UNIVERSITY OF KWAZULU-NATAL

THE EFFECT OF SUPPLEMENTING MILLET STOVER WITH GROUNDNUT HAULMS AND CEREAL BRANS ON FEED INTAKE AND GROWTH PERFORMANCE OF SHEEP

NOUROU ABDOU

2010

The effect of supplementing millet stover with groundnut haulms and cereal brans on feed intake and growth performance of sheep

By

NOUROU ABDOU

Supervisor

Prof. Ignatius V. Nsahlai

Submitted in fulfilment of the academic requirements for the degree of

Master of Science in Agriculture

In the Discipline of Animal and Poultry Sciences

School of Agricultural Sciences and Agribusiness

Faculty of Science and Agriculture

University of KwaZulu-Natal

Pietermaritzburg

2010

General Abstract

Feeding of animal has become increasingly a big challenge for smallholder farmers in the dry season in most of Sahelian countries. Sheep has an important role in social and economical activity of smallholder farmers. Millet stover (MS) and groundnut haulms (GH) are the main crop residues used. Among concentrates, millet bran (MB) and wheat bran (WB) are mostly used by smallholder farmers in feeding animals. However, these crop residues and concentrates are used inadequately. MS is a poor quality roughage diet, legume residues such as GH and brans are rich in nutritive value. The general objective of this study was to develop a feeding technology transferable to smallholder farmers by supplementing MS with GH, MB and WB to increase the growth performance of sheep during the dry season.

The first study evaluated the effect of chopping millet stover (*Pennisetum glaucum L.* R. Br.) in sheep feeding and the degradability *in sacco* of feeds. Two Holstein cows were used to determine the degradability *in sacco* of feeds. The potential dry matter degradability (g/kg) were 846, 809, 730, 410, 550 and 370 for millet bran (MB), wheat bran (WB), groundnut haulms (GH), millet stover, leaves plus sheath and stems of MS respectively. The potential nitrogen degradability (g/kg) of MB, WB and GH were 865, 908 and 817 respectively. The nitrogen content was 7.4, 15.1, 22.0 and 26.2 g/kg for MS, GH, millet bran and wheat bran respectively. The effects of chopping millet stover (MS) on dry matter intake in Oudah bicolor sheep were studied in Maradi, Niger. Four treatments were T0 (unchopped MS), T1 (MS chopped, 50 cm), T2 (MS chopped, 25 cm) and T3 (MS chopped, 10 cm). A randomized block design was applied on 36 sheep, implying 9 sheep per treatment (T0, T1, T2 and T3). The treatment T2 or 25 cm chopping size gave the best MS intake of 560 g/day.

The second study evaluated the effects of supplementing millet stover (MS) with groundnut haulms (GH), millet bran (MB) and wheat bran (WB). These supplements can improve the feed value of MS and promote live weight gain of sheep in the dry season. The purpose of this study was to develop a feeding technology transferable to smallholder farmers by supplementing MS. The study was conducted in two successive phases. The phase 1 of 66 days**,** evaluated the effect of GH, MB and WB supplementations on MS intake and growth performance of sheep, the phase 2 of 14 days, assessed the effect of GH, MB and WB supplementations on intake and digestibility of MS. Six treatments were constituted, namely, 1, 2, 3, 4, 5 and 6 formed by four levels of GH (0, 200, 400, 600g) and two others (600g GH + 100g MB) and (600g GH + 75 g WB) respectively. A randomized block design was applied on 36 Oudah bicolor sheep, implying 6 male lambs per treatment (1, 2, 3, 4, 5 and 6). The GH supplementation levels had a linear effect ($P<0.001$) on dry matter intake (DMI) of MS, cell wall and nitrogen. Millet stover intake (MSI) decreased significantly with increasing level of GH. However the total dry matter intake (TDMI) significantly increased with GH levels. MB increased ($P<0.05$) both TDMI, TOMI and nitrogen intake (NI), ($P<0.001$). WB increased MSI ($P<0.05$), TDMI and TOMI ($P<0.01$), NI ($P<0.001$) and cell wall intakes. GH supplementation had both a linear and quadratic effect on DM digestibility of MS, cell wall and nitrogen digestibility. GH had a linear and significant effect ($P<0.001$) on live weight gain (LWG) and efficiency. The maximum average daily gain (80.5 g/day) was obtained with treatment 6 followed by the treatment 5 (68 g/day). The animals of treatment 1 received MS stover alone and lost their weight (-19.13 g/day).

It is concluded that groundnut haulms, millet bran and wheat bran had good nutritive value whereas millet stover had low nutritive value. The 25 cm chopping size was the one to propose to smallholder farmers. The supplementation of MS as the basal diet with GH and brans enhanced sheep production through improvements in digestibility and intakes of TDM, TOM, cell wall and nitrogen.

Key words: Millet stover; groundnut haulms; millet bran; wheat bran, chopping; intake; degradability; growth performance; Oudah bicolor sheep.

Declaration

The research described in this thesis was carried out in the Discipline of Animal and Poultry Sciences, Scholl of Agricultural Sciences and Agribusiness, Faculty of Science and agriculture, University of KwaZulu-Natal, Pietermaritzburg Campus, under the supervision of Prof. Ignatius V. Nsahlai.

This is to declare that this thesis is the result of my own investigation and has not been presented in any previous application for a degree. All sources of information are shown in the text and listed in the references and all assistance by others has been duly acknowledged.

NOUROU ABDOU
UNIVERSITY OF KWAZULU-NATAL
PIETERMARITZBURG CAMPUS

Signed.................................. Date............................

I, Prof. Ignatius V. Nsahlai the supervisor, approved the release of this thesis for examination.

Signed.................................. Date............................

Acknowledgements

I would like to express my earnest thanks and appreciation to my major supervisor, Prof. I.V. Nsahlai for his unreserved academic support and guidance in the planning and execution of my research. His patience and active involvement in reading and correction of my dissertation are highly acknowledged.

I am very grateful to Prof. M. Chimonyo for his time and patience, and as well his academic contribution towards the accomplishment of this dissertation.

Many thanks to the staff of the Regional Centre for Agricultural Research (CERRA) and the service assistants of Zootechnic Station of CERRA Maradi, Niger for facilitating the execution of my field work in Niger and their assistance during my field work, respectively. I am also grateful to the entire staff of National Institute for Agricultural Research of Niger (INRAN) for their support and encouragement.

Many thanks to all the staff of the Department of Animal and Poultry Sciences of the University of KwaZulu-Natal for their kindness, understanding and perseverance throughout the period of my study. I wish to express my appreciation to the staff of Ukulinga Research Farm of the University of KwaZulu-Natal (UKZN) for their assistance during my field trial.

I wish to register my sincere appreciation to my entire family member for their moral support and understanding. My Thanks also goes to my relatives, friends and colleagues for their encouragements.

My due respect goes to my late father, Elhadji Abdou Maïkano, my late grandmother Hadjia Zeinabou (Magagia) for their moral upbringing, and to my living grandfather Elhadji Mansour and my mother Hadjia Absatou for their constant prayer and encouragement throughout the period of my studies.

This study research was funded by Forum for Agricultural Research in Africa (FARA). It’s my pleasure to thank the Executive Secretary of FARA, Prof. Monty Jones and support staff for their understanding. Commitments of the FARA coordinating Unit of UKZN are highly appreciated.

