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AVAILABILITY AND UTILIZATION OF FEED RESOURCES IN SMALL RUMINANT PRODUCTION AMONG SMALLHOLDER FARMERS IN NORTHERN GHANA

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AVAILABILITY AND UTILIZATION OF FEED RESOURCES IN SMALL RUMINANT PRODUCTION AMONG SMALLHOLDER FARMERS IN NORTHERN GHANA

BY

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JULY, 2018

DECLARATION

Student

I hereby declare that this thesis is the result of my own original research work and that no part of it has been submitted for another degree in this university or elsewhere.

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ABSTRACT

An evaluation of feed resource availability, utilization and options for improving efficiency of use was investigated in 2 Surveys and 3 Experiments. The first Survey was an assessment of existing feed resources in a crop-livestock production system for identification of critical seasonal shortages. Focus group discussions involving 150 crop – livestock farmers (108 men 42 women) and individual interviews with semi-structured questionnaires were used in collection of data. The results showed that existing feed resources were natural pasture, crop residues, and agro-industrial by-products. However, few farmers (18%) had stands of browse plants like *Leucaena leucocephala, Cajanus cajan and Gliricidia sepium*. Grazing of natural pasture provided 80% of annual DM requirement of ruminants and 20% supplemented by farmers with collected natural fodder, crop residues and purchased feed. Feed availability was highest between August and November; and a shortage gap occurred in the dry season which became critical between February and April. The second Survey involved an assessment of emerging feed markets in northern Ghana to determine the types and prices of feedstuffs sold. Data were collected from feed markets in Wa, Bolgatanga and Tamale in Upper West, Upper East and Northern regions respectively. A total of 170 respondents were interviewed for this study. Four categories of feedstuffs: crop residues, agro-industrial by-products (AIBPs), fresh grasses and leaves of local browse plants were found in all the three feed markets surveyed. Price of cowpea haulm was highest ($P<0.05$) at GH₵ 1.00 /kg DM whereas rice bran was the lowest at GH₵ 0.12 /kg DM. Prices of feedstuffs differed ($P<0.05$) among markets and were highest (GH₵ 0.58/kg DM) in Bolgatanga market and lowest (GH₵ 0.32/kg DM) in the Wa market. The CP content of feedstuffs had less influence on price variations. The effect of season on quantity and quality of forage in communal pasture was estimated in Experiment I to determine the extent of herbage

variations in different seasons observed in Survey I. Data were collected in early dry (Nov-Jan) and late dry (Feb-Apr) seasons, and early wet (May-Jul) and main wet (Aug-Oct) seasons using a 1-m^2 wooden quadrat. This Experiment was conducted as a randomized complete block design. The 3 regions were blocked, 3 communities in each region were replicates and 4 seasons as treatments. It included 9 communal pasture fields' herbage yield estimation, 3 in each region of northern Ghana. Six quadrat samples were taken per field in each season for 4 seasons. Also, residue yields of commonly grown crops were estimated at crop harvest. Herbage yield differed ($P<0.05$) among seasons. The values were 3.08, 1.71, 0.56 and 2.33 tonnes DM/ha for early dry, late dry, early wet and main wet seasons respectively. Season affected ($P<0.05$) nutritive quality of pasture. Crude protein content of the commonly grazed forage species differed ($P<0.05$) among seasons. The values obtained were 75, 45, 174 and 165 g/kg DM for early dry, late dry, early wet and main wet seasons respectively. Estimated crop residue generated as part of the feed resources showed that sorghum residue yield was 8.5 tonnes DM/ha and was highest ($P<0.05$) whereas cowpea had the lowest value (1.8 tonnes DM/ha). In order to address the low quality and quantity of feedstuff in the pasture, on-farm feed supplementation was investigated in Experiment II. This was to determine the effect of concentrate supplementation plus healthcare and season on the intake and voiding of DM and N and growth performance of sheep in the Northern, Upper East and Upper West regions of Ghana. The experiment was done as a randomized complete block design. Regions were blocked and communities in each region were replicates. A total of 36 smallholder sheep farms with an average of 18.6 ± 8.7 sheep per farmer were selected. The animals in each farm were randomly assigned to one of two feeding regimes as treatments. The treatments were none-concentrate supplementation (control) and application of a combined package of concentrate supplementary feed plus healthcare. Data were collected in each season. Animals on concentrate supplementation plus healthcare had higher (P<0.05) intake of DM (608 g DM/d) than control group (515 g DM/d). Season significantly (P<0.05) affected DM intake. The highest intake of DM was observed during early wet season (679 g DM/d) and lowest in main wet season (397 g DM/d). Faecal output was not affected (P>0.05) by supplementation. Season however, affected (P<0.05) faecal output. Nitrogen (N) intake was affected (P<0.05) by concentrate supplementation. The highest N intake was observed during early wet season (14 g/d) and the lowest in the late dry season (7 g/d). Highest N voiding was found in early wet season (6 g/d) and lowest in late dry season (4 g/d). Average daily gain of 34 g/d was observed in animals on concentrate supplementation plus health care and was higher (P<0.05) than 18 g/d in control group. The N content of faeces was higher in early dry and early wet seasons than in other seasons. Thus faeces could be collected as manure for improving poor soils. Due to the cost of concentrate feed, Experiment III was conducted to further investigate the growth performance of Djallonkè sheep on agro-residues supplementation that require minimal cost. The treatments were non-supplementation (T0), supplementation with sole groundnut haulm (T1), sole maize bran (T2) and combination of T1 and T2 in a ratio of 2:1. These 4 treatments were replicated 3 times in a completely randomized design. The supplementation affected (P<0.05) average daily gain of the animals. The Average daily gains of the various treatments were 21, 32, 31 and 46 g/d for T0, T1, T2 and T3 respectively. Therefore combined supplementation of crop residues and AIBPs improved the performance of sheep.

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DEDICATION

I dedicate this thesis to my mother Pokper Konlan for her care, love and trust in me.

LIST OF PUBLICATION AND CONFERENCE PAPERS

Journal articles

1. Konlan, S. P., Ayantunde, A. A., Addah, W., Dei, H. K., Karbo, N. (2017). Emerging feed markets for ruminant production in urban and peri-urban areas of Northern Ghana. Tropical Animal Health and Production. 50: 169 –176.

2. Konlan, S. P., Ayantunde, A. A., Addah, W. and Dei, H. K. (2017). The combined effects of the provision of feed and healthcare on nutrient utilization and growth performance of sheep during the early or late dry season. Tropical Animal Health and Production, 49: 1423–1430.

3. Konlan, S. P., Ayantunde, A. A**.,** Addah, W., Dei, H. K. and Avornyo, F. K. (2016). Evaluation of feed resource availability for ruminant production in Northern Ghana. International Journal of Livestock Research, 6: 39–59.

Conference papers

1. Konlan, S. P., Ayantunde, A. A., Addah, W., Dei, H. K. and Panyan, E. K. (2017). Effect of season on availability and quality of communal pasture for ruminant production in the Savanna ecological zone of Northern Ghana. Paper presented at the Ghana Society of Animal Production (GSAP) 20th International Biennial Conference, 1st – 5th August, 2017. University of Cape Coast, Ghana

2. Konlan, S. P., Ayantunde, A. A., Addah,W., Dei, H. K., Avornyo, F. K. and Karbo, N. (2016). Effect of concentrate feed supplementation plus healthcare and season on intake

and voiding of dry matter and nitrogen and growth performance of sheep in smallholder production system. Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) in Sudan and Guinea Savannas of West Africa Project Phase I Legacy Workshop. 12 - 13 December, 2016 Bamako, Mali. Book of abstracts, pp, 19.

3. Konlan, S. P., Ayantunde, A. A., Addah, W**.,** Dei, H. K, Avornyo, F. K. and Karbo, N. (2015). Nutrient used in smallholder small ruminant production system in Northern Ghana. University for Development Studies Annual Interdisciplinary Conference, 2nd – 3rd September, 2015, Wa Campus. Book of abstracts, pp, 13–14.

4. Konlan, S. P., Ayantunde, A. A., Addah, W**.**, Dei, H. K. and Hagan, B. A. (2014). Evidence of emerging feed market in Northern Ghana for ruminant production. Proceedings of 32nd Biennial Conference of Ghana Animal Science Association, 20th - 22nd August, 2014. University for Development Studies, Tamale. pp, 61–71.

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ABBREVIATIONS

AIBPs: Agro-industrial by-products

ADF: Acid detergent fibre

ADG: Average daily gain

ADL: Acid detergent lignin

AOAC: Association of Official Analytical Chemists

CP: Crude protein

DM: Dry matter

GSS: Ghana Statistical Service

ILRI: International Livestock Research Institute

IVOMD: *In vitro* organic matter digestibility

MoFA: Ministry of Food and Agriculture

NDF: Neutral detergent fibre

N: Nitrogen

OM: Organic matter

SSA: Sub-Saharan Africa

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the study

Poverty is the greatest human challenge in developing countries and about 766 million people in the world live on less than 2 United States Dollars (USD) per day (Max and Esteban, 2017). These people are considered as extremely poor and about 40% of them live in Sub-Saharan Africa (SSA) countries (Max and Esteban, 2017). Agriculture provides 60% of total employment in this region and about 70 to 80% of the population live in rural areas and depend heavily on crops and livestock production for their livelihood (Agyemang, 2012; FAO, 2012). Most of these smallholder farmers are poor and often have low productivity due to challenges in inputs and managements practices. However, research has estimated that this smallholder farmers produce 90% of agricultural products in SSA (FAO, 2012). An increase in productivity will directly reduce the poverty level of this population.

In Ghana, agriculture contributes about 20% of the GDP with livestock and poultry contributing about 6% (MoFA, 2016). The livestock sub-sector suplies meat, milk and eggs as source of protein. It also provides skin, bones and horns for other uses (Oppong-Anane, 2013). Animals are also used for socio-cultural purposes such as funeral performance, cerebration of festivals and marriage rites (Karbo and Agyare, 2002). About 70% of livestock and livestock products are produced by smallholder farmers in northern Ghana (Oppong-Anane, 2008).

Livestock has been reported to improve stability and resilliancy of farm interprises, serve as a store of wealth, provide ready cash, reduce risk of crop failure and help farmers to purchase imputs for farm expansion (Karbo and Agyare, 2002). Small ruminants are often sold by the smallholder farmers to buy foodstuffs (cereal grains) for households during food shortage, mostly in June to July in northern Ghana where most livestock species are produced (MoFA, 2004; Oppong-Anane, 2013). The crop-livestock production system is the dominant farming practice in northern Ghana in which over 70% of smallholder farmers rear sheep and goats as part of their production system (Oppong-Anane, 2008). Diseases, poor quality and unstable availability of feedstuffs have been reported as the major production constraints of the smallholder farmers (Smith, 2010; Amankwa *et al*., 2012; Oppong-Anane, 2013).

1.2 Justification of the study

Intensification of crop-livestock production system to increase productivity of smallholder farmers requires efficient use of feed resources especially crop residues and animal manure as an alternative to chemical fertilizers (Kang, 1993).

Smallholder farmers depend on natural pasture as the main source of feedstuffs for ruminant production and the occurrence of seasonal feed shortages is a major factor that limits the productivity of ruminants (Osei, 2012). It has become evident that storage of feedstuffs, development of pasture and judicious use of available feed resources in livestock production systems are the best practices for sustainable increase in production.

Also, the quality of feed resources is often not stable throughout the year (Annor *et al*., 2007). It was reported that change in season from wet to dry affects nutrient content of feed resources and reduces their digestibility (Minson, 1990; Agyemang, 2012). In these periods, the feeding levels may need to be adjusted to sustain productivity. Beside the effect of season on feed quality, population growth and urbanization have led to increasing practice of supplementary feeding among many smallholder farmers due to decreasing area of range land in urban areas. Most supplementary feeding trials are often done with provision of healthcare. Baiden *et al*. (2008) reported that concentrate feed supplementation and health provision increased average daily gain of lambs up to 72 g/d compared to 44 g/d for the control. According to Avornyo *et al*. (2015) provision of feed and health care intervention on open grazed small ruminants reduced mortality from 17% to 10%. Feed supplementation and health provision also led to shorter birth intervals, increased birth weight and preweaning growth rate (Karbo *et al*., 2004; Baiden *et al*., 2008; Smith, 2010). However, the nutrient composition of the supplementary feed offered by smallholder farmers is often unbalanced due to inadequate information on the nutrient content of feed ingredients, on-farm digestibility and inappropriate amounts of feed offered (Baiden *et al*., 2008; Ayantunde *et al*., 2014).

The efficient use of feed and other resources is vital in promoting integration and intensification in crop-livestock farming systems in maximizing output (Mariana**,** 2008). Practices associated with intensification of small ruminant production include increased concentrate feeding, fodder cultivation for stall feeding and improved housing units for animals (Karbo and Agyare, 2002). But does crop-livestock integration and intensification lead to increased resource use efficiency and higher productivity of the farming system? Even though intensification of the production systems often increases input use and strengthens income generation among farmers, it does not guarantee efficient resource use. To sustain intensification of sheep and goats production systems, it is necessary to harness the complementary benefits inherent in the system. The core issues in crop-small ruminant integration are nutrient use efficiency that directly affects production cost, and profitability.

One of the specific pathways that could help intensify small ruminant production is the efficient use of feed resources through optimum concentrate and crop residues supplementation. In this feed resource use efficiency, nutrient inflow, digestibility and faecal nutrient concentration are important but influenced by many other factors. One of these factors is nutrient content of feedstuff that greatly influences nutrient intake, digestibility and faecal nutrient content (Powell *et al*., 1996).

Nitrogen (N) is one of the major nutrients that impacts greatly on productivity of crop-livestock production systems. The intake of N in ruminants on natural pasture is influenced by seasonality due to changes in forage nutrient composition and species diversity (Powell *et al*., 1996). Schlecht *et al*. (1995) reported 2.9% increase in daily N intake from 1.3% during late dry season to 4.2% in early wet season of total dry matter (DM) intake among cattle in Mali. Powell *et al*. (1996) were of the view that in sheep and goats N intake from natural pasture is higher than cattle. Also, N intake and excretion are highly controlled by feeding regime and increases with legume forage and cereal based concentrate supplementation (Powell *et al*., 1996). Most high N containing feedstuffs are less available especially in urban areas. Farmers in these areas often buy them for supplementing their animals.

In relation to feed resource availability in urban areas for ruminant production, there is an emerging feed market in northern Ghana that makes feed available to urban and peri-urban ruminant farmers. This emanated from feed shortage constraint and has led to the collection of different types of feedstuffs for sale (Huseini *et al*., 2011). These feed resources are mostly bought by ruminant farmers and traders to supplement their animals. Some work has been done on forage collection, storage methods and the feeding effects of browses and crop residues in

Ghana (Antwi *et al*., 2010; Oppong-Anane, 2013). However, knowledge on nutritional quality and prices of these feedstuffs sold is not available but relevant for development of the feed market.

This work sought to fill in the knowledge gap on quantitative seasonal feed resource availability, nutritional quality and digestibility in northern Ghana throughout the year. This could help farmers meet the nutritional requirements of their animals to increase productivity. Also, an on-farm investigation on feed supplementation practices with concentrate and crop residues throughout the year in the small ruminant production system in northern Ghana needs to be conducted. This has not been done as a single study in northern Ghana but can improve the feeding strategies and reduce waste of feed resources. Lastly, the relationship between nutritional quality and prices of feedstuffs sold in the emerging livestock feed market that contribute to seasonal feed availability should be investigated to enhance development of the emerging feed market in northern Ghana.

1.3 Research questions

1. What are the existing and potential feed resources available for animal production in northern Ghana?
2. Does the communal pasture contain sufficient quantity and good quality of feed throughout year?
3. What are the commonly grazed forage species in the natural pasture? What level of nutrient do these contain?
4. How does change in season effects feed availability and quality at pasture?

5. Which feed types are sold at the market in northern Ghana for ruminant production?
6. Can concentrate supplementation help increase DM and N intake and digestibility in the smallholder sheep production system to improve productivity?

1.4 Main objective

The overall objective of this study was to estimate the effect of season on feed availability, utilization and growth performance of sheep in a smallholder production system in northern Ghana.

1.5 Specific objectives

The specific objectives were to:

i. assess availability of feed resources for ruminant production among smallholder farmers in northern Ghana

ii. determine feed quality and price relationship in an emerging feed market and the opinion of feed sellers and buyers on the market development

iii. estimate the effect of season on feed resources availability and quality in the communal pasture for ruminant production

iv. determine the effect of concentrate supplementation plus health care and season on intake and voiding of DM and N in a smallholder sheep production system in northern Ghana

v. identify the best and low cost feeding options that improve productivity in a smallholder sheep production system in northern Ghana

CHAPTER 2

2.0 LITERATURE REVIEW

2.1. Importance of Livestock

In many Sub-Saharan Africa (SSA) countries, livestock production contributes about 35% of agricultural gross domestic product (GDP) and employs about 70% of of the people especially in the rural areas (Winrock International, 1992; FAO, 2012). FAO (2012) estimated that smallholder farmers produce 90% of SSA agricultural products. In this region, livestock provides up to 18% of the dietary protein needs of the population with high quality animal protein to balance the high carbohyrdate diets of the people (Karbo and Agyare, 2002).

In Ghana, agriculture contributes about 20% of the GDP with livestock and poultry contributing about 6% (MoFA, 2016). The growth of the agricultural sector over the years contributed heavily to the economy of Ghana. However, this has been declining in recent years from 4.6% to 4.2% in 2014 and 2015 respectively. The livestock sub-sector suplies meat, milk and eggs as source of protein. It also provides skin, bones and horns for other uses (Oppong-Anane, 2013). Major livestock species reared in Ghana include cattle, sheep, goats, pigs and poultry. These animals are distributed among five agro-ecological zones (Figure 2.1) in Ghana (MoFA, 2016).

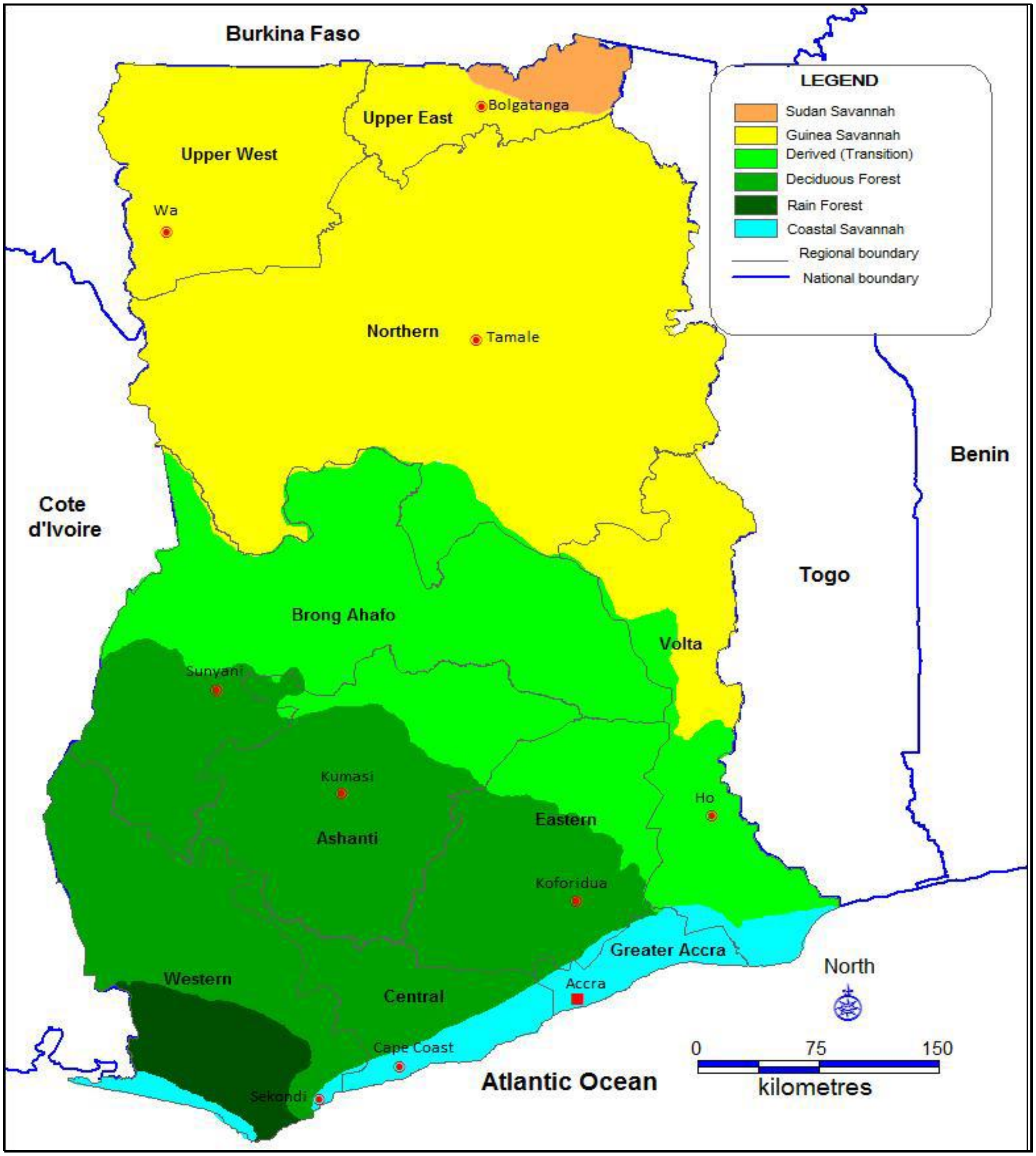


Figure 2.1 Agro-ecological map of Ghana. Source; MoFA (2001)

Livestock production significantly contributes to agriculture intensification and sustainability of crop production through residue utilization, provision of traction as well as soil fertility restoration (FAO, 2012). Among smallholder farmers, livestock improves the stability and resilliancy of farm interprise, serve as a store of wealth, provides ready cash, reduces risk of crop failure and helps farmers to purchase inputs (Karbo and Agyare, 2002). In the northern Savanna Ecological Zone, livestock production is adjunct to crop farming (Oppong-Anane, 2013). Production paramenters of livestock in Ghana and the population of farm animals in northern Ghana as a proportion of national population (Tables 2.1a and 2.1b) indicate that the higheset productivity of livestock is achieved in the northern Savannah Agro-ecological Zone (MoFA, 2004). This zone covers Northern, Upper East and Upper West regions and parts of Volta and Brog-Ahafo regions. Specifically, 70% of cattle, 30% sheep, 35% goats and 40% of pigs are produced in the northern Savannah Agro-cological Zone (Oppong-Anane, 2008).

Table 2.1a: Rainfall and livestock production in the Agro-ecological Zones of Ghana

Agro-ecological Zone	Annual rainfall (mm)[1]	Pasture yield (tons/ha DM)[2]	Livestock herd size[3]			Households ownership of livestock species (%)[4]		
			Cattle	Sheep	Goats	Cattle	Sheep	Goats
Coastal Savanna	800	3.5	6	6	7	3.1	18.3	34.7
Forest	2,200	-	6	6	6	0.3	27.1	38.3
Transitional	1,300	-	10	8.7	10.9			
Guinea Savanna	1,100	2.2	10	12	9	25.1	38.3	58.7
Sudan Savanna	1,000	-	12	11	15	-	-	-

Sources: [1]MoFA (2011), [2]Oppong-Anane (2006), [3]Oppong-Anane (2008), [4]MoFA (2004)

Table 2.1b: Livestock population in northern Ghana as a proportion of national population

Livestock species	Region/national	1992	1996	Growth rate
Cattle	Northern	448,765	429,460	-4.3
	Upper East	189,816	214,717	13.1
	Upper West	243,193	284,162	16.8
	Total	881,774	928,339	5.3
	Notional	1,159,431	1,247,861	7.6
	% of national	76.05	74.39	-2.2
Sheep	Northern	382,054	339,406	-11.2
	Upper East	519,000	211,670	-59.2
	Upper West	255,854	331,819	29.7
	Total	1,156,908	882,895	-23.7
	Notional	2,125,522	2,418,738	13.8
	% of national	54.43	36.50	-32.9
Goats	Northern	412,198	365,314	-11.4
	Upper East	185,768	192,689	3.7
	Upper West	361,932	542,316	49.8
	Total	959,898	1,100,319	14.6
	Notional	2,157278	2,532,710	17.4
	% of national	44.50	43.44	-2.4
Pigs	Northern	112,281	45,727	-59.3
	Upper East	28,084	36,767	30.9
	Upper West	43,611	68,886	58.0
	Total	183,976	151,380	-17.7
	Notional	413,243	354,678	-14.2
	% of national	44.52	42.68	-4.1

Source; Modified from VSD (1992 and 1996) in Karbo and Agyare (2002)

Crop-livestock production is the dominant farming system practiced in the northern Savanna Agro-ecological Zone. In this zone, over 70% of smallholder farmers in rural and per-urban areas rear sheep and goats as part of their production system (Karbo and Agyare, 2002; Oppong-Anane, 2013).

Diseases, mostly helminthiasis and *Peste des Petits Ruminant* (PPR), poor quality and unstable availability of feedstuffs are the major production constraints of the smallholder farmers (Amankwa *et al*., 2012; Smith, 2010; Oppong-Anane, 2013).

The constraints to livestock productivity have led to low domestic meat production in Ghana and has resulted in high importation of meat and other animal products (Osei, 2012). Although, MoFA (2016) reported significant decrease in meat importation from 2008 to 2016 in Ghana (Table 2.2) as a result of increase in national production, the average meat importation in this period is still over 40% of the national demand (MoFA, 2016). This underscores the need to accelerate production and reduce this importation. Improving small ruminant production among smallholder farmers by improving feed resource quality, availability and feeding practices could contribute substantially in reducing the meat importation in Ghana (Oppong-Anane, 2013).

Table 2.2: Production and importation of meat (tonnes) in Ghana from 2008 to 2015

Year	**Import**	**Domestic production**	**Total**	**% imported**
2008	125,208	100,935	226,143	55.37
2009	95,176	105,772	200,948	47.36
2010	91,904	111,390	203,294	45.21
2011	111,285	118,504	229,789	48.43
2012	97,720	127,038	224,758	43.48
2013	88,258	135,412	223,670	39.46
2014	45,817	143,603	189,420	24.19
2015	48,144	150,751	198,895	24.21
Mean	87,939	124,176	212,115	40.96
Min	45,817	100,935	189,420	24.19
Maxi	125,208	150,751	229,789	55.37

Source; MOFA (2016)

2.2.1 Existing feed resources for ruminant production in Ghana

Feed resources in Ghana can be classified as natural pasture, browse plants, improved pasture, crop residues and agro-industrial by-products (AIBPs) (Smith, 2010; Tolera *et al*., 2012). Major feed resources for ruminants include 1) natural pasture 2) forage re-growth in cultivated fields and 3) crop residues which become available after crops harvest (Awuma, 2012; Appong-Anane, 2013). Agro-industrial by-products from cereals, legumes and tuber crops also contribute to the feed resource pool (Ansah *et al*., 2012).

2.2.2 Natural pasture and browse plants in the various ecological zones of Ghana

The vegetation of Ghana which provides natural pasture is part of the West African complex vegetation that lies between the Sahara and the Gulf of Guinea. The main vegetation types in this region include coastal strand and mangrove, coastal savanna, forest, derived savanna and the interior savanna (Benneh *et al*., 990). These ecological zones influence natural pasture in Ghana.

Coastal strand and mangrove vegetation occurs along the coastline, lagoons and estuaries of the larger rivers. The total area of this zone is small, harbour high pest population and therefore has relatively little importance to pasture. It however, provides a niche for some non-farm animal species (Oppong-Anane, 2001).

The forest zone covers an area of about 135,670 km^2. It is divided into rain forest and semi-deciduous forest. There is high temperature in the forest compared to coastal zone. Annual rainfall ranges from 1500 to 2200 mm and is well distributed throughout the year. The zone promotes very rapid plant growth and has an even tree canopy at 30-40 metres high (Barnes and Addo-Kwafo, 1996). Pasture resources in the forest zone are not very significant compared to the

Savanna zones (Benneh *et al*., 1990). There is however, a herbaceous layer that includes few grasses in various portions of the forest floor. According to Oppong-Annane (2001) ruminant production is of minor importance in this forest zone due to heavy infestation of tsetse flies and other pests. Agriculture here is therefore, focused on food and tree crop farming.

The Transition zone is an expanding area along the forest boundaries where grassland is gradually replacing forest. This zone falls between the guinea savanna to the north and the forest to the south of Ghana. The vegetation is degraded forest with a wide range of tall grasses. Among the surviving forest trees are *Antiaris, Phyllanthus* and *Elaeis.* While *Borassus, Lophira, Daniellia, Lonchocarpus, Pterocarpus, Burkea* and *Parkia* represent the Savanna intrusions. Similarly, among the grasses, the humid zone representatives include *Pennisetum purpureum* and *Panicum maximum*, while the sub-humid zone species include *Andropogon gayanus, A. tectorum*, *Hyperthelia* and *Hyparrhenia* spp. (Fianu *et al*., 2001).

According to Oppong-Annane (2001) about 15% of the total land area of Ghana is used as natural pasture. The growth pattern of vegetation in these agro-ecological zones follows the rainfall pattern (Fianu *et al*., 2001). In the coastal savanna area, the growing period of annual vegetation is seven months and a "non-growing" period of five months while in the northern savanna area, the growing season lasts for five months and the "non-growing" period for seven months (Benneh *et al*., 1990). In both coastal and interior Savanna zones, about 80% of forage yield is achieved within the growing season. Herbage yield in different locations varies significantly even in the same ecological zone (Fleischer *et al*., 1996; Oppong-Anane, 2013). Fleischer *et al*. (1996) also reported herbage yield on the clayey and sandy soils of the coastal plains as 4.67 and 5.03 tonnes DM/ha. Other variability in forage availability and quality in the natural pasture in Ghana have also been reported and attributed to seasonal changes (Annor *et al*., 2007; MoFA, 2011).

Savanna zone is dominated by grassland vegetation in Ghana and divided into coastal Savanna and interior Savanna zones (Benneh *et al*., 1990; Duku *et al*., 2010). Grass cover of coastal Savanna is dominated by *Vetiveria fulvibarbis*, *Sporobolus* and *Imperata* sp with *Ctenium newtonii* on lighter soils where there is frequent grazing or cultivation of arable crops. Gravel dominated soils carry *Ctenium newtonii, Brachiaria falcifera*, *Schizachyrium schweinfurthii*, and *Andropogon canaliculatus* (Timpong-Jones *et al*., 2013). The more humid areas which lie to the north-western boundary of the Accra plains feature *Panicum maximum, Hyperthelia dissoluta* and occasionally *Andropogon gayanus* as indicators of the excellent pastures (Fianu *et al*., 2001; Assefa *et al*., 2013).

The Winneba-Cape Coast plains contain more woody vegetation than the Accra plains due to less human population pressure, cultivation and tree cutting activities. Patches of exhausted soils of abandoned farms are occupied by *Panicum* and *Hyperthelia* and frequently grazed areas are dominated by *Vetiveria fulvibarbis* and *Sporobolus* (Fianu *et al*., 2001). Benneh *et al*. (1990) estimated the carrying capacity of the coastal savanna plains to be about 2.5 ha / TLU. Estimated mean herbage yield in the coastal savanna is 3.5 tonnes DM/ha (Oppong-Anane, 2006; MoFA, 2011). Howerver, Timpong-Jones *et al*. (2013) reported herbage yield up to 7.21 tonnes DM/ha in the coastal savanna rangeland during peak vegetation cover.

Guinea savanna zone has unimodal rainfall that ranges from 800 to 1,500 mm (MoFA, 2011). Average ambient temperature is 28°C but the *harmattan* months of December and January are associated with lower temperatures that may fall to 13°C at night, while March and April may experience 40°C in the early afternoon (Benneh *et al*., 1990). The savanna zone covers an area of approximately 129,000 km^2. The interior savanna is typically Guinea and Sudan Savanna, with continuous grass cover interspersed with fire resistant trees (Oppong-Anane, 2013). A strip of degraded grassland vegetation at the north-eastern border of Ghana (about 7,200 km^2) is considered as Sudan Savanna on account of its shorter grass and shrubs (Benneh *et al*., 1990). The grasses growing in this area are not uniform but differ according to soil type and moisture regime. Dominant grass species include *Andropogon gayanus, Pennesitum sp* with *Hyparrhenia* and *Schizachyrium* as co-dominants in some areas. The tree cover includes *Butyrospermum, Khaya, Ceiba, Pterocarpus erinaceous, Ficus, Parkia, Anogeissus, Diospyros* and *Adansonia and Afzelia sp* (Fianu *et al*., 2001). Most of these tree species serve as browse plants for stall feeding of animals especially in the dry season (Ansah, 2015). The estimated annual herbage yield in the northern Savanna ecological zone is 2.2 tonnes DM/ha (Oppong-Anane, 2001).

Generally, forage species in the natural pasture of savanna ecological zones are characterized by rapid growth rate in the wet season and influences the availability of herbage in the dry season (MoFA, 2011). The quality of pasture in the coastal savanna zone is more stable compared to the northern interior Savanna on account of bimodal rainfall pattern and short duration of dry season in the zone (Oppong-Anane, 2001; Timpong-Jones *et al*, 2013). The nutritive quality of natural pasture in the northern Savanna zone however, varies widely in different seasons of the year (Karbo and Agyare, 2002). In areas where the supply of herbage is adequate during the dry season due to good vegetative growth during the wet season in the interior Savanna zone, it is often deficient in protein, vitamins and minerals due to the long period (7 months) of the dry season (Smith, 2010). It has been reported that protein content of natural pasture is often high (8-12% DM) at the beginning of the rainy season but low (2 to 4% DM) in the dry season (Oppong-Anane, 2001). Phosphorus (P) level also varies and ranges from 0.16 to 0.06% DM (Fleischer *et al*., 1996). The herbage from browse plants is relatively high in protein (12% DM), minerals and vitamins but low in availability (MoFA, 2011). The low availability of feed in terms of quantity and quality, negatively affects the production and reproductive performance of livestock (Compel *et al*., 2003). To improve forage quality, *Stylosanthes hamata* has been identified as one of the legume forages that are good for improving natural pasture (Barnes and Addo-kwafo, 1996; Fleischer *et al*., 1996). This has been introduced into an estimated area of 5,000 ha in the natural pasture of about 300 communities in the savanna zone of northern Ghana (FAO, 2006) as part of pasture improvement projects. In cultivated pasture, Fleischer *et al*. (1996) stated that mixed grass and legumes pasture field yield higher herbage DM than the pure stands of grass or legumes.

2.2.3 Crop residues and agro-industrial by-products

The importance of natural pasture is gradually declining due to expansion of crop production into grazing lands and land degradation whereas feed supplementation with crop residues and AIBPs is gradually becoming popular (Karbo and Agyare, 2002; Annor *et al*., 2007). In Ethiopia, about 70% of crop residues generated is estimated to have been consumed by animals (Zinash and Seyoum, 1991). Crop residues supplementation is relatively less in villages but growing in urban areas (Oppong-Anane, 2013).The common practice in the rural areas is *in situ* grazing of the crop residues after harvest together with standing hay in the natural pasture (Karbo and Agyare, 2002).

In Ghana, It has been estimated that 8 million tonnes DM of cereal stalks and 3.5 million tonnes DM of residues from legume, root and tuber crops are generated and potentially available as animal feed per annum (Oppon-Anane, 2010). In northern Ghana, over 5 million tonnes DM of crop residue is estimated to be generated annually (MoFA, 2011; Karbo and Agyare, 2002). However, the proportion of these crop residues that are being consumed by animals is very small due to problems of collection and alternative uses such as domestic fuel (e.g. sorghum and millet stalks) and thatch roofing (MoFA, 1998).

