fed as sole feed (Karbo *et al*., 1997). This is not in agreement with the current study. The low (ERD) recorded in this study is due to the high content of ADL and NDF in EMGH. Kamstra *et al.* (1958); Van Soest (1967) reported that poor digestibility is related to the extent of lignification of the cell wall components of the low-quality roughages. However, they are comparable to 415g/kg-489g/kg (41.5% - 48.9%) range reported by Etela and Dung (2011) but lower than 63.2% and 65.9% recorded by Foster *et al*. (2011). The lag time was longer for EMGH (7.3 in h) and shorter for LMGH (4.27 in h). The lag time before DM disappearance was longer for EMGH due to the greater NDF content. They are higher than 3.51 in h and 3.56 in h reported by Foster *et al*. (2011). The fractional rate of digestion was slower for LMGH (0.132/h) than EMGH (0.170/h). However, they

are higher than 0.11/h and 0.09/h recorded by Foster *et al*. (2011) in annual peanut and perennial peanut respectful.

The In Vitro Dry Matter Disappearance was higher in EMGH (70.2%) than in LMGH (63.1%) even though EMGH recorded the highest NDF and ADF (see Table: 9). The higher concentration of NDF and ADF in EMGH is reported to subdue rumen microbe activity due to low levels of fermentable carbohydrates (Wilson and Hatfield, 1997). This should have affected dry matter disappearance negatively. The IVDMD-value recorded for EMGH is comparable to 710g/kg (71%) reported by Fernandes *et al*. (2013) in peanut forage hay. But lower than range (75.18% - 84.13%) reported by Felix *et al*. (2018) in perennial peanut hay.

CHAPTER SIX

6.0. Conclusion and Recommendation

6.1. Conclusion

In conclusion, the nutritive estimates of the EMGH and LMGH varieties were all adequately good and can sustain the productive performance of ruminants when offered in right quantities. The concentrations of ADF and ADL were greater ($P < 0.05$) in the early- compared to late-maturing haulms whereas the extent of digestibility of the late-maturing varieties was higher than the early-maturing variety. The intake and growth performance of sheep did not however differ ($P = 0.69$).

Spontaneous heating is related to heat accumulation during bale storage. The bale temperature and pH recorded in this study suggests that the bales undergone changes in forage quality.

This study suggests that duration to maturity has no effect on the nutrient quality of groundnut haulms and on the growth performance of sheep.

6.2. Recommendation

It is recommended that EMGH and LMGH varieties can be incorporated in the diets of ruminants up to 45% without opposing effect on growth performance. This will cut down the cost of production and upsurge farmer's revenue. Since the cost of feeding contributes most to the cost of production of ruminants, using groundnut haulms which is an agro by-product and cheaper will be economical.

More studies should be conducted to ascertain the effect of early-maturing and late-maturing groundnut haulms on blood cellular and biochemical indices of sheep.

Farmers in Northern Ghana can curb the shortage of feed in the dry season (between February to May) by baling the agro by-products such as groundnut haulms after the farming season. But, it is

crucial to assess the nutrients availability to the targeted animals by conducting a feeding trial and determining the performance (such as growth rate) of animals fed on diet containing agro by-products such as groundnut haulms. Farmers/bale producers in sub-Saharan African countries like Ghana should have a better understanding of the factors that may have negative impact on bale during storage, take good decisions and produce high-quality bales.