To my wife, **Habsatou SALIFOU**, I thank you for the love, understanding and patience while I stay away from you during the period of my study. I just appreciate. To my children, **Mahaman Mansour** and **Abdoulaye** your patience and understanding are well acknowledged.

Last, but not the least, all thanks are due to Almighty Allah (SWT) for the most Wealthiest Bounties and Endless Mercies that put me through this programme to successful completion. My Lord, I thank You for all that You did to me in my life.

Table of Contents

List of tables

List of figures

List of abbreviations

ADF = Acid Detergent Fibre

ADL = Acid Detergent Lignin

AOAC = Association of official analytical chemistry

BWt = Body Weight

CERRA = Regional Centre for Agricultural Research

CF = Crude Fibre

Co = Cobalt

CILSS = Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel

CP = Crude Protein

Cu = Copper

DM = Dry Matter

DMN = Direction de la Météorologie Nationale du Niger

DP = Digestible Protein

E = Energy

FAO = Food and Agriculture Organization

FAOSTAT = Food and Agriculture Organization Statistics

g = gramme

GDP = Agricultural Gross Domestic Product

ILCA = Iternational Livestock Centre for Africa

INRAN = National Agricultural Research Institute of Niger

Kcal = Kilo calory

Kg = Kilogramme

ME = Metabolizable Energy

Mg = Mega gramme

MJ = Mega Joules

MM = Mineral Matter

MRA = Ministère des Ressources Animales

N = Nitrogen

Na = Sodium

NE = Net Energy

NDF = Neutral Detergent Fibre

NPN = Non Protein Nitrogen

NR = Nutritional Ratio

OM = Organic Matter

P = Protein

P = Phosphorus

PPM = Part Per Million

PPR = Peste des Petits Ruminants

UF = Feed Unit

UKZN = University of KwaZulu-Natal

RELMA = Regional Land Management Unit

RGAC = Recensement General de l'Agriculture et du Cheptel

S = Sulphur

SSA = Sub-Saharan Africa

SAS = Statistical Analysis System

VFA = Volatil Fatty Acids

Zn = Zinc

Chapter 1

General Introduction

1.1 Background

In Niger, livestock contributes annually about 11% of the national agricultural Gross Domestic Product (GDP) and more than 35 % of the agricultural GDP. The recent statistics on livestock were about 7.5 million cattle, 9.2 million sheep, 11 million goats and 1.6 million camels (RGAC-Niger, 2007). Livestock plays an important role in the smallholder farming system. Livestock products represent a source of quality food and mobilizable income of farmers' households. Indeed, the main part of monetary income of the pastoral and agro-pastoral households comes from milk, yoghurt, butter, cheese and the sale of live animals. Livestock products represent a significant portion of healthy and balanced diets by providing calories and proteins which are of great importance in the prevention of malnutrition. They contribute to healthy, balanced diets, food security and may contribute to decreasing problems of food availability due to seasonal variability caused by climate change. Livestock constitutes, for the large majority of households, an important source of income and an economic factor of stability.

In Niger, more than 80 % of the human population are farmers and the human population is growing quickly (SDR-Niger, 2010). Crop-livestock linkages are becoming increasingly important. But the rainy season (June to September) is too short with often a decreasing rainfall, and the dry season is too long (October to May) with forage shortages occurring from March to June. Therefore, the agro-pastoral system has developed and is predominant. This system is practised by all farmers as well as livestock farmers who came and settled in agricultural zone where rainfall is good for cultivation. In this zone, animals are generally fed on natural pastures and crop residues.

However, in the dry season, all the herds live together with transhumance herds in the agricultural zone despite the feed deficiency mostly between April and June. This period is also characterized by the availability of highly fibrous forages. So, farmers struggle to feed the animals with stored crop residues after coming back from pastures. At that particular period, the pastures are scarce and would not satisfy the animal maintenance.

Besides its importance in livestock number, sheep has also an important role in the culture and the economical activity of people. Sheep meat constitutes the first choice in religious feasts and ceremonies (marriages, baptisms). Thus, in rural areas and suburbs, men and women prefer to fatten sheep for sale in big livestock market or for export. In the livestock markets, sheep are more popular (50 %) than both cattle and goats (25 %) (MRA-Niger, 2000). Also, in terms of selling, sheep are sold (64 %) more than both cattle and goats (36 %) because of high demand for sheep meat (MRA-Niger, 2000).

Sheep meat is more appreciable than other meats. The use of crop residues in fattening sheep has increased the income and livelihood of smallholder farmers (Siddo, 2001; Issa et al., 2006). According to MRA-Niger (2000), in 1998, about 2 billions, 1.7 billion and 301 millions FCFA were the incomes from respectively sheep, goats and cattle exportation. The demand of sheep meat increases from day to day according to population growth. However, in the dry season, animals are fed on cereal or/and legumes residues generally with low growth performance while the meat demand increases. For this reason, some studies (Moctar, 1996; Dan-Gomma, 1998; Siddo, 2001; Sangar**é** et al., 2005; Issa et al., 2006; Ayatounde et al., 2007) focus on sheep production to respond to that demand and to help farmers to increase their livestock income.

To reduce the forage deficiency in the dry season, the smallholder farmers store about 53 % of cereal and legume residues after harvesting crops (INRAN, 1996). However, cereal crop residues have low nutritive value; they have high fibre levels which limit their degradability in the rumen. They are low in protein and energy; and deficient in important minerals and vitamins (Chenost and Kayouli, 1997; Ben Salem and Smith, 2008). They have high content of cellulose, hemicellulose and lignin, which constitute about 60 to 80 % of the plant. Cellulose content is high which constitutes about 32-47 % the dry matter (DM) of the plant (Chenost and Kayouli, 1997). The high cell wall characteristic explains the low intake and low digestibility of cereal crop residues. Many studies have shown that the feeding value of these cereal residues is limited (Boukary, 1999; Koralagama et al., 2008). Animals when given these feeds without adequate supplementation perform poorly.

Several methods have been introduced to improve the feeding value of crop residues among which are physical treatment, chemical treatment and dietary supplementation (Chenost and Kayouli, 1997). However, the first two technologies cost much for farmers and sometimes the technical control constitutes a big handicap. Therefore, the technological adoption has not been significant. Rather, the best way to improve the quality of crop residues is to chop (manual physical treatment) and supplement the dietary since most of the farmers are poor and produce the supplements in large quantities on-farm. In addition, the supplementation technique is easily accessible and adopted by farmers.

Ruminants can effectively use the fibrous feeds due to the action of rumination and rumen microbes. When there is a deficiency of feed resources, nutritive feed supplements are required to satisfy the rumen activity. The feeds should provide nitrogen, energy and minerals to optimize the rumen ecosystem. Among the feed resources, crop residues and agro-industrial by-products are the feed supplies used by smallholder farmers to fill the feed gaps during the period of acute deficiency of feed resources (Sangar**é** et al., 2005; Ayatunde et al., 2007; Karalama et al., 2008). Research works have shown that fattening sheep with legume haulms, tree legumes and tree pods increase growth performance of sheep (Nianogo et al., 1995; Karimou, 1996; Dan-Gomma, 1998; Siddo, 2001; Issa et al., 2006). Most tree legumes, however, contain substantial levels of polyphenolic compounds.