In terms of quality, cereal crop residues are generally of low nutritive value because of their relatively low digestibility (<500 g/kg DM), low crude protein (<50 g/kg DM) and low minerals and vitamins content (Owen, 1994). These deficiencies make cereal crop residues unpalatable and reduces intake to as low as 15 g DM/kg live weight per day (Owen, 1994; Singh *et al*., 2011). The limitations outlined have led to underutilization of the cereal crop residues as feed resources in many places including northern Ghana as large amounts of these residues (30 - 100%) are left in the field or burnt (Karbo and Agyare, 2002). Many possibilities of improving cereal residues use like urea treatment and chopping to reduce bulkiness (Karbo *et al*., 1997; Addah *et al*., 2015) are less adopted by farmers. Many attempts to encourage farmers to collect crop residues from the field for storage and to preserve the quality have also been slowly practiced probably due to labour involved. Notwithstanding this, other researchers have reported that crop residues, such as groundnut and cowpea haulms, pigeon pea waste, maize, sorghum and millet stover, constitute the bulk of ruminant feed during the dry season (Karbo and Agyare, 2002; Smith, 2010). Other contributing crop residues are plantain, cassava, yam and sweet potato peels (Oppong-Anane, 2010). Good knowledge of nutritional value of these crop residues, methods of utilization in supplementary feeding and application of good health management as well as improved housing of ruminants are vital package of best practices. When these are practiced appropriately, ruminant production will be sustain among smallholder farmers (Onwuka *et al*., 1997; Karbo and Agyare, 2002; Oppong-Anane, 2013). Research and extension education to augment knowledge of farmers for the adoption of these technologies are needed in the ruminant production to increase returns among smallholder farmers. Table 2.3 presents nutritional compositions of some crop residues commonly fed to ruminants in northern Ghana.

Table 2.3: Nutritional composition of commonly fed crop residues and agro-industrial by-products in smallholder farming systems

Feedstuffs	DM%	OM%	Ash%	CP%	NDF%	P%	ME (MJ/kg)
Crop residues							
Cowpea haulm	94.0[3]	80.0[6]	20.0[6]	18[1]	45.6[6]	0.3[3]	7.7[6]
Groundnut haulm	94.6[2]	94.0[2]	0.6[2]	18.2[1]	42.2	0.2[1]	10[2]
Pigeon pea waste	90.0[3]	-	-	7.5[3]	-	0.05[3]	-
Sorghum stover	-	98.97[6]	0.13[6]	4.4[5]	73.6[6]	0.12[5]	6.9[6]
Maize stover	93.4[8]	95.2[8]		5.3[5]	71.9[8]	0.15[5]	-
Agro-industrial by-products							
Rice bran	91.78[4]	74.9[4]	16.9[4]	6.7[4]		0.8[1]	11.3[4]
Wheat bran	92.7[4]	87.5[4]	5.2[4]	15.5[4]	36.7[6]	-	16.5[4]
Pito mash	92.9[4]	88.5[4]	4.4[4]	28.8[4]	-	-	17.8[4]
Rice straw	93.7[3]	90.6[1]	10.4[1]	3.4[3]	19.8[6]	0.05[3]	7.3[1]
Yam peels	95.3[7]	90.2[7]	9.8[7]	4.9[7]	-	-	10.2[7]
Cassava peels	86.3[3]	-	5.7[9]	4.6[3]	19.6[9]	0.06[3]	17.7[9]

[1]Onwuka *et al*. (1997), [2]Romney *et al*. (1993), [3]Karbo *et al*. (1997), [4] Abarike *et al*. (2012), [5]Mosimanyana and Kiflewahid (2006), [6]Tunde and Ayantunde, (2016), [7] Omole *et al*. (2013), [8]Li *et al*. (2014), [9]Oppong-Anane (2013).

Other feed resources available are AIBPs from households and agro-processing industries. The use of these feed resources for supplementary feeding has not been given much research attention though there is high potential for their use in improving livestock productivity (Teye *et* *al*., 2011). Common AIBPs used in feeding livestock by smallholder farmers in Northern Ghana include: cotton seed, soybean cake, groundnut cake, brewers' spent grain (pito mash), cereal bran (maize, sorghum and millet bran) (Ansah *et al*., 2012; Oppong-Anane 2013). Others are wheat bran, rice bran/husk and corn milling waste (Karbo *et al*., 1997; Teye *et al*., 2011; FAO, 2014).

There are some challenges in the use of these AIBPs in feeding animals. Whole cotton seed and other cotton by-products, contain gossypol in the kernel and seed coat (FAO, 2014). This free gossypol in the seed (0.03-0.3%) is harmful to most animal species and particularly monogastrics and pre-ruminants (Aydin *et al*., 2008). When the content of gossypol in cotton seed exceeds 50 and 100 ppm it becomes harmful to poultry and pigs respectively. Church (1991) however, stated that there is no ill-effect in adult sheep, goats and cattle when fed raw cotton seed due to gossypol detoxification by rumen microbes.

In the case of cereal bran, the main issue is the relatively low crude protein content (Marichatou, 2011) and possibility of mycotoxin contamination occurring at storage that affects productivity of animals negatively (Martins *et al*., 2007; FAO, 2014). Feeding aflatoxin contaminated feed exerts carcinogenic and hepatotoxic effects and suppresses the immune system of animals (Aydin *et al*., 2008; Sultana and Hanif, 2009). For instance about 493 cattle were reported dead and 1200 fell sick after consumption of high concentration of aflatoxin contaminated feed in India (Ilyas, 2007). Over 100 species of fungi can infect plants and produce mycotoxins (Akande *et al*., 2006).

2.2.4 Feed resource use in smallholder production systems

Feeding is a major factor in livestock production and a major constraint to farmers particularly during the dry season due to scarcity and low quality of natural pasture (Reddy *et al*., 2003; Singh *et al*., 2011). Agyemang (2012) stated that alternative land use pressure such as infrastructural development and expansion of crops fields to feed the growing population have led to declining size of grazing land in SSA. These have necessitated feed supplementation with crop residues and AIBPs among resource-poor farmers (Oppong-Anane, 2010). Regrettably, the inability of farmers to feed animals adequately throughout the year still remains the major set-back of meat and milk production in northern Ghana (Annor *et al*., 2007; Agyemang, 2012). Abegaz *et al*. (2007) reported seasonal variations in feed resource constraint in Ethiopia highlands in which feed availability become low during late dry and early rainy season in the natural pasture. During the cropping season in most communities in Northern Ghana, animals are tethered or herded to prevent crops damage (Karbo and Agyare, 2002). This practice does not give ruminants the full access to available forage to graze and to produce to their genetic potentials (Campel *et al*., 2003).

Where crop residues are available for animals, the intake of these residues differs significantly depending on the types of crop and the amount offered (Owen, 1994) as a main feed source. Some crop residues are preferred to others and higher rate of crop residues offer (more than 3% of the live weight of animals) lead to higher intake (Owen, 1994). Singh *et al*. (2011) offered legume crop residues at 1.5 kg DM/d to growing rams as a basal diet with or without other feed supplements under confinement and observed an intake of 46% for millet straw, 50% for maize stover, 53% for sorghum stover, 86% for cowpea haulm and 94% for groundnut haulm indicating higher preference for legumes over cereal residues. Among the cereals residue, sorghum stover had higher intake of 797 g DM/d and millet had lowest intake of 714 g DM/d. Addition of 300 g groundnut haulm to the cereal residue basal diet increased DM intake from 50 to 57% whereas the addition of 200 g of wheat bran to cereal stover increased DM intake from 50 to 60% of the feed offered (Singh *et al*., 2011). Intake of crop residues therefore increases with increasing amount of offer due to selective eating of more nutritive parts and combination of cereal and legume residues (Owen, 1994; Singh *et al*., 2011).

2.3.1 Contribution of feed market to ruminant production

Small ruminants fattening enterprises in peri-urban areas of West Africa is an important economic activity and depends heavily on purchased feed (Ayantunde *et al*., 2015). Fattening is catalyzed by festive occasions such as Islamic festival of Eidul-Adha (Dan-Gomma, 1998; Hiernaux, 2004; Bayala *et al*., 2014). Feed limitation is however the main constraint to this valuable enterprise. Scarcity of feed in the natural pasture during the dry season (Annor *et al*., 2007) has triggered high demand for feedstuffs in urban areas and greatly affects seasonal stability of prices of feedstuffs (Ayantunde *et al*., 2014). As a result of increasing livestock population and the associated growth in the demand for feed, livestock feed/fodder markets are emerging in many cities and towns in many countries and are usually located near or within livestock markets (ILRI, 2009; Ayantunde *et al*., 2014).

In Sub-Saharan Africa, feed/fodder market is generally not developed. Some traditional feedstuffs traded in this region include crops residues, natural grass, conventional fodder species and fodder trees (Jabber, 2008). Ochieng (2007) reported the specific feedstuffs in the above and categorized feedstuffs to be; crops residues (groundnut haulms, cowpea haulms and maize stover), natural grass [Kikuyu grass (*Pennisetum clandestinum*), star grass (*Cynodon sp*), Rhode grass (*Chloris gayana*), setaria (*Selaria sphacelata*)], conventional fodder species such as napier grass (*Pennisetum purpureum*), sweet potato vines (*Ipomea batata*), vetch (vicia sp), Desmodium (*Desmodium uncinatum*, *D. intortum*), fodder trees like Calliandra (calliandra calothyrsus), and leucaena (*Leucaena leucocephala*). Concentrate and AIBPs such as fish meal, soybean meal, cassava chips and cereal bran are also commonly sold (Ochieng, 2007; Ayantunde *et al*., 2014). The prices of feedstuffs commonly traded in some countries are presented in Table 2.4.

Table 2.4: Commonly traded feedstuffs and their prices in some countries

Country	Name of feedstuff	Price/kg DM		
		Amount	**Local currency**	**USD**
India	Sorghum stover[1]	3	Rupees	0.07
Bangladesh	Napier grass[2]	0.88	Taka	0.01
	Rice bran[2]	9	Taka	0.13
	Rice straw[2]	0.72	Birr	0.04
Tanzania	Maize stover[3]	0.49	Shelling	0.35
Ethiopia	Bush hay[4]	3.78	Birr	0.21
	Bran of cereal grain[4]	4.68	Birr	0.26
	Haulms of legumes[4]	2.88	Birr	0.16
Mali	Cowpea hay[5]	658	FCFA	1.32
	Groundnut haulms[5]	556	FCFA	1.11
	Bush hay[5]	166	FCFA	0.33
	Cotton seed cake[5]	164	FCFA	0.33
	Concentrate[5]	161	FCFA	0.32
	Bran of cereal grain[5]	140	FCFA	0.28
	Browse[5]	162	FCFA	0.32
Nigeria	Cowpea haulm[6]	20	Naira	0.13
	Groundnut Haulm[6]	109	Naira	0.72

[1]Blummel and Parthasarthy (2008), [2]Raha (2008), [3]Gebremedhin *et al*. (2008), [4]Jabbar (2008), [5]Ayantunde *et al*. (2014), [6] Samireddypalle *et al* (2017), USD = United States Dollars

These traded feedstuffs contribute greatly to urban and peri-urban feed availability and consequently livestock productivity. The relationship between price of feedstuffs and quality has been reported to be weak and quality does not appear to influence the price at the market for many feedstuffs (Jabbar, 2008; Ayantunde *et al*., 2014). A market survey by ILRI (2009) in Ethiopia reported price of poor quality fodder to be 50% lower than the good quality fodder. Ayantunde *et al*. (2014) further indicated that, feedstuffs of the same quality could be sold at different prices depending on the season and market location.

In Ghana, feed shortage constraint has led to the collection of naturally occurring browse plants, crops residue and AIBPs in an increasing rate as feed for ruminants especially sheep and goats (Karbo and Agyare, 2002; Huseini *et al*., 2011). The emerging livestock feed market is growing in northern Ghana where over 70% of livestock in the country is produced (Adams and Ohene-Yenkyera, 2014). The main feedstuffs sold are crop residues and bran of cereal grains (Awuma, 2012) as well as some indigenous browses such as *Ficus* sp and *Pterocarpus erinaceus* (Huseini *et al*., 2011). In Mali, feed market survey showed that, cowpea haulm, groundnut haulm, cottonseed cake, bush hay (*Andropogon gayanus and Schizachyrium exile*), cereal bran (maize, millet, sorghum and rice), browse (shrub/tree) were the major types of feedstuff sold (Ayantunde *et al*., 2014). Cereal straws (sorghum, millet or maize straws) were not sold throughout the year. This was attributed to low nutritive value (Owen, 1994), bulkiness and transportation difficulties.

According to Ayantunde *et al*. (2014), the prices of cowpea haulm and groundnut haulm were consistently higher than the other feeds and increased from October immediately after harvest, to August, in the wet season. The authors added that the price of these crop residues in Burkina Faso (cowpea and groundnut haulm) corresponded to availability and was highest during the wet season (June to September) and lowest after harvest (October and November). Prices of agricultural by-products such as cottonseed cake, cereal bran, and concentrate feed have been reported to be consistent across seasons and suggest year-round stable availability. Price of legume residues (cowpea hay and groundnut haulm) was observed to be twice that of cereal bran for most part of the year except in the three months following harvest (October, November and December) where cereal bran price was lower (Ayantunde *et al*., 2014). The higher legume residue price is an impetus for farmers to increase its cultivation to harvest more residues for sale or feed their animals (Larbi *et al*., 2003).

2.4.1 Nutrient intake, digestibility and faecal excretion in farm ruminants

In ruminants, concentrate supplementation improves the efficiency of rumen microbial N synthesis and increases DM digestibility to about 15% (Wanapat *et al*., 2007). Fernandez-Rivera *et al*. (1995) reported DM digestibility of 58, 55 and 58% in cattle, sheep and goats respectively, when fed different forage species and crop residues under confinement. *In vivo* digestibility studies that involves total collection of faeces of small ruminants grazing from natural pasture is quite challenging due to accuracy of faecal collection but can be done with care to reduce errors (Cottle, 2013). It is however, done easily with animals fed *ad libitum* under confinement for forage utilization and nutritive quality evaluation (Coleman, 2005). Katelaars (1986) stated that under free access to feed, ruminants excrete constant amount of faeces per unit live weight or metabolic weigh ($W^{0.75}$). Conrad *et al*. (1964) observed dairy cattle faecal excretion of 10.7 g DM /kg live weight and indicated that this output was constant over a wide range of digestibility.

Also, Konandreas and Anderson (1982) estimated that the potential faecal output (F g DM /d) of cattle could be predicted using the relation below.

$$F \text{ (g DM /d)} = f \text{ g DM/kg } W^{0.75}$$

Were F is daily faecal output (g DM /d) and *f* is a constant that depends on the physiological state of the animal.

Konandreas and Anderson (1982) further estimated the values of *f* as 42, 45 and 49 g for dry, pregnant and lactating cows respectively, and suggested that these estimates could be used for feeds in a range of digestibility from 42 to 65%. However, some experimental evidence suggests that *f* decreases as feed digestibility increases (Katelaars, 1986). Fernandez-Rivera *et al*. (1995) reported average daily faecal output of ruminants as 2385, 345 and 197 g DM/d for cattle, sheep and goats respectively, under intensive management system fed assorted forage species *ad libitum.* A study by International Trypanotolerance Centre (ITC, 2014) estimated daily faecal output of Djallonkè and Djallonkè × Sahelian crossbred sheep under semi-intensive management system to range from 358 to 616 g DM/d and 219 to 475 g DM/d, respectively. Table 2.5 contains the digestibility, faecal excretion and weight gain of animals under different feeding regimens. ITC (2014) reported that sheep faeces contain 2.0 ± 0.4% N and 0.9 ± 0.2% phosphorus.

Table 2.5: Effect of different feeding regimes on digestibility, faecal output and growth performance of ruminants

Animal species	Feeding regime	Dry matter digestibility (%)	Range of faecal output (g DM/d)	weight gain (g/d)
Cattle	Intensive feeding system	35–84[1]	168–7222[1]	360–940[6]
Sheep	Intensive feeding system	24–81[1,2]	39–989[1]	20–48 [2, 3]
	Semi-intensive (supplementation and grazing)	50–73[7]	219–616[5]	25–60[4,5]
Goat	Intensive *ad libitum* feeding	31–83[1,5]	32–560[1]	12–57[5]

[1]Fernandez-Rivera, *et al*. (1995), [2]Konlan *et al*. (2012), [3]Karbo *et al*. (1998), [4]Osafo *et al*. (2008), [5]ITC (2014), [6]Lapitan *et al*. (2004), [7]Sun and Zhou (2007)

Fernandez-Rivera *et al*. (1995) observed that nutrient content of available ruminant feed and its digestibility greatly influences nutrient intake and faecal nutrient content. Nitrogen is one of the major nutrients that impact greatly in the productivity of crop-livestock systems. The intake of N in ruminants grazing from natural pasture is influenced by seasonality and diversity of forage species (Powell *et al*., 1996). Schlecht *et al*. (1995) reported an increase in cattle daily N intake from 1.3% during late dry season to 4.2% in early wet season of total DM intake in Mali. Powell *et al*. (1996) mentioned that sheep and goats N intake from natural pasture is higher than cattle. Ayantunde *et al*. (2008) reported an increase of 170% in N intake, 24% in faecal N and 260% urinary N output in sheep fed bush hay basal diet and supplemented with groundnut haulms and millet bran under an intensive feeding system. Nitrogen intake therefore increases with legume crop residues and cereal bran supplementation. Also, faecal N content of sheep has been reported to increase when fed browses than crop residues (Somda *et al*., 1993). Lignin, tannins and related phenolic compounds content in feedstuff affect N absorption and shifts urinary N excretion to faecal N associated with undigested feed compounds in faeces (Reed *et al*., 1990). Faecal N content of ruminants is higher in the wet season than the dry season and yearly differences do occur due to differences in annual rainfall pattern (Somda *et al*., 1993; Schlecht *et al*., 1995). Somda *et al*. (1993) suggested that the shift of urinary N to faecal N and from faecal soluble to insoluble N makes the N more available for recycling in crop-livestock systems when the faecal matter is used to replenish soil fertility. Values of N balance studies in cattle and sheep are presented in Table 2.6.

Table 2.6: Effect of feed supplementation on intake and voiding of N in cattle and sheep

Nitrogen intake and voiding	**Cattle [1]**		**Sheep [2, 3]**	
	Minimum	**Maximum**	**Minimum**	**Maximum**
Total N intake (g/d)	97	182	5	14
Total N voided (g/d)	33	50	4	9
Total N retention (g/d)	36	98	2	7
Urine-N (g/d)	2.3	6.4	0.4	3.6
Faecal soluble - N (g/kg DM)	-	-	14	22
Faecal insoluble - N (g/kg DM)	-	-	12	26

[1] Powell *et al*., (1994),[2] Wanapart *et al*. (2007) , [3]Ayantude *et al*. (2008)

Mariana (2008) stated that African dairy cattle retain minimal dietary N and reported faecal N content of the dairy cow to be about 83%. Reynolds and De Leeuw (1995) also concluded that livestock in tropical smallholder systems retain less than 20% of ingested N for productive purposes. This suggests that tropical animals have limited ability to utilize dietary N or it is in a form that is not digestible. Nitrogen content of fresh and dried faecal samples has been reported to be similar (Schlecht *et al*., 1993) as N losses due to drying is about 1.9 g N/kg DM of faeces and statistically insignificant. Nitrogen content of dried faeces therefore does not need correction for losses associated with samples drying (Schlecht *et al*., 1995). There are however, several sources of uncertainties in the estimation of N recovery in ruminant faeces that lead to under estimation. Spanghero and Kowalski (1997) in a review of number of N balance experiments with lactating cows stated that under estimation of N voiding occurs in urinary-N losses through evaporation or unaccounted dermal losses as sources of errors. Losses of ammonia after excretion in the faeces and drying of wet samples, though small, causes underestimation of faecal N. Volatile N losses therefore, causes underestimation of urinary-N unless urine is collected in diluted HCl or H_2SO_4 acid solution (Schlecht *et al*., 1995; Spanghero and Kowalski, 1997). Dermal N losses are often small and very difficult to estimate and are usually ignored (Powell *et al*., 1994). After taking into consideration the errors associated in estimating N voiding, Spanghero and Kowalski (1997) reported that N recovery in faeces of dairy cattle varies from 55 to 87%.

Another factor that affects N flow in ruminants is intake and availability of fermentable carbohydrates in the diet. Carbohydrates increase microbial activities and result in higher fermentation rate and faecal N content emanating from increased ammonia utilization and rumen microbial population (Delev *et al*., 2001). On the other hand, low N intake in feed reduces microbial fermentation and may result in N deficiency in animals. In extreme cases of poor protein diet as in late dry season in most tropical humid to arid areas, the metabolized N is recycled in the rumen resulting in net loss. In such situations the animal loses weight and may die in severe cases (Delev *et al*., 2001; Mariana, 2008). The amount of faecal N in ruminant is therefore a function of intake and microbial fermentation dynamics and consequently affects the productive performance of animals positively or negatively depending on dietary N content and digestibility level (Powell *et al*., 1994; Delev *et al*., 2001).

2.5.1 Management and productivity of small ruminant in smallholder farms

In northern Ghana, the mean flock size of small ruminants kept by smallholder farmers is 10 ± 6 animals (Karbo and Agyare, 2002; Oppong-Anane, 2010; Baah *et al*., 2012). Amankwah *et al*. (2012) observed high flock size of 21 ± 13 per household in Upper West region of Ghana. These animals were reared mostly for sale in critical times to offset household food and financial needs. The animals are mostly reared under semi-intensive systems where feed supplementation is minimal throughout the year (Oppong-Anane, 2010). They are usually not housed in the dry season (Duku *et al*., 2010).

Awuma (2012) reported that tethering sheep and goats during cropping season is common in many communities to prevent crop destruction. This limits accessibility of green forage to animals. The practice partly accounts for abortions, weight loss, susceptibility to diseases, pests and sometimes death during rainy season (Otchere *et al*., 2002). In the dry season animals grazed freely around but feed quality is often poor and scarce leading to low growth performance (Oppong-Anane, 2013). During the dry season, the growth of animals under the open grazing management system fluctuates widely with some animals losing weight (MoFA, 2010; Baah *et* *al*., 2012). For instance the weight gain of small ruminants in the dry season ranges from -0.5 to 51.5 g/d in Djallonkè sheep, -2.7 to 82 g/d in Djallonkè × Sahelian crossbred sheep and 10.2 to 57.4 g/d in West African Dwarf goats (ITC, 2014). This wide growth variation that included weight losses is influenced by differences in farmer management practices and feed availability variations in the pasture (Annor *et al*., 2007; Karbo and Agyare, 2002; MoFA, 2010).

CHAPTER 3

3.0 GENERAL MATERIALS AND METHODS

3.1.1 Biophysical characteristics of the study location

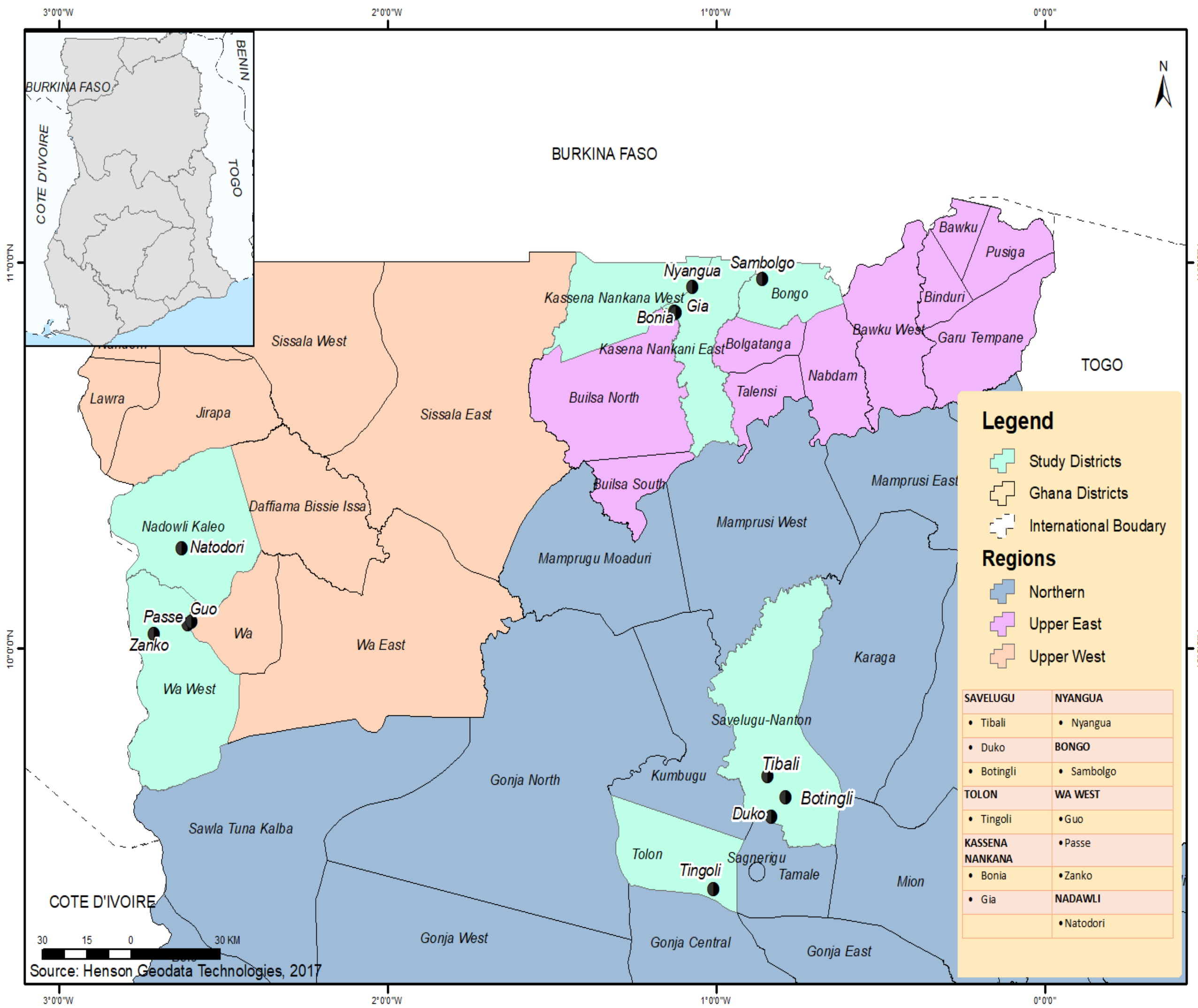
The study was conducted in 3 political administrative regions of Northern Ghana (Northern, Upper East and Upper West regions). This area represents approximately 40% of the landmass of Ghana and contains 17% of the human population (GSS, 2012). The 3 regions are located within latitude 9^{o} 38" S and 10^{o} 24" N and longitude 2^{o} 61" W and 0^{o} 84" E in the Guinea and Sudan Savanna agro-ecological zone. The annual amount of rainfall in the area ranges from 1000 to 1200 mm. The rainfall pattern is unimodal and begins in April to October and sometimes irregular in nature (MOFA, 2011; Oppong-Anane, 2013). Length of growing season is 150-200 days with dry spells of up to 10 days or more in the rainy season. The vegetation consists of short, deciduous, widely spaced, fire-resistant trees and shrubs, which do not form close canopy. The general ground floral is covered with grass and forbs of varying heights. More often, the soil surfaces are bare in the dry season due to frequent outbreak of bush fire (Amankwah *et al*., 2012). Maize, millet, sorghum, groundnut, cowpea and soya beans are the major crops grown in the 3 regions (Kombiok *et al*., 2005).

The specific districts and communities (Table 3.1 and Figure 3.1) where the study was conducted were selected based on a review of bio-physical and socio-economic status of the communities in the area from MoFA data. Communities were classified into clusters based on similarities in the length of growing period (LGP) and market access to agricultural input and the sale of farm produce. Three clusters were selected, one in each region (Table 3.1) and communities then chosen randomly from them.

Table 3.1: Administrative and geographical location of the study sites

Region	District	Community	Latitude	Longitude
Northern	Salvelugu	Tibali	9.666837	-0.84398
	Salvelugu	Duko	9.562964	-0.83237
	Salvelugu	Botingli	9.6117	-0.78867
	Tolon	Tingoli	9.3758738	-1.00936
Upper East	Kassena Nakana	Bonia	10.87064	-1.12764
	Kassena Nakana	Gia	10.869269	-1.122731
	Kassena Nakana	Nyangua	10.935432	-1.073623
	Bongo	Sambolgo	10.955178	-0.859288
Upper West	Wa West	Guo	10.062071	-2.608257
	Wa West	Passe	10.037027	-2.710677
	Wa West	Zanko	10.067212	-2.595719
	Nadawli	Natodori	10.257167	-2.626606

Source: CERSGIS legon-Accra, (2013)



September, 2017: Henson Geodata Technologies, Accra.

Figure 3.1: Locations of study communities in the map of northern Ghana

3.2.0 Research approach and experimental design

3.2.1 Research approach

The research approach used included surveys and experiments. There were 2 feed evaluation studies made up of community and feed market assessment, seasonal estimation of feed resource quantity and quality in the communal pasture. In addition to these surveys, 3 field experiments were conducted to determine the effect of concentrate, crop residues and AIBPs supplementation on intake and voiding DM and N and growth performance of sheep grazing on natural pasture in smallholder production systems to collect data for the entire study.

3.2.2 Assessment of community feed resource availability for ruminant production

Feed Assessment Tool (FEAST) developed by ILRI (2012), was used to conduct qualitative and quantitative community survey on the impact of feed constraints on livestock production. The FEAST tool consists of participatory rural appraisal (PRA) tool for qualitative data collection in the community, a semi-structured questionnaire for household quantitative data collection on crop-livestock production systems and excel template for analysis of the quantitative data collected.

The PRA participants were crop and livestock farmers purposively selected based on the ownership of crops and animals farms in the study communities. The identified farmers were classified into 3 based on wealth (i.e. average, above average and below average) using existing standards in the community **(**Duku *et al*., 2010). Focus group discussions were used to collect data from 150 farmers in all (25 in each community). After the PRA sessions, 108 farmers were interviewed with FEAST semi-structured questionnaire for quantitative data collection on their farming systems and feed resource availability. They included 18 farmers per community (6 in each class).

3.2.3 Feed quality and price relationship at the emerging feed market

A survey on feed market was conducted to gather quantitative and qualitative data on the performance of emerging feed market in the area and to determine relationship between prices of feedstuffs and quality. Semi-structured questionnaire was used to collect data on the profile of feed sellers and buyers, types of feed sold and the prices at the market. Samples of the feed sold were bought for quality determination.

Feed market data collection begun with a reconnaissance market survey that covered number of markets in the study area. Three major markets in the area were purposively selected based on dominance of feed sold. Feed sellers and buyers were then interviewed with semi-structured questionnaire. This was done quarterly for each season for one year. Samples of feedstuffs sold in the markets were also bought per quarter from three different sellers for each feed type per market. The price/kg DM of feedstuffs in the markets was determined by using 3 samples of each feedstuff. Three samples per feed type per market were pooled, sub-sampled and analyzed to determine the nutritive quality.

3.2.4 Effect of season on availability and quality of natural pasture

Estimation of feed resource quantity and quality in communal pasture was done in 4 seasons of the year in a randomized complete block design (RCBD). The design contained 3 blocks and 3 replicates per block. The blocks and replicates were regions and communities respectively. Dry matter yield and nutrient composition of forage in the pasture (grass and forbs) were determined. Browse plants in pasture field were excluded. A 1 m^2 quadrat was used to estimate the DM yield (Nitis, 1997). This was done in each season for one year. The quadrat samples were collected by throws and biomass inside the quadrat harvested. The dry weight of the biomass harvested was taken and DM yield in kg/ha determined. The same sampling method was done in cultivated fields at crop harvest to estimate crop residue yields of commonly cultivated crops in the farming system whose residues are fed to ruminants. The crop residues were collected to ground level excluding the roots. Commonly grazed forage species in the natural pasture were sampled, pooled per community and sub-sampled. These sub-samples were analysed at the laboratory and determined their nutritional composition.

3.2.5 Effect of concentrate supplementation and season on DM and N intake and voiding and growth performance of sheep

Experimental animals and management: Smallholder sheep (dominantly cross breeds with Djallonkè and Sahelian parental pedigree) farms in the selected communities were used for this work. The animals were kept under semi-intensive system of management, identified by ear-tagging and offered supplementary feed in groups per farm.

The experiment was conducted as a randomized complete block design. It covered 3 regions that served as blocks and 2 study communities in each region also as replicates plots. Parameters determined was intake and voiding of DM and N and growth performance of sheep. Animals in the pen of these farmers were randomly assigned to one of 2 feeding regimes as experimental treatments. In the first regime, sheep were grazed daily in the natural pasture from 09:00 to 17:50 h and offered crop residues and or AIBPs (75 g DM/d) upon return from grazing (control), in the second regime, sheep were treated similarly as in the first regime but were also offered concentrate supplementary feed (180 g DM/d) plus healthcare (CH). Healthcare provided included best health care practices needed in livestock production.

The data collected in this experiment included; samples of commonly grazed forage species by observing sheep grazing on pasture and all supplementary feed offered for laboratory analysis.

Intake of supplementary feed was determined by weighing feed offered and leftover. Animals were weighed monthly and daily weight gain determined. Two rams were sub-sampled per farm for twenty 24 h faecal matter collection using faecal bags for small ruminants (Arnold, 1960; Karbo *et al*., 2008). Total DM intake of sheep was calculated using the ratio method as given in the equation bellow (Lippke, 2002; Stuth *et al*., 2009; Cottle, 2013):

Dry matter intake (kg DM/d) = [Faecal output (kg DM/d)]/ [1 - coefficient of diet digestible]

3.2.6 Growth performance of Djallonkè sheep supplemented with locally available agro-residues

Groundnut haulm and maize bran are the commonest supplementary feed offered to small ruminants in northern Ghana by smallholder farmers (Ansah *et al*., 2012; Oppong-Anane, 2013). An on-farm experiment was conducted to assess the effect of these agro-residues on the growth performance of sheep. It was investigated in a completely randomized design (CRD). This included; 4 treatments and 3 replications. The treatments were non supplementation (T0), sole groundnut haulm supplementation (T1), sole maize bran supplementation (T2) and combination of T1 and T2 in a ratio of 2:1 (T3). The treatments were allocated at random to one farmer per treatment and replicated in 3 communities. The groundnut haulm was offered at 300 g DM/d (Ngwa and Tawah, 1992; Singh *et al*., 2011) in T1, maize bran at 200 g DM/d (Malau-Aduli *et al*., 2005; Singh *et al*., 2011) in T2 and animals on T3 given combination of both T1 and T2 at 200 and 100 g DM/d respectively. Supplementary feed intake was determined by weighing feed offered and leftovers daily and animals weighed monthly to determine weight gain.

3.3.0 Laboratory analysis

3.3.1 Chemical parameters determination

All samples collected were oven-dried at 105 ^{o}C for 12 h. Fresh forage and faecal samples were air-dried to about 85% DM before oven-drying. All dried samples were milled to pass through 2 mm sieve for analysis at the CSIR-Savanna Agricultural Research Institute, Nyankpala. The milled samples were then analyzed for DM, organic matter (OM), N, crude protein (CP), fibre components [neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)] as well as *in vitro* dry matter digestibility (IVDMD) and organic matter digestibility at ILRI Nutrition Laboratory in Addis Ababa, Ethiopia.

Proximate analysis of DM, OM, ash, N, and CP content of feed and faecal samples were done following AOAC (1990) approved methods.

3.3.2 Dry Matter

Feed and faecal samples DM were determined by weighing 10 g of each sample into an aluminum bowl and placed in an oven at 105 ^{o}C for 12 h, after which samples were cooled in a desiccator. The DM% was then determined by the relation;

Dry matter % = (Dry sample weight × 100) ÷ Fresh sample weight

3.3.3 Ash

Ash was determined by placing 5 g of oven dried samples into pre-weighed porcelain crucible and heated at 550 ^{o}C in muffle furnace for 5 h. The crucibles with the samples were then cooled in desiccator and weighted. The percentage of ash was calculated as follows;

Ash% (DM) = (Weight of Ash × 100) ÷ weight of dry sample

Organic matter percentage was also determined by taking the difference of dry sample weight and ash weight.