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APPENDICES

Appendix 1: Genstat output for growth performance

```
Genstat 64-bit Release 18.2 ( PC/Windows 8) 15 July 2019 19:01:52
Copyright 2016, VSN International Ltd.
Registered to: ghana uni

 ____________________________________________

 Genstat Eighteenth Edition
 Genstat Procedure Library Release PL26.2
 ____________________________________________

  1  SET [WORKINGDIRECTORY='C:/Users/agolisi/Documents']
  2  "Data taken from unsaved spreadsheet: New Data;1"
  3  DELETE [REDEFINE=yes] _stitle_: TEXT _stitle_
  4  READ [PRINT=*; SETNVALUES=yes] _stitle_
  7  PRINT [IPRINT=*] _stitle_; JUST=left

Data imported from Clipboard
 on: 15-Jul-2019 19:05:39

  8  DELETE [REDEFINE=yes] TRT,DMI_kg,INI_WT,FIN_WT,WT_Change_kg,ADG_kg,FCR
  9  UNITS [NVALUES=*]
 10  FACTOR [MODIFY=no; NVALUES=22; LEVELS=2; LABELS=!t('EMGH','LMGH')\
 11  ; REFERENCE=1] TRT
 12  READ TRT; FREPRESENTATION=ordinal

      Identifier        Values       Missing        Levels
             TRT            22             0             2

 14  VARIATE [NVALUES=22] DMI_kg
 15  READ DMI_kg

      Identifier       Minimum          Mean       Maximum        Values       Missing
          DMI_kg        0.4916        0.6954        0.9020            22             0

 22  VARIATE [NVALUES=22] INI_WT
 23  READ INI_WT

      Identifier       Minimum          Mean       Maximum        Values       Missing
          INI_WT         11.35         14.63         20.48            22             0

 26  VARIATE [NVALUES=22] FIN_WT
 27  READ FIN_WT

      Identifier       Minimum          Mean       Maximum        Values       Missing
          FIN_WT         13.99         18.89         23.95            22             0

 30  VARIATE [NVALUES=22] WT_Change_kg
 31  READ WT_Change_kg

      Identifier       Minimum          Mean       Maximum        Values       Missing
    WT_Change_kg        -0.1800        4.261         6.590            22             0
```

```
34  VARIATE [NVALUES=22] ADG_kg
35  READ ADG_kg
```

Identifier	Minimum	Mean	Maximum	Values	Missing
ADG_kg	-0.004000	0.09469	0.1464	22	0

```
41  VARIATE [NVALUES=22] FCR
42  READ FCR
```

Identifier	Minimum	Mean	Maximum	Values	Missing
FCR	-0.005683	0.1360	0.2291	22	0

```
49
50  %PostMessage 1129; 0; 100001 "Sheet Update Completed"
51  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
52   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=INI_WT
```

Two-sample t-test

Variate: INI_WT
Group factor: TRT

Test for equality of sample variances

Test statistic F = 1.39 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.61

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	14.66	6.119	2.474	0.7458
LMGH	11	14.61	8.505	2.916	0.8793

Difference of means: 0.055
Standard error of difference: 1.153

95% confidence interval for difference in means: (-2.351, 2.460)

Test of null hypothesis that mean of INI_WT with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = 0.05 on 20 d.f.

Probability = 0.963

```
53  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
54   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=WT_Change_kg
```

Two-sample t-test

Variate: WT_Change_kg
Group factor: TRT

Test for equality of sample variances

Test statistic F = 2.74 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.13

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	4.411	1.598	1.264	0.3812
LMGH	11	4.111	4.378	2.092	0.6309

Difference of means: 0.300
Standard error of difference: 0.737

95% confidence interval for difference in means: (-1.238, 1.838)

Test of null hypothesis that mean of WT_Change_kg with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = 0.41 on 20 d.f.

Probability = 0.688

```
55  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
56   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=FIN_WT
```

Two-sample t-test

Variate: FIN_WT
Group factor: TRT

Test for equality of sample variances

Test statistic F = 2.07 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.27

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	19.07	5.254	2.292	0.6911
LMGH	11	18.72	10.863	3.296	0.9937

Difference of means: 0.355

Standard error of difference: 1.210

95% confidence interval for difference in means: (-2.170, 2.879)

Test of null hypothesis that mean of FIN_WT with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = 0.29 on 20 d.f.

Probability = 0.773

```
57  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
58   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=FCR
```

Two-sample t-test

Variate: FCR
Group factor: TRT

Test for equality of sample variances

Test statistic F = 1.67 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.43

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	0.1463	0.001955	0.04422	0.01333
LMGH	11	0.1257	0.003266	0.05715	0.01723

Difference of means: 0.0206
Standard error of difference: 0.0218

95% confidence interval for difference in means: (-0.02485, 0.06604)

Test of null hypothesis that mean of FCR with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = 0.95 on 20 d.f.

Probability = 0.356

```
59  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
60   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=DMI_kg
```

Two-sample t-test

Variate: DMI_kg
Group factor: TRT

Test for equality of sample variances

Test statistic F = 2.42 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.18

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	0.6753	0.00599	0.07738	0.02333
LMGH	11	0.7155	0.01451	0.12045	0.03632

Difference of means: -0.0402
Standard error of difference: 0.0432

95% confidence interval for difference in means: (-0.1302, 0.04984)

Test of null hypothesis that mean of DMI_kg with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = -0.93 on 20 d.f.