Agro-industrial by-products should also be used to improve the quality of cereal crop residues. They are rich in nitrogen and metabolisable energy. Common examples are cottonseed cakes, groundnut cakes, wheat, and millet bran in Niger. However, the high cost and availability of cotton seedcakes and groundnut cakes are principal constraints to smallholder farmers (Zoundi et al., 2006). Millet and wheat bran are more accessible, at affordable prices in the market. Millet bran is obtained from the processing of millet grain for household food and is generally available with smallholder farmers. This study uses wheat and millet bran obtained from the smallholder farmers as concentrates to supplement the roughage diets.

As, indicated above, crop residues are deficient in minerals. Thus, mineral block should be bought as a supplement to compensate for that deficiency. Mineral block is a natural local product made from saline clay in Niger. It is used as a mineral supplement by some farmers in animal feeding.

1.2. Objectives

The overall goal of this study is to improve the feeding value of millet stover (MS) by supplementing with groundnut haulms (GH), millet bran (MB), wheat bran (WB) and mineral block to increase the growth performance of sheep during the dry season. The specific objectives are to characterise the nutritive value of MS, GH and cereal brans; to determine the best chopping size of millet stover in sheep feeding; and to evaluate the effects of GH on the intake and digestibility of MS and the growth performance of sheep.

1.3 Hypothesis

- Chopping of millet stover could increase the intake and reduce the feed wastage;
- Degradability of stems is lower than leaves and whole millet stover;
- Supplementing sheep fed on millet stover with groundnut haulms source of protein and energy would improve live weight gain;
- Millet bran and wheat bran could improve rumen activity and therefore the digestibility and intake of millet stover.

Chapter 2

Literature review

2.1 Introduction

Livestock is the second sector of agricultural economy after crops in most West African countries. It contributes about 35 % of Agricultural Gross Domestic Product (GDP). Nowadays, small holder farmers have become crop-livestock farmers. This situation allows them to adapt to the climate change resulting from the uncertain rainy season. Thus, smallholder farmers sell their animals to buy crops and other family needs to improve their livelihood. They often raise sheep, goats and other livestock. Smallholder farmers generally evolve to crop-livestock systems in which crop residues are stored and used for animal feeding to generate some income in the dry season. Legumes crop residues in African tropical countries are high in nutritive value but cereal crop residues have low nutritive value. The latter are low in crude protein and high in fibre contents which decrease their digestibility and intake. Thus, feeding strategies based on local available feed resources are required in order to increase the feeding value of cereal crop residues in African tropical countries. For alleviating these constraints of low quality residues, the feeding strategies should be chemical treatment, physical treatment or supplementation of cereal crop residues. Thus, one can achieve the goal of improving the feeding value of high roughage diets and therefore the increase of smallholder farmers' incomes. Agro-industrial by-products and tanniniferous fodders could be used in a supplementation technique to improve the feeding value of cereal crop residues but these supplements have shown their limit due to their high cost and unavailability. To reach the above aims, the best way is the strategic supplementation by which cereal crop residues as millet stovers should be supplemented in the dry season with legume crop residues such as groundnut haulms and cereal bran since both are the main crop residues produced by smallholder farmers in West Africa. On the other hand, mineral blocks are locally available; they should be used as a supplement to improve the use of cereal crop residues by animals. Thus, the nutritive value of cereal crop residues may be improved by supplementing with legumes crop residues, cereal bran and minerals.

2.2 Overview of livestock production in Niger

In West Africa, particularly in the tropical areas, the natural resources constitute the basis of human life. In the Sahel, 7 out of 10 people still live today in rural areas and nearly 80 % of this population live in the hyper arid, arid or semi-arid zones (Issa, 2006). The Sahelian economies are founded primarily on the exploitation of the natural resources. In the rural areas, 95 % of the population exploit lands vulnerable to desertification and among this population, 62 %, more than 27 million of people live below the poverty line (CILSS, 2002). Crops and livestock production are at the heart of natural resource usage in West Africa. Crops and livestock activities, which primarily characterise the economy of these areas, are dependent on availability of soils, biomass and water.

The importance of livestock in West Africa agricultural economy is huge. In this area, livestock is an essential and vital component of the production systems; it contributes for example 11% to 15% of national gross domestic product (GDP) in Cameroon, Central African Republic and Chad (Kamuanga, 2002). In Niger, livestock contributes annually about 11% of national GDP and more than 35 % of the agricultural GDP. The recent statistics on livestock gave about 7.5 million cattle, 9.2 million sheep, 11 million goats and 1.6 million camels (RGAC-Niger, 2007). However, the real contribution of the livestock sector to GDP is generally under estimated because all roles of this sector are not taken into account in the national economy (Kamuanga, 2002).

Livestock is a main source of income for farmers when the access to the market makes it possible to sell live animals and livestock products and when the use of animal ploughing and animal draught is evaluated (Kamuanga, 2002; Randolph et al., 2006; Francis et al., 2009). Indeed, when the control of the animal speculations is well managed, the livestock systems advantages are huge. Also, crop-livestock systems offer many advantages. Crop residues can be used to feed animals and the animal energy such as ploughing and animal dejection such as faeces can be used to increase crop productions.

In Niger, ruminants are generally raised in semi extensive system. In the dry season, they are supplemented with crop residues, tanniferous forages and agro-industrial by-products. Large variations of Sahelian climate, however, cause significant deterioration in the nutritive value of crop residues (Reed and Van Soest, 1985).

The low nutritive value of feeds is the major constraint to livestock productivity in sub-Saharan Africa especially during the long dry seasons (Chenost and Kayouli, 1997; Makkar, 2007; Sancoucy and Hassoun, 2007). In fact, ruminants are fed on poor basal diets, which are low in nitrogen and minerals and sometimes contain antinutritional substances, such as tannins. These factors reduce rumen fermentation and, consequently decrease the intake and digestibility of feeds (Murphy and Pablo, 1999). Therefore, poor animal performance is registered.

In Niger, as well as in the other countries of West Africa, efforts have been made both by government and development projects to test and adjust new technologies appropriate to local conditions. Concerning animal nutrition, technology for treating straw with urea and supplementation with multi-nutritional blocks have been popularized but poorly adopted by farmers. This is due to a lot of reasons. The high cost and low availability of urea could be the main obstacles to the adoption of the technology and the priority for farmers with urea is to fertilise their fields (Ben Salem and Smith, 2008). On the other hand, the duration of treatment and handling of urea balance, often cause a risk of toxicity to animals. The low consumption of multi-nutritional blocks by animals, especially small ruminants, due to its hardness could be another reason for non-adoption (Zoundi, 2006).

When the control of the animal speculations is well managed, the livestock systems experience huge advantages. On a farm scale, livestock products represent the source of farmers' incomes. The main parts of monetary income of the pastoral and agro-pastoral systems come from milk marketing and derived products such as yoghurt, cheese and the sale of live animals. Livestock represents for a large majority of farmers, a factor of food stability. Indeed, in the case of food unavailability due to the rainy season uncertainty, with livestock income, farmers can buy food to secure their households. The world's average value in 1990-1992 of the meats and produced milks was estimated at 214,9 million dollars, higher than the value of the most sold cereals (corn, and rice) in the developing countries (FAO, Agriculture Horizon 2010) cited by Kamuanga (2002).