Organic matter % (DM) = [(Dry sample weight – Ash weight) × 100] ÷ Dry sample weight

3.3.4 Nitrogen

Nitrogen was determined by Kjeldahl method in a digestion and distillation apparatus. For each sample, 1 g was weighed into a kjeldahl flask, 10 grams of potassium sulphate, 0.7 g of mercuric oxide, and 25 ml of sulphuric acid were added. The solution was heated moderately (60 ^{o}C) for 2 h with occasional stirring. It was then cooled and 90 ml of distilled water added. About 2 pellets of zinc were added while stirring the content on heat. 10 ml of sulphuric acid and sodium hydroxide was added. The content was then distilled for 30 minutes into sulpheric acid with methyl-red indicator and titrated with sodium hydroxide to turn it from red to yellow. Blank sample was run using sucrose in place of sample and used in calculating the results. The sulpuric acid consumed was determined and used in calculating N content with the relation

1 ml of acid ≈ 1.4 mg of nitrogen

Nitrogen % (DM) = (Total weight of nitrogen × 100) ÷ Dry sample weight

Crude protein was calculated from nitrogen content with the relation;

Crude protein % (DM) = Total nitrogen (%) × 6.25

The fibre content [neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)] and dry matter digestibility (DMD) were determined following Goering and Van-Soest (1970) procedure.

3.3.5 Neutral detergent fibre

This was done by weighing 0.5 g of each sample into a glass crucible and put into digestion apparatus. Cold neutral detergent of 25 ml was added to each sample. Sodium lauryl sulphate of 150 g and 50 ml of tri-ethylene glycol were added. In a separate flask, 22.8 g of anhydrous disodium hydrogen phosphate was dissolved in distilled water. The two solutions were mixed and diluted to 5 L. The pH was adjusted to 6.9 – 7.1 with either NAOH or HCl. The samples were boiled and refluxed for 30 minutes, additional 25 ml of cold neutral detergent reagent and 2 ml of amylase dissolved in 90 ml of distilled water and 10 ml of tri-ethylene glycole was added. The samples were boiled and refluxed for another 30 minutes, filtered and washed 3 times with 25 ml of hot (about 80 ^{o}C) distilled water under vacuum. The crucibles with the samples were removed from the digestion apparatus and dried at 105 ^{o}C for 12 h. The samples were cooled in a desiccator and weighed with the fibre residue. The crucible with the fibre residues were then placed in the muffle furnace at 55 ^{o}C for 4 h. After this the crucibles with the ash were cooled at room temperature in a desiccator and weighed. The NDF was then calculated by the relation;

Neutral detergent fibre (g) = Dry fibre weight – ash fibre weight and

Neutral detergent fibre % (DM) = (NDF weight × 100) ÷ Dry sample weight

3.3.6 Acid detergent fibre

Each sample (1 g) was taken and put in a glass crucible and placed into a Fibretec apparatus. Exactly 100 ml of cold acid detergent reagent was added. The samples were boiled for 60 minutes to digest. After this, the digesta was filtered and washed 3 times with 25 ml of hot deionized water. The crucibles were removed from the Fibretec apparatus and dried at 105 ^oC for 12 h. The crucibles with the samples were cooled in desiccators, weighed and placed in a muffle furnace for 4 h. crucibles with its content were cooled at room temperature in desiccators after the ashing and weighed. Acid detergent fibre content was then calculated by the relation;

Acid detergent fibre (g) = Dry fibre weight – Ash weight. Whereas

Acid detergent fibre % (DM) = (Acid detergent fibre weight × 100) ÷ Dry sample weight

3.3.7 Acid detergent Lignin

The procedure for determining ADF was followed up to the drying of sample in an oven for 12 h. After which 25 ml of 75% sulphuric acid was added to each sample and placed back into the Fibretec apparatus. The crucibles with samples were allowed to stay for 3 h. The Fibretec apparatus pressure was increased by moving its pressure knob. This was done 3 times within the 3 h to ensure digestion of the samples. After this digestion, the content of the crucibles were filtered and washed 3 times with 25 ml of deionized water. The crucibles were then removed from the Fibretec apparatus, dried at 105 ^oC for 12 h. After cooling in desiccators, the crucibles were weighed and placed in a muffle furnace at 550 ^oC for 4 h. Crucibles were then cooled to room temperature in desiccators and weighed. The content of ADL was then determined by;

Acid detergent Lignin (g) = Dry fibre weight – Ashed weight. Whereas

Acid detergent Lignin % (DM) = [(Dry fibre weight – Ashed weight) × 100] ÷ Sample weight

3.3.8 Dry matter digestibility

Dry matter digestibility of feed samples was determined by following the procedures for determination of NDF, ADF and ADL to the oven drying of the residue after digestion process as described in section 3.3.5 to 3.3.7 in this chapter. The oven dried feed residues left were weighed and *in vitro* dry matter digestibility (IVDMD) determined as follows;

In vitro Dry matter digestibility (IVDMD) g = dry feed sample weight – dry residue weight

%IVDMD = [(Sample weight – Dried residue weight) × 100] ÷ Sample weight

3.3.9 *In vitro* organic matter digestibility

Menke and Steingass (1988) method was used in determining the *in vitro* organic matter digestibility (IVOMD) of feed. Approximately 2 g of each dry sample was weighed and placed in 100 ml graduated glass syringe. Buffer mineral solution (Appendix I) was prepared and placed in a water bath at 39 °C under continuous flushing with CO_2. Rumen fluid was collected from three ruminally fistulated male cattle after the morning feeding. Rumen fluid was pumped with a manually operated vacuum pump from the rumen into pre-warmed thermos flask. The rumen fluid from the three cows was mixed and filtered through four layers of cheesecloth and flushed with CO_2 to ensure that it id anaerobic. The anaerobic rumen fluid was added to the buffered mineral solution (1:2 v/v), and maintained in a water bath (39 °C).

The buffered rumen fluid (30 ml) was pipetted into each syringe. The syringes were immediately placed in a water bath and maintained at 39 °C. The volume of gas produced after 24 h fermentation was recorded and used to estimate IVOMD. The net volume of gas produced was computed by subtraction of the blanks from the treatments. The IVOMD were then calculated using CP and ash content of sample in DM basis and the 24 h net gas production according to Menke and Steingass (1988) equation.

$$\textbf{IVOMD\% (DM)} = 15.38 + (0.845 \times 24\ \text{h net gas in ml/2g dry sample}) + (0.595 \times \text{CP}\ \%) + (0.181 \times \text{Ash}\ \%)$$

3.4.1 Statistical analysis

Analysis of the data collected from the surveys was done using FEAST excel template and SPSS software programme version 17. The data gathered from the experiments on forage quantity and quality in communal pasture in each season of the year, intake and voiding of DM and N and growth performance of animals were analyzed using General Statistics software (Discovery Edition 4; VSN International, 2011). The procedures followed were descriptive and general ANOVA analysis. Treatment means were separated by Duncan's multiple range tests in SPSS analysis and Fisher's Protected Least Significant Difference in the General Statistics software analysis. The details of statistical analytical procedures are given under each survey or experimental activity.

3.5.0 Organization of work

The whole research work was organized into two surveys and three field experiments. Each study has been put into one chapter for clarity and to achieve the general objective of the work.

CHAPTER 4

4.0 SURVEY I: FEED RESOURCE AVAILABILITY FOR RUMINANT PRODUCTION IN A SMALLHOLDER FARMING SYSTEM

4.1.0 Introduction

The first survey was conducted to gather information on the availability of feed resources in the farming system of smallholder farmers, their production practices and constraints to ruminant production in the study area.

The productivity of livestock in Northern Ghana is constrained by many factors of which quantity and quality of feed during the dry season constitute a major challenge (Oppong-Anane, 2013). Accessibility to available feed in the wet season is another limitation in some communities due to cultivation of arable crops in compound farms (Awuma, 2012). This feed challenge together with other constraints contributes significantly to low livestock productivity.

The major factors that cause decline in the nutritive quality and availability of feed are senescence and bush fires (Smith, 2010). This makes it difficult for livestock to meet their nutritional requirement in the dry season under the existing extensive and semi-intensive management systems with low input practiced by most smallholder farmers in northern Ghana. Indeed many of the ruminants reared depend heavily on the poor quality feed during the dry season (Karbo and Agyare, 2002). Such a situation has long been recognized to result in cyclic body weight gain in the rainy season and weight loss in the dry season (Annor *et al*., 2007). As a result of inadequate diagnosis of feed constraint, the implementation of technological interventions often tend to adopt trial-and-error approach which most of the times fail to adequately address feed and other related constraints (Duncan *et al*., 2012). It is therefore important to fully understand the spectrum of the feed constraints to enable the development of sustainable technological interventions to address the issue. These calls for detailed assessment of available feed resources as well as identify other constraints that can be addressed alongside feed constraint to improve smallholder livestock productivity.

4.1.1 Objectives

- To determine the existing feed resources
- To identify critical seasonal feed shortages and related constraints to productivity.

4.2.0 Materials and methods

4.2 .1 Study area

The study was conducted in Northern, Upper East and Upper West Regions of Ghana. The specific communities included: Tingoli and Tibali in Northern Region, Gia and Bonia in the Upper East Region and Papu and Guo in the Upper West Region (Figure 3.1). The communities were selected based on access to market and availability of agricultural products for sale.

4.2.2 Data collection

Qualitative and quantitative surveys were carried out using FEAST (Duncan *et al.*, 2012). Feed Assessment Tool was chosen because it offers opportunity for broad based diagnosis of livestock production systems and identification of site specific feed and other related production constraints and opportunities.

The first component of the FEAST activity was PRA. Farmers were selected based on crops and livestock ownership by Ministry of Food and Agriculture (MoFA) extension agents and community lead farmers. These farmers were categorized into three classes (i.e. average, above average and below average) in terms of land and livestock assets ownership (Table 4.3.1) at the beginning of the PRA using the community existing standards **(**Duku *et al*., 2010). A total of 150 farmers in all the six communities were selected for the PRA. In each community, 25 farmers (15 men and 10 women) were involved in the Focus group discussions. Checklist of questions were used for this purpose. These questions were asked by a facilitator for the PRA participants to give their views until consensus was reached and recorded. Monthly rainfall intensity was scored by farmers on a scale of 0 – 5 (0 = no rainfall and 5 = heaviest rainfall) using their last three years of farming experiences. Seasonal changes that had impact on feed resources were also identified by classifying the months into seasons. After the PRA, quantitative data were collected with semi-structured questionnaire through individual interview of 108 farmers in all the study communiies. This covered all the 3 classes of farmers selected in each community. The respondents were household heads or representatives who had good knowledge of the households farming systems.

The questionnaire was designed to provide information on species of livestock owned, utilization of crop residues, natural/cultivated forage and feed purchases (Appendix II).

Monthly feed availability in the natural pasture was estimated by respondents on a scale of 0 – 10 (where 10 = excess feed available, 5 = adequate feed available and 0 = no feed available*).* The results of the scores of farmers were used in estimating annual feed trends in the study area. The data were collected between September and October in 2013.

4.2.3 Data analysis

The data analysis was done using FEAST Excel template (Duncan *et al*., 2012). Other data such as area of crops cultivated, livestock ownership, crop residue utilization and purchased feed were analyzed with SPSS (2007) version 17 using the procedure of general linear model. The regions were fixed factors and area of cultivation, crop residues used, purchased feed by households were variable factors. Means were separated by Duncan's multiple range tests at 0.05 levels.

4.3.0 Results

4.3.1 Household characteristics and sources of income

Household size differed significantly (14.9 ± 1.03, 8.5 ± 1.06 and 11.1 ± 1.07 for Northern, Upper East and Upper West Regions respectively). The highest ($P<0.05$) was observed in Northern Region (14.9 ± 1.03) and the lowest in Upper East Region (8.5 ± 1.06). The classification of farmers based on land and livestock assets owned is shown in Table 4.3.1. The community's criteria used in categorizing the farmers was similar in all the regions but the proportions of households in each category in each region differed. In Upper West Region the communities studied had the highest average farmers of 55% and the least above average farmers of 15%.

Table 4.3.1: Wealth categorization of farmers

Category of farmers	Size of farmland (ha)	Livestock holdings (No. small ruminants)	Households (%)
Northern Region			
Smallholder	Less than 3	Less than 6	32
Average	3 to 10	6 to 30	50
Above average	More than 10	More than 30	18
Upper East Region			
Smallholder	Less than 3	Less than 6	30
Average	3 to 10	6 to 30	50
Above average	More than 10	More than 30	20
Upper West Region			
Smallholder	Less than 3	Less than 6	30
Average	3 to 10	6 to 30	55
Above average	More than 10	More than 30	15

The livelihood activities and household income sources of farmers are presented in Figure 4.3.1. The main source of income was the sale of crop produce. Animals and animal products were the second major source of income. Off-farm activities (petty trading and artisan works) contributed significantly especially in Northern and Upper West Regions. Other sources of household income included activities such as repairs of items in households, welding and repairs of motors and bicycles.

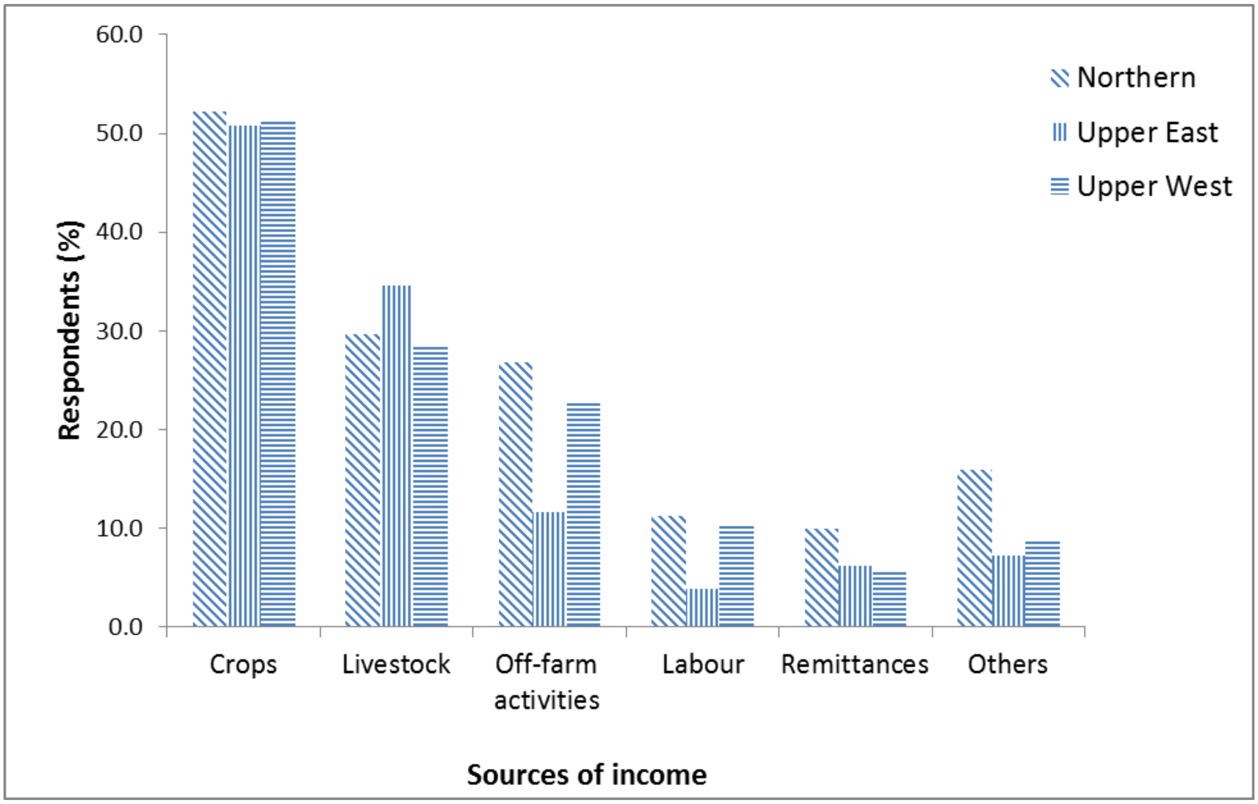


Figure 4.3.1: Sources of household income

4.3.2 Farming system practice

Mixed crop-livestock farming was the common practice among smallholder farmers in the study area in which over 90% of the households grow crops and rearing at least one kind of farm animals.

There were no significant differences (P>0.05) in the size of farm lands in all the 3 regions (Table 4.3.2). The average area of cultivated farm land was estimated to be about 3.4 hectares per household. Livestock holdings (TLU) per household, however, differed (P<0.05) and the Upper East Region had the highest value (Table 4.3.2).

Table 4.3.2: Average farm size (ha) and livestock holdings (TLU) per household

Region	**Farm size (ha)** ± SEM	**n**	**Livestock holding (TLU) ± SEM**	**n**
Northern	3.49 ± 0.41	37	1.04 ± 0.20^{ab}	26
Upper East	3.18 ± 0.44	28	1.53 ± 0.21^{b}	21
Upper West	3.46 ± 0.39	25	0.66 ± 0.23^{a}	25
SED	0.58	-	0.30	-
P value	0.81	-	0.03	-

Means with different superscript down the column are significantly different at P<0.05, TLU = Tropical Livestock Unit – ‘‘hypothetical’’ animal of 250 kg live weight = 1TLU (Jahnke, 1982). The conversion factors were; cattle = 0.5, Sheep/Goat = 0.1, Pig = 0.2, Chicken = 0.01, Turkey 0.03, Horse = 0.8, Donkey = 0.4 TLU for each species of animals (FAO, 2003). SED= Standard error of differences of means, SEM= standard error of means, n =Number of observations

4.3.3 Diversity of livestock species kept by farmers

Major species of farm animals reared in the study area were cattle, sheep, goats, donkeys, pigs and poultry. There were more households who owned cattle and bullocks in Upper East Region than Northern and Upper West Regions (Table 4.3.3). Ownership of sheep and goats was similar among the 3 regions. All farmers interviewed owned poultry birds. Ownership of pig and donkeys were quite low (15%).

Table 4.3.3: Ownership of various species of livestock

Species of animals	Households (%)			Mean
	Northern Region	Upper East Region	Upper West Region	
Cattle	40	75	20	45
Bullocks	10	65	12	29
Sheep	91	90	51	77
Goats	87	97	80	88
Pigs	3	30	13	15
Donkeys	10	36	0	15
Poultry	100	100	100	100

The number of animals (TLU per household) in the 3 regions is presented in Table 4.3.4. Number of various animal species kept by households was similar ($P>0.05$) except that of cattle which was significantly higher ($P<0.05$) than the other species.

Table 4.3.4: Ownership of livestock species per household

Region	Animals species	Mean TLU ± SEM	n
Northern Region	Cattle	2.54 ± 0.35^{b}	24
	Sheep	0.87 ± 0.35^{a}	24
	Goats	0.60 ± 0.37^{a}	22
	Poultry	0.18 ± 0.34^{a}	25
	Donkeys	1.00 ± 0.86^{a}	4
	SED	0.925	-
	P value	0.001	-
Upper East Region	Cattle	4.24 ± 0.48^{b}	19
	Sheep	0.95 ± 0.54^{a}	15
	Goats	0.88 ± 0.49^{a}	18
	Poultry	0.28 ± 0.49^{a}	18
	Donkeys	0.85 ± 0.66^{a}	10
	Pigs	1.12 ± 0.66^{a}	10
	SED	0.821	-
	P value	0.001	-
Upper West Region	Cattle	2.57 ± 0.21^{a}	12
	Sheep	0.17 ± 0.21^{b}	12
	Goats	0.39 ± 0.17^{b}	19
	Poultry	0.24 ± 0.16^{b}	22
	Pigs	0.46 ± 0.28^{b}	7
	SED	0.319	-
	P value	0.001	-

Means with different superscripts down the column are significantly different at $P<0.05$ TLU = Tropical Livestock Unit –''hypothetical'' animal of 250 kg live weight = 1TLU (Jahnke, 1982), The conversion factors were; cattle = 0.5, Sheep/Goat = 0.1, Pig = 0.2, Chicken = 0.01, Turkey 0.03, Horse = 0.8, Donkey = 0.4 TLU for each species of animals (FAO, 2003).SED= Standard error of differences of means, SEM= standard error of means, n =Number of observations

4.3.4: Feed resource availability and utilization

The available feed resources in the regions included: crop residues, natural pasture, cultivated fodder and purchased feed. Common crop residues were legume residues such as groundnut haulm, soybean residue and cowpea haulm (Table 4.3.5). These were collected by farmers and offered as supplementary feed. The cereal stovers were not collected but grazed *in situ* after crop harvest on the farm. Few farmers sold some of the groundnut and cowpea haulms collected. About 40% of the cassava residues were used as feed similar to that of groundnut haulm.

Table 4.3.5: Crop residues utilization

Crop residues	Collected and fed to animals (%)	Uncollected (%)	Collected and sold (%)	n
Groundnut haulm	45.21	46.49	7.87	47
Cowpea haulm	25.93	67.41	6.66	27
Soybean vines	35.46	64.55	1.66	11
Maize stover	20.26	76.29	-	58
Millet stover	10.00	80.00	-	10
Sorghum stover	12.22	76.67	-	9
Rice straw	13.75	83.25	-	40
Cassava peels	41.43	58.57	-	7
Yam peels	8.96	91.04	-	24

N = Number of observations, - = Nill

Pigeon pea (*Cajanus cajan*) and *Leucaena leuccocephala* were the two fodder plants cultivated in the fields of few (18%) farmers in all the regions (Figure 4.3.2). Other available fodder species were *Gliricidia sepium* and *Ficus gnaphalocarpa*. The estimated mean area of the *Leucaena leuccocephala* plantation was comparatively higher in Upper East Region than the other regions whereas the pigeon pea mean area was similar among regions and mostly planted on the border of crop fields either as a border between two different crops or between two farmers' fields.

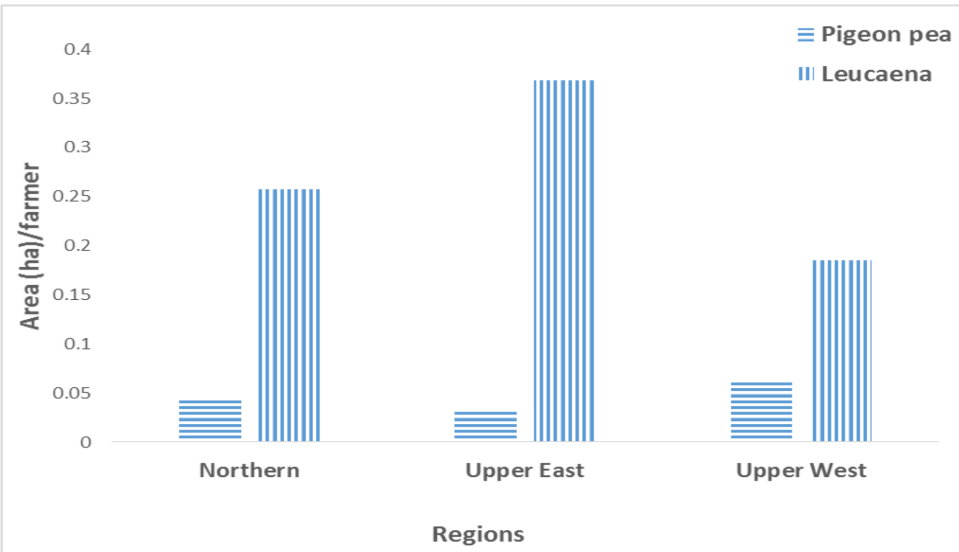


Figure 4.3.2: Types of fodder crops cultivated by farmers

Predominantly purchased feeds were maize bran, corn milling waste, rice bran and pito mash (brewers' spent grain). Estimated prices of these feedstuffs and yearly mean quantity of purchased feed are presented in Table 4.3.6.

The prices of pigeon pea and corn milling waste were higher ($P<0.05$) in Northern and Upper West Regions compered to Upper East Region. Maize bran was the most common feed purchased in all the regions.

Table 4.3 6: Estimated prices and quantity of purchased feedstuff in the last 12 months

Feed type	Price (GHS/kg DM)	Quantity per year (kg DM)	n
Northern Region			
Maize bran	0.51 ± 0.08^{a}	261.66 ± 35.16^{a}	14
Brewers' spent grain	0.22 ± 0.17^{a}	540.33 ± 80.26^{b}	3
Cowpea haulm	0.45 ± 0.17^{a}	140.00 ± 80.26^{a}	4
Cassava peelings	0.30 ± 0.34^{a}	144.00 ± 62.17^{a}	5
Pigeon pea residue	1.05 ± 0.17^{b}	96.67 ± 80.26^{a}	3
SED	0.245	113.5	-
P value	0.018	0.001	-
Upper East Region			
Maize bran	0.35 ± 0.12	175.00 ± 123.03	3
Brewers' spent grain	0.48 ± 0.12	267.02 ± 123.03	3
Cassava peelings	0.15 ± 0.12	200.00 ± 123.03	3
Rice hulls/bran mixed	0.22 ± 0.08	276.66 ± 86.99	6
Corn milling waste	0.48 ± 0.10	244.20 ± 106.54	4
SED	0.167	174	-
P value	0.155	0.096	-
Upper West Region			
Maize bran	0.14 ± 0.02^{a}	274.44 ± 51.19^{b}	9
Brewers' spent grain	0.16 ± 0.02^{a}	200.00 ± 62.70^{ab}	6
Rice hulls/bran mixed	0.33 ± 0.02^{b}	26.25 ± 76.79^{a}	4
Corn milling waste	0.34 ± 0.03^{b}	52.00 ± 68.68^{a}	5
SED	0.028	108.6	-
P value	0.001	0.03	-

Means with different superscript down the column within a region are significantly different at $P<0.05$, SED= Standard error of differences of means, n =Number of observations, 2.19 GH₵ ≈1USD at the time of study

The results showed that about 80% of the annual diet requirement of ruminants was obtained from grazing in pasture in Northern and Upper West Regions (Figure 4.3.3)

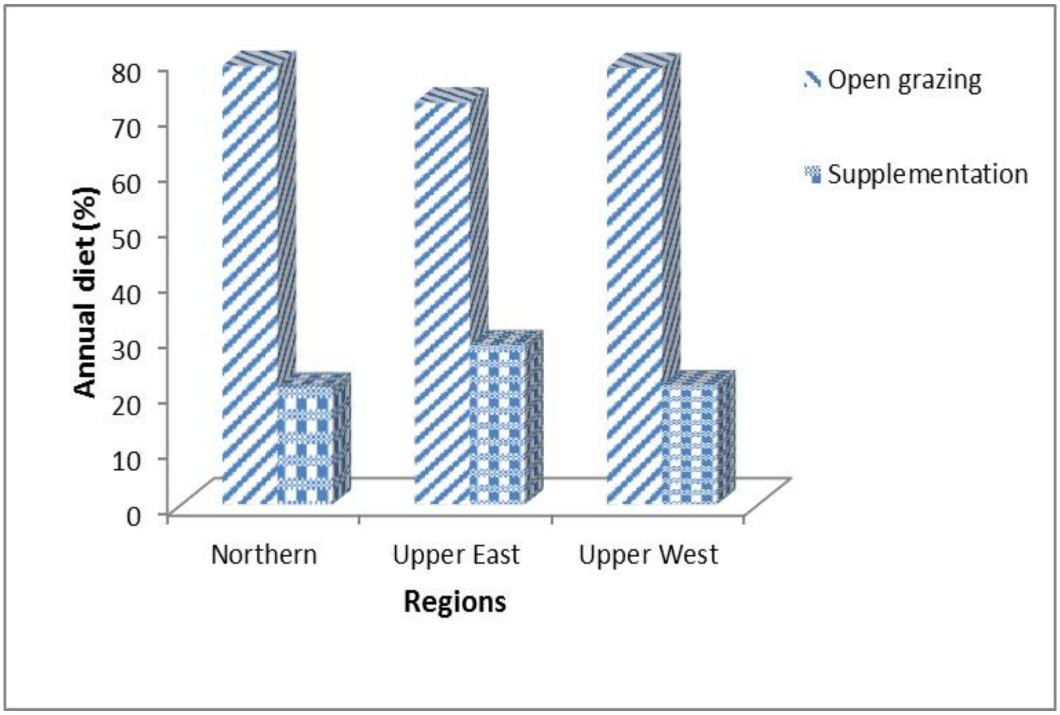


Figure 4.3.3: Contribution of grazing and supplementation to annual DM requirement of ruminants

The fodder grazed comprised grass and legume forage species and uncollected crop residues on cultivated fields. Supplementary feed accounted for about 20% of ruminant annual diet requirement in Northern and Upper West Regions whereas it was slightly higher in Upper East Region. Supplementary feedstuffs were mostly crop residues, home-processed AIBPs and purchased feed of these two categories.

4.3.5: Seasonality of feed resource availability

The results of scores of farmers on monthly rainfall intensity and distribution among the regions are presented in Figure 4.3.4. The rainfall distribution pattern was similar throughout northern Ghana with little differences at the beginning and end of the rainy season. Seven months of rainfall (April to October) with peak rains in July to September and 5 months of dry period (November to March) were reported during the PRA discussions

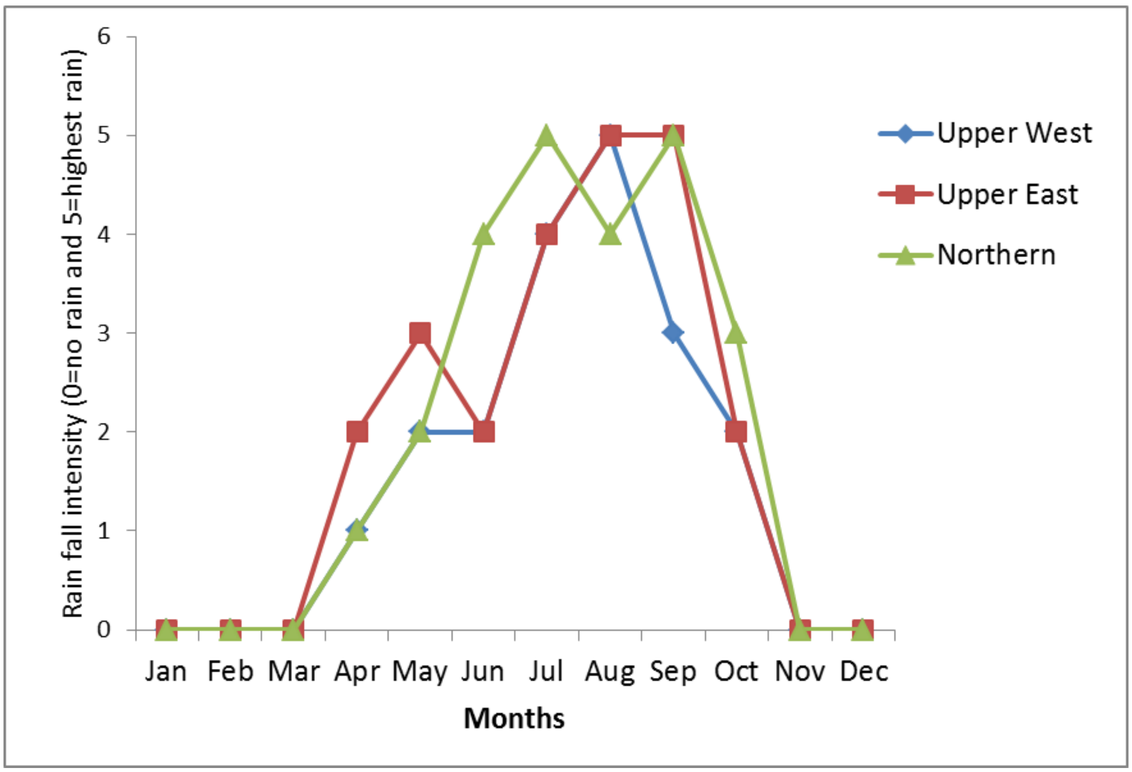


Figure 4.3.4: Annual rainfall distribution pattern

The rainfall pattern influenced the occurrence of two distinct seasons namely, dry and wet seasons. The PRA discussions further indicated the existence of two sub-seasons with slight differences that have impact on quality and availability of feed in the pasture in both wet and dry seasons. The sub-seasons in the dry season were windy-dry and occurred from November to January (early dry season). The second part of the dry season is warm-moist dry beginning from February to April (late dry season) and in the wet season the sub-seasons were early wet with little rainfall from May to July and the main wet season with frequent and heavy rainfall from August to mid-October.

The annual availability of natural pasture was found to be in line with rainfall pattern and increased from June to October in the rainy season but declined as the dry season approached (Figure 4.3.5 a, b and c). This pattern of feed fluctuations was similar among the 3 regions. In the rainy season, natural pasture was inaccessible to animals in some communities due to restricted movement of ruminants to prevent damage to crops. Natural pasture was about 80% available for ruminant at the peak of rainy season and toward crop harvest. Feed gap was found during the late dry season (February to April) with availability of 20% in the natural pasture in Northern and Upper West Regions but lowest in Upper East Region of about 10%. Figure 4.3.5 a, b and c show the monthly trend of feed resource availability for ruminants in the study area. Crop residues were prominently fed towards the end of the year and in the first two months of the year. Feeding harvested green forage or browses was prominent during cropping season when animals were under confinement.