Probability = 0.363

```
61  TTEST [PRINT=summary,test,confidence,variance; METHOD=twosided; GROUPS=TRT; CIPROB=0.95;\
62   VMETHOD=automatic; NTIMES=4999; SEED=0] Y1=ADG_kg
```

Two-sample t-test

Variate: ADG_kg
Group factor: TRT

Test for equality of sample variances

Test statistic F = 2.74 on 10 and 10 d.f.

Probability (under null hypothesis of equal variances) = 0.13

Summary

Sample	Size	Mean	Variance	Standard deviation	Standard error of mean
EMGH	11	0.09802	0.000789	0.02809	0.00847
LMGH	11	0.09135	0.002162	0.04650	0.01402

Difference of means: 0.0067
Standard error of difference: 0.0164

95% confidence interval for difference in means: (-0.02750, 0.04083)

Test of null hypothesis that mean of ADG_kg with TRT = EMGH is equal to mean with TRT = LMGH

Test statistic t = 0.41 on 20 d.f.

Probability = 0.688

Appendix 2: SAS output for In Sacco degradability

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The NLIN Procedure
Dependent Variable DMrem

Grid Search

a	k	L	r	Sum of Squares
50.3200	0.1147	9.0000	42.1900	2218.4

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The NLIN Procedure
Dependent Variable DMrem
Method: Marquardt

Iterative Phase

Iter	a	k	L	r	Sum of Squares
0	50.3200	0.1147	9.0000	42.1900	2218.4
1	59.9481	0.0594	3.3487	31.1748	463.1
2	65.5986	0.0833	2.5137	31.7786	182.6
3	65.7462	0.0971	3.6725	31.6310	154.6
4	65.6358	0.1014	3.6670	31.7414	150.7
5	65.5927	0.1026	3.7110	31.7845	150.6
6	65.5794	0.1030	3.7220	31.7978	150.6
7	65.5758	0.1031	3.7249	31.8014	150.6
8	65.5749	0.1031	3.7256	31.8023	150.6
9	65.5747	0.1031	3.7258	31.8025	150.6
10	65.5746	0.1031	3.7258	31.8026	150.6

NOTE: Convergence criterion met.

Estimation Summary

Method	Marquardt
Iterations	10
R	7.453E-6
PPC(k)	3.497E-6
RPC(k)	0.000014
Object	1.076E-9
Objective	150.5768

Observations Read	16
Observations Used	16
Observations Missing	0

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	9727.6	3242.5	258.41	<.0001
Error	12	150.6	12.548		
Corrected Total	15	9878.2			

The NLIN Procedure

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
a	65.5746	2.8153	59.4407	71.7086
k	0.1031	0.0140	0.0727	0.1335
L	3.7258	0.7381	2.1176	5.3341
r	31.8026	1.2852	29.0023	34.6028

Approximate Correlation Matrix

	a	k	L	r
a	1.0000000	-0.2066571	-0.5203891	-0.4565123
k	-0.2066571	1.0000000	0.6478985	0.4526868
L	-0.5203891	0.6478985	1.0000000	0.1614831
r	-0.4565123	0.4526868	0.1614831	1.0000000

The NLIN Procedure
Dependent Variable DMrem

Grid Search

a	k	L	r	Sum of Squares
50.3200	0.1147	9.0000	42.1900	1714.6

The NLIN Procedure
Dependent Variable DMrem
Method: Marquardt

Iterative Phase

Iter	a	k	L	r	Sum of Squares

0	50.3200	0.1147	9.0000	42.1900	1714.6
1	62.0265	0.0502	4.1938	33.7142	1111.5
2	62.6306	0.0746	5.5733	33.7611	779.3
3	63.2037	0.0850	5.5059	33.1752	721.7
4	63.0861	0.0887	5.6070	33.2933	719.5
5	63.0299	0.0897	5.6276	33.3495	719.3
6	63.0125	0.0900	5.6341	33.3669	719.3
7	63.0075	0.0901	5.6360	33.3718	719.3
8	63.0062	0.0901	5.6365	33.3732	719.3
9	63.0058	0.0901	5.6366	33.3736	719.3
10	63.0057	0.0901	5.6367	33.3737	719.3

NOTE: Convergence criterion met.