The processing sector of animal products considerably generates employment, which in the long term, would limit rural depopulation. In the rural area, dairy production is an activity which requires a lot of labourers in the farm. In dairy farming, labourers are used for more than 40% of the production costs. The transformation of milk and meat generates a lot of employment where agricultural factories are developed (FAO, 1994) cited by Kamuanga (2002). Livestock products such as meat and milk can be produced continuously during the year for consumption and marketing and effective methods of conservation exist even in traditional societies.

Livestock products provide calories and proteins which are of great importance in the prevention of malnutrition. The per capita animal protein intake distinguishes the rich countries and poor countries. It is 50 g/day/person in developed countries and 17g/day/person in developing countries (FAOSTAT, 1999) cited by Boutonnet et al. (2000). The per capita animal protein intake has decreased since 1982 to 11 g/day/person in 2000. This is very insufficient since the minimum supply is 20 g/day/person (Laage de Meux, 1998) cited by Boutonnet et al. (2000). The individual mean availability of animal production has decreased in Sub Saharan Africa since the last decade. However, cattle, sheep, and goats meat is about 2/3 of the total consumed meat, so this is higher than pig and poultry meat consumption in Sub Saharan Africa. According to Boutonnet et al. (2000) the prediction in 2020, of the consumption of meat in town would be superior by 1.8 to rural zones in Sub Saharan Africa.

2.3 Livestock production systems

There are three great livestock systems; namely the pastoral or extensive system, the sedentary or semi extensive system and the intensive system.

2.3.1 The extensive system

The extensive system, also called the pastoral system, is practised in zone of 150 - 350 mm rainfall by pastoral populations which are characterised as pure herders who do not practise agriculture, livestock products are their only resources. They adopt transhumance for searching for pastures and water. In this system cattle predominate more than sheep and goats. Herd feed resources are mainly natural pastures. Animals are raised based on their ability to use pastures and tanniniferous trees of natural grazing lands. Traditionally the principal purpose is prestige, the availability of pastures orders the movements of herds which define the nomad or transhumant systems. The dairy production occupies a significant place in the management of this system. Although, the sale of live animals is not the principal purpose of this activity, it is the principal source of monetary income (Boutonnet et al., 2000).

Nowadays, in consideration of the degradation of pastures, the effect of dryness leading to animal losses and the crops domination on pastoral zones, herders have gradually modified their systems of livestock production and have adopted crop cultivation. This situation leads them to sedentarisation (Boutonnet et al., 2000).

2.3.2 The semi-extensive system

The semi-extensive system is also called the peasant system or the agro-pastoral system owing to the fact that it combines crops and livestock production. This system is practised in zone of 350 - 800 mm rainfall by livestock farmers who have adopted crop production, and the farmers who have adopted livestock production. The combination of animal species makes it possible to provide manure and animal draught. In this system, sheep and goats dominate more than cattle. Therefore, it should be noticed that there is a significant relationship between livestock farmers and crop farmers. This relationship is called the manure contract in which the livestock farmers' animals fertilize the farmers' fields while farmers' crops residues feed the livestock farmers' animals.

Both of these producers choose sheep and/or cattle among their herds and fatten them in order to reap profit from livestock. Dairy production is in fact an additional livestock profit. With an increasing population, the crop-livestock system is growing up significantly in Sahelian zones. Thus, the use of crop residues in ruminants feeding has been increasing. So, one can note the progression of agro-pastoral systems while the pastoral systems decrease from day to day. Nowadays most livestock farmers practise agriculture (Boutonnet et al., 2000) and the animals are fed on crop residues such as groundnut haulms, cowpea haulms, cereal stover and agro-industrial by-products namely cereal bran, cottonseed cake, etc.

2.3.3 The intensive system

The intensive livestock system is practised mostly by rich farmers for dairy and meat production. It is more developed especially in suburban zones in order to satisfy the high demand of the urban population. In this system, cattle and sheep are only used. Animal feeds or forages which are generally produced on the farm such as crop residues, cultivated forages and the concentrates; but these are bought in the market or imported. The main feed used is groundnut and cowpea haulms, cotton seedcake, groundnut cake and wheat and millet bran. The system requires a lot of investment and huge cost of labour.

2.4 Role of sheep

Sheep contribute both to subsistence and cash income generation (RELMA, 2007; Francis et al., 2009). The importance of raising sheep differs from one livestock system to another. In the extensive system, the role of sheep is prestige generally. Indeed, the livestock breeders prioritize the number of sheep to the benefit gained from the animal, but they sell them to buy food and to celebrate ceremonies (Francis et al., 2009). These roles are the same even in the semi extensive system which is implemented by smallholder farmers. These also sell sheep to provide security in bad crop years. However, in the smallholder farming system, sheep production and cash income generation are more attractive than animal numbers. Thus, they raise sheep to increase their incomes (Sangaré et al., 2005; Ayatounde et al., 2007) by selling them in local livestock markets. As for the intensive system, sheep are raised and fattened mostly for exportation to other West African Countries such as Nigeria, Senegal and Cote d'Ivoire where the price is much better.

Sheep meat is the first choice in Niger because of the religion. These animals are preferably slaughtered during the annual religious feast of Muslim (Aid-El-Kebir) and ceremonies such as marriages and baptism. But the procurement depends on the purchasing power of people. This explains why sheep meat is more used in urban areas where people have higher purchasing power than rural areas where people are generally satisfied with goats meat because of their weak revenue.

2.5 Challenges of sheep production in smallholder farming systems

2.5.1 Feed availability

In Sahelian countries such as Niger, feeding animals is the most important problem due to unreliable rainfall which results in frequent droughts. Thus, sheep are liable to under feeding and malnutrition which affect production and provoke abortion, prenatal death and sometimes the death of entire flocks (Ben Salem and Smith, 2008). The most vulnerable are growing, older and pregnant animals. To alleviate this problem, agro-industrial by-products such as cottonseed cake and wheat bran are used. However, these supplements are not accessible to all smallholder farmers as well as livestock farmers. Thus, smallholder farmers use stored crop residues despite their poor nutritive value at this particular period to decrease the gap (Chenost and Kayouli, 1997; Ben Salem and Smith, 2008). So, feed insufficiency affects the growth of sheep mostly in the difficult period of feed scarcity which occurs from April to June.

2.5.2 Diseases

It is well known that diseases affect animal production (Francis et al., 2009). The most important diseases which affect sheep are parasitic gastro-intestinal and pulmonary infections. These cause diarrhoea, enteritis and pneumonia. Malnutrition and parasitism contribute to reducing animal production, and both are factors which can predispose animals to infectious diseases. The most important infectious diseases which affect sheep are small ruminant pest (PPR) and pasteurellosis. All efforts are made by the national livestock service through the National vaccination campaign to vaccinate all the categories of livestock. Thus, most infectious diseases have been completely eradicated.

2.6 Characteristics of forages

2.6.1 Physical characteristics of forages

According to Leng (1990), low-quality forages are defined here as those forages which are less than 55 % digestible and are deficient in true protein (say less than 80 g crude protein (nitrogen x 6.25; CP)/kg) and low in soluble sugars and starches (usually less than 100 g/kg).