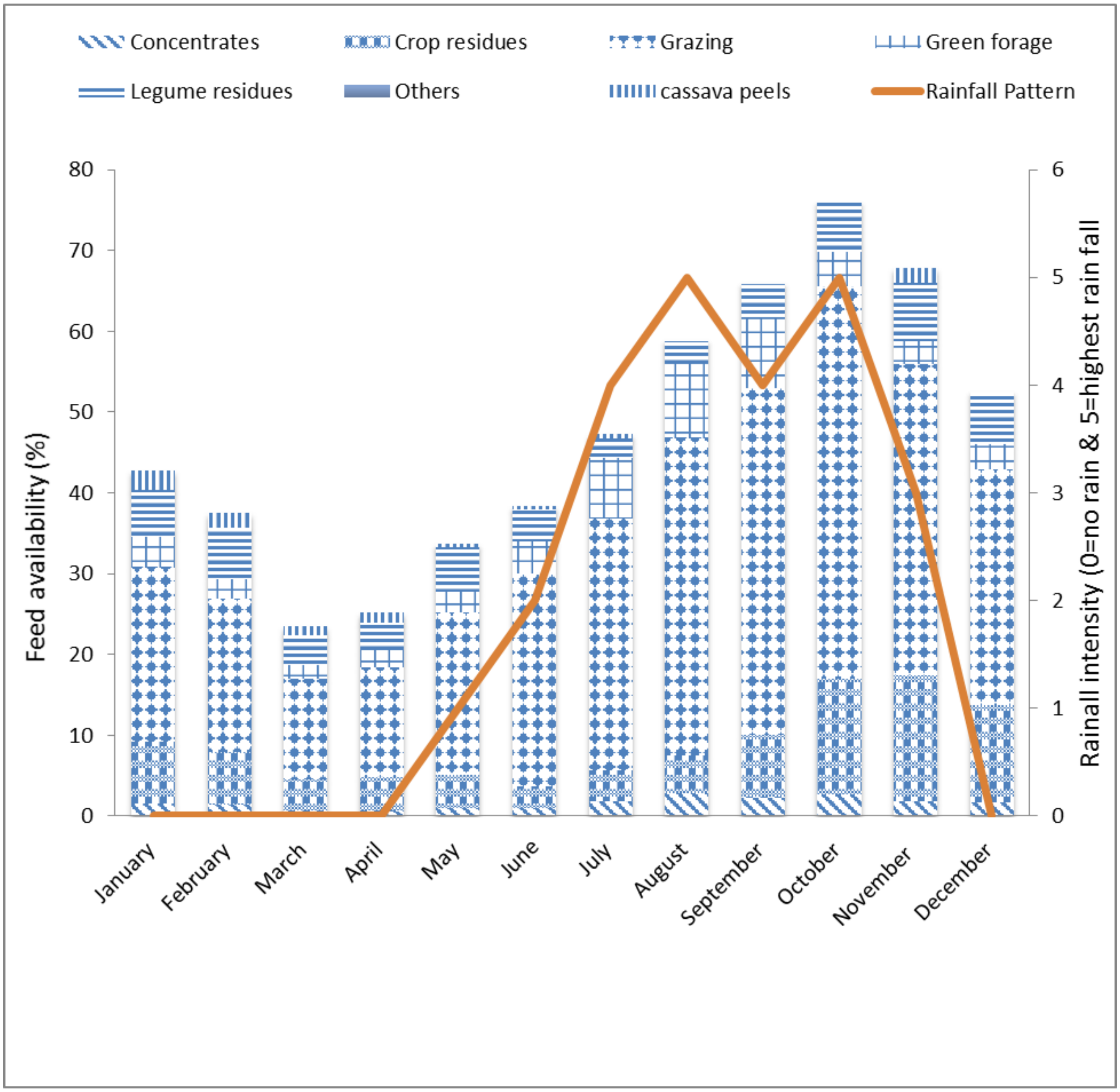


Figure 4.3.5a: Rainfall pattern and available feed resources in the Northern Region of Ghana

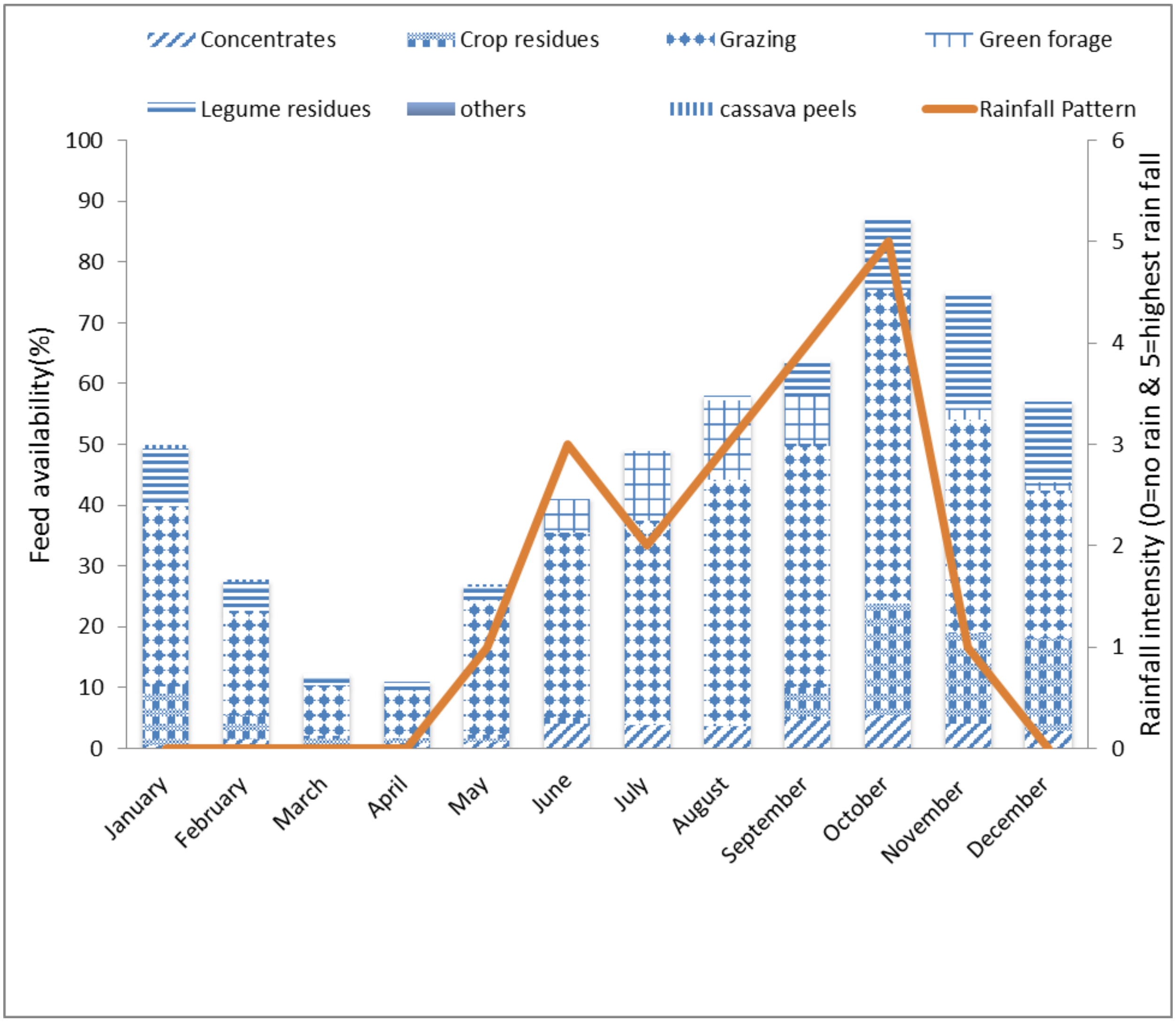


Figure 4.3.5b: Rainfall pattern and available feed resources in the Upper East Region of Ghana

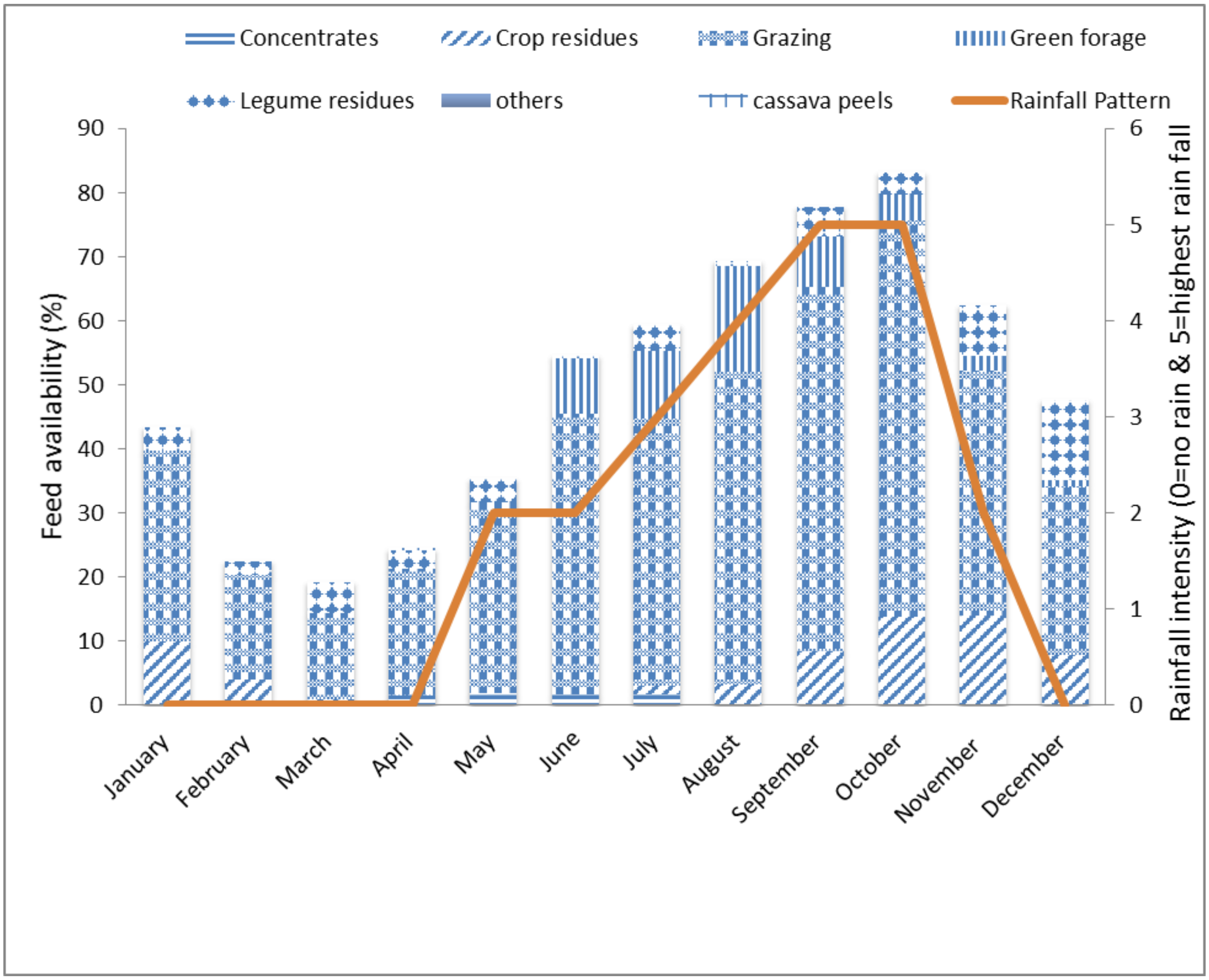


Figure 4.3.5c: Rainfall pattern and available feed resources in the Upper West Region of Ghana

4.3.6: Constraints and opportunities of livestock production

The major constraints to livestock production are presented in Table 4.3.7. High incidence of diseases and associated mortalities was ranked as the most critical constraint in Upper East and West Regions. Dry season feed shortage was second most important constraint. Other constraints were poor housing, lack of improved breeds and dry season water shortage. The existing major livestock production opportunities identified during PRA sessions included: availability of pasture, market for the sale of livestock and input purchases, access to water for human and animals, presence of veterinary service providers, and availability of labour for employment.

The level of availability of these opportunities were ranked (Low = 1-25%, Moderate = 26-50%, High = 51-75% and very high = 76-100%). This is illustrated in figure 4.3.6 a, b and c to show the ease at which these opportunities can be utilized in the regions.

Table 4.3.7: Pair wise ranking of constraints to livestock production

Region	**First**	**Second**	**Third**	**Fourth**	**Fifth**
Northern	Poor housing structures	High incidence of disease and mortality	Inadequate feed in the dry season	High cost of veterinary drugs	Low market price of animals
Upper East	High incidence of disease and mortality	Dry season feed and water shortages	Inadequate technical knowledge	Poor housing structures	Lack of improved breeds
Upper West	High incidence of disease and mortality	Dry season feed and water shortages	Lack of improved breeds	Inadequate veterinary service	Poor housing structures

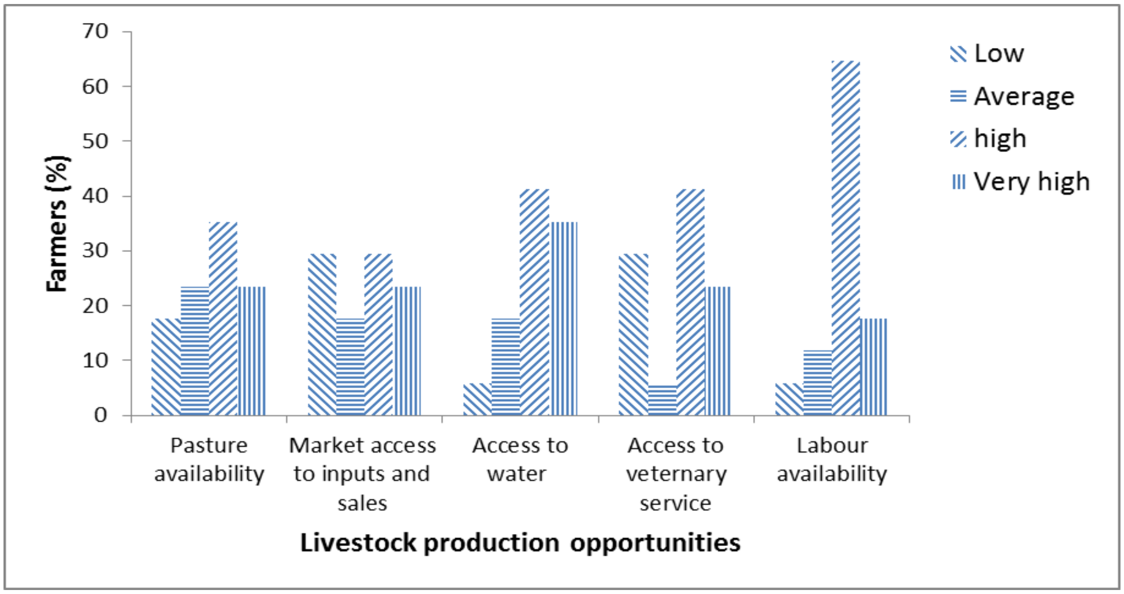


Figure 4.3.6a: Opportunities for improving livestock production in the Northern Region of Ghana

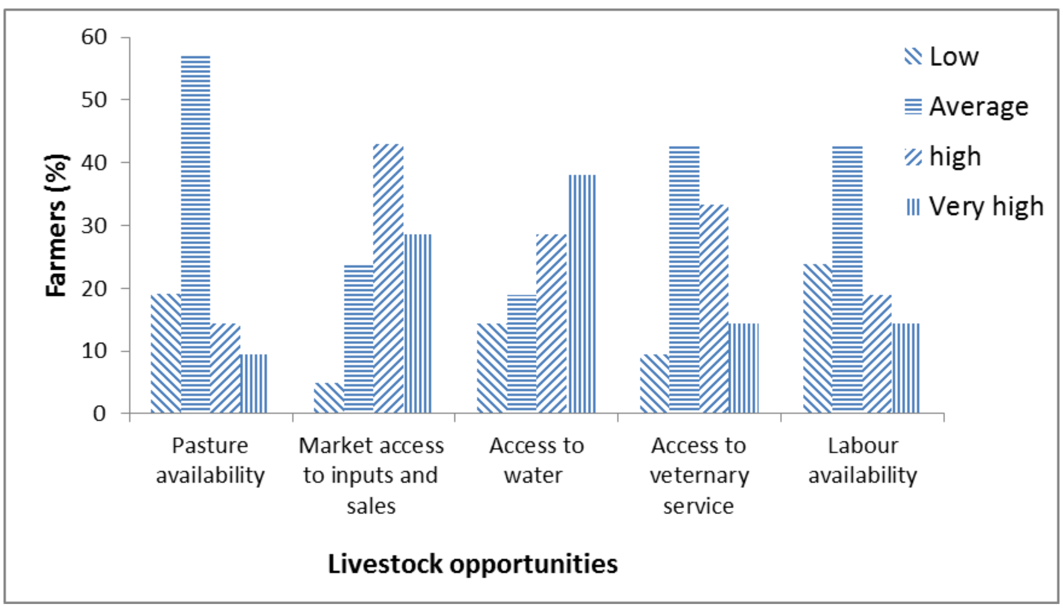


Figure 4.3.6b: Opportunities for improving livestock production in the Upper East Region of Ghana

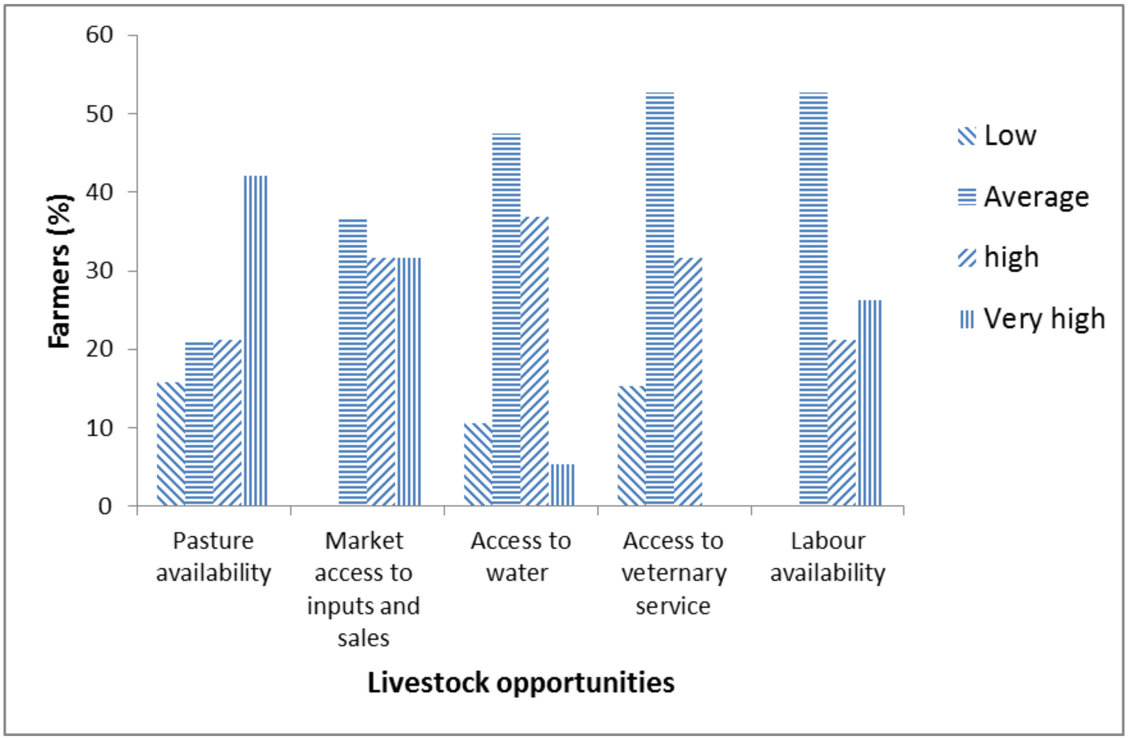


Figure 4.3.6c: Opportunities for improving livestock production in the Upper West Region of Ghana

The common livestock diseases in the area included mange, anthrax, helminthiasis, *Peste des Petits Ruminants* (PPR) and trypanosomiasis. Animal health services provided by MoFA's veterinary officers and private veterinary professionals included: deworming, wound dressing, management of cases of dystocia, and vaccinations against common diseases like PPR and anthrax. About 10% of the farmers in each region practiced ethno-veterinary treatment. About 50% of the required veterinary service needs were not available in the communities due to inadequate veterinary personnel.

4.4.1 Discussion

The household sizes of 8.5, 11.1 and 14.9 for Upper East, Upper West and Northern Regions respectively, were recorded. The main occupation of these households is agriculture that often relied heavily on family labour. The households, therefore, had motivation for larger family sizes. The values of household size obtained in this study were higher than those reported, by GSS (2012) for Northern (7.7) Upper East (5.8) and Upper West (6.2) Regions. The difference may be due to the rural nature of the communities in which this work was carried out compared to both urban and rural data used in GSS (2012) report. Low education of households head and polygamy contributed significantly to the high household size in the study area. FAO (2012) attributed large household size in rural areas to low education of household heads and the labour intensive nature of most smallholder farming activities. Oppong-Anane *et al*. (2008) stated polygamous marriage system as one of the factors responsible for the large household size in northern Ghana.

The highest source of households' income generated from agriculture suggests that it was the main source of livelihood for the households in northern Ghana. This is in line with the report of MoFA (2006) on sources of households' income in northern Ghana. Also, Amole and Ayantunde (2015) reported similar findings in Burkina Faso.

The higher contribution of off-farm activities to household income in Northern and Upper West Regions could be attributed to the proximity of the study communities to the regional capitals where trading activities were quite high compared to the villages far from the regional capitals (MoFA, 2007).

The prevalence of the crop-livestock integrated farming system was to diversify the household production systems. This reduces the overall losses in case of crop failure. This confirms the observation made by other researchers (MoFA, 1998; Agyemang, 2012; Oppong-Anane, 2013). Cultivation of crops at the homestead referred to as ‘compound farming’ was also very common but not in every community as in some places communal agreement had to be made annually as to whether they would do compound farming or not (Kombiok *et al*., 2005). This communal agreement has implications on ruminant grazing during the cropping season. If the community chooses to do compound farming, all animals will have to be confined during the cropping season otherwise they are allowed to graze freely.

The similarity of the estimated farm size of 3.4 ha per household observed in all the regions indicated that the farming systems and land use were similar in the 3 regions. The people of Northern Ghana are known to be predominantly smallholder farmers. The mean farm size recorded in this study was between 4.7 ha per household as reported by Ohene-Yankyera (2004) in the Northern Region and 2 ha per household reported by Karbo and Agyare (2002) in the same region. The differences observed might be attributed to differences in communities studied by the researchers. The current study sites were mainly rural and the one reported by Karbo and Agyare (2002) included peri-urban communities where there were more competing land uses. Farm size is influenced by many factors that farmers consider in deciding the area to cultivate. These include: land tenure system, availability of labour, availability of mechanical or animal traction implement and animals for land preparation (Ohene-Yankyera, 2004).

Higher herd size (1.53 ± 0.21 TLU) per household observed in Upper East Region than the other regions implied there was high livestock density in Upper East Region although there were comparatively less feed resources in that region for livestock production (Oppong-Anane, 2013; Adam and Ohene-Yankyera, 2014). The highest ownership of animals in Upper East was reported to thrive on good feed supplementation and other best management practices (Karbo and Agyare, 2002).

The average livestock herd size of 1.07 TLU per household obtained in this study was close to the national mean of 1.3 TLU among smallholder farmers in Ghana (FAO, 2012). The difference could be due to the limited coverage of this work as compared to the country wide data used by FAO in their report. However, the Upper East Region flock size of 1.53 TLU obtained in this study was higher than the reported national mean. The higher number of small ruminants (sheep and goats) ownership in the regions could be attributed to the ease of acquisition and feeding management as compared to large ruminants. Adams and Ohene-Yankyera (2014) made similar observation in their work on the characteristics of subsistent small ruminant farmers in the same area. This suggests that the vulnerable household members (women and children) who cannot acquire land for crops farming are able to rear sheep and goats as a source of income. Also, the liquidity of small ruminants is far easier and this makes them the preferred option of store of wealth among smallholder farmers as compared to cattle that are difficult to acquire or sell (FAO, 2012; Adams and Ohene-Yankyera, 2014). The cultural importance of poultry, sheep and goats in the area is another factor that makes it mandatory for every household to own at least one of these species (Karbo and Agyare, 2002; MoFA, 2011; Oppong-Anane, 2013). Widespread use of bullocks for land preparation and other traction activities among smallholder farmers in

Upper East more than Northern and Upper West Regions (Awuma, 2012) have led to high percentage ownership of bullocks in Upper East than the other 2 regions.

The high dependence of farmers on natural pasture and uncollected crop residues as feed (constituting 80% of ruminant annual DM requirement) observed in this work has been widely reported in northern Ghana (Annor *et al*., 2007; Awuma, 2012; Oppong-Anane, 2013). The presence of limited cultivated fodder (Karbo *et al*., 1998) and purchased feed (Omutomi *et al.*, 2015) for ruminant supplementation are emerging practices of livestock production. This was an indication of some intensification of livestock production among smallholder farmers. Also, the practices gave indication of increase in investment in the livestock sector in SSA due to feed shortage constraint (Smith, 2010). However, these practices may need further investigation for development.

The collection of leguminous crop residues for supplementary feeding in the dry season and utilization of AIBPs for the same purpose are good practices that reinforce crop livestock integration (Jayasuriya, 2002; Smith, 2010). On the other hand, the higher percentage of uncollected cereal crop residues in the study area constitutes unutilized feedstuff that could have been used to increase livestock productivity. These cereal crop residues are mostly burnt during bush fire outbreaks and hence not being utilized by animals. Adams and Ohene-Yankyera (2014) reported similar findings and suggested that more extension education on crop residues usage was needed in the study area.

The limited cultivation of pigeon pea (*Cajanus cajan*) and *Leucaena* as fodder plants was also reported by Karbo and Agyare (2002). The high estimated price of pigeon pea residues

(1.05±0.17 GH₵/kg DM) may be attributable to its perceived good quality (Ayantunde *et al*., 2014). The entire feed market needs further investigation to ascertain whether feed price matches its nutritive quality and to identify the opportunities and constraints of this emerging feed market for development.

The relationship between annual feed availability and rainfall pattern in this study agrees with the report that feed availability is a function of land use and rainfall pattern (Jayasuriya, 2002). Also, Annor *et al*. (2007) stated that feed becomes more available and accessible to ruminants only after crop harvest when animals are allowed to graze freely. Inaccessibility of green forage to animals in some communities in the study area during the cropping season was also reported in the same study area by Awuma (2012).

Seasonal scarcity of feed resources in the study area during the dry season (February to May) was similar to reports from other places in the tropics. Thus it was a major constraint to ruminant production where animals depended largely on natural pasture (Annor *et al.,* 2007; Smith, 2010). Beside low feed available for ruminants during this lean season it was poor in quality too. These residues were characterized by high fibre content (>700 g of cell wall material/kg DM), low metabolizable energy (<7.5 MJ/kg DM), low levels of crude protein (20-60 g of crude protein/kg DM) and low to moderate digestibility (30-45%). This kind of feed limit small ruminant daily intake to less than 20 g DM /kg live weight (Owen *et al*., 1989) and reduce the ability of animals to satisfy their nutritional requirement leading to weight loses (Smith, 2010). Most of the residues were also deficient in fermentable carbohydrates as reflected by the relatively low organic matter digestibility (Jayasuriya, 2002).

It is known that chemical treatment can increase the potential feeding value of the crop residues. For instance alkali treatment of fibrous residues like urea as source of ammonia has been well researched and the benefit well established (Owen *et al*., 1989) but the adoption of this technology was low in the study area. Thus farmers did not exploit the full potential of their cereal residues. Another category of crop residues with limited usage by few farmers was less fibre-high protein haulms from leguminous crops (groundnut, cowpea, and soy beans). These were only available to about 20% of the farmers as most farmers did not store them after harvest.

Also, AIBPs such as corn milling waste, rice and maize bran, brewers' spent grain are generally less fibrous (< 700 g but above 400 g of cell wall material/kg DM) and contain relatively high amount of crude protein (> 60 g/kg DM) (Jayasuriya, 2002). This category of feed was, however, not available to many smallholder farmers during the critical period of feed shortage. The presence of browse plants such as *Gliricidia sepium, Leucaena leucocephala, Ficus gnaphalocarpa and Ptericarpus erinaceous* in the feed resources which contain approximately 250-350 g of crude protein/kg DM (Jayasuriya, 2002) was considered good in balancing the high fibre-low protein feedstuffs. However, these browse plants are limited to few farmers (Ansah *et al*., 2015). Crop residues conservation and planting of fodder plants have been given some consideration by few farmers in the study area but more effort is needed to make many farmers adopt this technology to address the feed shortage problem in the dry season.

The constraints identified in this study confirm other findings regarding livestock production in the area (Amankwah *et al*., 2012; Oppong-Anane, 2013). The ranking of diseases and associated mortality in this study as first among the constraints agrees with the report of Clotey *et al.* (2007). Under-nutrition due to feed shortages and inadequate healthcare provision contributes significantly to the diseases and mortalities (Smith, 2010). Therefore, good nutritional provision is needed to combat diseases and mortality (Campbell *et al*., 2003). Notwithstanding the constraints identified, the current study showed the existence of potential feed resources for livestock production that can be exploited to satisfy the animal protein requirements of the people. Previous reports of other workers also ascribed to this assertion and opined that northern Ghana is endowed with good resources and opportunities for livestock production (Duku *et al*., 2010; Oppong-Anane, 2013; Adams and Ohene-Yankyera, 2014). The common livestock diseases and inadequate health care services found in this work were also reported by Oppong-Anane (2013). The gap in veterinary service needs of farmers needs to be addressed by increasing veterinary service providers to reduce mortality of animals (Clotey *et al.,* 2007) and to increase investment returns in animal production.

4.5.1 Conclusion and recommendation

In conclusion, the study found that approximately 80% of ruminant annual DM requirement was obtained from grazing in the pasture and 20% by supplementation. There was dry season feed shortage which was quite critical from February to May. This feed shortage was very severe in Upper East Region where natural pasture availability was about 10% compared to about 20% in

Northern and Upper West Regions. High incidence of disease and mortality and dry season feed scarcity were the major livestock production setbacks. Few farmers had recognized the effect of feed shortage and resorted to fodder planting and conservation as potential source of feed for ruminants. It is recommended that supplementary feeding should be done during the critical feed shortage period. Also, best practices of livestock healthcare and feeding management interventions could help address the major constraints of livestock production in the area.

CHAPTER 5

5. SURVEY II: ASSESSMENT OF QUALITY AND PRICE OF FEEDSTUFFS SOLD IN THE EMERGING FEED MARKETS IN NORTHERN GHANA

5.1.0 Introduction

The second survey was conducted to assess the emerging feed market and ascertain the types of feed sold and the relationship between prices of feedstuffs and quality.

Feed resources used by many farmers for ruminant production in Ghana are natural pasture, crop residues and AIBPs. However, rapid urbanization in most parts of Ghana is reducing the availability of pasture and thereby increasing demand for livestock feed in urban and peri-urban areas (Oppong-Anane, 2013).

The declining availability of natural pasture is a constraint to productivity especially in the dry season. In the wet season, accessibility to forage is a constraint to ruminant production in some communities due to cultivation of crops in compound farms (Awuma, 2012). This necessitates tethering of animals and limiting their grazing area.

The scarcity of natural pasture has created a high demand for feed and motivated feed sellers to collect browses, crop residues and AIBPs for sale (Huseini *et al*., 2011) especially to small ruminant traders who use them to fatten their animals for sale. The increasing demand for collected fodder has triggered the emergence of livestock feed markets in urban and peri-urban areas. This emerging feed market contributes to the alleviation of feed shortage mostly in urban areas. A feed market survey by ILRI (2009) in Ethiopia indicated an increased feed sale in urban areas due to increasing demand. If the quality of the feedstuffs sold is known, it could influence prices for market development. Knowledge of the nutrient composition of these feed resources can also help buyers and sellers to obtain value for money from feed sold in the market (Ayantunde *et al*., 2014). For sustainable development of these feed markets in Ghana, there is the need to gather data on the types of feed, prices and nutritional characteristics of the feed sold at the markets. This will be relevant to both feed buyers and sellers in their decision-making.

5.1.1 Objectives

- To document the types of feed sold, prices of feed and the relationship between feed nutritive quality and price.
- To assess the opinion of feed sellers and buyers on the emerging feed market development.

5.2.0 Materials and methods

5.2.1 The study area

The study was conducted in 3 livestock feed markets located at Tamale, Bolgatanga and Wa in Northern, Upper East and Upper West Regions respectively (section 3.1.1).

5.2.3 Selection of feed markets

Information on livestock feed trading activities in terms of the types of feed sold and availability in all the major markets in each region was obtained from the Regional MoFA Animal Production Officers in the 3 political administrative regions of northern Ghana through personal contacts. A reconnaissance market survey was then conducted to determine the types of feed sold in all the markets in each region. One market was selected per region based on dominant sale of feedstuffs. Feed sellers and buyers in these markets were then interviewed based on their willingness to participate in the survey.

5.2.4 Data collection

Data were collected quarterly in all 4 seasons for one year. The seasons were early dry, late dry, early wet and the main wet seasons. Data were collected in each season in December 2013 and March, June and September of 2014.

Semi-structured questionnaire was used to collect qualitative and quantitative data from sellers and buyers of feedstuffs in the markets. A total of 170 respondents (55, 62 and 53 in Tamale, Bolgatanga and Wa markets, respectively) were interviewed. Data collected included profile of feed sellers and buyers, type of feed sold at the market and their prices, seasonality of feed sold, constraints and the opinion of feed buyers and sellers concerning the market development.

Three samples of each feed sold in each market were randomly bought per season from 3 different sellers for each feed type to determine the price/kg feed sold. The price of each feed was then expressed on DM basis.

5.2.5 Laboratory analysis

For chemical analysis, the 3 samples collected per each feed type in each market were pooled per market and sub-sampled resulting into 3 samples per season from the 3 markets (Tamale, Bolgatanga and Wa markets). These were milled to pass through 2 mm sieve. Proximate composition of the milled samples was then determined by the AOAC (1990) method at ILRI Animal Nutrition Laboratory in Addis Ababa, Ethiopia. The NDF, ADF and ADL contents were determined following Goering and Van-Soest (1970) procedures. The IVOMD of samples were calculated using CP and ash content of samples on DM basis and 24 h net gas production according to Menke and Steingass (1988) equation (Section 3.3.8).

5.2.6 Statistical analysis

The data was analyzed using Statistical Package for Social Sciences version 17 (SPSS, 2007). To obtain percentage of feed sales and purchases by respondents, descriptive statistics from SPSS was used. Data on the effect of season on feed prices and nutrient content parameters were analyzed with analysis of variance with markets as replicates. The model used for the analysis is given below;

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where Y_{ij} is observations on prices of feedstuffs and nutrient content (DM, ash, CP, NDF, ADF, ADL and IVOMD), μ is the overall mean effect, S_i is effect of season (early dry, late dry, early wet and main wet seasons) and e_{ij} is the residual error effect. The means were compared using LSD and significance declared at $P<0.05$. Linear regression analysis was done to determine relationship between feed CP concentration and price. The effect of change in CP concentration on prices variation of feed was also estimated.

5.3.0 Results

5.3.1 The profile of feed traders

There were more males (72%) than females (28%) among the traders interviewed. Of these, 87% were married whereas 13% were not. Many more farmers (46%) were involved in buying feed for feeding their animals than selling (41%), whereas others (13%) were involved in retailing. Feed buyers were mostly peri-urban livestock farmers or livestock traders mostly involved in small ruminant production or trading.

Respondents were mostly adults with a few elderly people (Table 5.3.1). Children (13%) were second to adults (73%) in the trade. Over 50% of the feed sellers and buyers had no formal education (Table 5.3.2) and could neither read nor write. They were followed by about 18% of respondents who started formal education but did not complete primary school. Most of those who had no formal education or had partial formal education were involved in the sale of feed whereas those with good secondary and tertiary education were involved in buying feed.

Table 5.3.1: Age (years) distribution of the respondents (%) at each market location

Age group[1]	**Market**			**Total**
	Wa	**Bolgatanga**	**Tamale**	
Children (≤ 15)	13.3	-	-	13.3
Young adults (16-30)	5.0	1.7	4.4	11.1
Adults (31-65)	17.8	32.2	23.4	73.3
Elderly (>65)	-	0.6	1.7	2.2
Total	36.1	34.4	29.4	100.0

[1]GSS, (2012), Total number of respondents = 170, - = No observation

Table 5.3.2: The educational status of feedstuff sellers and buyers

Educational level	Buyers (%)	Sellers (%)	Both (%)	Total
Never been to school	37.3	10.2	3.0	50.6
Koranic education	12.0	2.4	1.8	16.3
Primary school dropout	4.2	12.0	1.8	18.1
Completed primary	3.0	-	-	3.0
Secondary school dropout	3.6	0.6	-	4.2
Completed secondary	5.4	1.8	-	7.2
Tertiary	0.6	-	-	0.6
Total	66.3	27.1	6.6	100.0

Number of respondents = 158, - = No observation

5.3.2 Seasonality of demand and supply of feedstuffs

The sale and purchase of feedstuffs by traders at the markets in all seasons are presented in Table 5.3.3a and 5.3.3b. The results indicated that feed was sold throughout the year at the Bolgatanga and Tamale markets. At Wa market, most sellers (53%) sold feed only in the dry season or during festive occasions. The quality of all feed sold was rated by over 50% of both sellers and buyers to be good whereas few (20%) perceived the quality to be fair in all the markets.