Estimation Summary

Method	Marquardt
Iterations	10
Subiterations	7
Average Subiterations	0.7
R	6.063E-6
PPC(k)	5.279E-6
RPC(k)	0.000019
Object	6.19E-10
Objective	719.2658
Observations Read	16
Observations Used	16
Observations Missing	0

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	10700.6	3566.9	59.51	<.0001
Error	12	719.3	59.9388		
Corrected Total	15	11419.9			

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The NLIN Procedure

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
a	63.0057	6.1892	49.5206	76.4908
k	0.0901	0.0227	0.0408	0.1395
L	5.6367	1.3904	2.6073	8.6660
r	33.3737	2.8874	27.0826	39.6647

Approximate Correlation Matrix

	a	k	L	r

a	1.0000000	-0.2210653	-0.6474736	-0.4665168
k	-0.2210653	1.0000000	0.3661207	0.4738636
L	-0.6474736	0.3661207	1.0000000	0.0733362
r	-0.4665168	0.4738636	0.0733362	1.0000000

The NLIN Procedure
Dependent Variable DMrem

Grid Search

a	k	L	r	Sum of Squares
50.3200	0.1147	9.0000	42.1900	4496.1

The NLIN Procedure
Dependent Variable DMrem
Method: Marquardt

Iterative Phase

Iter	a	k	L	r	Sum of Squares
0	50.3200	0.1147	9.0000	42.1900	4496.1
1	68.1979	0.1699	4.5992	28.2648	587.5
2	75.6228	0.1568	4.7997	27.5772	335.5
3	75.5903	0.1605	4.8105	27.6097	334.8
4	75.6020	0.1601	4.8060	27.5980	334.7
5	75.6009	0.1601	4.8065	27.5990	334.7
6	75.6010	0.1601	4.8064	27.5989	334.7

NOTE: Convergence criterion met.

Estimation Summary

Method	Marquardt
Iterations	6
R	5.493E-6
PPC(k)	3.31E-6
RPC(k)	0.000029
Object	2.06E-9
Objective	334.7475
Observations Read	16
Observations Used	16
Observations Missing	0

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F

Model	3	13547.8	4515.9	161.89 <.0001
Error	12	334.7	27.8956	
Corrected Total	15	13882.6		

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
a	75.6010	4.1433	66.5736	84.6285
k	0.1601	0.0279	0.0994	0.2208
L	4.8064	0.5678	3.5692	6.0436
r	27.5989	1.7941	23.6898	31.5080

The NLIN Procedure

Approximate Correlation Matrix

	a	k	L	r
a	1.0000000	-0.1765181	-0.5398532	-0.4330228
k	-0.1765181	1.0000000	0.5598303	0.4076416
L	-0.5398532	0.5598303	1.0000000	0.1158413
r	-0.4330228	0.4076416	0.1158413	1.0000000

The NLIN Procedure
Dependent Variable DMrem

Grid Search

a	k	L	r	Sum of Squares
50.3200	0.1147	9.0000	42.1900	3168.9

The NLIN Procedure
Dependent Variable DMrem
Method: Marquardt

Iterative Phase

Iter	a	k	L	r	Sum of Squares
0	50.3200	0.1147	9.0000	42.1900	3168.9
1	48.6727	0.1422	6.8826	32.8417	493.5
2	48.5672	0.1851	8.2744	32.9473	486.4
3	48.4817	0.2197	8.6626	33.0328	480.1
4	48.4500	0.2414	8.9231	33.0644	479.6

5	48.4392	0.2490	8.9957	33.0753	479.5
6	48.4364	0.2505	9.0107	33.0781	479.5
7	48.4359	0.2507	9.0129	33.0785	479.5
8	48.4359	0.2507	9.0132	33.0786	479.5

NOTE: Convergence criterion met.

Estimation Summary

Method	Marquardt
Iterations	8
R	2.263E-6
PPC(k)	0.000011
RPC(k)	0.000094
Object	3.91E-10
Objective	479.4876
Observations Read	16
Observations Used	16
Observations Missing	0

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	6781.2	2260.4	56.57	<.0001
Error	12	479.5	39.9573		
Corrected Total	15	7260.7			

The NLIN Procedure

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
a	48.4359	3.8732	39.9969	56.8749
k	0.2507	0.3657	-0.5461	1.0475
L	9.0132	4.3847	-0.5403	18.5667
r	33.0786	2.2389	28.2006	37.9566

Approximate Correlation Matrix

	a	k	L	r
a	1.0000000	-0.2498156	-0.2695886	-0.5780347
k	-0.2498156	1.0000000	0.9812887	0.4321809
L	-0.2695886	0.9812887	1.0000000	0.3825915
r	-0.5780347	0.4321809	0.3825915	1.0000000