Table 2.1 Estimation of forage quality with respect to NE and DP (Boudet et Rivière, 1968)

Quality	Net Energy (MJ/kg DM)	Digestible Protein in % DM	Nutritional Ratio in g DP/FU/kg DM
Poor	NE<3.10	DP < 2.5	NR < 55
Fair	3.10<NE<3.45	2.5<DP<3.4	55<NR <68
Good	3.45<NE<4.15	3.4<DP<5.3	68<NR <88
Excellent	4.15<NE	5.3<DP	88 <NR

MJ=megajoules, DP=digestible protein, FU=feed units, NE=net energy NR=nutritional ratio, DM=dry matter, 1 MJ= 239 Kcal= 0.145 FU, NR*:* is the quotient of DP (in g per kg of DM, or in %.) over NE, expressed in FU/kg DM., 1FU (for ruminants consuming roughage) = 6.9 MJ = 1650 Kcal.

According to Kayouli (1976, 1994), in tropical zones, straws and stalks of cereal and grasses are poor (Table 2.1 and Table 2.2). They are rich in fibre and lignin which decrease their digestibility in the rumen. It should be noted that the nutritional value of these forages, particularly straw, presents a great variability. This variability depends mainly on the botanical family, species, phenological stage, maturation conditions, conditions for harvesting and storage (Boudet, 1971, 1991; Buldgen 1997; Grenet, 1997). A study in Burkina Faso (Zoungourana, 1995) showed that the digestibility in vivo of *Andropogon gayanus* changed from 56% in the green stage to 31% at the drying stage when the plant has become very rich in fiber. The same author noted that the quantity of dry matter intake by sheep decreased from 63 to 26 g DM/kg $LW^{0.75}$ from the beginning of the rainy season to the beginning of the dry season respectively. Indeed, it has been noted that significant variations in the nutritive value of Sahelian forages are due to the phenological stage (Boudet, 1991).

2.6.2 Chemical characteristics of forages

Due to their particular physiology resulting in a very early lignification, tropical forages are generally of lower quality than temperate forages (Chenost and Kayouli, 1997). Legumes crop residues and tree leaves have high fiber and high protein and agro-industrial by-products have low fibre and high protein (Jayasuriya, 2002). The study of Jayasuriya classified animal feeds (Table 2.2) based on fibre and protein contents. Cereal straws and stovers have high fiber and low protein (Table 2.3).

Table 2.2 Proximate composition of some common feedstuffs found in developing countries in Africa and Asia (Jayasuriya, 2002)

Classification	CP g/kg DM	CF g/kg DM	NDF g/kg DM	Digestibility % DM	Ash g/kg DM
High fiber-low protein	20-60	>300	>700	20-45	15-120
High fiber-high protein	60-350	100-300	400-700	50-70	10-150
Low fiber-low protein	<60	120-200	-	40-60	30-120
Low fiber-high protein	200-600	30-300	-	60-80	20-200

CP : Crude Protein ; CF: Crude Fibre ; NDF : Neutral Detergent Fibre

The proportion of plant cell walls and their degree of lignification increases with the age of the plant and affects the digestibility negatively. From a nutritional context tropical forages have the following disadvantages. They have a high cell wall content namely, hemicellulose, cellulose and lignin which constitute about 60 to 80 % of the plant. Cellulose is the most important constituent which is about 32-47 % of DM of the plant (Chenost and Kayouli, 1997). It is a homopolyoside constituted by long linear chains of ß 1-4 glucose, called cellobiose, associated into microfibrils which lead to a formation of fibres of which some zones have a high crystallinity. True cellulose is fully digestible (Chenost and Kayouli, 1997).

Table 2.3 Extreme values of chemical composition and digestibility of some tropical crop residues (Chenost et al., 1993; Kayouli, 1979, 1988, 1994a, b)

Forage	Number of samples	Origin	DM %	Crude Fibre (DM %)	Crude Protein (DM %)	Digestibility in sacco (72 h) or Rexen (*) cellulase digestibility
Rice straw	35	Niger, Cambodia	91	35–40	3–5	35–41
Rice straw	15	Madagascar, Mauritania	90		3–7	30–35(*)
Wheat straw	30	Tunisia	89	37–43	2–5	39–35
Sorghum stalks	18	Niger, Togo, Burkina Faso	90	32–45	2–8	32–44
Maize stalks	8	Tanzania, Gambia	90		3–5	34–46 (*)
Millet stalks	23	Niger, Togo	90	35–46	2–7	32–40
Panicum spp.	15	Niger, Togo, Burkina Faso	90	36–45	2–5	35–45
Andropogon gayanus	7	Niger, Burkina Faso, Gambia	90	40–47	2–3	30–38

The hemicelluloses are amorphous hetero-polymers made up from the hexoses (glucose, mannose, galactose) and mostly from the pentoses (xylose, arabinose). The molecular chains of these macromolecules are relatively short. They constitute a polysaccharidic matrix which is often associated with phenolic constituents surrounding the cellulose fibres (Thompson, 1983). Hemicelluloses are only partially digestible (Reed and Van Soest, 1984). According to Grenet and Barry (1990), the interactions between lignin and polysaccharides influence strongly the speed and intensity of degradation of the walls. Lignin is entirely indigestible and lowers digestibility of cell wall carbohydrates (Reed and Van Soest, 1984). Indeed, it is phenolic heteropolymers, which are bound to hemicelluloses. The organization is made around the cellulose microfibres and forms a dense lattice which is resistant mechanically (Chenost and Kayouli, 1997).

Tropical forages have low nitrogen value. Crop residues are low in total nitrogen (Chenost and Kayouli, 1997). The same is true of native perennial grasses where the nitrogen level decreases sharply with age (Zoungrana et al., 1999). In the dry season and after the flowering stage, the nitrogen level decreases considerably. The nitrogen of tropical forages is often inaccessibly related of cell wall lignification (Dulphy, 1978). The nutritional value of leaves is generally higher than that of stems (Ramasin et al., 1986, Norton, 1998b). The leaves have a lower level of fibre and are higher in nitrogen, but the availability of this nitrogen is limited by higher silica content than the stems (Smith, 1987).

Finally, all these forages have a high deficiency of minerals, both macro-nutrients (P, Na), trace elements (Cu, Zn, Co, S) and vitamins, particularly A and D3 (Chenost and Kayouli, 1997; Lowry et al., 1992; Preston and Leng, 1987).

2.7 Nutritive value of topical forages

The importance of a feed depends on its nutritive value which is determined by four factors. Namely, the concentration of the nutrients in it, the voluntary intake, the proportion of the nutrients digested, and the efficiency of using absorbed nutrients (Norton, 1998a; Paya Hamid et al., 2007). The forage value describes its ability to provide the nutrients required in quantity and quality to ensure the animal production (Leng, 1986). This ability is linked to the voluntary intake, potential digestibility, protein/energy ratio, carbohydrate fermentation and the potential "by-pass" of proteins, lipids and starch (Leng, 1987; Norton, 1998b). Associated with nutritive value, the relation protein/energy (P/E) is an important indicator of feeds digestibility (Preston, 1982; Preston and Leng, 1980, 1987). The microbial fermentation in the rumen, which provides protein to ruminants, is highly dependent on the P/E relationship. Low microbial growth due to inadequate nitrogen intake influences the relation P/E negatively. Ingestion is more sensitive to the relation P/E and the relative proportions of the VFA (Leng, 1986). According to Murphy and Pablo (1999), the important contribution of legume nitrogen may be reduced greatly by their tannin content.