Table 5.3.3a: Seasonal feed sales in the selected markets

Season	Respondents (%)			Total
	Wa	Bolgatanga	Tamale	
Only early dry season (Nov-Jan)	13.2	3.1	-	16.3
Only late dry season (Feb-April)	30.5	-	-	30.5
Only early wet season (May-July)	3.1	-	-	3.1
Only wet season (Aug-Oct)	-	-	1.6	1.6
Throughout the year (Jan-Dec)	15.6	14.1	9.4	39.1
Festive seasons[1]	9.4	-	-	9.4
Total	71.9	17.2	10.9	100.0

Number of respondents =164, Festive seasons[1] (Charistmas and Ramadan), - = No observation

Table 5.3.3b: Seasonal feed purchase in the selected markets

Season	Respondents (%) at different markets			Total
	Wa	Bolgatanga	Tamale	
Only early dry season (Nov-Jan)	1.7	14.3	1.7	17.6
Only late dry season (Feb-April)	4.2	14.3	0.8	19.3
Only early wet season (May-July)	-	-	5.9	5.9
Only wet season (Aug-Oct)	-	-	-	0.0
Throughout the year (Jan-Dec)	6.7	16.0	24.4	47.0
Festive seasons[1]	1.7	0.8	7.6	10.1
Total	14.3	45.4	40.3	100.0

Number of respondents =162, Festive seasons[1] (Charistmas and Ramadan) - = No observation

Groundnut haulm was found to be the most common crop residue in all the 3 markets. It was the dominant feed sold by feed sellers in the 3 markets. Cereal straws such as sorghum and millet were not found in any of the markets. Majority of feed sellers (47%) and buyers (37%) traded in feedstuffs during the early and late dry seasons (Table 5.3.3a and b). Merchandising of feed in the 3 markets was observed not to be seasonal as many respondents sold (40%) or bought (47%) feed throughout the year.

5.3.3 Types of feed sold and their prices

Different types of feedstuff were sold in the markets (Appendix III). These were categorized into 4 groups. The first group was leguminous crop residues. It comprised groundnut haulm, cowpea haulm, cowpea pods, potato vines, pigeon pea residues. The second group was peelings of cassava, yam and plantain. The third group was AIBPs made up of bran of maize, rice, sorghum, millet, and soybean. The fourth group was local browse species such as *Pterocapus erinaceous, Ficus sp* and *Afzelia sp.*

Nature and price range of the most commonly sold feedstuffs are presented in Table 5.3.4. The widest price range was found in groundnut haulms. These feedstuffs went through 2 to 3 stages of market chain. That is field collection or grain processing point to final consumers and through retailer to final consumer (Figure 5.3.1). The final consumer/buyer then offered the feed to his/her animals. Some of the feedstuffs were sold on demand as producers did not have the primary intention of selling them. Examples of such feedstuffs were AIBPs like corn milling waste, bran of maize and sorghum and yam peelings. The price comparison of the four categories of feedstuffs sold in the study area are presented in Table 5.3.5. Cowpea haulm had the highest

(P<0.05) price (GHS1.05/kg DM) among the crop residues and pigeon pea residues was lowest (GHS 0.32/kg DM). Among AIBPs prices, Cowpea bran was highest and rice bran lowest

Table 5.3.4: The nature and price range (GHS/kg DM) of common feedstuffs sold

Feed type	Nature of feed	Unit of measure	Price
Groundnut haulms	Dried haulms	Bundles/bags	0.08−0.62
Cowpea haulm	Dried haulms	Bundles	0.82−1.05
Ficus sp	Fresh leaves and twigs	Bundles	0.2−0.43
Afzelia sp	Fresh leaves and twigs	Bundles	0.04− 0.49
Pterocapus erinaceous	Fresh leaves and twigs	Bundles	0.05−0.72
Maize bran	Dried chaff of grains	Bags and bowls	0.23−0.68
Sorghum bran	Dried chaff of grains	Bags and bowls	0.25−0.53
Rice bran	Dried chaff of grains	Bags and bowls	0.04−0.23

1USD ≈3.05 GH**S** at the time of study (2014)

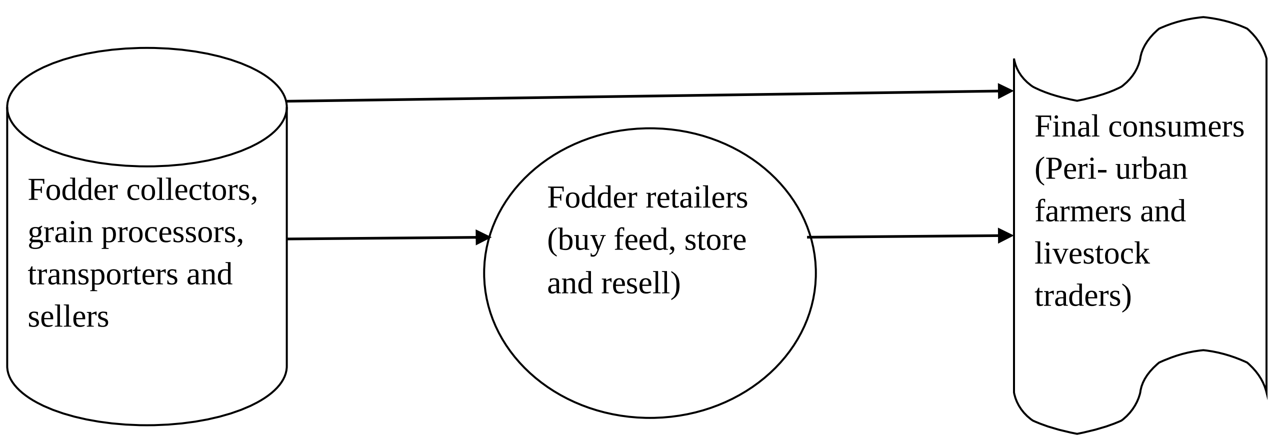


Figure 5.3.1: Feedstuff market chain

Table 5.3.5: Prices (GHS/kg DM) of different kinds of feedstuffs sold in the study markets

Name of feedstuff	n	Price/ kg DM (GHS)
Crop residues	**36**	
Pigeon pea residues		0.32[a]
Groundnut haulms		0.46[ab]
Bambara beans tops		0.59[bc]
Potatoe vines		0.68[cd]
Cowpea pods		0.81[e]
Cowpea haulms		1.05[f]
SED		0.090
P value		0.001
Cassava, yam and Plantain peels	**12**	
Cassava peels		0.24[a]
Yam peels		0.27[a]
Plantain peels		0.39[b]
SED		0.036
P value		0.001
Agro-industrial by-products	**12**	
Corn milling waste		0.22[a]
Cowpea bran		0.55[c]
Dawadawa pulp		0.43[bc]
Maize bran		0.47[bc]
Millet bran		0.24[a]
Brewers' spent grain		0.38[b]
Rice bran		0.21[a]
Sorghum bran		0.25[a]
Soya bean bran		0.39[b]
SED		0.063
P value		0.001
Browses	**12**	
Afzelia sp		0.49
Ficus sp		0.41
Pterocapus erinaceous		0.62
SED		0.058
P value		0.066

Means with different superscripts down the column are significantly different ($P<0.05$), SED = Standard error of differences of means, n = number of sellers interviewed, 1 USD ≈ 3.05 GHS at the time of study (2014)

Prices of feedstuffs sold in all the market were highest (P<0.05) in Bolgatanga market in the Upper East Region compared to the other two markets (Table 5.3.6a). Brewers' spent grain was the most expensive (GHS 0.66/kg DM) feedstuff in Bolgatanga market whereas rice bran had the lowest price of GHS 0.04 /kg DM at the Wa market.

Table 5.3.6a: Prices (GHS/kg DM) of feedstuffs that were found in all markets

Name feedstuff	Market location			SED	P value
	Tamale	Bolgatanga	Wa		
Groundnut haulms	0.31^a	0.54^b	0.34^a	0.048	0.001
Cassava peels	0.24	0.27	0.25	0.047	0.752
Corn milling waste	0.36	0.25	0.26	0.065	0.199
Maize bran	0.49	0.48	0.32	0.091	0.128
Brewers' spent grain	0.41^a	0.66^b	0.31^a	0.118	0.015
Rice bran	0.14^b	0.20^b	0.04^a	0.039	0.001
Yam peels	0.37	0.34	0.43	0.093	0.632

Means with different superscripts along the rows are significantly different (P<0.05), 1USD ≈ 3.05 GH**S,** SED Standard error of differences of means.

The effect of season on the prices of feedstuffs is shown in Tables 5.3.6b. Generally, the prices of feedstuffs that differed among seasons were higher (P<0.05) in early dry and late dry seasons. Prices of the local browses were highest (P<0.05) in early dry season than the other 3 seasons. Season did not affect the prices of most AIBPs and crop residues. However, brewers' spent grain and cowpea pods prices were significantly higher (P<0.05) in early dry season (Table 5.3.6b).

Table 5.3.6b: Effect of season on prices (GHS/kg DM) of feedstuffs

Feedstuff	Season				SED	P value
	Early dry	Late dry	Early wet	Main wet		
Browses						
Afzelia sp	0.83^{b}	0.44^{a}	0.40^{a}	0.28^{a}	0.070	0.001
Faidherbia albidah fruits	0.86^{a}	0.70^{a}	0.80^{a}	1.34^{b}	0.167	0.021
Ptericarpus erinaceous	0.85^{c}	0.75^{bc}	0.50^{ab}	0.38^{a}	0.144	0.036
Ficus sp	0.56^{b}	0.42^{ab}	0.24^{a}	0.27^{a}	0.095	0.011
AIBPs						
Sorghum bran	0.27	0.31	0.26	0.18	0.038	0.050
Soya bean bran	0.30	0.35	0.37	0.55	0.112	0.219
Millet bran	0.18	0.21	0.21	0.19	0.048	0.870
Corn milling waste	0.20	0.34	0.29	0.33	0.076	0.266
Maize bran	0.42	0.37	0.44	0.48	0.112	0.798
Brewers' spent grain	0.70^{b}	0.35^{a}	0.23^{a}	0.48^{ab}	0.129	0.006
Rice bran	0.15	0.15	0.08	0.13	0.055	0.559
Cassava peels	0.26	0.21	0.27	0.27	0.056	0.509
Crop residues						
Groundnut haulms	0.37	0.41	0.54	0.51	0.095	0.259
Yam peels	0.47	0.25	0.42	0.44	0.108	0.195
pigeon pea residues	0.40	0.28	0.29	0.29	0.105	0.648
Cowpea haulms	1.44	0.87	1.00	0.88	0.258	0.170
Cowpea pods	1.35^{b}	0.33^{a}	0.35^{a}	0.66^{a}	0.345	0.005
Plantain peels	0.26	0.27	0.25	0.29	0.023	0.915

Means with different superscripts in rows are significantly different ($P<0.05$), SED = Standard error of differences of means, AIBPs = agro-industrial by-products, 1 USD ≈ 3.05 GHS at the time of study, Cowpea haulm had the highest price but it was not significantly different (P>0.05) in all the 4 seasons. The results further showed that the most available and cheapest feedstuff was rice bran. Seasonal prices of all the feed traded in all seasons have been presented in Figure 5.3.2. Prices were higher (P<0.05) in early to late dry seasons than in other seasons. Prices were generally higher (P<0.05) in Bolgatanga market than Tamale and Wa markets.

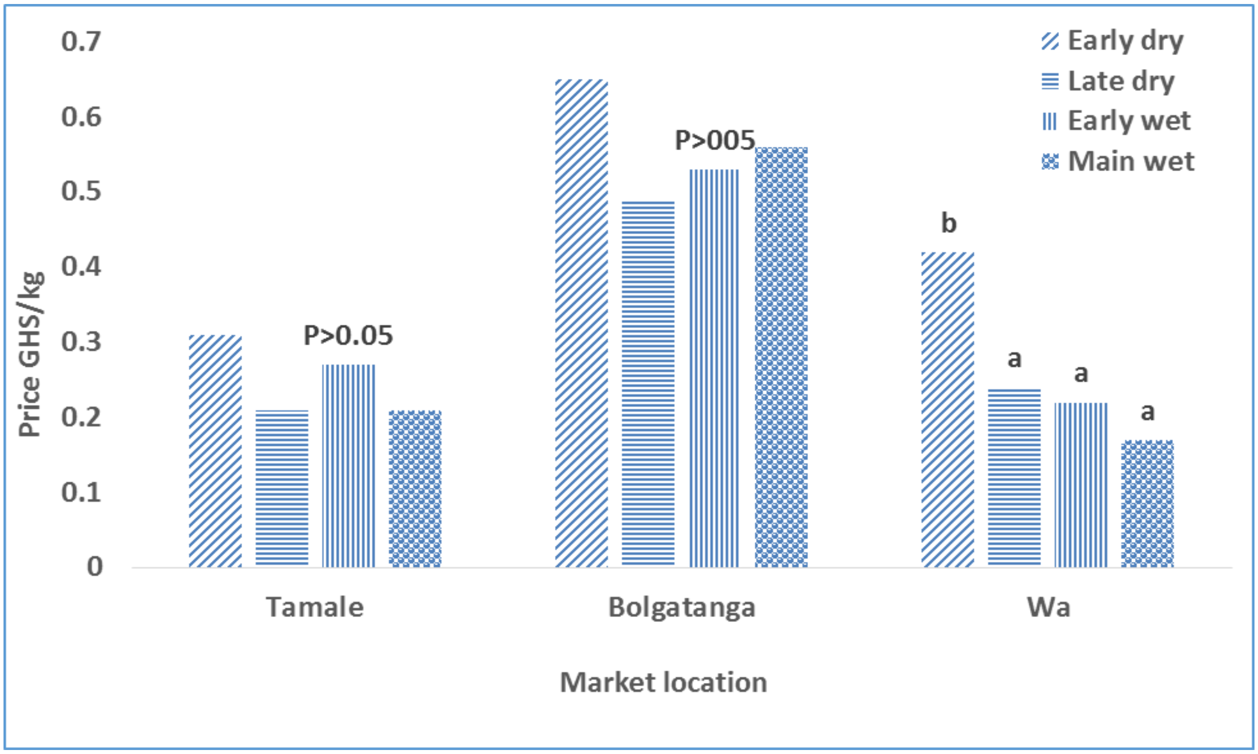


Figure 5.3.2: The effect of season on prices of feedstuff in the markets

5.3.4 Relationship between price and nutritional quality of feedstuff

A comparison of the nutritive quality and prices of feedstuff showed that feed quality had less influence on the prices in all the markets and in all seasons (Tables 5.3.7a, b, c). The concentration of CP and IVOMD of brewers' spent grain were superior (CP = 25%; IVOMD = 60%) among all the feedstuffs but the price of brewers' spent grain was significantly lower

(P<0.05) than cowpea haulms which had the highest (P<0.05) price (GH**S**1.00). Rice bran had the poorest quality (CP) and the lowest price.

Table 5.3.7a: Effect of season on nutrient content (%) and price (GH₵) of browses

Browses	Season(n=3)	DM	CP	NDF	ADF	ADL	IVOMD	Price
Afzelia sp	Early dry	91.95^{ef}	15.46	52.82^{abc}	38.27^{ab}	13.86^{bcd}	59.73	0.83^{ef}
	Late dry	91.04^{de}	15.93	52.26^{ab}	39.84^{abcd}	11.03^{ab}	68.13	0.54^{bcd}
	Early wet	$92.71f^{g}$	17.81	63.52^{d}	43.35^{cd}	18.84^{e}	43.06	0.73^{def}
	Main wet	92.87^{g}	14.99	53.38^{abc}	36.70^{a}	16.68^{de}	51.32	0.25^{a}
Ficus sp	Early dry	90.29^{bc}	12.34	50.22^{a}	37.10^{a}	9.43^{a}	50.52	0.41^{ab}
	Late dry	89.93^{b}	13.76	52.18^{ab}	43.35^{cd}	13.80^{bcd}	49.74	0.48^{bc}
	Early wet	90.43^{bc}	13.8	53.41^{abc}	44.27^{d}	15.17^{cd}	44.61	0.70^{cde}
	Main wet	88.84^{a}	11.46	56.64^{c}	52.39^{e}	23.05^{f}	41.97	0.38^{ab}
P. erinaceous	Early dry	91.53^{de}	14.9	52.72^{abc}	38.75^{abc}	12.31^{abc}	54.81	0.94^{f}
	Late dry	91.53^{de}	14.9	52.72^{abc}	38.75^{abc}	12.31^{abc}	54.81	0.68^{cde}
	Early wet	91.70^{de}	16.75	56.41^{bc}	42.02^{bcd}	13.65^{bcd}	46.55	0.68^{cde}
	Main wet	91.37^{de}	16.16	56.9^{c}	40.82^{abcd}	14.14^{bcd}	49.22	0.38^{ab}
SED		0.368	1.782	2.059	2.293	1.733	4.844	0.113
P values	Feed (F)	0.001	0.003	0.083	0.001	0.03	0.005	0.014
	Season (S)	0.008	0.236	0.001	0.001	0.001	0.001	0.001
	F × S	0.001	0.868	0.005	0.001	0.001	0.162	0.015

The means with different superscripts in columns are significantly different P<0.05, DM = dry matter, CP = Crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *in vitro* organic matter digestibility, SED =Standard error of differences of means. 1 USD ≈ 3.05 GH**S** at the time of study.

Table 5.3.7b: Effect of season on nutrient composition (%) and price (GHS) of agro-industrial by-products

Feedstuff	Season (n=3)	DM	CP	NDF	ADF	ADL	IVOMD	Price
Corn milling waste	Early dry	90.72	9.5	29.6	6.4	1.91	65.46	0.32^{bc}
	Late dry	90.89	8.54	50.4	10.66	2.84	56.24	0.30bc
	Early wet	90.97	9.97	35.86	8.91	1.72	53.25	0.18^{ab}
	Main wet	89.14	10.67	37.86	5.75	1.47	59.63	0.26^{bc}
Maize bran	Early dry	90.36	12.06	43.94	10.22	1.23	60.25	0.40^{c}
	Late dry	91.06	10.3	49.81	11.16	1.16	56.87	0.39^{c}
	Early wet	90.77	11.57	61.52	15.07	1.91	50.68	0.34^{bc}
	Main wet	89.87	12.55	46.58	9.43	1.88	64.81	0.36^{bc}
BSG	Early dry	91.51	23.08	61.41	30.99	8.72	58.82	0.34^{bc}
	Late dry	92.10	22.48	60.86	34.09	9.49	59.18	0.28^{bc}
	Early wet	92.23	22.24	61.86	34.3	10.21	51.58	0.18^{ab}
	Main wet	92.18	23.54	59.43	32.58	8.44	52.4	0.72^{d}
Rice bran	Early dry	91.97	7.55	63.09	40.17	12.98	39.77	0.19^{ab}
	Late dry	92.17	5.63	61.3	39.95	12.55	35.67	0.19^{ab}
	Early wet	92.79	6.57	64.16	42.78	13.77	35.03	0.05^{a}
	Main wet	91.78	6.43	60.87	42.28	15.49	35.7	0.05^{a}
SED		0.529	2.841	7.234	3.863	2.709	9.857	0.095
P values	Feed (F)	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Season (S)	0.005	0.708	0.222	0.326	0.955	0.402	0.012
	F × S	0.234	1.000	0.294	0.966	0.989	0.985	0.004

Means with different superscripts in columns are different at P<0.05, DM = dry matter, CP = Crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *in vitro* organic matter digestibility, SED =Standard error of differences of means, BSG = Brewers' spent grain. 1 USD ≈ 3.05 GH**S** at the time of the study,

Table 5.3.7c: Effect of season on nutrient composition (%) and price (GHS) of legume crop residues

Feed name	Season (n=3)	DM	CP	NDF	ADL	ADF	IVOMD	Price
Groundnut H	Early dry	90.83^{c}	09.83	42.88^{ab}	9.58^{cde}	40.6	52.81^{ab}	0.34^{ab}
	Late dry	91.28^{cde}	12.17	51.92^{cde}	8.73^{c}	43.31	64.74^{bc}	0.30^{a}
	Early wet	92.06^{ef}	10.51	56.78^{e}	11.75^{ef}	49.6	53.86^{ab}	0.72^{c}
	Main wet	90.78^{bc}	11.2	52.24^{cde}	9.39^{cd}	44.62	49.36^{a}	0.59^{bc}
Cowpea H	Early dry	89.84^{a}	09.62	39.54^{a}	4.70^{a}	24.81	66.43^{bc}	1.44^{f}
	Late dry	89.95^{ab}	08.84	45.63^{abc}	6.02^{ab}	35.46	64.52^{bc}	1.16^{e}
	Early wet	90.98^{cd}	11.87	53.42^{cde}	8.90^{cd}	40.86	56.09^{abc}	1.00^{de}
	Main wet	90.88^{c}	9.85	50.43^{bcd}	7.58^{bc}	37.46	55.13^{abc}	0.81^{cd}
Pigeon pea R	Early dry	91.56^{cde}	07.71	59.81^{e}	11.70^{ef}	46.27	48.31^{a}	0.44^{ab}
	Late dry	92.47^{f}	8.25	50.97^{bcd}	12.70^{f}	41.12	45.03^{a}	0.28^{a}
	Early wet	91.04^{cd}	10.27	52.26^{cde}	11.03^{def}	39.84	68.13^{c}	0.28^{a}
	Main wet	91.76^{def}	9.09	51.61^{bcde}	11.86^{ef}	40.48	56.58^{abc}	0.27^{a}
SED		0.424	1.677	4.234	1.113	5.392	6.635	0.13
P values	Feed (F)	0.001	0.06	0.02	0.001	0.003	0.16	0.001
	Season (S)	0.096	3.22	0.065	0.042	0.281	0.478	0.009
	F × S	0.003	0.595	0.012	0.03	0.15	0.009	0.001

Means with different superscripts in same columns are different at P<0.05, DM = dry matter, CP = Crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = in vitro organic matter digestibility, H = Haulm, R = Residue, SED = Standard error of differences of means, 1 USD ≈ 3.05 GHS at the time of the study.

The prices of browse plants differed (P<0.01). *Ptercarpus erinaceous* had the highest price (GH**S** 0.67 /kg DM) and the *Ficus sp* lowest (GHS 0.49 /kg DM). However, CP content was higher in

Afzelia sp (16.05%) and lowest in *Ficus sp* (12.84%) which also had the lowest price (Table 5.3.7a).

For prices of common AIBPs, brewers' spent grain was the most expensive (GHS 0.38/kg DM) though this was not significantly different from the price of maize bran (GHS 0.37/kg DM). Price of rice bran (GHS 0.12/kg DM) was the least expensive (Table 5.3.7b). In terms of quality, CP content was highest in brewer's spent grain (22.84%) which was consistent with the price. Corn milling waste and maize bran had similar CP content although the price of maize bran was higher ($P<0.05$) and comparable to brewers' spent grain.

The prices of the legume crop residues was statistically different ($P<0.05$) with cowpea haulm being the most expensive. In terms of quality CP contents of legume crop residues were generally similar (Table 5.3.7c) but tended to be lower ($P>0.05$) in pigeon pea residues. As the season changed from early dry season to the main wet season, price decreased ($P<0.05$) whereas the CP content of legume crop residues remained stable.

Regression analysis of feed CP concentration and price [y = 0.322 + 0.011 (CP)] in all the seasons showed positive relationship but was weak (coefficient 0.011), not significant ($P>0.05$) and small R square value (R^2= 3.6%). The relationships of CP content and prices of feedstuffs (GHS) within each season were generally low and not significant ($P>0.05$) except main wet season (Table 5.3.8).

Table 5.3.8: Relationship between CP content and prices of feedstuffs

Season	Parameter	Coefficient	Standard error	P value	R^2
Early dry	Constant	0.575	0.162	0.001	-
	Crude protein	-0.009	0.013	0.830	0.002
Late dry	Constant	0.319	0.131	0.450	-
	Crude protein	0.008	0.011	0.450	0.021
Early wet	Constant	0.029	0.123	0.027	-
	Crude protein	0.012	0.010	0.206	0.057
Main wet	Constant	0.094	0.092	0.313	-
	Crude protein	0.026	0.007	0.001	0.317
Year-round	Constant	0.032	0.066	0.001	-
	Crude protein	0.011	0.005	0.039	0.036

5.3.5 Reasons for feed sales and purchases

Among the feed sellers, 40% sold feed to generate extra income for the households while over 50% of feed buyers purchased feed due to seasonal feed scarcity. Income generation and feed shortage were therefore the main drivers of feed trading activities. Other reasons for trading in feedstuffs have been presented in Figures 5.3.3a and 5.3.3b.

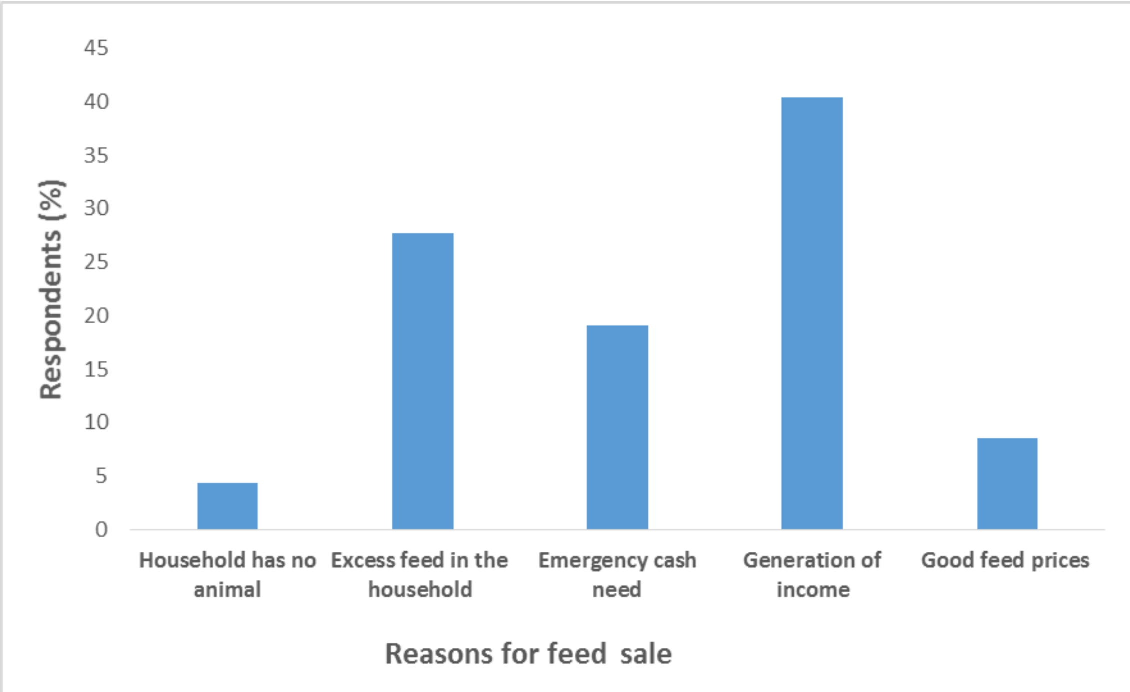


Figure 5.3.3a: Reasons for selling feedstuffs

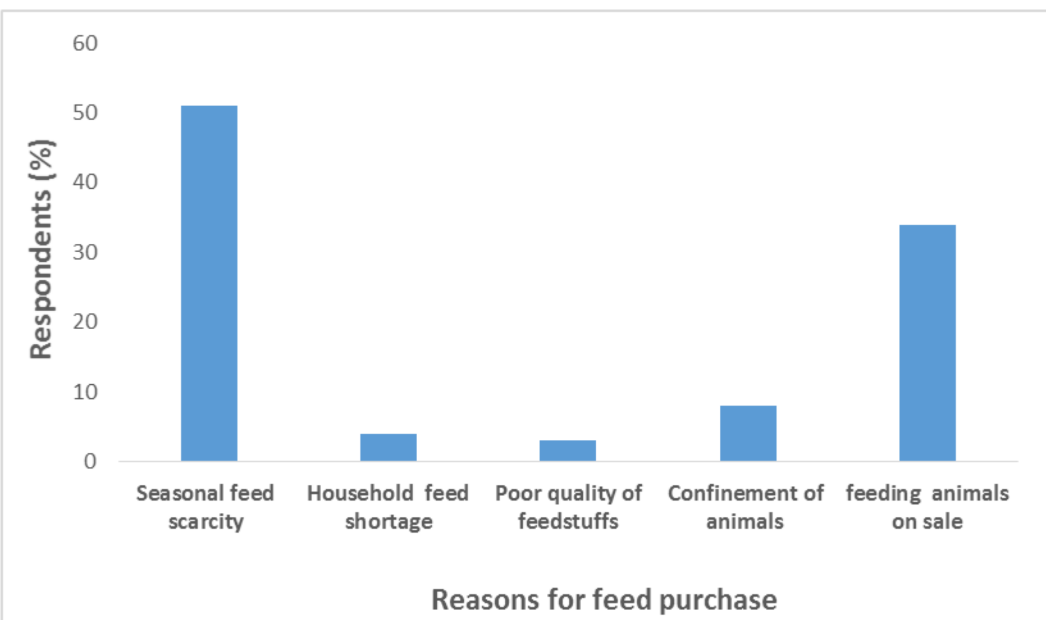


Figure 5.3.3b: Reasons for buying feedstuffs

About 90% of the respondents perceived that the emerging feed market had very good growth potential as opposed to 6% who thought the feed market did not have the potential to grow. Feed traders who reported high feed market growth potential were of the view that the major driving factor of the emerging feed market was growing feed demand due to increasing ruminant production and trading in livestock and livestock products (Figure 5.3.4).

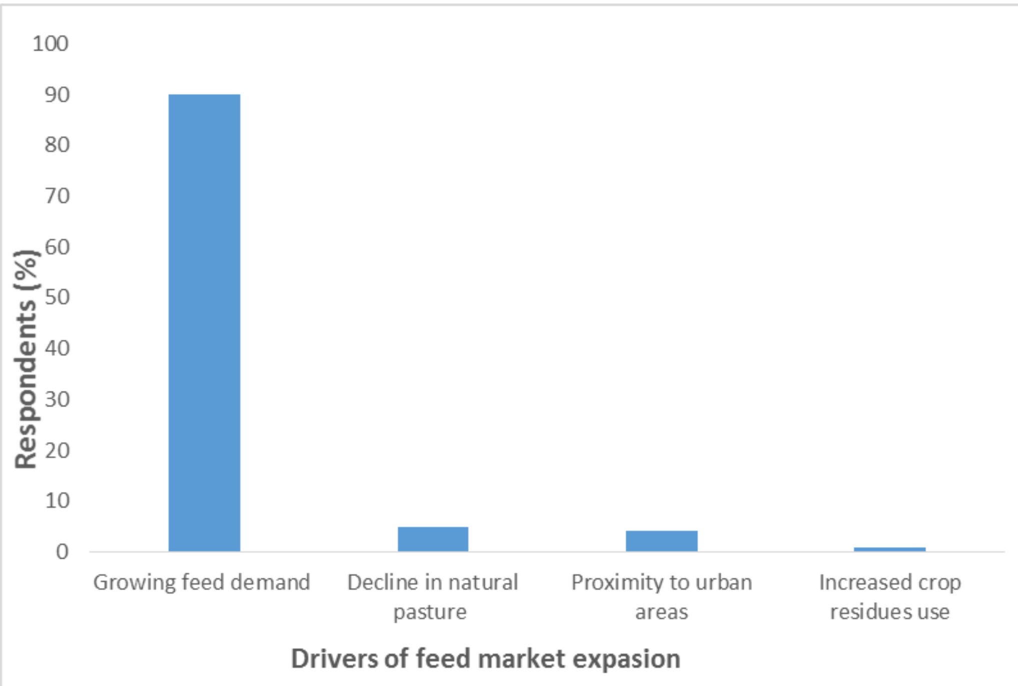


Figure 5.3.4: Drivers of feed market expansion

5.3.6 Uses of purchased feedstuff

Fifty percent (50%) of feed buyers used their purchased feedstuff to fatten animals for sale whereas others (35%) offered the feed to their animals to increase productivity of the flock. About 10% of feed buyers retailed their feed. A few respondents (5%) bought feed for feeding their selected animals. These included pregnant and lactating dams.

5.3.7 Constraints of the emerging markets for livestock feedstuffs

Table 5.3.9 shows six main constraints to the development of the emerging livestock feed markets that were identified in the study area. Lack of credit and inadequate storage facilities were ranked as the major constraints.

Table 5.3.9: Constraints of the emerging feed market

Feed market constraints	Respondents (%)			Total	n
	Tamale	Bolgatanga	Wa		
Lack of credit facilities for traders	7.38	8.54	6.37	22.29	154
Inadequate storage facilities	7.67	7.96	6.51	22.14	153
Lack of permanent market stalls	5.35	8.39	4.78	18.52	128
No efficient transport system	6.22	4.49	5.93	16.64	115
Bad road network	3.33	2.03	5.21	10.56	73
Lack of feed bailing technology	4.20	3.47	2.17	9.84	68
Total	34.15	34.88	30.97	100.00	691

There were multiple responses given by some individual respondents, n = Number of observations

5.4.1 Discussion

The high participation of economically productive age group (73%) in the trading of feedstuffs indicated that the business would have good growth potential. Also, the high trading of feedstuffs suggested that it could be a viable source of income generation. Similar observation of about 20% of total income of youth involved in feed trade was generated from the sale of feedstuffs (Datta, 2012). The search for alternative sources of income has been one of the motivating factors pulling people into this trade as confirmed in similar reports on browse plants sale by Huseini *et al*. (2011) in the Upper East Region of Northern Ghana. The participation of both males and females in the feed trade in this study further agrees with their findings. This suggests that the involvement of people in the trade of feedstuff did not show gender discrimination. However, the high proportion of males observed in this study was contrary to the report of Huseini *et al*. (2011) in which females dominated in the trade of browse plants. This difference was attributed to the categories of traders interviewed. In this study, both feed sellers and buyers were interviewed; whereas Huseini *et al*. (2011) interviewed only feed sellers.

The presence of men, women, elderly and the young in the feed trade as either sellers or buyers of feedstuffs suggested that social status had no effect on feed trade and did not create barriers against some category of people. Educational status, however, had an influence on the sale of feed as 60% of the sellers never had any form of formal education. The other category of people who were involved in the fodder trade was those who could not secure formal employment because they had no secondary education. Few people (8%), with secondary and tertiary education participated in the feed trade largely as feed buyers for their backyard small ruminant production.

The observation that most of the feedstuffs sold were crop residues and forage from natural pasture is in line with the report of Ayantunde *et al*. (2014) who observed that cowpea hay, groundnut haulm, cottonseed cake, bush hay and cereal bran were the major feedstuffs sold in Mali. The non-availability of cultivated fodder in the markets was an indication of an emerging feed market and that commercial forage production was not practiced in northern Ghana. In places where the feed market was developed, there were forage farmers who cultivated forage purposely for sale (Nyangaga *et al*., 2009). The lack of cultivated pasture also suggested high dependence of livestock farmers on natural pasture and crop residue for ruminant production. The trading of feedstuffs such as crop residues, AIBPs, annual forage species and perennial browse plants is an indication that farmers regard these feed resources as very important for ruminant production in the area. This was consistent with other findings reported in the feed trade (Huseini *et al*., 2011; Ayantunde *et al*., 2014). Singh *et al*. (2013) reported similar observation in their exploratory study of fodder markets in India. Crop residues were also found to be high among the feed types sold in Ethiopia (ILRI, 2009). The presence of AIBPs such as maize bran, corn milling waste and rice bran in feed market creates an opportunity for the formulation of good supplementary concentrate diet at lower cost since formulated feed for ruminants was not found in any of the 3 markets studied.

The observation that fodder trading activities were done throughout the year suggested that it was a promising venture and could be a source of livelihood for the people involved in the trade. This contributed in addressing some of the unemployment problems in the area. The finding that fodder trading peaks in early and late dry seasons indicated the existence of feed shortage in these seasons (Annor *et al*., 2007; Smith, 2010). Low feed trading activity in the wet season implied that some of the feed buyers such as peri-urban livestock farmers were able to get feed from the natural pasture for their animals during that period; thus did not buy feedstuffs. This reduced feed demand and consequently, feed trading activities declined. This observation is associated with the undeveloped nature of the feed market in Ghana relative to huge volumes of feed sold throughout the year in other developed feed markets (Nyangaga *et al*., 2009). However, the increasing livestock population and trading activities is a strong base for the growth of the feed markets as reported by 90% of the traders interviewed. Also, over 50% of the traders perceived that the quality of feed sold was good and could sustain the development of feed markets.