A study in Niger (Boukary, 1999) showed that the legume crop residues (Table 2.4) have a relatively higher amount of crude protein (>100 g / kg DM) than cereal crop residues. Their fibre content is also less (< 700 g/kg DM) than in crop residues.

Table 2.4 Nutritional value of the main crop residues and agro-industrial by-products in Niger (Boukary, 1999**)**

		% DM				
Feed	DM	MM	OM	CP	CF	ADF
Crop residues						
Cowpea haulms	92.00	8.50	91.50	15.30	22.97	36.42
Groundnut haulms	92.00	9.80	90.20	11.11	28.14	33.78
Agro-industrial by-products						
Sunflower cake	95.00	8.80	91.22	29.55	24.29	37.47
Malt	93.00	4.70	95.30	26.52	18.24	27.55
Cotton seeds	94.00	4.60	95.40	21.50	23.41	28.40
Wheat bran	91.00	5.40	94.62	16.92	6.80	11.93
Millet bran	93.00	11.90	88.00	10.82	11.49	13.53
Maize bran	93.00	3.17	96.80	10.39	6.70	8.31
Sorghum bran	93.00	8.30	92.70	9.70	10.08	12.00
Rice bran	95.00	25.00	75.01	5.87	34.79	58.78
Industrial rice bran	91.00	8.60	91.40	6.50	33.86	54.60

DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; CP: Crude Protein; CF: Crude Fibre; ADF: Acid Detergent Fibre

2.8 Strategies to improve the value of poor fodder

Annual and perennial graminaceae of the natural pastures consumed by animals in the dry season as well as straws and stovers of cereals are poor fodder (Preston, 1984). All these fodders are characterised by high percentages of lignified walls and very low contents of nitrogen, minerals and absorbable sugars (Smith, 1987; Lowry et al., 1992; Chenost and Kayouli, 1997). Only ruminants can use poor quality fodders efficiently according to their particular digestive physiology. The simultaneous effect of rumination and microbial fermentation in the rumen by action of the micro-organisms makes it possible to degrade these fodders into fine particles and to extract the nutritive elements. These are used by the animal through the final products of this fermentation which are the volatile fatty acids (VFA) and the microbial matter which is digested through the enzymatic process in the abomasum (true stomach) and the small intestine. However, the intake and digestibility of poor quality fodders are low. Thus, without supplementing them, poor quality fodders can only cover animal maintenance. So, the need for improving the nutritive value of these fodders is great.

2.8.1 Forage treatments

The forage treatments consist of modifying the physico-chemical structure of low quality forages to render them more accessible to rumen microorganisms in order to increase their digestibility and intake (Chenost and Kayouli, 1997). One can find physical, chemical and biological treatments. The physical and chemical treatments are the most known. In animal production, it is appropriate to supplement treated fodder.

2.8.1.1 The physical treatment

The physical treatment is realised through the following ways. Namely, the mechanical treatment, the thermal treatment by using steam, and the treatment using radiation techniques with gamma rays. The last two treatments are difficult and delicate to use in practice. The mechanical treatment is done by chopping, crushing, grinding or cooking in order to reduce the size of the forage particles; this increases the ease of handling and forage degradation by the rumen’s microbes. The mechanical treatment sometimes requires costly equipment which is not accessible to small scale farmers; that is why this technique is not used by most of farmers.

2.8.1.2 The chemical treatments

The chemical treatments improve forage quality and are easier to put into practice (Chenost and Kayouli, 1997). The treatments are generally made by alkali (potassium, caustic soda, ammonia etc.) which can hydrolyse the chemical bonds formed between undegradable lignin and the cell wall polysaccharides (cellulose and hemicelluloses). Indeed, chemical treatments render cell structure significantly fragile, and facilitate their attack by electrolytes and cellulolytic enzymes from rumen microbes. These microorganisms can thus colonise the vegetable matter more rapidly and decompose it to a digestible nutrient more quickly.

In tropical Africa, urea treatment has been shown as the most important chemical treatment which highly improves the poor forage value. Indeed, the urea treatment makes it possible to improve the nitrogen value of low quality fodder, which confers to them an additional advantage compared to the treatment with soda or other alkaline reagents. However, an excessive amount of urea or faulty treatment of roughages may harm, or even kill animals due to ammonia toxicity. Therefore, urea treatment has not been widely used. Its adoption by farmers is extremely limited (Owen and Jayasuriya, 1989; Devendra, 1991). The treatment of poor quality forages is not the only way to ensure animal production. Forage supplementation with feeds rich in nitrogen, energy and mineral is another way which can enhance animal production.

2.8.2 Supplementation

Rumen microbes need some nutrients to allow them to use poor quality forage efficiently. The potential nutritive value of poor quality forage cannot be exploited by animals if rumen microbes do not receive nutritive elements to ensure their activities. For a high animal production, it should be important to bring the "additional" supplement required for that production (Smith, 1987; Chenost and Kayouli, 1997). Supplementation consists of bringing nutritive elements (nitrogen, energy, minerals and vitamins) unavailable or insufficient in forages to allow the rumen microbes to better digest them (Leng, 1987). However, the supplementation should take into account the nutritional aspect and the socio-economic considerations, namely the availability, the cost and the aptitude of the technique for being implemented by farmers.

The minimum supplementation can just ensure the animal maintenance; in this case, the minimum feed supplements enable rumen microbes to function well and to ensure all conditions for the maintenance of good cellulolysis. These supplements provide to rumen microbes the nutritive elements needed for their self-multiplication and for the degradation of the carbohydrates from the cell wall of poor quality forages. Fermentable nitrogen may come from either green forage rich in nitrogen or urea, which can generate ammonia necessary for microbial synthesis (Preston, 1984). In addition, it is necessary to supplement with minerals and vitamins (Leng, 1987; Chenost and Kayouli, 1997).

The supplements should supply nitrogen and energy to the animal in proportion according to production requirements without hindering the cellulolytic activity of the rumen. The supplements should also ensure a good balance of fermentation and the digestion of final products from the total ration in order to achieve the target production levels (Preston, 1984, Leng, 1987, 1990; Chenost and Kayouli, 1997).

The energy supplement has to be brought without hindering the cellulolytic activity. It should be rich in easily degradable cell walls such as grass and green forages. These supplements, according to their starch content might constitute between one third and half of the total dry matter of the ration. The supplements should be brought to animals as regularly as possible during the day (Chenost and Kayouli, 1997). Degradable proteins and the various forms of non-protein nitrogen (NPN) provide ammonia which cellulolytic microbes use to synthesise their own substance and they have to be provided proportionally to the amount of digestible energy of the ration (Chenost and Kayouli, 1997).

Numerous research works (Leng, 1987; Norton, 1998a; Norton 1998b) have shown that, particularly in the case of poor quality fodder, it is also useful to supply supplementary crude proteins in the least degradable form in addition to the degradable nitrogen. These are supplements such as oilseed cake, animal proteins, and legume proteins rich in tannins as leguminous shrubs (*Leucaena leucocephala, Gliricidia, Sesbania, Acacia,* etc.) which can improve the nutritive value of low quality fodder. Indeed, these proteins ensure the supply of amino acids necessary to the host animal to carry out its production (milk, growth, work, reproduction). The total nitrogen requirement for animal production cannot be covered only by the synthesis of rumen microbes; it is thus preferable to supply a small amount of food proteins that is able to escape the rumen degradation (Leng, 1987).