The similarity in nutritive quality of crop residues and AIBPs with change in seasons was an indication that the storage system did not affect the quality of these feedstuffs in all seasons. International Trypanotolerance Centre (ITC, 2014) reported similar findings in Gambia. The stability in CP content of leguminous crop residues could be associated with early collection and good storage practices by the feed sellers. This agrees with the report of Antwi *et al*. (2010) on crop residues storage practice by farmers.

The high price of cowpea haulm relative to other feedstuffs could be attributable to the perception of farmers that it was high in quality and very good for ruminants (Ayantunde *et al*. 2014) but the chemical analysis showed that the quality of cowpea haulm in terms of CP content was similar to other leguminous crop residues. It was also partly due to pricing of the feed based on units of measure (bowls, bundle or bags) but not by weight. This made bulky feedstuffs like cowpea haulm to attract higher price compared to other crop residues. The other reason was that cowpea haulm had highest demand, and attracted highest price. It is therefore worth stating that, expensive feedstuffs are not necessarily the most nutritious feedstuffs. This was evidenced by the weak regression estimate (coefficient = 0.011) between feed CP concentration and price in all the seasons. The poor relationship (R^2 = 3.6%) was an indication of low CP contribution to price variation of feedstuffs. On the other hand, it was clear from the low quality and price of rice bran that in situations where farmers could easily determine the quality of feed, they match the price with quality. In this study, the lowest price of rice bran was due to the poor quality (using physical appraisal and previous knowledge of farmers on the intake of sole feed by animals) which did not need any technical knowledge to determine. The relationship of price of feed with quality therefore depended on good knowledge of feed quality by buyers. If buyers are fully aware of high quality feed they will pay a higher price for it. Mesfin *et al*. (2014) reported similar observation in Ethiopia. Thus the nutritional evaluation of feedstuffs is very important for making recommendation of the best feedstuff to buyers.

The prices of groundnut and cowpea haulms (0.62 and 1.00 GH₵/kg DM respectively) in this study were lower than the prices reported by Ayantunde *et al*. (2014) in similar studies in Mali. The difference in feed prices could be attributed to the availability of alternative feed resources that are not sold in Ghana. The availability of natural pasture and fewer animals fattening enterprises in Ghana have led to low demand for feed and consequently lower feed prices compared to Mali.

The relatively high prices of feed in the Upper East Region (Bolgatanga market) may be attributable to higher livestock population per unit area and less natural pasture for grazing due to pressure on land for other uses in the region compared to Northern and Upper West Regions where there are fewer animal numbers per unit area and more natural vegetation for grazing. Other workers reported similar findings in Northern Ghana (Huseini *et al*., 2011; Amankwah *et al*., 2012).

The higher prices of feed in early and late dry seasons emanated from increased animal fattening enterprises by farmers and livestock traders during these seasons as observed by Amankwah *et al*. (2012). Some farmers fatten their animals meant for sale for 2 or 3 weeks before selling them towards the end of the calendar year in early dry season. In late dry season to early wet season, there is a high feed demand from peri - urban livestock farmers due to low feed supply from natural pasture. This situation is often caused by bush fires (Annor *et al*., 2007).

The highest (42%) ranking of income generation as the major reason for people engaging in the sale of feedstuff suggested that the feedstuff trading could create good source of employment opportunity when developed by policy makers. The over 50% farmers who purchased feedstuff due to seasonal feed scarcity is in consonance with the observation in Ethiopia that most farmers buy feedstuff for animals in the lean season (ILRI, 2010). Other reasons (Figure 5.3.5a and 5.3.5b) that were provided for the sale and purchase of feedstuff by the traders suggested that the trading of feedstuffs was one of the poverty coping strategies among low income households in the study area.

The market constraints identified by the respondents such as lack of bailing technology, inadequate storage facilities and lack of permanent market stalls were also reported by Singh *et* *al*. (2013) who did a similar feed market study in India. These constraints impede feed trading activities and need the attention of policy makers to address them.

5.5.1 Conclusion and recommendation

Trading in feedstuffs was found to be a year-long activity but mainly in early and late dry season. Crop residues were the dominant feedstuffs sold. Prices of feedstuffs differed at different market locations and between seasons. Prices were higher at Bolgatanaga market and in early to late dry season. The quality of AIBPs and leguminous crop residues was not affected by season. Crude protein concentration of feedstuffs sold was found to have less effect on price variation. Major constraints of the feed markets were lack of permanent market stalls, inadequate storage facilities and credit. The emerging feed market however, has very high growth potential due to increasing urban livestock production and trading activities.

The creation of permanent market stalls and provision of storage facilities by local authorities could create more opportunities for the development of the feed market. This could increase the income generation capacity of people involved in feed trading and consequently increased urban and peri-urban feed availability for ruminant production.

CHAPTER 6

6.0 EXPERIMENT I: EFFECT OF SEASON ON AVAILABILITY AND QUALITY OF PASTURE IN COMMUNAL GRAZING LAND

6.1.0 Introduction

The trade in feedstuffs throughout the year in northern Ghana suggested that there were constraints in forage availability in the pasture. The extent of herbage variations in different seasons observed in Survey I as reported by farmers which became acute from February to April annually was not quantified. This experiment was conducted to estimate quantitatively the pasture availability and quality variations across seasons in one year.

Increasing livestock population has triggered high feed demand among farmers especially in urban and peri-urban areas (Guendel, 2002; Graefe *et al*., 2008). The increase in feed demand coupled with decline in pasture availability leads to feed shortage especially in the dry season (Smith, 2010). The shortage of biomass from natural pasture affects animal productivity as most farmers depend on it. Therefore, the use of crop residues in crop-livestock systems has been increasing as a backup to natural pasture (Samdup *et al*., 2010).

Also, MoFA (2006) estimated that about 15% of the total land area is covered by natural pasture and largely located in Savanna areas. According to FAO (2006) the annual total DM yields of the pasture was 1.97 and 2.17 tonnes/ha in Coastal and Guinea Savanna ecological zones respectively. About 80% of the forage yields are achieved within the growing season. Variability of herbage yield in different locations in the same ecological zone has been reported by others (Fleischer *et al*., 1996; Timpong-Jones *et al*., 2013). For instance, the herbage yield of South-

Eastern to Western coastal Savanna rangeland of Ghana ranged from 0.58 to 7.21 tonnes/ha with a mean herbage yield of 3.15 tonnes/ha during the peak vegetation cover (Timpong-Jones *et al*., 2013). This variability in herbage yield in the same ecological zone in which higher values were observed in the South-Western and lower values in the South-Eastern parts indicates that there is no uniformity in herbage yield. Fleischer *et al*. (1996) reported herbage yield on the clayey and sandy soils of the coastal plains as 4.67 and 5.03 tonnes/ha respectively. Other changes in forage availability and quality in rangelands in Ghana have also been reported by other researches and attributed to seasonal changes (FAO, 2006; Annor *et al*., 2007). However, quantitative data on the rate of herbage yield changes across seasons are inadequate especially in the Savanna zone of northern Ghana. Therefore estimating forage yield and quality in grazing areas during the distinct seasons in the year and crop residue yield will provide information on potential feed available for ruminant production. This information will be beneficial to smallholder farmers in northern Ghana.

6.1.1 Objectives

- To estimate quantity and quality of pasture in all the seasons in the communal grazing land.
- To estimate crop residue yield in cultivated fields as potential feed resources for ruminant production.

6.2.0 Materials and methods

6.2.1 Study area

The study was conducted in the 3 political administrative regions of Northern Ghana as mentioned (Section 3.1.1). The data were collected in 3 communities in each region. The specific communities were Tibali, Bontingli and Duko in Northern Region, Gia, Nyangua and Sambolgo in Upper East, Zanko, Guo and Passe in the Upper West Region.

6.2.2 Experimental design and data collection

This experiment was conducted in a randomized complete block design (RCBD). The 3 regions were blocked, 3 communities in each region were replicates and 4 seasons as treatments. The data collected included quantity of forage yield/ha in all the 4 seasons (early dry, late dry, early wet and main wet seasons) for one year in the communal pastures of the study communities. Estimation of crop residue yield/ha at crop maturity was also done. Specifically, the crop residues yield data were collected in October-November, 2014. The forage yield estimation data was collected in December, 2014 in the early dry season, and then in 2015 March (during late dry season), June (early wet season) and September (main wet season). This was done in different $1m^2$ plots per season but in the same communal pasture fields. The quadrat yields estimation method was used to estimate forage yield (Nitis, 1997). A $1m^2$ wooden quadrat was used for the data collection. Samples of forage available in the communal pasture were taken from 8 quadrats thrown randomly in each communal pasture during each season. The forage in each quadrat was harvested to the grazing level of sheep and goats (10 and 60 cm, above ground level in dry and wet seasons respectively). Samples were taken from each quadrat within 3 km radius at different locations in each communal pasture within the distance covered by small ruminants during grazing.

The most commonly grazed forage species in the pasture of each community were identified by closely following grazing sheep. These were sampled, pooled and sub-sampled for laboratory analysis to determine the composite chemical composition in all the seasons. Also, some commonly grazed forage species were identified in the wet season with the help of specialist at Horticulture Department of University for Development Studies. , their pure samples were taken and chemical composition determined. The crop residue yields of crops commonly cultivated in the area whose residues are often fed to ruminants (maize, sorghum, rice, groundnut, cowpea and soybean) were estimated at harvest. Three samples of each crop residue in each community were taken randomly at crop maturity in $1m^2$ quadrat. The crop residues in each quadrat were collected to ground level leaving the roots. Pure samples of each crop residue in each square meter of the quadrat were sampled, pooled, sub-sampled and analyzed for their chemical composition. The dry weight of biomass harvested was taken and yield/ha determined using the equation given below according to t'Mannetje (1978).

$$Y = R \times 10{,}000$$

Where Y is dry biomass yield per hectare and R is dry biomass yield per quadrat.

6.2.3 Laboratory and data analysis

All samples collected were oven-dried and milled to pass through 2 mm sieve and analyzed for DM, Ash, N, CP, IVOMD, NDF, ADF and ADL at ILRI Nutrition Laboratory in Addis Ababa, Ethiopia. The laboratory analysis for DM and ash were done using AOAC (1990) approved methods. Nitrogen content was determined by the Kjedahl method and CP calculated as N x 6.25. Goering and Van-Soest (1970) procedure was used to determine the fibre fractions (NDF, ADF and ADL) of the samples. The IVOMD of samples were calculated using CP and ash content of sample on DM basis and 24 h net gas production according to Menke and Steingass (1988) equation (Section 3.3.8).

6.2.3 Statistical analysis

The data on seasonal forage yield including crop residues kg DM/ha and chemical composition such as DM, N, CP, NDF, ADF, ADL and IVOMD were analyzed with GenStat Eleventh Edition (VSN International, 2008) using general ANOVA analytical procedure. Treatment means were separated by Least Significant Differences at 0.05 level.

6.3.0 Results

6.3.1 Pasture availability in the communal grazing land

The forage yield in communal pastures differed ($P<0.05$) in all the seasons (Figure 6.3.1). Early dry season had the highest forage yield of 3.08 tonnes DM/ha and early wet season had the lowest yield (0.56 tonnes DM/ha). Change in season significantly affected the amount of forage available for ruminants in the communal grazing land in the study area.

Quantity of forage available in the 3 regions of northern Ghana during each season were significantly different ($P<0.05$). Lower values were observed in Upper East Region (Figure 6.3.2) compared to Northern and Upper West Regions. The variations in the forage yield were not the same with changing seasons throughout the year. The differences were more prominent in early dry season and early wet season than the late dry and main wet seasons.

Commonly grazed forage species identified (Appendix IV) in the communal pasture were the same and were found in all the study sites (Table 6.3.1). Few improved species (*Andropogon gayanus, Chrysopogon zizanioides* and *Stylosanthes hamata)* were however found in some communal pastures in the study area.

Change in seasons affected chemical composition of commonly grazed forage species. The CP content of commonly grazed species differed ($P<0.05$) among seasons. The values obtained were 75, 45, 174 and 165 g/kg DM for early dry, late dry, early wet and main wet seasons respectively. The details of other chemical components of these forage species are presented in Table 6.3.2. The chemical composition of the pure identified forage species at their vegetative stage of growth during the wet season (early wet and main wet season) are presented in Table 6.3.3. Among the grass, CP content differed ($P<0.05$) and was highest in *Rotteboellia* *cochinchinensis* and lowest in *Andropogon gayanus*. Also, IVOMD of the grass was highest (P<0.05) in *Dactyloctenium aegyptium* and lowest in *Andropogon gayanus*. The forbs did not show significant differences (P>0.05) in all the chemical components determined.

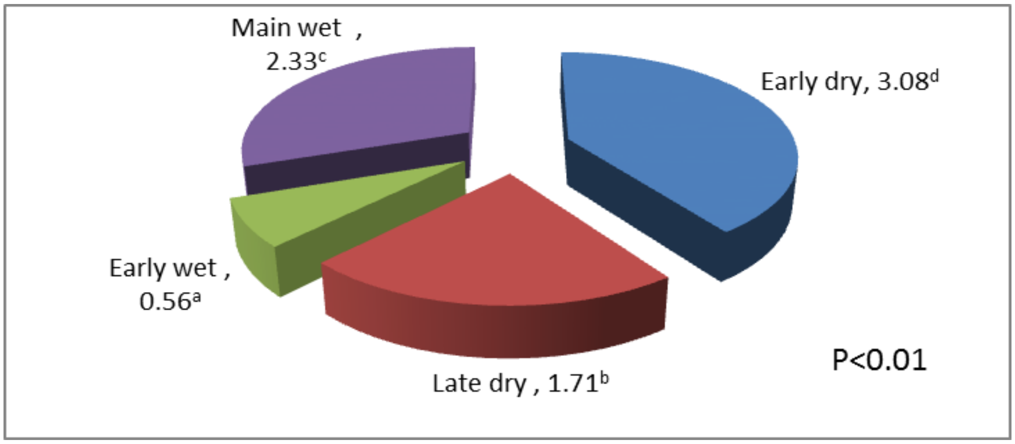


Figure 6.3.1: Effect of season on forage yield in natural pasture (tonnes DM/ha)

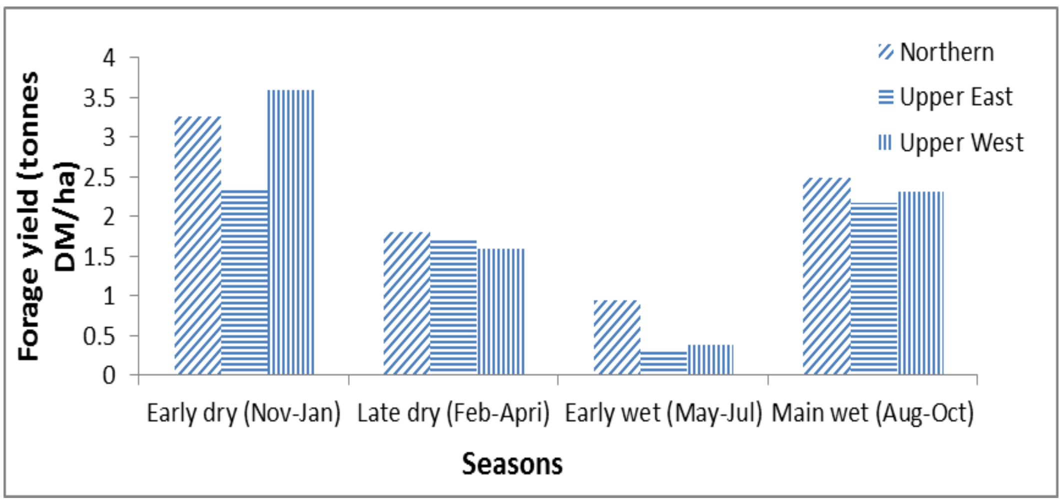


Figure 6.3.2: Effect of season and location on the yield of pasture

Table 6.3.1: Presence of commonly grazed forage species in the communal pasture

Common name	Scientific name	Forage species occurrences		
		Northern	Upper East	Upper West
Africa fountain grass	*Pennisetum pedicellatum*	✓	✓	✓
Gamba grass	*Andropogon gayanus*[2]	✓	-	✓
Tropical crabgrass	*Digitaria ciliaris*[1]	✓	✓	✓
Jamaican crabgrass	*Digitaria horizontalis*[1]	✓	✓	✓
Egyptian finger grass	*Dactyloctenium aegyptium* [1]	✓	✓	✓
Itch grass	*Rotteboellia cochinchinensis*	✓	✓	✓
Vertiva grass	*Chrysopogon zizanioides*[2]	✓	✓	-
Carpet grass	*Axonopus compresus*	✓	✓	✓
Verano stylo	*Stylosanthes hamata*[3]	✓	✓	-
Punamava	*Boerhavia difusa/ercta*[1]	✓	✓	✓
Sida	*Sida acuta*	✓	✓	✓
Goat head/hispid starbur	*Acanthospermum hispidum*	✓	✓	✓
Feather lovegrass	*Eragrostis tennella*	✓	✓	✓
Crowfoot grass	*Eleusine indica*	✓	✓	✓
Amaranthus	*Amaranthus spinosus*	✓	✓	✓

✓ Present, - Not found, [1]Species occurred in early wet season, [2]Species were found only in two regions, [3]improved forage species,

Table 6.3.2: Effect of season on chemical composition (g/kg DM) of natural pasture

Season (n=3)	**DM**	**Ash**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**
Early dry season	911.76	117.92	75.13[a]	530.76[ab]	471.83[b]	142.6[b]	399.62[a]
Late dry season	911.80	121.32	44.83[a]	443.72[a]	498.10[b]	164.39[b]	388.17[a]
Early wet season	918.97	138.29	173.98[b]	669.54[c]	368.64[a]	71.29[a]	606.72[b]
Main wet season	920.99	134.02	165.37[b]	659.86 [b]	376.01[a]	87.72[a]	543.72[b]
SED	4.788	48.777	19.255	54.825	35.563	12.996	35.82
P values	0.213	0.154	0.001	0.017	0.023	0.001	0.002

Means with different superscripts in the columns are significantly different at P<0.05. DM = dry matter, CP = Crude protein, NDF = Neutral detergent Fibre, ADF = Acid detergent fibre, ADL= Acid detergent lignin, IVOMD = In vitro organic matter digestibility, SED = Standard error of differences of means

Dactyloctenium aegyptium had the highest value (641 g/kg DM) of IVOMD and *Andropogon gayanus* had the lowest (258g/kg DM). The CP content of legumes (130 g/kg DM) was significantly higher (P<0.05) than that of grass CP (83 g/kg DM). The concentration of other chemical parameters between legumes and grass forage species differed (Table 6.3.3). Dry matter content was, however, similar.

Table 6.3.3. Chemical composition (g/kg DM) of some forage species during the wet season

Forage species	DM	Ash	CP	NDF	ADF	ADL	IVOMD
Grass							
Andropogon gayanus	915.5	708.3	53.1[a]	798.92	492.48	78.19	224.41[a]
Axonopus compresus	908.8	106.9	78.6[ab]	626.81	389.29	73.86	338.00[ab]
Dactyloctenium aegyptium	904.8	99.0	94.8[bc]	586.67	351.73	73.45	607.69[d]
Digitaria ciliaris	919.4	148.4	60.6[a]	702.16	454.00	70.80	432.10[bcd]
Digitaria horizontalis	920.4	105.5	94.2[bc]	742.90	459.73	82.92	530.22[cd]
Eleusine Indica	915.9	114.1	89.9[bc]	722.58	448.49	70.57	474.41[bcd]
Pennisetum pedicellatum	920.5	121.7	52.3[a]	764.95	502.06	76.81	406.79[bc]
Rotteboellia cochinchinensis	924.1	74.2	109.3[c]	678.33	405.55	95.62	442.42[bcd]
SED	6.12	24.34	12.453	682.43	59.511	10.347	85.678
P values	0.09	0.10	0.001	0.098	0.228	0.319	0.014
Legumes/forbs							
Acanthospermum hispidum	916.54	153.75	109.94	499.86	403.32	108.71	512.99
Amaranthus spinosus	923.22	203.22	121.02	515.84	364.53	98.00	428.80
Boerhavia difusa	909.46	139.81	181.39	408.75	335.85	96.69	632.15
Sida acuta	914.22	106.89	107.85	644.65	423.29	7043	549.09
SED	8.500	60.214	49.460	112.745	91.031	23.758	11.147
P values	0.479	0.490	0.447	0.291	0.778	0.466	0.386
Forage class							
Grass	916.2	105.0	82.6	702.9	437.8	77.8	432.1
Legumes	915.9	150.7	130.1	517.4	381.7	93.5	530.8
SED	3.10	17.71	16.37	37.90	31.67	7.13	41.99
P values	0.92	0.02	0.01	0.01	0.09	0.04	0.03

Means with different superscripts in the columns are significantly different at $P<0.05$ within the grass or forage species. n= 3 for each forage species, DM = dry matter, CP = Crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, ADL= Acid detergent lignin, IVOMD = In vitro organic matter digestibility, SED = Standard error of differences of means

6.3.2 Residues yield and quality of commonly cultivated food crops

Commonly cultivated crops in the area whose residues are mostly used in feeding ruminants include cowpea, groundnut, soybean, maize, and sorghum. The residue yield (DM/ha) of these crops is presented in Figure 6.3.3. The highest ($P<0.05$) residue yield of 8.5 tonnes DM/ha was observed in sorghum whereas cowpea had the lowest residue yield of 1.8 tonnes DM/ha.

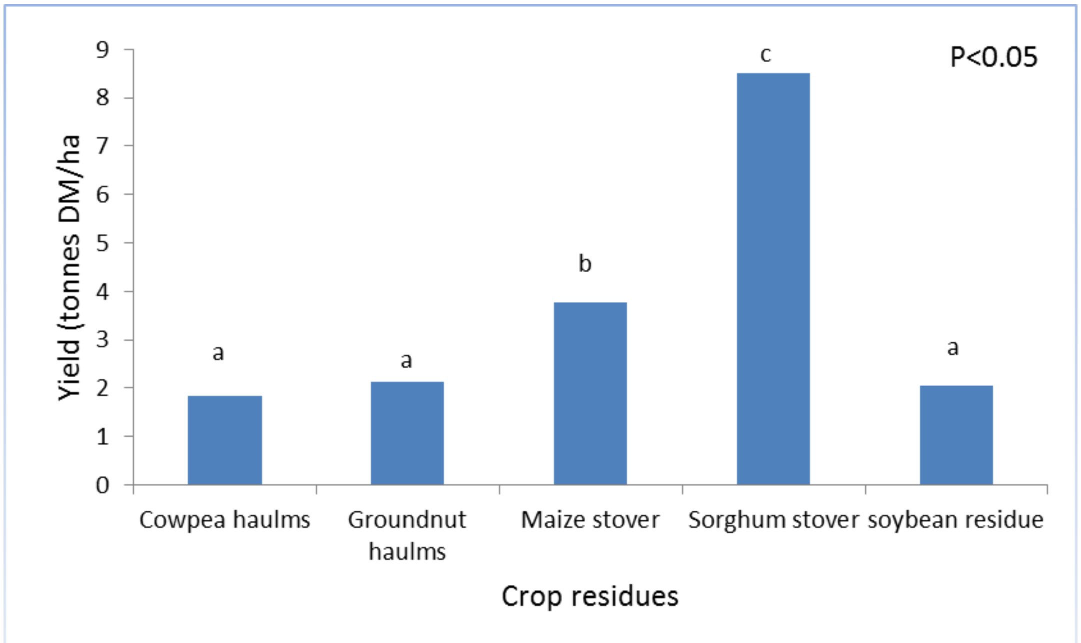


Figure 6.3.3: Residue yield of commonly cultivated food crops

The chemical compositions of the legume crop residues were not significantly different ($P>0.05$) in most of the chemical parameters (Table 6.3.4). The CP content was however, highest ($P<0.05$) in groundnut haulms compared to the CP content for cowpea haulms and soybean residues. The nutritional composition of the cereal crop residues was similar in all chemical parameters determined.

Table 6.3.4: Chemical composition (g/kg DM) of crop residues during harvest

Crop residues (n=3)	**DM**	**Ash**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**
Legumes							
Cowpea haulms	908.8	71.6	91.4[a]	568.7	716.8	101.2	525.9
Groundnut haulms	907.9	96.1	114.1[b]	526.9	655.2	97.9	549.1
Soybean residues	908.4	94.4	94.8[a]	600.9	712.4	114.3	506.7
SED	3.92	14.93	6.96	28.63	39.87	8.06	26.60
P Values	0.98	1.21	0.01	0.05	0.25	0.12	0.30
Cereals							
Maize stover	915.5	71.8	52.4	547.3	837.7	60.7	655.7
Sorghum stover	916.0	65.8	38.9	526.6	800.1	55.9	685.5
SED	6.85	6.99	7.95	19.99	23.88	7.04	28.46
P Values	0.94	0.41	0.11	0.32	0.14	0.50	0.31

Means with different superscripts down the column are significantly different at P<0.05 within legumes or cereal residues. DM = dry matter, CP = Crude protein, NDF = Neutral detergent Fibre, ADF = Acid detergent fibre, ADL= Acid detergent lignin, IVOMD = In vitro organic matter digestibility, SED = Standard error of differences of means

6.4.1 Discussion

The forage yield was observed highest in the early dry season and lowest during early wet season following the forage growth pattern. Most forage species attain their highest vegetative growth and maturity at the end of wet season in October. These forage species contained their highest foliage in early dry season with low moisture levels. This accounted for the highest forage yield observed during early dry season. The lowest forage yield in the late dry season could be attributable to depletion due to grazing, bush burning and other human uses of the dry fodder in the communal pasture. Similar observations have been made by other workers in the area (FAO 2006; Annor *et al*., 2007; MoFA, 2011). The values obtained were however lower than the reported herbage yield of 4.7 - 5.0 tonnes DM/ha in the coastal Savanna zone of Ghana (Fleischer *et al*., 1996) but fell within herbage yield range of 0.6 - 7.2 tonnes DM/ha in the South-Eastern to South-Western coastal Savanna (Timpong-Jones *et al*., 2013). The lower values reported in this study could be attributable to the differences in the ecological zones and soil types as these factors affect forage yield significantly (Duku *et al*., 2010). The coastal Savanna has shorter duration of dry season that influences higher forage yield (MoFA, 2011) than in the Guinea Savanna zone. The values were however, similar to the annual forage yield of 1.97 tonnes DM/ha reported by FAO (2006) in the Guinea Savanna ecological zone of Ghana.

The declining quality of forage in the pasture from early wet season to late dry season as indicated by the chemical composition of commonly grazed forage species was a result of forage maturity and lignin accumulation. This was also reported by FAO (2006) in a similar study. The significant variability in nutritive quality of forage in the pasture among the seasons is a common phenomenon in the area. This is triggered by humidity and temperature variation among the seasons. Antwi *et al*. (2010) reported that high variation in ambient temperature and moisture levels affected the quality of standing hay in the dry season. The CP content (50-80 g/kg DM and 160-170 g/kg DM for dry and wet seasons respectively) of commonly grazed forage species in the pasture in this study was higher than the 20-40 g/kg DM and 80-120 g/kg DM for dry and wet seasons respectively reported by FAO (2006) in Ghana. The differences could be attributed to sampling techniques and location of sample collection (Singh *et al*., 2011).

The seasonal variations in availability of forage in the pasture have implications for the accessibility of feed to ruminants. The comparatively high available forage in the pasture during the main wet and early dry seasons suggests favourable conditions for higher productive performance of ruminants during these seasons. This agrees with the report of other studies (Smith, 2010; Karbo and Agyare, 2002). Compel *et al*. (2003) emphasized that deficiency of feed in terms of quantity and quality negatively affects the productive and reproductive performance of grazing livestock. The lower quantity and quality of forage in the pasture during the late dry season implies grazing animals will need supplementary feeding to maintain their potential production performance.

The forage species identified in the communities in northern Ghana were similar to the report of Adjololo *et al*. (2014) in their study of forage species, herbage yield and nutrient quality under orange plantation in Sourthern Ghana. The slightly higher nutritional content of commonly grazed forage species identified in the area compared to the values reported in Niger (Tunde and

Ayantunde, 2016) may be attributed to the differences in ecological zones and sampling techniques.

The highest sorghum residue yield compared to all other crops was due to the high vegetative growth attributes of the sorghum plant compared to the other plants in this study. This is in consonance with the findings of Ayamga *et al*. (2015) in their study of total annual crop residues production in the Lawra-Nandom district of Upper West Region. Ayamga *et al*. (2015) found that the sorghum crop generates the largest quantity of residues among cereals in the district, and contributes up to 59% of the total annual crop residues produced in that area. Kombiok *et al*. (2005) also reported that the sorghum crop has highest vegetative growth level among the cereal crops in northern Ghana. Unfortunately, sorghum stover is less used in feeding animals due to other competing domestic uses such as fuel and usage in the weaving industry (Karbo and Agyare, 2002). The intake of sorghum stover by ruminants is also reported to be low due to high lignin content (Singh *et al*., 2011). The crop residues yield obtained in this study was higher than the reported values (13, 6, 2.3, and 5 tonnes DM/ha for maize, groundnut, soybeans and cowpea respectively) by Singh *et al*. (2011) in a review of grain and residue yield of crops in the arid ecological zone of West Africa in crop-livestock integration system productivity. The values however, fell below the range of 10-16, 11-17, 3-6 and 1-5 tonnes DM/ha for maize, sorghum, groundnut and soybean residue yield respectively as reported by Reddy *et al*. (2003). The differences could be attributable to varietal, rain fall patterns, inputs used, agronomic practices and soil fertility (Reddy *et al*., 2003; Kombiok *et al*., 2005).

The similarity of the chemical composition of legume crop residues may be due to the similarity of soil types and rainfall pattern of the area. Onwuka *et al*. (1997) reported similar findings in Nigeria. The CP values (90 and 110 g/kg DM for cowpea and groundnut haulms respectively) obtained in this study were lower than the 180 g/kg DM CP content for both residues reported by Onwuka *et al*. (1997) but close to 100, 120, and 30 g/kg DM CP content for cowpea, groundnut and maize residues respectively, reported by Opoku (2011) in the same Savanna ecological zone of northern Ghana. The slight differences could be due to varietal differences, soil and agronomic practices (Reddy *et al*., 2003). Tunde and Ayantunde (2016) reported lower ADF content of 390 to 490 g/kg DM and higher IVOMD of 600 to 610 g/kg DM for cowpea and groundnut haulms in the arid ecological zone of Niger compared to the current observations. The difference in the fiber content and digestibility may be attributed to the difference in the time of residues collection after harvest. Early collected residue has low lignin and fibre content and high digestibility compared to late collection (Singh *et al*., 2011).

6.5.1 Conclusion and recommendation

The study found that forage availability in communal pasture varied in all the 4 seasons. The yield was highest during early dry season and lowest in the early wet season. More cereal crop residues were generated than the residue of legumes in the smallholder farming system. Sorghum residue was found to be highest among the cereals, whereas groundnut residue dominated the legumes. The nutritive quality of forage in the pasture was highest during early wet season and lowest during late dry season. Therefore it is recommended that supplementation of herded or free grazing ruminants is necessary during the late dry season for sustainable productivity.

CHAPTER 7

7.0 EXPERIMENT II: EFFECT OF CONCENTRATE FEED SUPPLEMENTATION PLUS HEALTHCARE AND SEASON ON INTAKE AND VOIDING OF DRY MATTER AND NITROGEN AND GROWTH PERFORMANCE OF SHEEP IN SMALLHOLDER PRODUCTION SYSTEM

7.1.0 Introduction

Variability of herbage availability and quality in the pasture as observed in experiment I makes it very important for supplementation of animals but good supplementation practices are vital to reduce cost and maximize productivity. Experiment II was conducted to determine the effect of concentrate feed supplementation and season on the growth performance of sheep under stallholder production system as a way of increasing productivity to meet demand.

In developing countries, population growth combined with increasing literacy rate and increase earning power have led to increased demand for livestock products (Agyemang, 2012). According to Thornton (2010), this demand is expected to double in SSA and Asia. Livestock productivity is however, constrained by many factors such as climate variability, urbanization and competing land use that limit the availability of range land and feed resources for grazing animals. In this region, over 70% of the animal products are produced by smallholder farmers (FAO, 2014). These farmers however, depend highly on natural pasture and crop residues as sources of feedstuffs. Productivity of ruminants in this smallholder farming systems is often constrained by inadequate feed availability and diseases and pests (Agyei et al. 2004; Addah and Yakubu 2008) and limit the genetic productive ability of animals (Osei, 2012). Feed limitation is a major constraint both in the dry and wet season as accessibility to green forage becomes a challenge in some communities due to compound farming (Awuma, 2012).

Another factor limiting productivity is decreasing quality of natural pasture with changing seasons. For instance it has been reported that protein content of natural pasture is often high in wet season (80-120 g/kg DM) and becomes extremely low in the dry season (20 to 40 g/kg DM) (FAO, 2006). In areas where the supply of pasture is adequate in the dry season, it is often deficient in protein, vitamins and minerals. One way of dealing with these constraints may be increasing efficiency of nutrient use in crop-livestock production system. Conservation and judicious use of these feed resources in the production systems are best practices that could contribute substantially to efficient nutrient utilization for sustainable productivity. Knowledge on nutritional quality of available feed resources throughout the year is needed for efficient nutrient utilization. This could help farmers meet the nutritional requirements of animals for improved productivity as well as reduce feed wastage (Diogo *et al*., 2010).

Also, efficient utilization of dietary nutrients could dependent on the interaction between the nutritional quality of the feed and the health of the animal. Interruption of normal physiological functions due to disease or pest infestation may reduce the efficiency of utilization of dietary nutrients (Campbell *et al*., 2003). Unlike nutrition, economic impact of diseases and pests on animal production is particularly difficult to quantify due to the complexities of their effects on productivity (Thornton, 2010).

Nutrient use efficiency is best promoted through intensification and integration of the production systems. This increases the potential of nutrient use and minimizes feed waste (Diogo *et al*., 2010). To sustain intensification, it is necessary to harness the complementary benefits inherent in crop-livestock systems. The core issue in crop-livestock integration is thus nutrient use efficiency that directly affects production cost and profitability. Specific pathways that could intensify ruminant production include increased biomass production and conservation as feed for livestock, improving feed digestibility through optimum supplementation of animals with good quality concentrate feed and crop residues and provision of health care (Diogo *et al*., 2010; Thornton, 2010; Agyemang, 2012). Estimation of collectable animal manure (faecal droppings) for improving infertile soils for sustainable yield of crops in the smallholder production system is critical.

In feed resource use efficiency, nutrient inflow, retention and faecal nutrient concentration are influenced by many factors. The nutrient content of feed greatly influences nutrient inflow, retention and faecal nutrient content (Powell *et al*., 1996). Nitrogen is one of the major nutrients that impact greatly on productivity of crop-livestock systems. The intake of N in ruminants from natural pasture is influenced by seasonality due to changes in forage composition and diversity (Powell *et al*., 1996). Schlecht *et al*. (1995) reported 2.9% increase in daily N intake from 1.3% during late dry season to 4.2% in early wet season of total DM intake of cattle in Mali. Intake of N in sheep and goats from natural pasture was reported to be higher than cattle (Powell *et al*., 1996). Also, intake of N and excretion are highly controlled by feeding regime and increases with legume forage and cereal based concentrate supplementation (Powell *et al*., 1996). Ayantunde *et al*. (2008) observed an increase of 170% N intake, 24% faecal N content and 260% urinary N in sheep supplemented with 600 g DM/d of groundnut haulms and 400 g DM/d of millet bran. The significant increase in urinary N suggest higher N digestibility and metabolism.