2.9 Use of crop residues in livestock production

In Niger supplementation is practised in order to ensure the animal maintenance and production. It is used to improve milk and meat production, to ensure the animal reproduction and animal draught. In mixed crop-livestock system, farmers supplement more for fattening and animal draught.

In dry areas, forage has a low nutritive value and is rich in fiber (Leng, 1987; Van Soest, 1987; Ben Salem and Smith, 2008). The quality of crop residues is low and the feed supplementation is expensive. The crop residues are varied and differ from one area to another. In Central and West Africa one finds the stovers of millet, sorghum and maize, the rice and wheat straws, the stems of cotton and the haulms of groundnut and cowpea. According to Boukary (1999) and Jayasuriya (2002) the haulms of major legume crops (groundnut, cowpea), are generally high quality forage (CP > 100 g/ Kg DM) and very palatable to all animal species. Crop residues are intended specially for feeding the domestic animals in the dry season. Thus, the majority of peasants store crop residues at the end of the harvest in the fields or around their houses. The storage is done either on the trees or on the forks of large trees, in the shed, on the house roofs and even on the floors. The importance of stocks varies according to the residue production and the importance of livestock. In Niger, crop residues are used as a very important part of animal supplementation (Table 2.5).

Table 2.5 Production of cereal stubbles, haulms and brans as part of supplementation (Tonnes) (INRAN, 1996**)**

	Cereal stubbles	Haulms (groundnut & cowpea)	Cereal brans
National Production	9.096.300	1.351.030	1.148.600
Supplementation part	3.446.600	1.158.720	-

Crop residues have multiple destinations as habitation construction, cooking and animal feeding. However, the parts of residues allocated to each type of use vary not only between residues (only 19.2% of sorghum stubble is left on the fields, against 53.3% for millet stubble) but also from one region to another. The proportion used for supplementation varies from 24 to 53% of the total production (Table 2.5).

In Sahalian zones, particularly in agricultural zones, the herds go to grazing camps either alone or led by a shepherd during the day and come back in the evening. They benefit from the common grazing land right after harvests. When the fodder deficit is announced in the dry season, animals do not have enough to graze at the pastures, so they lose weight and become thin. This justifies the use of animal supplementation in order to attenuate the fall of weight, to keep the animal maintenance and in certain cases to guarantee the animal production. It should be noted that the cowpea and groundnut haulms are intended for lactation, fattening and plough oxen. However, the experimentation in savannah zones has shown that only in zones where the population density is raised and the majority of the lands are under agriculture pressure, that the animals consume more than 50% of the residue of cereals in common grazing land (Powel, 1985 cited by Kamuanga, 2002). The practice of crop residue storage and its use in supplementation is not developed yet in the area of savannah of Central Africa, except in the most populated zones such as the extreme North of Cameroun (Nsoya et al., 1998 cited by Kamuanga, 2002). The studies in Soudano-Sahelian Africa gave an estimate of about 70 % of crops residues contribution in animal feeding during the dry season (Scoones, 1995; Hiernaux et al., 1998; Picardy, 2000; Ickowicz et al., 2000).

2.10 Use of tanniniferous fodder in livestock production

2.10.1 Contribution of tanniniferous fodder

Fodder trees and shrubs are high tanniferous fodder. In the arid and semi-arid zones, the contribution of fodder trees and shrubs is very high in animal production. This contribution ranges from 52% in cattle, 57% in sheep, 65% in goats and 100% in camels in tropical

Africa especially in the dry season when the pastures are lower and poor. Tanniniferous fodders supply animals with protein, vitamins, and minerals. Thus, they supplement animal diet particularly in the dry season (Le Houérou, 1980; Dicko, 1992a; Ngwa et al., 2000). Towards the end of the rainy season and in the dry season, forage grasses of savannah and steppe lose their nutritive value. Consequently, animals need supplementary protein and forage. At this time, tanniniferous forages have already produced new leaves and constitute the most accessible forages and may provide supplement forage when green grass is scarce or dried (César and Gouro, 2006).

Compared to grasses, tanniniferous forages have a relatively higher concentration of crude protein, minerals and neutral detergent fibre (NDF) plus acid detergent lignin (ADL). However, their average concentration in acid detergent fibre (ADF) and their average of dry matter digestibility are both low. The nutrient contents of tanniniferous forages have less variation in the dry season contrary to the grasses which become straw and consequently lose their nutritive value in this period. Tanniniferous forages are important as livestock feeds during the dry season (Dicko and Sikena, 1992b).

To study the supplementation effects of tanniniferous forages, a feeding trial (74 days) on sheep was conducted by Kouonmenioc (1992) to compare various diets of tanniniferous forages with *pennisetum purpureum* (grasses) basal diet. The study showed a significant difference between sheep fed on grasses and those which were fed on tanniniferous forages and grasses. However, the sheep fed on grasses only registered a drop in weight and mortality (60%) during the two months of the study but those which were supplemented with tanniniferous forages experienced an average daily weight gain of 64 g for the best supplement.

2.10.2 Nutritive value and nutritional constraints of tanniniferous forages

Tanniniferous forage constitutes an important animal feed resource during the dry season. It is estimated that at least 50% of the annual consumption of metabolizable energy (ME) for ruminants in Sahelian countries is provided by tanniniferous forages (Fall, 1991).

Le Houérou (1980) observed that tanniniferous forage species from West Africa have good quality due to their ability to supply protein (22 g / kg dry matter) and energy (0.87 UF / kg dry matter). Twenty trees per hectare produce 2500 kg of fruits per year with a forage value of 19,000 UF, as many as 19,000 kg of barley (Rivière, 1978). Fall (1991) has shown that the fodder trees of West Africa have a crude protein content higher than most grasses. Studies conducted in Senegal (Fall, 1991) have shown that the levels of total nitrogen in the leaves of *Acacia raddiana* vary between 16-20% of dry matter (DM) and for *Acacia seyal* between 13-17%. The leaves of *Bauhinia rufescens* contain on average 15% of total nitrogen per kg DM, while the leaves of *Balanites aegyptica*, have a maximum of 19% CP / kg DM during the rainy season. However, the quantity of protein present in tanniniferous forages vary with season, species, tissue considered, the age of the plant and its stage of development (Fall et al., 2000). Fall (1991), reports that the leaves of *Acacia albida* collected in the dry and cold season are richer in protein than samples collected during the dry and warm season.

The table below (Table 2.6) shows the nutritive value of tanniniferous forages of which leaves and pods are rich in protein but pods are richer than leaves. However, leaves and pods have also a high content of fibres.