Furthermore, faecal N content of sheep has been reported to increase when fed browses than other crop residues (Somda *et al*., 1993). Lignin, tannins and related phenolic compounds content of feed significantly affect N absorption and shifts urinary N excretion to faecal N associated with undigested feed in the faeces (Reed *et al*., 1990). Somda *et al*. (1993) observed that the shift of urinary N to faecal and from faecal soluble to insoluble N makes the N more available for recycling in the crop-livestock system when the faecal matter is used to replenish soil fertility. This manure application is a common practice among smallholder farmers in West Africa. There is however inadequate information on nutrient use by sheep in smallholder production systems in Ghana.

7.1.1 Objective

To determine the effect of concentrate feed supplementation plus healthcare and season on intake and voiding of DM and N and growth performance of sheep in a smallholder production system

7.2.0 Materials and methods

7.2.1 Study area

This study was conducted in the 3 political administrative regions of northern Ghana which consists of Northern Region, Upper East and Upper West Regions (Section 3.1.1). The specific communities were; Tingoli and Tibali in the Northern Region, Bonia and Gia in Upper East Region, and Guo and Natorduori in the Upper West region.

7.2.2 Experimental design and management of animals

The study was conducted as a randomized complete block design with region as a block. Thirty six (36) smallholder sheep farmers with an average flock size of 18.6 ± 8.7 in each farm were involved in the study. Feed supplementation, grazing, faecal voiding (Appendix V) and growth performance of 819 animals were investigated from the pens/flock of the 36 smallholder farmers. The mean initial weight of the sheep was 15 ± 6.3. The study was conducted in 4 seasons. These seasons were; early dry season, late dry season, early wet season, and main wet season.

Animals in each pen were randomly assigned to one of 2 feeding regimes. In the first regime, sheep were grazed daily on a natural pasture from 09:00 to 17:50 h and offered crop residues and/or AIBPs (75 g DM/d) upon return from grazing (control), in the second regime, sheep were treated similarly as in the first regime but were also offered supplementary concentrate feed (Table 7.2.1) plus healthcare (CH). The concentrate feed was offered at 180 g DM/d representing 1.2% of average live body weight of the animals. All supplementary feeds were offered in groups of 3-5 animals in plastic or aluminum head pans with animals having good access to feed. The crop residues offered were groundnut haulm, pigeon pea residue, cowpea haulm, cassava and yam peels. These were sampled, dried, pooled per type and sub-sampled for analysis. Chemical compositions of the crop residues and AIBPs offered during each season were determined.

The dominant forage species grazed by animals from natural pasture were identified by observing grazing animals between 09:00 to 11:00 h and 16:00 and 17:00 h each day for 6 d in each season. Commonly grazed forage species included *Pennisetum pedicellatum, Sida acuta,* *Digitaria ciliaris, Andropogon gayanus, Amaranthus spinosus, Axonopus compresus* and *Eragrostis tennella.* Samples of commonly grazed heterogeneous forage species were then collected and composited. The nutrient content of the heterogeneous forage species in the natural pasture were determined. The fresh samples were oven dried, composited and analyzed for chemical composition.

Prior to the commencement of the study, all animals were vaccinated against PPR and offered prophylactic treatment against worms and ticks. Sheep on CH received scheduled prophylactic healthcare and therapeutic medications every 3 months. This included vaccination (0.06 ml/kg; Botswana Vaccine Institute, Botswana) against *Peste de Petit Ruminant*, prophylactic treatment with Tectin Injectable Ivermectin (0.02 ml/kg; Mobedco-Vet, Jordan). Multivitamins were also administered intramuscularly via injection (0.5 ml/kg) with Introvit multivitamin (Interchmiewerken, Holland). Animals were dewormed with Albendazole 25% (0.3 ml/kg; Kela, Belgium). Ectoparasites were also controlled with Amiraz 20% acaricide (Mobedco-Vet, Jordan) and wounds were treated with Oxytetravet aerosol wound spray (Mobedco-Vet, Jordan) and potassium permanganate (Mobedco-Vet, Jordan). Sheep in the control group were occasionally given treatments by farmers when ill health was detected.

Two rams (≥ 12 months) were sub-sampled from each pen for digestibility study in each season starting from last quarter of 2013 and ended in the third quarter of 2014. Specifically, the digestibility was conducted in early dry (December, 2013), late dry (March, 2014), early wet (June, 2014) and main wet (August, 2014) seasons.

7.2.3 Determination of dry matter and nitrogen in feed and faeces

Dry matter intake of supplementary concentrate and crop residues were determined by weighing feed offered and left-over daily. Faecal matter voided for 24 h was collected from the 2 rams per pen for 6 d via total collection faecal bags (Arnold, 1960) after 6 d of adjustment to feacal bags wearing. Animals were weighed every 30 d and average daily gain estimated as total body weight gain divided by 30 to obtained monthly ADG. Total feed intake (g DM/d) was estimated from the 24 h total faecal collection and IVDMD of the feed consumed by animals per the samples taken and analyzed in the laboratory using the method of Cottle (2013) as given in the equation below.

$$\text{TDM intake g/d} = \text{Faecal output of grazing animals (g/d DM)} \times \frac{100}{100 - \text{DMD\%}}$$

Where TDM is total dry matter, DM is dry matter and DMD is dry matter digestibility.

Forage intake from natural pasture was determined by the difference of total DM intake and the intake of supplementary feed (DM). Intake of N (g DM/d) was estimated from the total intake of DM and N concentration in laboratory analyzed samples of the consumed feed whereas N in faeces (g/d DM) was determined from faecal DM output and N concentration in the faeces.

Table 7.2.1: Analyzed chemical composition of formulated concentrate feed

Item	Inclusion level of ingredients (g/kg DM)
Ingredient composition	
Maize	300
Maize bran	282
Wheat bran	150
Fish meal	40
Soybean meal	50
Whole cotton seed	150
Common salt	8
Premix	10
Dicalcium phosphate	10
Chemical composition of concentrate feed	
Dry matter	904.4
Organic matter	899.4
Crude protein	156.9
Neutral detergent fibre	420.7
Acid detergent fibre	158.1
Acid detergent lignin	32.5
IVOMD (g/kg)	554.8

DM = Dry matter, IVOMD = in vitro organic matter digestibility, Premix included; vitamins A, B_2, B_6, B_{12} D, E, K_3, Nicotinic acid, Pantothenic acid, Folic acid, Choline chloride, cobalt, Iron, methionine, lysine, selenium, Iodine, and Manganese

7.2.4 Laboratory analysis

All feed and faecal samples collected were oven-dried and milled to pass through 2 mm sieve for analysis. The milled samples were then analyzed for chemical composition at ILRI Nutrition Laboratory in Addis Ababa, Ethiopia. The DM, OM, and N were determined according to AOAC (1990) methods. Dry matter of feed or faeces was determined at 105 ^{o}C for 12 h in an oven. Sub-samples (2 g) of each feed type and faeces were placed in a muffle furnace and ashed at 550 ^{o}C for 5 h to determine ash and OM. Nitrogen was determined by the Kjeldahl method according to AOAC (1990) procedure and CP obtained by N × 6.25. Neutral detergent fibre, ADF and ADL were determined following the procedures of Goering and Van-Soest (1970). Whereas the IVOMD of samples were calculated using CP and ash content of samples on DM basis and 24 h net gas production (Menke and Steingass, 1988) equation (Section 3.3.8).

7.2.5 Statistical analysis

Data on the intake and voiding of DM and N, weight gain of animals and ADG were analyzed in a 2 × 4 factorial arrangement of treatments by ANOVA using General Statistics software (Discovery Edition 4; VSN International, 2011). The factors were 2 feeding regimes and 4 seasons. Data on the fixed effects of feed supplementation plus healthcare, season and feed supplementation plus healthcare × season on DM and N inflow and outflow in feed and faeces and weight gain of sheep were analyzed with pen as the experimental unit using the following model

$$Y_{ijk} = \mu + CH_i + S_j + CHS_{ij} + \beta_k + e_{ijk}$$

Where Y_{ij} is the observation (intake and voiding of DM and N, weight gain, ADG); μ is the overall mean effect; CH_i is the effect of concentrate supplementation plus healthcare (CH) or control; S_j is the effect of season (early dry, late dry, early wet or main wet); CHS_{ij} is the interaction between feed plus healthcare supplementation and season, βk is the random effect of each administrative region, and e_{ij} is the residual error.

Data on the effects of season on nutrient composition of feedstuffs were however, analyzed for the effect of season alone by the model below;

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where; Y_{ij} is the observation (DM, CP, NDF); μ is the overall mean effect; S_i is the effect of season (early dry, late dry, early wet or main wet) and e_{ij} is the residual error.

Differences of means were declared and compared at 0.05 by Fisher's protected least significant difference procedure.

7.3.0 Results

7.3.1 Chemical content of supplementary feed and commonly grazed forage species

Crude protein content of the formulated feed was 157 g/kg DM with over 50% IVOMD. The detail values of other chemical components are provided in Table 7.2.1.

Crude protein content of leguminous crop residues offered was not significantly different ($P>0.05$). Acid detergent fibre content however, differed ($P<0.05$) among the crop residues. The highest ($P<0.05$) ADF content was found in pigeon pea residue (459 g/kg DM) and lowest in cowpea haulms (346 g/kg DM). Season did not affect ($P>0.05$) CP content and IVOMD of the crop residues. It however, affected ($P<0.05$) the ADL content. The highest value (119 g/kg DM) was observed during early dry season and lowest in early wet season (82 g/kg DM). Other chemical parameters of the crop residues have been presented in Table 7.3.1a. Crude protein and fibre content of root and tuber crop residues offered differed ($P<0.05$). The CP content for yam peels was 63 g/kg DM and was higher ($P<0.05$) than 42 g/kg DM observed in cassava peels whereas ADF content of yam peels was significantly lower ($P<0.05$) than that of cassava peels (Table 7.3.1b.).

Table 7.3.1a: Effect of season on chemical composition (g/kg DM) of leguminous crop residues offered to sheep

Crop residues (N=12)	Season (N=3)	OM	CP	NDF	ADF	ADL	IVOMD
Cowpea (*Vigna unguiculata)* haulms	Early dry	913	96	395	248	47	664
	Late dry	873	88	456	355	60	645
	Early wet	899	119	534	409	89	561
	Main wet	881	98	504	375	76	551
Groundnut (*Arachis hypogaea*) haulms	Early dry	844	98	429	406	96	528
	Late dry	866	122	519	433	87	647
	Early wet	885	105	568	496	118	539
	Main wet	856	122	522	446	94	494
Pigeon pea (*Cajanus cajan*) residues	Early dry	883	86	567	468	104	609
	Late dry	890	79	468	454	138	467
	Early wet	884	117	584	458	150	545
	Main wet	884	117	584	458	150	545
P values	Feed	0.017	0.459	0.012	0.001	0.001	0.122
	Season	0.53	0.238	0.004	0.112	0.001	0.221
	Feed × season	0.298	0.541	0.169	0.465	0.098	0.117

OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *In vitro* organic matter digestibility.

Table 7.3.1b: Effect of season on chemical composition (g/kg DM) of root and tuber crop residues offered to sheep

Crop residues (n = 12)	Season (n = 3)	OM	CP	NDF	ADF	ADL	IVOMD
Cassava (Manihot	Late dry	933	44	420	179	72	684
esculenta) peels	Early wet	946	38	360	129	46	601
	Main wet	927	46	385	197	91	574
	Early dry	900	40	357	156	75	572
Yam (Dioscorea sp) peels	Late dry	957	56	830	84	21	703
	Early wet	950	65	792	95	26	670
	Main wet	939	59	803	96	39	532
	Early dry	851	72	468	193	94	430
P values	Feed	0.870	0.004	0.001	0.028	0.014	0.577
	Season	0.003	0.919	0.015	0.200	0.011	0.024
	Feed × season	0.24	0.612	0.053	0.091	0.06	0.354

OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *In vitro* organic matter digestibility.

Table 7.3.1c: Effect of season on chemical composition (g/kg DM) of AIBPs offered to sheep

AIBPs (N=12)	**Season (N=3)**	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**
Rice (*Oryza sativa*) bran	Early dry	805	75	631	402	130	398
with hulls	Late dry	805	56	613	399	126	357
	Main wet	773	66	642	428	138	350
	Early dry	799	64	609	423	155	357
Maize (*Zea mays*) bran	Early dry	936	121	439	102	12	603
	Late dry	953	103	498	112	12	569
	Main wet	933	116	615	151	19	507
	Early dry	931	125	466	94	19	648
Corn milling waste	Early dry	937	95	296	64	19	655
	Late dry	923	85	504	107	28	562
	Main wet	805	100	359	89	17	533
	Early dry	943	107	379	57	15	596
Brewers' spent grain (Pito	Early dry	911	231	614	310	87	588
mash)	Late dry	907	225	609	341	95	592
	Main wet	866	222	619	343	102	516
	Early dry	857	235	594	326	84	524
SED		52.920	28.412	72.336	38.626	27.092	98.573
P Values	Feed	0.001	0.001	0.001	0.001	0.001	0.001
	Season	0.170	0.708	0.222	0.326	0.995	0.402
	Feed × season	0.716	1.000	0.294	0.966	0.989	0.985

OM = organic matter, CP = crude protein, NDF=neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVOMD = *In vitro* organic matter digestibility, *Agro-industrial by-products = AIBPs , SED = Standard errors of differences of means*

Nutrient content of AIBPs supplementary feed differed ($P<0.05$) in all the chemical components determined (Table 7.3.1c.). Crude protein content was highest (228 g/kg DM) in brewers' spent grain and lowest (65 g/kg DM) in rice bran. *In vitro* organic matter digestibility was also highest in corn milling waste and lowest in rice bran. Season did not affect the chemical components of the AIBPs offered.

Season however, significantly affected ($P<0.05$) chemical composition of commonly grazed forage species in the communal pasture. The CP content of commonly grazed forage species was highest ($P<0.05$), (142 g/kg DM) during early wet season and lowest (61 g/kg DM) in the late dry season. *In vitro* organic matter digestibility followed the same trend as in seasonal CP content (Table 7.3.2) whereas ADL content of the commonly grazed forage species was highest ($P<0.05$), (102 g/kg DM) during the late dry season and lowest (66 g/kg DM) in early wet season.

Table 7.3.2: Effect of season on chemical composition (g/kg DM) of commonly grazed forage species

Item	Season (N=24 (6 in each season))				SED	P value
	Early dry	Late dry	Early wet	Main wet		
Organic matter	870.82	822.20	832.82	867.39	21.781	0.077
Crude protein	63.24 ^{a}	60.93 ^{a}	141.69^{b}	119.86^{b}	11.369	0.001
Neutral detergent fibre	684.16	675.87	613.65	681.59	28.336	0.056
Acid detergent fibre	602.54^{b}	681.59^{c}	474.19 ^{a}	490.66 ^{a}	26.216	0.001
Acid detergent lignin	86.18^{b}	102.11^{c}	65.45 ^{a}	73.11^{ab}	6.641	0.001
IVOMD	564.38^{b}	445.99^{a}	633.93^{b}	625.66^{b}	54.906	0.006

Means with different superscript across the rows are significantly different (P<0.05), IVOMD = *In vitro* organic matter digestibility, SED = Standard error of differences of means

7.3.2 Intake and voiding of dry matter and nitrogen in sheep under a smallholder production system

The intake of supplementary feed was higher (P<0.05) among animals on CH as expected (Table 7.3.3). Intake of DM from natural pasture was similar between control and CH but total intake of DM was higher (P<0.05) among animals on CH than control (608 versus 515 g DM/d). Intake of supplementary feed declined significantly from early dry season (274 g DM/d) to main wet season (70 g DM/d) as crop residues offered decreased towards main wet season. Intake from pasture differed (P<0.05) among seasons. The highest (P<0.05) intake (573 g DM/d) was observed during early wet season and lowest (274 g DM/d) in late dry season. Consequently, total intake of DM was highest (P<0.05) (679 g DM/d) during the early wet season and lowest

(397 g DM/d) in main wet season (Table 7.3.4). The interaction between CH and season did not significantly affect (P>0.05) the intake of DM.

Concentrate supplementation plus healthcare provision did not affect (P>0.05) daily faecal voiding of rams (251 versus 264 g DM/d for CH and control respectively). There were however, significant (P<0.05) effects of season on faecal voiding of animals. The highest (321 g DM/d) was observed during the early dry season and lowest (169 g DM/d) in main wet season. The interaction between CH and season did not affect (P>0.05) faecal voiding of rams.

Total N intake was higher (P<0.05) among animals on CH than those on the control group but N voiding in faecal matter was similar between the two treatments. Season significantly affected (P<0.05) N intake. The highest value (14.2 g/d) was observed during early wet season and lowest (7.1 g/d) in late dry season. Effect of season on N retention was also significantly higher (P<0.05) in CH than control group. The interaction of CH and season did not affect total N intake but N voiding was significantly affected (P<0.05). The highest value was observed in early dry season among animals on CH and lowest in late dry season in control group.

Table 7.3.3: Effect of feed supplementation plus healthcare on intake and voiding of DM and N, growth performance and mortality of sheep under a smallholder production system

Item	Treatment		SED	P Value
	CH	Control		
Dry matter intake and voiding (g/d)				
Supplementary intake	203.45	109.73	14.647	0.001
Intake from pasture	404.89	405.09	20.858	0.992
Total intake	608.33	514.82	23.483	0.001
Faecal DM	251.22	263.68	11.411	0.277
Nitrogen intake and voiding (g/d)				
Supplementary intake	5.20	1.38	0.335	0.001
Intake of N from pasture	5.31	6.71	0.557	0.013
Total N intake	10.50	8.09	0.633	0.001
Nitrogen retention	5.16	4.02	0.510	0.027
Faecal N content	5.92	5.03	0.270	0.669
Growth performance of sheep (kg)				
Initial weight	15.79	15.53	0.502	0.608
Final weight	18.38	17.07	0.590	0.029
Weight gain	2.59	1.54	0.336	0.002
Average daily gain (g/d)	33.64	18.86	4.171	0.001
Mortality (%)	2.97	6.86	1.332	0.004

CH = concentrate supplementation plus healthcare, SED = Standard error of differences of means

Table 7.3.4: Seasonal effect of supplementation plus healthcare on intake and voiding of DM and N and mortality in sheep under smallholder a production system

Item	Early Dry		Late dry		Early wet		Main wet		SED	P values		
	CH	Control	CH	Control	CH	Control	CH	Control		Trt	Season (S)	Trt × S
Intake and voiding of DM (g/d)												
Supplementary feed intake	282.18^{e}	264.77^{de}	216.76^{ed}	136.98^{b}	179.15^{bc}	33.39^{a}	135.70^{b}	03.76^{a}	29.295	0.001	0.001	0.010
Intake from pasture	451.06	441.05	301.09	247.00	554.61	590.91	312.79	341.40	41.715	0.992	0.001	0.400
Total DM intake	667.82	578.04	583.27	511.77	733.76	624.30	448.49	345.16	46.965	0.001	0.001	0.943
Faecal DM	321.11	320.80	262.74	284.63	257.31	274.44	163.71	174.84	22.822	0.277	0.001	0.912
Mortality (%)	2.78	7.76	3.54	6.58	4.06	6.32	1.57	6.87	2.668	0.819	0.944	0.819
intake and voiding of N (g/d)												
Supplementary	5.37^{d}	1.84^{ab}	4.77^{d}	3.24^{c}	5.37^{d}	0.40^{a}	5.28^{d}	0.05^{a}	0.670	0.001	0.019	0.001
Intake from pasture	4.62^{ab}	4.66^{ab}	3.47^{a}	2.65^{a}	9.58^{c}	12.95^{d}	3.56^{a}	6.57^{b}	1.115	0.013	0.001	0.016
Total N intake	9.98	6.50	8.23	5.88	14.95	13.35	8.84	6.62	1.266	0.001	0.001	0.763
Retention of N	3.95	3.83	2.59	2.49	9.17	6.83	5.03	2.84	1.020	0.027	0.001	0.184
Faecal N content	6.76^{c}	5.26^{b}	3.79^{a}	4.11^{a}	6.52^{c}	5.78^{bc}	3.81^{a}	3.78^{a}	0.540	0.669	0.001	0.023

Means with different superscripts in the same row among seasons are significantly different ($P<0.05$). ADG = Average daily gain, DM = dry matter, N= Nitrogen, CH = concentrate supplementation plus healthcare, SED = Standard error of differences of means, Trt = Treatment, S= season

7.3.3 Growth performance of sheep

Animals on CH had ADG of 34 g/d and was significantly higher (P<0.05) than 18 g/d in control group. Consequently total weight gain of animals on CH was significantly higher (P<0.05) than those in the control group (2.3 versus 1.5 kg) during the entire period of the study. Change in seasons affected (P<0.05) the effect of supplementation on ADG of animals and resulted in significant differences (P<0.05) in ADG among seasons (Figure 7.3.1). The effect of CH on ADG of animals was higher in early dry and main wet season compared to other seasons. Mortality was generally higher (P<0.05) among animals on control (Table 7.3.3) compared to those on concentrate feed and health provision (6.9% vs 3.0%). Change in seasons however, did not affect (P>0.05) mortality rate, although the values were higher among control animals in main wet and early dry season (Table 7.3.4).

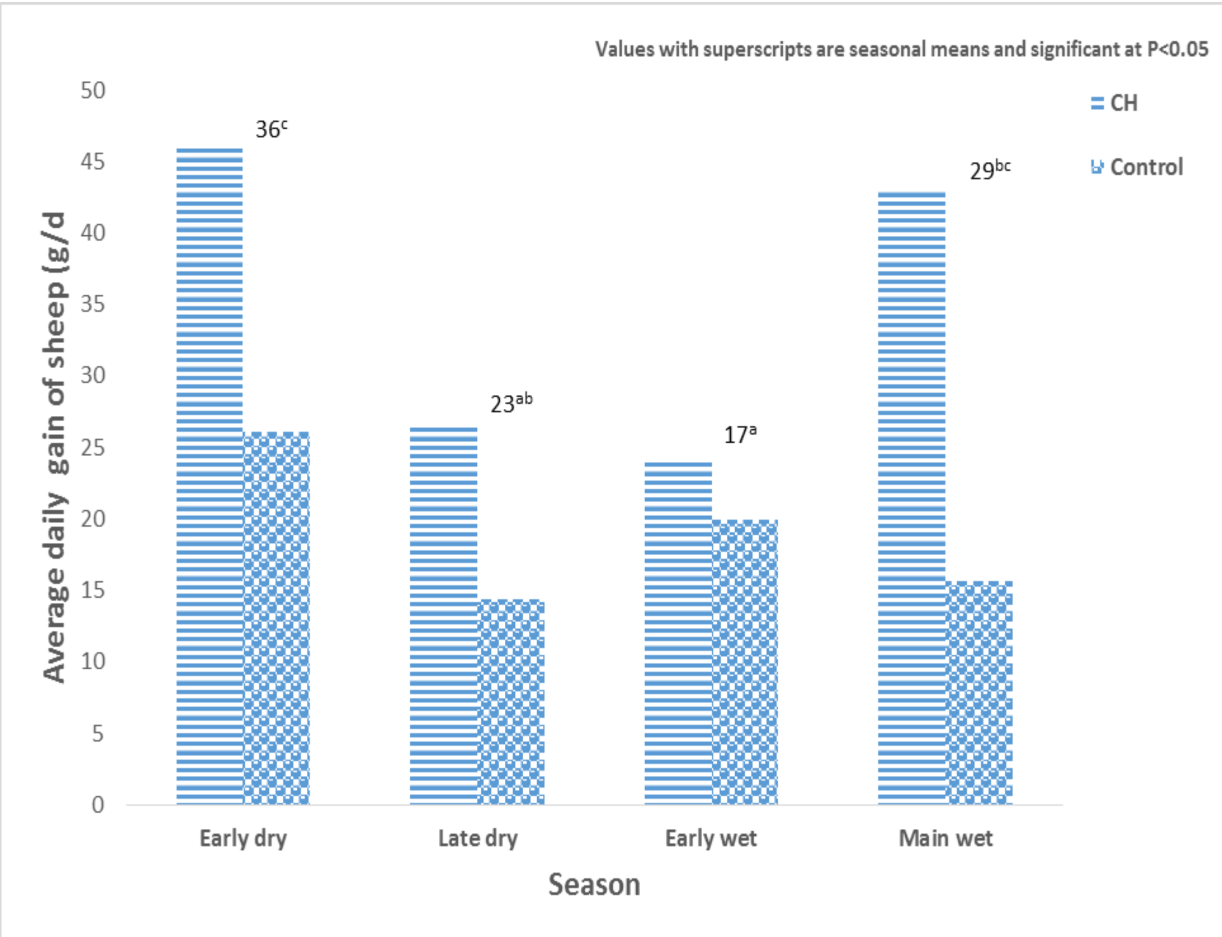


Figure 7.3.1: The effect of season and concentrate supplementation on ADG of sheep.

7.4.1 Discussion

Supplementary feeding of sheep is a common practice among farmers in the study area. This emanated from farmers awareness of the significant role of this practice in animal productivity. The high utilization of crop residues and AIBPs as supplementary feed by farmers was due to the availability of these feed resources in their farming system. Farmers found it less expensive in terms of time and money to acquire them for their animals. Some of the farmers did not collect enough crop residues, hence their animals were not adequately supplemented during the late dry season. This suggests that the traditional motive of keeping animals at home as a form of savings still dominates among farmers and interest of rearing animals as a business venture is very low (Clottey *et al*., 2007; Chah, *et al*., 2013).

The high ADF and ADL content of pigeon pea residue observed among the leguminous crop residues could be attributable to the long period of pigeon pea growth pattern that allowed it to accumulate more structural carbohydrates in the tissues compared to groundnut and cowpea which were short duration annual plants. Karbo *et al*. (1998) stated that pigeon pea could grow more than one cropping season with little soil moisture during the dry season. Stability of the crude protein content of crop residues with change in seasons confirms the report of Antwi *et al*. (2010) and is attributable to the preservation method of the collected residues. Shade dried cowpea haulm protected against sun and rain was observed to have stable CP content in the dry season of about 5 months compared to decreasing CP content of standing cowpea hay (Antwi *et al*., 2010). The significant increase in IVOMD of crop residues in early wet season may be due to the long storage time that weakens the structural integrity of crop residues and facilitates high digestibility. Abarike *et al*. (2012) reported similar observation in a fodder preservation study.

The observed variation in CP content of commonly grazed forage species in the natural pasture which was found to be higher during the wet season (130 g/kg DM) than in the dry season (62 g/kg DM) could be attributed to the change in species composition of forage and maturity with change in seasons. The values obtained were similar to the previous reports of other workers (Smith, 2010; Karbo and Agyare, 2002). The current values were however, lower than the reported 187 g/kg DM CP content in the natural pasture during the wet season (FAO, 2006).

The higher intake of DM among animals on CH than the control (608 versus 515 g/d) resulted from concentrate supplementary feeding. Feed intake of animals often increased with increasing amount of concentrate feed offer. The same observation was reported by Owen (1994). The similarity of DM intake from natural pasture observed in this study could be attributable to the presence of pasture in the communal grazing land. Animals are able to utilize the available fodder in the pasture for their survival. The present values of DM intake among supplemented sheep are higher than 463 g DM/d reported by Salim *et al*. (2002) in Bangladesh. Similar trend of high intake of DM among concentrate supplemented sheep than those in the control group agrees with the observation made by other workers in similar studies (Salim *et al*., 2002; Farid *et al*., 2010).

The significant effect of season on the intake of DM in the sheep production system was largely due to feed availability differences in the natural pasture. In the communal pasture of the study area, there were some amount of fodder in all seasons but the quantity available and quality changed greatly with season. High amount of forage with fairly good quality is often found during the main wet to early dry seasons (Smith, 2010). This becomes very poor in quality and limited in availability to animals during late dry season. This variation in feed quality and availability influences the intake of DM among animals in smallholder systems in different seasons. Nguyem *et al*. (2013) observed higher intake of DM in sheep during the wet season compared to dry season and attributed his findings to higher availability of forage in the pasture as the major factor. The highest intake of DM in sheep during early wet season in this report could be attributable to the availability of high quality sprouting forage, the ability of sheep to graze on low pasture and the unrestricted access of sheep to pasture during this period (FAO, 2014;

Awuma, 2012). Variation in feed availability and quality that decreases grazing resources in natural pasture from wet season to dry season has been reported to result in low intake of DM in sheep during the late dry season (Powell *et al*., 1995; Smith, 2010).

The similarity of faecal voiding (DM outflow) in both animals on CH and control (251 vs. 264 g/d DM respectively) suggested that there was higher DM retention among animals on CH. This might be due to improved rumen environment and microbial activity. Similar observation was reported by Joomjantha and Wanapat **(**2008) in concentrate supplementation of buffaloes. Daily faecal outputs recorded in this work are comparable to the report of FAO (2005) and the findings of ITC (2014) in sheep faecal output under free range management system, similar to this current study in which faecal voiding of 219 to 272 g DM/d was reported in sheep. The current faecal output values are however lower than 345 g DM/d observed by Fernandez-Rivera *et al*. (1995). The difference could be attributed to environmental and breed differences of the sheep.

The variation in faecal voiding among seasons where the highest value (320 g DM/d) was observed during early dry season compared to other seasons could be attributable to high intake of DM. The availability and accessibility of forage to animals were high in natural pasture during that period and could result in high faecal output. Also, the maturity of forage and its lignin content could lead to low degradability resulting in high faecal voiding as undigested feed (Campbell *et al*., 2003). Low CP content of the natural pasture as the dry season progressed (Antwi *et al*., 2010) could contribute to the result obtained.

The higher intake of N in animals on CH emanated from the concentrate supplementary feed. Formulated concentrate feed with elevated CP content often lead to higher intake of N in supplemented ruminants. Similar observation was made by Tadele (2014) who reported higher intake of N in sheep fed grass hay and supplemented with soaked or roasted lupin grains compared to control. The similarity of N content of faeces in both treatments despite higher intake of N in animals on CH suggested higher N retention among animals on CH. This is consistent with the reports that concentrate supplementation of ruminants on poor roughage diet improves feed degradation and nutrient retention due to increased rumen microbial activities (Joomjantha and Wanapat**,** 2008; Singh *et al*., 2011).

Highest intake of N observed in early wet season in this work resonates well with the report of Salim *et al*. (2002) in similar studies. The variation in forage quality among seasons with higher N and lower fibre content of commonly grazed forage species in communal pasture during early wet season (FAO, 2006) have led to this higher intake of N in that season. Schlecht *et al*. (1995) reported similar increased intake of N from 1.3% in late dry season to 4.2% in early wet season in rangeland among ruminants in the Sahel region of West Africa. This is attributable to forage growth and senescence influenced by the rainfall pattern as stated by other researchers (Smith, 2010; FAO, 2014; Tadele, 2014).

The higher intake of N and retention in early wet season could be attributable to the higher protein content of the sprouting forage which contains high N and is easily digestible during the early wet season than other seasons. The low fibre content of the young forage makes it more digestible. Similar observation was made by Smith (2010). Higher intake of N from natural pasture is also linked to selective grazing of animals on high quality young sprouting forage species during early wet season (Powell *et al*., 1996). They are able to do this because animals are mostly not confined during that period as planting of crops has not fully begun (Annor *et al*., 2007; Awuma, 2012)

This high intake of N from natural pasture during early wet season resulted in higher faecal N content in that season compared to other seasons. The 6.2 g DM/d of faecal N concentration obtained in this season is closer to 6.1 g DM/d of faecal N content of sheep reported by Powell *et al*. (1995). The high feacal N content during early wet and early dry seasons suggested that good quality manure is produced during that period and if collected through improved housing, the farmers could use it for soil fertility improvement to increase crop yield.

The ADG of 34 and 18 g/d for animals on CH and control treatment respectively indicated that the application of CH improved weight gain of animals. This is directly linked to the high intake of DM and N from the concentrate feed. Similar findings were reported by Konlan *et al*. (2012) when concentrate containing graded levels of shea nut cake was offered to Djallonkè rams as a supplementary diet. The ADG obtained were similar to the report of ITC (2014) on live weight gain of sheep in Gambia but lower than 53 to 57 g/d reported by Karbo *et al*. (1998) when pigeon pea forage cuttings were supplemented to sheep with untreated or urea-treated rice straw as the basal diet in the same area. The ADG of 34 g/d in animals on CH is also lower compared to 72 g/d reported by Ansah *et al*. (2012) when high level (400 g DM/d) of AIBPs formulated diet was supplemented to sheep in addition to free grazing in the natural pasture. The lower values obtained may be attributable to differences in supplementary feed type, amount offered and management of animals.

The high effect of season on the weight gain of animals in which the early dry season had the highest ADG (Figure 7.3.1) came from the high availability of fodder and full accessibility to animals during the early dry season compared to the other 3 seasons. This finding agrees with many reports of cyclic body weight gain in the wet season and weight loss in the dry season due to poor fodder quality and low availability in natural pasture attributed to bush fires in the area during late dry season (Karbo *et al*., 1998; FAO, 2006; Annor *et al*., 2007; Ansah *et al*., 2012). The consistently higher ADG of sheep on CH especially in the late dry season suggests that when supplementary feeds are strategically offered, feed digestibility and utilization improves in animals and weight loss may not occur as often observed in this study area.

The low mortality rate observed among animals on CH treatment as compared to control (3.0 vs 6.9%) is directly due to the provision of concentrate supplementary feed and the orthodox health care. The improved nutrition and health status of the animals might have increased the immune system of animals on CH treatment. This made them more resistant to diseases that would have normally led to the death of some animal (Campbell et al., 2003). Baiden et al. (2009) reported similar observation among sheep and goats in coastal Savanna ecological zone of Ghana. The current mortality rate obtained in both treatment and control groups of animals (3.0 vs 6.9%) is lower than the 25 to 30% sheep mortality rate reported by Jagbesie (2006) in a survey of small ruminant mortality in Savelugu district in the Northern Region of Ghana. This differences could be attributed to improve management system over the years and the initial briefing of the farmers on livestock management in this work. It is however close to ewe mortality rate of 7.5 % in semi – intensively management systems in the dryer areas of SSA countries among smallholder farmers (FAO, 2002).

7.5.1 Conclusion and recommendation

Concentrate supplementation plus healthcare increased daily intake of DM and N to about 17 and 18% respectively, with no effect on DM and N voided in faeces. Season significantly affected intake of DM and N. Early wet season had the highest DM inflow compared to the other 3 seasons. Nitrogen inflow was also highest in early wet season. The highest faecal output was observed in the early dry season among supplemented animals than control and the lowest faecal output was in the main wet season. Nitrogen content of faeces was however, highest during the early wet season and lowest in late dry season. Mortality reduced significantly whereas weight gain of sheep increased from 18 to 34 g/d due to the concentrate supplementation plus healthcare provision.

High quality manure was produced during early wet and early dry seasons due to high faecal N content in these seasons and could be collected through improved housing for improving poor soils to increase crop yield. The practice of good healthcare and concentrate supplementary feeding of sheep especially during the late dry season is therefore recommended for improving the productivity of animals in smallholder farming systems.

CHAPTER 8

8.0 EXPERIMENT III: GROWTH PERFORMANCE AND MARKET VALUE OF GROWING DJALLONKÈ SHEEP SUPPLEMENTED WITH LOCALLY AVAILABLE AGRO-RESIDUES IN A SMALLHOLDER PRODUCTION SYSTEM

8.1.0 Introduction

Experiment III was conducted to determine the effect of crop residues and AIBPs supplementation on the growth performance and market value of sheep in the study area. This was done to provide on-farm information for improving the productivity of animals with locally available and less costly feedstuffs due to the cost of feed ingredients in concentrate formulated feed used in experiment II.

In Ghana, about 8 million tonnes of cereal stover and 4 million tonnes of residues from legume, root and tuber crops are generated per annum and potentially available as feed resources with less cost (Oppong-Anane, 2010). Karbo and Agyare (2002) reported the annual crop residue generation in northern Ghana to be about 5 million tonnes. The collection of these crop residues for supplementary feeding of ruminants is wide spread and growing at a high rate among smallholder farmers (MoFA, 2011). This practice is a shift from the traditional *in situ* grazing after harvest due to increasing ruminant production and competition. Major crop residues commonly collected and fed to ruminants in northern Ghana include groundnut haulms, cowpea haulms and pigeon pea waste (Karbo *et al*., 1998; Oppong-Anane, 2010). Other feed resources available are AIBPs from households and agro-processing industries. Over 80% of smallholder farmers in Ghana have knowledge on the use of these AIBPs in feeding ruminants (Teye *et al*., 2011). However, much research attention has not been given to these AIBPs even though there is high potential for their use in improving livestock productivity especially in fattening of small ruminants for sale. Common AIBPs that are used for feeding livestock by smallholder farmers in northern Ghana include: bran of maize, sorghum and millet, cotton seed, soybean cake and brewers' spent grain (Ansah *et al*., 2012; Oppong-Anane, 2013). Others are rice bran and corn milling waste (Teye *et al*., 2011; FAO, 2014). Research and extension education are needed to augment the knowledge of farmers on the appropriate use of these feedstuffs to increase ruminant productivity especially in small ruminant fattening enterprises to increase profitability.

Many experimental results of other researchers (Owen, 1994; Smith, 2010; Singh, 2011) indicate that the intake of crop residues differs significantly depending on the types of crop residue and the amount offered. Some crop residues are preferred to others. The offer of crop residues to animals in high quantities is reported to result to higher DM intake (Owen, 1994; Singh, *et al*., 2011). Also, digestibility of crop residues increases when offered with energy-based concentrate feed such as maize bran than sole supplementary feeding (Smith, 2010; Singh, 2011). Unfortunately, most smallholder farmers in northern Ghana offer one agro-by-product as supplementary feed at a time and this does not allow efficient utilization of the feed by animals.

Also, small ruminants are often sold by smallholder farmers to satisfy their family cash needs in different seasons of the year. It has been reported that most farmers sell their animals at the beginning of cropping season in May to June (Clotey *et al*., 2007). Amankwa *et al*. (2012) observed that farmers have two major seasons of selling their small ruminants and this occurs in June to August and November to February (around festive occasions such as Christmas and Ramadan). The motives of these seasonal sales are distress and demand driven with animals being sold at low prices during the distress sale season (Amankwa *et al*., 2012). Most farmers sell about 11% of their animals per annum (Amankwa *et al*., 2012) to address the financial needs of their households. Most farmers however do not make any conscious effort to condition their animals for sale by way of fattening to attract good market price. It is envisaged that the crop residues and AIBPs could be used appropriately to improve the condition of the whole flock or animals that farmers intend to sell to attract higher price than non-conditioned animals.

8.1.1 Objective

To determine the supplementation effect of groundnut haulm and maize bran on growth performance and market value of animals due for sale in the flock during one of the sales seasons (November to February).

8.2.0 Materials and methods

8.2.1 Study area

The study was carried out in Savelegu-Nanton District of the Northern Region (longitude 0^o 58 W and latitude 9^o 25 N). It has a unimodal rainfall pattern that begins in May and ends in October. The mean annual rainfall is 1200 mm. Temperature generally fluctuates between 15 °C (minimum) and 42 °C (maximum) with a mean annual temperature of 28 ^{o}C and mean annual relative humidity of 54% (MoFA, 2011). The specific communities in Savelegu-Nanton district of Northern Region were the study was conducted include Tibali, Duko and Botingli. This study started in December, 2014 and ended in February, 2015.

8.2.2 Experimental design and management of animals

The study was conducted in a completely randomized block design (CRBD). There were 3 communities that served as blocks in which 4 treatments were replicated in each block. The treatments were Non-supplementation (T0), supplementation with sole groundnut haulm (T1), sole maize bran (T2) and combination of T1 and T2 in a ratio of 2:1 (T3). The treatments were allocated randomly to sheep belonging to 4 farms with an average flock size 12 ± 1.6 in each community, one treatment per farm and replicated in the 3 communities. The farmers were selected based on sheep ownership and their willingness to co-operate with the data collection procedure. In each community, one field assistant was appointed and trained to assist farmers in weighing daily supplementary feed offered and orts. Weighing scales were given to the community assistants in each community. This data was used to estimate supplementary feed intake.

All the sheep in the pen of each farmer were offered the supplementary feed but data was taken from animals that were 1 year old and bellow for this study. The ages of the animals were estimated using their dentition. Average initial weight of the selected growing sheep in the pens was 12 ± 3.6 kg. Farmers were encouraged to collect enough groundnut haulms that could feed their flock for the period from their crop fields or other fields in the community. Maize bran was bought from corn mill operators in the communities and at the Savelugu market.

Animals on control were grazed from 08:00 h to 17: 30 h and housed at night. Animals on T1 were offered groundnut haulm at 300 g DM/d (Ngwa and Tawah, 1992; Singh *et al*., 2011) in addition to grazing from pasture. The sheep on T2 were offered maize bran at 200 g DM/d due to the bloating effect in ruminants associated with high intake of concentrate based feed (Malau-Aduli *et al*., 2005; Singh *et al*., 2011) whereas animals on T3 were given combination of both T1 and T2 at 200 and 100 g DM/d respectively. In T3, maize bran was offered for about 30 minutes after which groundnut haulm was offered. The supplementary feedstuff was offered at 07:00 h daily in groups of 3 to 5 animals in a plastic or aluminium head pans before animal were let out for grazing. All animals were dewormed with Albendazole 25% (Kela, Belgium) at 0.3 ml/kg live weight and injected with Tectin Injectable Ivermectin (Mobedco-Vet, Jordan) at 0.02 ml/kg live weight as prophylactic treatment before the start of the experiment.

8.2.3 Data collection and analysis

Animals were weighed monthly to determine weight gain for each 30 d and average daily gain determined. Farmers were individually interviewed and their experiences in the sale of animals used to estimate the market price in GHS/kg live weight of the selected animals in each flock. Samples of groundnut haulms and maize bran offered were taken weekly and composited for laboratory analysis.

The samples were analyzed for chemical composition at ILRI Nutrition Laboratory in Addis Ababa, Ethiopia (Table 8.2.1). The DM and OM were determined according to AOAC (1990) methods. Nitrogen was determined by the Kjeldahl method according to AOAC (1990) procedure and CP calculated as N × 6.25. The fibre components (NDF, ADF and ADL) were determined following the procedure of Goering and Van-Soest (1970). The samples IVOMD were calculated using the CP and ash content of samples on DM basis and 24 h net gas production (Menke and Steingass, 1988) equation (Section 3.3.8).

The data collected were analyzed for the effect of treatment on growth performance and market prices of the sheep using General Statistics software (Discovery Edition 4; VSN International, 2011) following ANOVA analytical procedure. Data on the effect of treatment on weight gain and market price of animals were analyzed for the effect of treatment by the model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where Y_{ij} is observation (ADG and price of animals); μ is the overall mean effect; T_i is the effect of treatment (T0, T1, T2 and T3) and e_{ij} is the residual error.

Differences of treatment means were declared and separated at 0.05 levels with LSD.

Table 8.2.1: Chemical composition of groundnut haulms and maize bran offered to sheep

Components (g/kg DM)	**Groundnut haulms**	**Maize bran**
Dry matter	915.0	905.1
Ash	288.2	465.0
Crude protein	7.86	10.6
Neutral detergent fibre	429.2	360.1
Acid detergent fibre	416.9	81.4
Acid detergent lignin	103.2	08.8
In vitro organic matter digestibility	506.7	630.9

8.3.0 Results

8.3.1 Feed intake and growth performance of animals

Over 90 % of all supplementary feeds offered were consumed in all the treatments with little negligible orts that were not measured. Supplementation increased ($P<0.05$) the weight gain of sheep (Table 8.3.1). The weight gain of animals on both groundnut and maize bran supplementation (T3) was highest ($P<0.05$) among the treatments and lowest was found in control group. Consequently, the ADG of 21, 32, 31 and 46 g/d for T0, T1, T2 and T3 respectively, were obtained. Animals on T3 had the highest ($P<0.05$) ADG compared to the other treatments. The combined effect of groundnut haulms and maize bran supplementation resulted in about 120% increase in ADG of animals while the sole supplementation of both led to about 50% increase in ADG.

Table 8.3.1: Effect of groundnut haulms and maize bran supplementation on growth performance of yearling sheep in a smallholder production system.

Growth performance	T0	T1	T2	T3	SED	P Value
Initial weight (kg)	12.86	13.36	13.93	12.96	1.263	0.828
Final weight (kg)	14.24^{a}	15.68^{b}	15.64^{b}	16.75c	0.491	0.004
Weight gain (kg)	1.56^{a}	2.40^{b}	2.37^{b}	3.47^{c}	0.491	0.002
ADG (g/d)	20.87^{a}	32.04^{b}	31.45^{b}	46.23^{c}	6.543	0.003
Increase in ADG (%)	-	53.52	50.69	121.51	-	-

Means with different superscripts along the rows are significantly different at $P<0.05$, T0 = non supplementation, T1 = supplementation with only groundnut haulms (300 g DM/d), T2 = supplementation with only maize bran (200 g/d DM) and T3 supplementation with groundnut haulms (200 g DM/d) and maize bran (100 g DM/d). SED = Standard error of differences of means

8.3.2 Price per kg live weight of sheep

The estimated price/kg live weight of the animals was GHS 6.00 ± 1.3 in the district at the time of the study. The prices of animals on the treatments are presented in Figure 8.3.1. Animals on T3 attracted the highest ($P<0.05$) price of GHS 100.00 and the lowest price of GHS 89.00 was found among the control group. An increase in price of animals to about 6% was observed when sole groundnut haulms or maize bran was offered to the animal at 300 and 200 g DM/d in T1 and T2 respectively. In T3, there was synergetic effect of 13% increase in market price when animals were offered both groundnut haulms and maize bran at a ratio of 2:1 amounting to 300 g DM/d of supplementary feed.

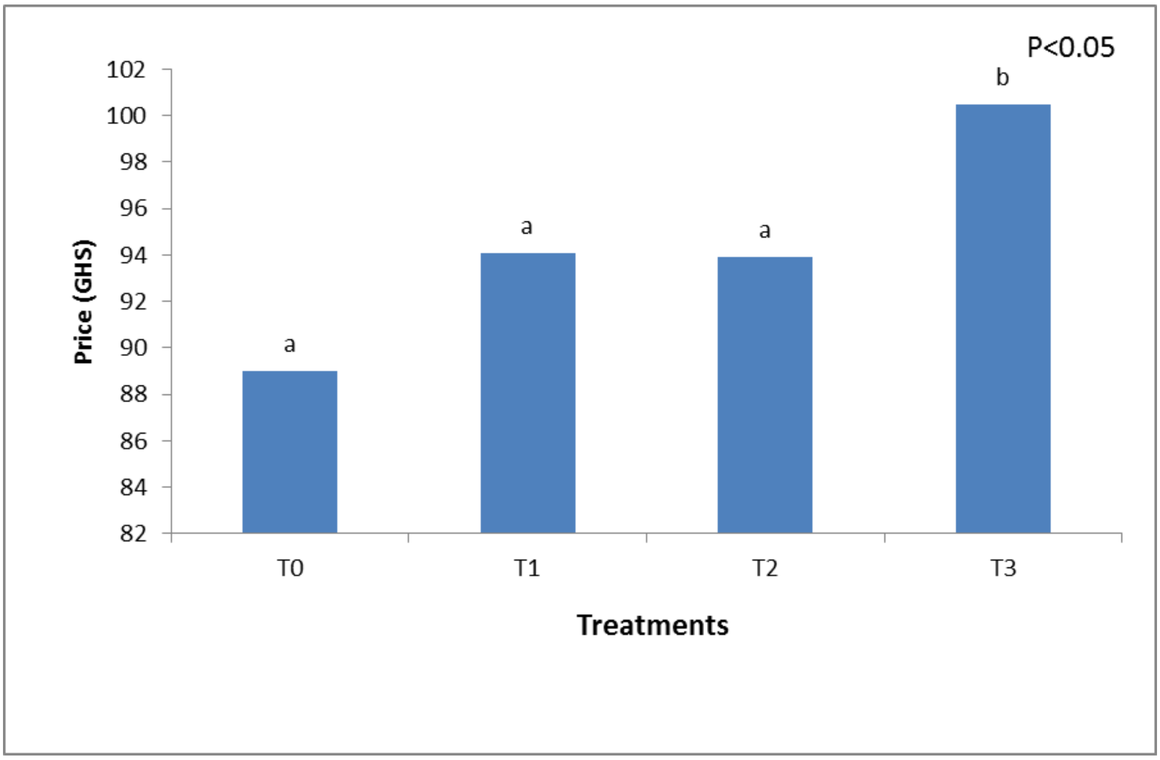


Figure 8.3.1: Effect of supplementing locally available crop residues on the price of sheep

8.4.1 Discussion

The synergistic effect of combined groundnut and maize bran supplementation on total weight gain in T3 could be attributed to the appropriate provision of energy and protein needed in the rumen that created good rumen environment for increased forage digestion. Wanapart and Khampa (2007) reported similar observation. The ADG obtained in this study was similar to the range of 25 to 60 g/d in sheep grazing from natural pasture with concentrate supplementation (Osafo *et al*., 2008; ITC, 2014). It is however; lower than the reported 71 and 74 g/d in Djallonkè sheep supplemented with mixture of AIBPs at 200 and 400 g DM/d and grazing on natural pasture (Ansah *et al*., 2012) during the wet season. The differences in ADG could be attributed to the differences in the time of the year in which this work was carried out and initial weights of animals. The nutritive quality of natural pasture in wet season is far greater than in the dry season (Smith, 2010; Oppong-Annane, 2010). In a similar experiment, in which rice bran-based energy diet was supplemented to cattle on natural pasture, it led to 24% increase in average daily gain from 170 g/d in control to 210 g/d among supplemented group of cattle (Teye *et al*., 2010).

The higher price of animals on both groundnut haulms and maize bran suggested that the supplementation had increased the market value of animals with a little increase in production cost from the purchase of maize bran since the groundnut haulms were collected at the fields of farmers. The estimated price of about 90 to 100 Ghana cedis (GHS 3.48 ≈ 1 USD at the time of study) per sheep with a mean live weight of 16 kg observed in this report fell within the range of 90 to 150 Ghana cedis reported at Tamale Livestock Market for similar animals in February (Zibilim, 2015, personal communication). This is however; lower than the price of 150 to 200 Ghana cedis for an average Djallonkè sheep (18 kg live weight) in December, 2012 at Wa market (GNA, 2012).

Amankwa *et al*. (2012) observed that most farmers in northern Ghana sell about 11% of their animals per annum. Clotey *et al*. (2007) reported that provision of animal healthcare service increased market value of small ruminants to 34% by the time products of animals get to the final consumer. The market value addition in the system in terms of number of animals ready for sale and in good condition and attracting higher prices is estimated to increase up to 50% when farmers practice good feeding regime, proper housing and sanitation in their farms (Clotey *et al*., 2007). This will lead to higher profit margin of people involved in the small ruminant production and trading industry.

8.5.1 Conclusions and recommendations

The supplementation of sole groundnut haulms or maize bran increased ADG of sheep but the increase was doubled when both groundnut and maize bran were offered as a combined feed supplement. The price of sheep increased by 6% when sole groundnut haulms or maize bran was offered to animal at 300 or 200 g DM/d but the effect was 13% increase in animal market price when both feed were simultaneously supplemented at 200 g DM/d of groundnut haulms and 100 g DM/d of maize bran. Farmers are therefore encouraged to offer crop residues and AIBPs as a combined feed supplement for higher productivity.

CHAPTER 9

9.1 GENERAL DISCUSSION

The farming system in the study area was a mixed crop-livestock system in which over 90% of crop farmers also kept at least one kind of farm animal or poultry. This suggested that livestock production is adjunct to crop farming in northern Ghana. Oppong-Anane *et al*. (2008) reported similar finding in a study of livestock production and development trends in Ghana. This mixed crop-livestock farming system has influenced the major income source of the farmers towards crop and livestock production as obtained in the first survey of this study. Amole and Ayantunde (2015) reported similar results of farmers earning high percentage of their income from agriculture in Burkina Faso. The economic and socio-cultural important animals in northern Ghana were cattle, sheep, goats and local poultry. This was also stated by Karbo and Agyare (2002) as important farm animals in the smallholder production systems. The major constraints affecting the productivity of these animals were poor health and inadequate availability of feed resources.

The common feed resources available for the production of these animals include natural pasture and browse plants (80%) for open grazing and collected crop residues and AIBPs (20%) for supplementation. The pasture included naturally grown forage, uncollected crop residues and other forage plants in the cultivated fields (Annor *et al*., 2007; Smith, 2010). Few (18%) farmers planted browse plants in their cultivated field mostly near their homes purposely to provide fodder for their animals as copping strategies adopted to manage feed shortages. This was also observed by Karbo *et al*. (1998). Other farmers especially in urban and peri-urban areas purchased leguminous crop residues and AIBPs to increase their supplementary feed stock. Same observation was made by Ayantunde *et al*. (2014) in Mali. The natural pasture and browses were available in grazing areas throughout the year. Also, AIBPs was found in all the seasons of the year but crop residues were mostly available in early and later part of the dry season. The presence of natural pasture in the wet and crop residues in dry season in northern Ghana were influenced by the rainfall pattern and farming system (Karbo and Agyare, 2002; Annor *et al*., 2007; Ohene-Yankyera, 2014). However, the natural pasture availability and quality varied significantly across seasons in the year and posed challenges to feeding of animals. The highest herbage yield (3.1 tonnes DM/ha) was observed in the early dry and the lowest (0.6 tonnes DM/ha) in early wet season whereas late dry and main wet seasons herbage yield obtained were 1.7 tonnes DM/ha and 2.3 tonnes DM/ha respectively as observed in experiment I of this study. Late dry and early wet seasons were therefore the period with acute shortage of herbage in the pasture fields in terms of quantity and fall in line with the report of Annor *et al*. (2007). The quality of natural pasture in terms of N content was however, highest during early wet season and lowest in the late dry season. This was also reported by Powell *et al*. (1995). Oppong-Anane (2013) observed that supplementation of animals with crop residues and AIBPs was practiced by many farmers during the dry season in the study area. This could be an adaptation strategy against the low pasture quality and availability to improve the nutrition of animals and sustain productivity. The purchase of feedstuffs by some farmers for supplementary feeding indicated an increase in investment to counter feed shortages and low feed quality challenges in the dry season. Similar findings were reported in Mali by Omutoni *et al*. (2016).

The emerging feed market could contribute substantially to feed availability in northern Ghana as reported by Huseini *et al*, (2011). The observed sale of crop residues, AIBPs and leaves of local browse plants in the emerging feed market could be attributed to the increasing demand for these feedstuffs emanating from increasing livestock production and trading activities in urban and peri-urban areas where farmers do not have access to natural pasture. Similar observation was reported by Ayantunde *et al*. (2014) in Mali. The presence of AIBPs such as maize bran, corn milling waste and rice bran in the feed market creates an opportunity for the formulation of concentrate supplementary feed at lower cost for ruminants.

The utilization of the feed resources in the area by farmers for livestock production had some challenges emanating from the crop-livestock production system. For instance, the intake of DM and N declined during the main wet season in experiment II and was attributed to the tethering or herding (restrictions) of animals in many communities during the cropping season that denied them access to best green herbage. Another challenge to the feed utilization was low feed digestibility (about 400 g/kg DM) during early and late dry season due to low CP (55 g/kg DM) and high lignin (164 g/kg DM) content of dry fodder in the natural pasture compared to wet season (Table 6.3.4). FAO (2006) reported similar variability in pasture quality in a study of feed resources in Ghana. The variation in feed availability and quality that led to decrease in pasture from wet season to dry season was also reported to result in low intake of DM among animals during the late dry season. This observation was also reported by others (Powell *et al*., 1995; Smith, 2010).

In order to overcome the inadequate feed resource availability and utilization constraints in certain seasons as stated earlier, pasture development and crop residue conservation as well as appropriate supplementation are needed to achieve sustainable year-round livestock production. Pasture development activities to improve herbage yield and quality was not found in the study area except the observed few (18%) farmers who planted some browse plants in their crop fields for harvesting browse leaves for their animals in the cropping season.

The supplementation of animals with crop residues and AIBPs that addresses low feed quantity and quality constraints is a common practice in the study area (Karbo and Agyare, 2002, Annor *et al*., 2007; MoFA, 2011; Oppong-Anane, 2013). The appropriateness of the supplementation in terms of feed ingredients combination and amount offered to animals for improved utilization in all the seasons is a key factor in addressing this problem (Ayantunde *et al*., 2014). In Experiment II of this study, it was observed that formulated concentrate feed increased intake of DM in sheep than control (608 versus 515 g

DM/d). This came from increased amount of daily feed offered and quality of the concentrate supplemented. Similar trend of high DM intake among concentrate supplemented sheep than control group was observed by other workers (Salim *et al*., 2002; Farid *et al*., 2010). The increase in DM and N intake was highest during early wet season than the other 3 seasons. Powell *et al*. (1995) reported similar seasonal variation in N intake among ruminants in Mali. The increased feed offered in terms of quantity and the combination of the concentrate feed ingredients improved feed utilization and resulted to increased ADG of sheep from 18 to 34 g/d. This showed that appropriate supplementation could address the problem of poor quality of feed and low pasture availability in the dry season. Good combination of leguminous crop residues and cereal bran in a ratio of 2:1 improved feed utilization and growth performance of animals as observed in experiment III of this study.

However, the availability and affordability of concentrate feed ingredients (cereal grains) are challenging to most smallholder farmers as it is also the main food for the people in the study area (Oppong-Anane *et al*., 2008). The crop residues and AIBPs are the affordable feed ingredients for supplementation but farmers often run out of stock due to low collection from the fields. Ohene-Yankyera (2014) reported that most farmers in northern Ghana collect only leguminous crop residues but the cereal residues were left in the field. The developing livestock feed market could contribute substantially to feed availability in northern Ghana. Most feed sellers are motivated by the increasing feed demand to increase collection and conservation of feedstuffs to enable them sell in all the seasons. This could help farmers who are prepared to buy feed to address feed limitation challenges.

9.2 General conclusion

In this work, feed shortage was observed in the dry season in the study communities and became acute from February to May. The feed shortage was more severe in Upper East Region than Northern and Upper West regions during the critical period. The occurrence of diseases and associated mortalities were also found to be a major constraint in addition to dry season feed scarcity in affecting livestock production. Herbage yield in the communal pasture of the study sites varied among the four seasons. The highest yield was obtained during early dry season and lowest in the early wet season. Herbage quality was however highest during early wet season and lowest in late dry season.

There was an emerging livestock feed market in which crop residues, AIBPs and leaves of browse plants were sold. The prices of feedstuffs differed at different markets and seasons and were higher at Bolgatanaga market and in early to late dry season. The quality (CP content) of feedstuffs sold was not affected by change in seasons except the browse plants. The CP concentration of feedstuffs was found to have less effect on price variation. Feed traders opined that the feed market has very high growth potential due to increasing urban livestock production and trading.

Concentrate feed supplementation increased intake of DM and N to about 17 and 18% respectively. Season affected the intake and voiding of DM and N in the sheep production system. The ADG of animals increased from 18 to 34 g/d due to the concentrate supplementation.

9.3 Recommendations

The present results imply that improved animal production could be achieved through increase feed resource conservation and the use of best practices in supplementary feeding. This could address the feed shortage constraints of livestock production in northern Ghana.

Government and local authorities should provide permanent market stalls and storage facilities to help accelerate feed trade in the study area. This could increase urban and peri-urban feed availability for ruminant production.

Farmers are encouraged to offer supplementary feed to their animals especially during the late dry season due to poor quality of pasture to improve their productivity. Also, farmers are encouraged to supplement crop residues and AIBPs simultaneously for efficient feed utilization and higher productivity.

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APPENDICES

Appendix I: Fermentation buffer solution for In vitro digestibility

• 630 ml of bicarbonate buffer

• 315 ml of macromineral solution 45

• 0.16 ml of micromineral solution

• 1.6 ml of resazurine solution

• 945 ml distilled water

• 60 ml of fresh prepared reducing solution

• 660 ml rumen fluid.

Bicarbonate buffer

• 35 g sodium bicarbonate ($NaHCO_3$)

• 4 g ammonium carbonate

• Dissolve in 500 ml distilled water and then make up to 1litre.

Macromineral solution

• 6.2 g potassium dihydrogen phosphate (KH_2PO_4)

• 5.7 g disodium hydrogen phosphate (Na_2HPO_4)

• 0.6 g magnesium sulphate ($MgSO_4.7H_2O$)

• Dissolve in 500 ml distilled water and then make up to 1 l.

Micromineral solution

• 10 g manganese chloride ($MnCl_2.4H_2O$)

• 13.2 g calcium chloride ($CaCl_2.2H_2O$)

• 1 g cobalt chloride ($CoCl_2.6H_2O$)

• Dissolve in 50 ml distilled water and then make up to 100 ml.

Resazurine

• 0.1 g resazurine in 100 ml distilled water.

Reducing solution

• 996 mg sodium sulphide ($Na_2S.9H_2O$)

• Dissolve in 94 ml distilled water

• 6 ml 1 *N* sodium hydroxide solution (NaOH)

• 1 *N* NaOH = 4 g NaOH in 100 ml distilled water.

Appendix II: Modified Feed Assessment Tool (FEAST) for feed availability survey data collection

Introduction

Feed Assessment Tool (FEAST) comprises Participatory Rural Appraisal (PRA) guide and semi-structured questionnaire for interview of individual farmers. It is a systematic method for assessing local feed resource availability and use with a view to designing interventions or strategies aimed at optimizing feed utilization. Feed for livestock is often cited as the main constraint to improved productivity in smallholder livestock systems. Overcoming this constraint is challenging and technical feed interventions tend to adopt trial-and-error approach which often fails because the nature of the problem is often not adequately diagnosed and therefore the means to deal with it is not properly designed. The purpose of the Feed Assessment Tool (FEAST) described here is to offer a systematic and rapid methodology for assessing feed resources at site level with a view to developing a site-specific strategy for improving feed supply and utilization through technical or organizational interventions. This FEAST was modified to suit the local condition and used for data collection for feed resource evaluation survey in the study area.

Components of the tool

The tool comprises two main elements. The first is a focused PRA exercise which aims to provide an overview of the farming system with particular emphasis on livestock feed aspects. The second component is a brief quantitative questionnaire designed to be completed with selected farmers under the guidance of the FEAST facilitator. Output from the FEAST consists of a report in a defined format along with some quantitative information on overall feed availability and seasonality.

Focused PRA discussion

Preliminary scoping exercise with local stakeholders

Visit to the area to meet key local stakeholders including agricultural officials and key farmers to get a general understanding of the livestock production system;

Identify target livestock systems and farmers;

Invite a representative group of 15 to 25 men and women farmers to a half day meeting to assess the constraints and opportunities of improving livestock feeding systems. This meeting will consist of a participatory diagnosis with farmers and other stakeholders and visits to local farms to confirm from the ground-truth the earlier discussions and to provide an opportunity for further discussion

Brief quantitative questionnaire

The goal of this section of the questionnaire is to gather specific information from individual farmers about their farming practices, from which the main elements of feed supply and the level of livestock production are obtained.

Part I: Feed assessment tool – PRA discussion guide

Name of site/village:

Name of sub-district:

Name of district:

Number of households in village (*to be considered a household, the dwelling must have a kitchen*)**:**

GPS co-ordinate of PRA location:

Number of participants present: **.............males** **.........females**

1. General farming system description.

Objective: *Obtain a general picture of the farming and livestock system in the area*

1.1. What is the typical (or average) farm size *("farm size" is considered to be cultivated land)*? Also consider additional lands that may be leased or shared.

Acres, hectares or local units *(circle one)* *If local units what is the conversion ratio?* ***1 hectare =*** ***local units***

1.2. What is the typical (or average) household size? On average, how many people have been living continuously in each household for the past 6 months?

1.3. How does the monthly rainfall pattern vary over the past 3 year (on a scale of 0-5, where *5 = heavy rainfall* and *0 = no rainfall*)?

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Rainfall pattern (score 0-5)												

1.4. Name the seasons that occur in this area and influence cropping activities and livestock feeding. In which months do the various seasons occur (tick the appropriate boxes in the table below).

No. of season	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1.												
2.												
3.												
4.												
5.												

1.5. 1.5 What livestock species are raised within the area? What are the animals mainly used for (eg. production of milk for sale, production of milk for household consumption, meat production, draught, manure production etc.)? What percentage (%) of households in the area owns each species? What is the average number of animals per household?

Livestock species	Use	% of HH that owns the species.	Average number of animals per HH
Local Dairy cows			
Improved dairy cows			
Draught cattle			
Fattening cattle			
Sheep			

Goats			
Pigs			
Poultry – village			
Poultry – commercial			
Camels			
Horse			
Donkeys			

2. Management of livestock species

Objective: *Understand how livestock are managed within the area*

2.1. How are animals in the area managed (including how livestock are housed, the primary style of feeding (eg. stall fed, tethered, open grazing) and the level of feed processing undertaken (eg. Chopping, urea treatment, mixing etc.))?

Housing –

Style of feeding (stall fed, tethered, open grazing) –

Feed processing (chopping, urea treatment, mixing etc

Additional comment

2.2 What veterinary (or animal health) services are available to farmers (including clinical treatments needs and accessibility)

3. Problems and opportunities within the livestock system

<u>Objective:</u> *Find out if feed is likely to be a major factor limiting animal production, if it is recognized by farmers and what farmers see as potential solutions.*

3.1. List the major problems faced by farmers in the area with reference to livestock production. What do farmers view as the solution to these identified problems?

Main problems
Problem 1
Solution
Problem 2
Solution
Problem 3
Solution
Problem 4
Solution
Problem 5
Solution

3.2 Complete pair-wise comparisons for these problems in the Table below. For each comparison, record which problem is identified as the more important of the two.

Comparison			Which problem is more important to farmers?
Problem 1	v	Problem 2	
Problem 1	v	Problem 3	
Problem 1	v	Problem 4	
Problem 1	v	Problem 5	
Problem 2	v	Problem 3	
Problem 2	v	Problem 4	
Problem 2	v	Problem 5	
Problem 3	v	Problem 4	
Problem 3	v	Problem 5	
Problem 4	v	Problem 5	

3.3 From the comparison table above, count how many times each problem was rated by the farmers as the most important. The problem with the highest number is considered to be the most important problem limiting animal productivity in the area.

Problems	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
Number of times the problem was considered the most important					

4.1 Farmers should be classified (small, medium and large) within the area/community for individual interviews. Categorization will be based on the amount of land utilised for farming. In previous questions the average farm size was determined. Use this figure as a starting point, add ownership of animals if accepted by farmers to determine:

- how much land or number of animals a **small** (below average land size)**, medium** (average land size) and **large** (above average land size) farmer would have. The cut-off points between the categories should be determined by the farmers.

Based on this information, determine the distribution of farmers in the area/community, i.e. percentage of farmers in the area that would be considered small, medium and large. Record this information in the table below.

Category of farmer	Range of land size	Livestock holding	% of households that fall into the category
Landless	0	0	
Small farmer			
Medium farmer			
Large farmer			

After filling this table, interview equal number of individual farmers from each category (**small, medium** and **large**). Try to select individuals that have land holdings towards the middle of each category.

This should be the end of the PRA section of the survey

Part II Questionnaire for the interview of individual farmers

This section of the survey should be carried out with individual farmers in each household based on their own farms. More than 5 farmers should be interviewed to represent each category of farmers' classification as described

1.0 Background information

Respondent name	
Category of respondent	Below average, average and above average *(circle one)*
How much land do you farm (hectares)?	
Occupation	
Name of village	
Name of district and subdistrict	
GPS co-ordinate of village	
Date	

2. **Livestock holdings**

What types of livestock do you currently own? What is the dominant breed?

Species of livestock	Number of animals
Local Dairy cows – lactating	
Local dairy cows - non lactating (dry)	
Local dairy heifers (>6mths old - < 1st calving)	
Local dairy calves (<6mths old) – female	
Local dairy calves (<6mths old) – male	
Improved dairy cows – lactating	
Improved dairy cows - non lactating (dry)	
Improved dairy heifers (>6mths old - < 1st calving)	
Improved dairy calves (<6mths old) – female	
Improved dairy calves (<6mths old) – male	
Bulls or castrated male cattle (> 2 year)	
Bulls or castrated male cattle (>6mths old - < 2 years)	
Sheep	

Goats	
Pigs	
Poultry	
Donkeys	

3: Crops grown on farm

What crops are grown on <u>your</u> farm? How much would you <u>normally</u> expect these areas to yield (in local units)? What do you do with the residue material (as a percentage)? ***(INTERVIEWER: EXCLUDE CROPS GROWN SOLELY FOR FODDER PRODUCTION. DETAILS FOR THESE CROPS WILL FOLLOW)***

Crops	**Area**	**Local unit**	**1ha= how many local units**	**Yield**	**Local unit**	**1 tonne= how many local units**	**Residue use (%)**				
							Feeding	**Burnt**	**Mulching**	**Sold**	**Other (specify)**

4: Cultivated fodder

What plants (including deliberately planted forage trees) are deliberately grown on <u>your</u> farm for the sole purpose of <u>feeding</u> livestock? How much area is used to grow these crops?

Fodder crops grown	Area (in local units)	Local unit	1ha= how many local units

5: Feeding of livestock with collected and purchased feedstuffs

Do you collect any naturally occurring green fodder material from surrounding areas? Or buy any feedstuffs for livestock feeding? Naturally occurring green fodder can include: thinning, weeds from cropping areas, roadside weeds, naturally occurring grasses, or any other green material that is naturally occurring and can be offered to livestock. If so, how much does this material contribute to the diet (as a percentage)?

Contribution of supplementary feeding to the diet of ruminants (%)	

6. Purchased feed

What feeds do you purchase over a typical 12 month period? Feeds can include: crop residues, green fodder, commercially available mixed concentrate feeds, industrial by-products or any other material that is purchased for the purpose of livestock feed. What is the price of these feeds? How much do you purchase (in kilograms) each time you purchase the feed? How many times throughout the year do you purchase each feed?

Feeds purchased	Price/ local unit	Local unit name	1 kg = how many local units	Quantity purchased each time you purchase feed (local unit)	Number of times purchased throughout the year

7. **Grazing**

Considering everything eaten by livestock (eg. crop residues, roadside grasses cut and brought back to animal, grown fodder material, purchased feed), how much does **grazing** contribute to this over the course of a year (as a percentage)?

Contribution of grazing to the diet (%) of ruminants	

8. **Contributors to household income**

What percentage (%) of household income do each of these sources listed below contribute in your house?

Income Source	**Contribution to Income (%)**
Food crops	
Livestock	
Laboring/service	
Off- farm business	

Remittances	
Other (Specify)	
Must add to 100%	***100***

9. **Seasonality of feed in the pasture**

(*<u>Make the following sections quicker and easier for respondents, show them their responses as they are answering. it will allow them to visualize trends).</u>*

a. How does the availability of feed vary over an average year in the pasture? (on a scale of 0-10, where *10 = excess feed available*, 5= *adequate feed available and 0=no feed available*)

Month	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Feed availability (score 0-10)												

Questionnaire completed.

Thank the participants for their time!!

APPENDIX III: Assorted feedstuffs sold at the markets

Feed venders serving customers at the market

Livestock trades interacting with feed vendors at the market

Appendix IV: Commonly grazed forage species in Northern Ghana

Axonopus compresus

Chrysopogon zizanioides

Sprouting *Andropogon gayanus*

Digitaria ciliaris

Pennisetum pedicellatum

Digitaria horizontalis

Appendix V: Supplementation of animals and grazing from pasture in all seasons

a. Concentrate supplementary feed being offered to sheep

b. Animals grazing on pasture in farm land during early dry season

c. Animals grazing on pasture during late dry season

d. Animals grazing on pasture during early wet season

e. Tethered animals during main wet season for grazing

f. Weighing of animals and faecal samples collection