Table 2.6 Nutritive value of tanniniferous forages of Niger (Boukary, 1999)

Scientific name	DM	% DM				
		MM	**OM**	**CP**	**CF**	**ADF**
Acacia albida L	93.00	7.50	92.47	18.83	16.97	25.76
Acacia albida P	92.00	5.00	95.00	12.66	24.50	28.89
Acacia raddiana L+C	93.00	6.10	93.86	13.48	13.95	17.17
Acacia seyal P	94.00	6.40	93.57	14.70	26.24	30.92
Acacia nilotica P	94.00	3.90	96.07	9.56	18.55	23.51
Boscia senegalensis L	93.00	12.00	87.77	18.04	27.69	29.58
Ziziphus mauritiana. L+T	93.00	7.60	92.39	18.04	17.04	24.25
Ziziphis mauritiana L	92.00	3.90	96.05	12.00	11.56	28.45
Salvadora persica L	90.00	7.60	92.39	17.16	13.50	21.93
Maerua crassifolia L	91.00	13.90	86.11	23.74	10.60	14.18
Balanites aegyptica L	92.00	14.00	86.00	15.34	15.76	23.91
Pilostigma reticulatum L	94.00	12.00	88.18	6.73	21.92	34.05
Pilostigma reticulatum P	93.00	3.90	96.07	10.17	28.42	37.05
Bauhinia rufescens L	93.00	5.70	94.28	14.43	16.85	22.92
Bauhinia rufescens P	92.00	11.30	88.60	12.51	30.78	42.10
Prosopis chilensis P	93.00	5.20	94.78	15.91	11.52	29.17
Prosopis juliflora P	92.00	4.40	95.58	9.14	16.58	22.92
Leptadenia. pyrotechnica T	95.00	23.00	76.95	8.42	46.55	56.70
Guiera senegalensis L	94.00	4.30	95.68	8.07	27.74	43.30
Sclerocarya birrea L	92.00	9.90	90.14	5.79	10.66	35.67

L: Leaves; P: Pods; T: Twigs; CF: crude fibre

Tropical legumes contain relatively lower fibers than grasses and therefore greater nutritional value. However, they are richer in lignin than grasses (Lowry et al., 1992). The low digestibility of tropical legumes is related to the proportion of vascular tissue rather than lignin content. Indeed, the vascular tissues of legumes are totally indigestible by ruminal bacteria (Grenet, 1997). In West Africa, tanniniferous forages are rich in minerals and do not contain silica (Le Houérou, 1980). They contain sufficient quantities of phosphorus (0.15%), Mg (0.6%) and K (1.5%). Some shrubs may have deficiencies in P, due mostly to poor soil in this element (Le Houérou, 1980).

The studies on the nutritional value of 4 species of Acacia (*A. albida, A. nilotica, A. sesberiana, A. tortilis*) showed that the fruits of Acacia are rich in crude protein content and low in metabolizable energy (Reed and Soller, 1987). According to Dicko (1992b), tanniniferous forages are important sources of nitrogen, which can sometimes cause serious problems due to the high content of anti-nutritional compounds (tannins) and antimetabolic (mimosine). Tannins affect on the one hand the voluntary intake by reducing the dry matter digestion in the rumen, which increases the retention time of particles in the rumen; and on the other hand, the tannins of forage tissue (usually located in leaf parts) precipitate salivary proteins causing an astringent taste in the mouth, thus resulting in a reduction of forage intake (Provenza et al., 1990). It has been argued that excessive consumption of phenolic compounds could contribute to inhibit the performance of animals because of the specific interaction between their composition, concentration and nutritional compounds (Reed and Soller, 1987). According to Provenza et al. (1990), tanniniferous forages form complex bonds with proteins and carbohydrates, thus inhibiting the assimilation of these nutrients, particularly in the intestines. Despite these aspects of tanniniferous forages, the main obstacles of using tanniniferous forages to feed ruminants in Sub-Saharan Africa relate to both environmental and socio-economic factors.

2.11 Use of agro-industrial by-products in livestock production

The principal sources of agro industrial by-products used in supplementation in West Africa are cottonseed cake, groundnut cake, wheat and rice bran, malt, cane-trash, and molasses. However, the acquisition of certain by-products by peasants is difficult as the products are very expensive; on the other hand we should take into account their non-availability in the rural market and the transport problems. Generally, cottonseed cake and groundnut cake are imported; molasses, cane-trash and malt are used by rich farmers around the suburbs, whereas these by-products are not accessible to smallholders. However, millet and sorghum bran are produced locally by craftsmen. These by-products are principally used by smallholders to supplement their animals. Supplementation of agro-industrial by-products goes hand in hand with that of the crop residues and a peak of distribution is observed during the tough period of the dry season (April-June). Lactating cows and fattening animals are prioritised (Abdou, 2004) according to the objective of producers.

The cottonseed cake is rich in total nitrogen and energy. Proteins in cottonseed have good resistance to degradation in the rumen. When fed to ruminants, cottonseed cake provides good results in fattening, milk production and maintenance of livestock and oxen. However, the high content of gossypol in cotton seed is often a handicap of its use. Malts are very rich in total nitrogen and moderately rich in fat and fibre. The cellulose of malts is very degradable while proteins are not degradable in the rumen and are an excellent source of by-pass protein.

2.12 Feeding strategies

Many techniques of feeding have been introduced by the National Agricultural Research Institute in Centre and West Africa. These techniques focus on the improvement of crop residues value and the use of agro-industrial by-products in order to enhance the livestock productivity and farmers income. However, a lot of research should still be done to increase the feeding value of roughage diets.

The seasonal fattening of sheep constitutes an activity to which the farmers devote themselves during the dry season. In the particular case of the central plateau of Burkina Faso and in spite of the relative profitability of the activity, the farmers are confronted with the difficulties of access to inputs. These problems of food are due to multiple causes, namely the low availability of agro-industrial by-products and their high costs, and especially the limitation in the financial capital of the farmers (Zoundi et al., 2006). The context of Burkina Faso is identical to Niger and others countries of West Africa. So, this situation justifies the need for developing feeding systems with lower cost, by taking into account the local socio-economic realities of farmers. For this reason several investigations have already been led, with the aim of improving the feeds value and the digestibility of the low quality forages through physical, chemical and biological treatments (Denis et al., 1995; Kafedzhiev et al., 1998). We can also improve the nutritive value of low quality forages high in fibre through the nitrogen supplements (Al-Jassim et al., 1998), by using the feeds such as oilseed cake, legume forages, etc. (Manyuchi et al., 1997) and the use of poultry manure (Gihad**,** 1979; Griffith, 1994).

During the last decades, significant progress was also accomplished by the formulation and the use of multi-nutritional blocks as supplements for the animals evolving on the natural pastures and the animals which receive poor quality fodder as basal diet (Sanchez, 1998). Thus, some research has shown that supplementation with multi-nutritional blocks allows an optimal use of low quality fodder by improving the rumen microbial activity which may reduce the use of concentrates (Chenost and Kayouli, 1997; Forsberg et al., 2002). However, the study on the use of multi-nutritional blocks as a substitute of concentrate for fattening sheep has shown that the partial substitution of concentrate by the multi-nutritional blocks resulted in a loss of weight gain of about 27 % (Zoundi et al., 2006). Thus, one can understand that on the technical level, the use of such feed in partial replacement of concentrates cannot appear very attractive to the smallholder farmers. But, if the use of multi-nutritional blocks makes it possible to increase the activity of rumen microbes and consequently the digestibility of low quality forages, further research should be done in order to improve the multi-nutritional blocks intake by small ruminants since its intake is low due to its hardness (Zoundi et al., 2006).

The degradation of natural resources in Sudano-Sahelian zones of sub-Saharan Africa increases from day to day and this situation limits the agricultural production and exposes the rural populations to recurring food shortages. However, this area has the advantage of a prevalence of crop-livestock mixed systems which interactions show several economic and environmental interests (McIntire et al., 1992; Steinfeld et al., 1996a; Steinfeld et al., 1996b; Jahnke, 1998). According to peasants, fattening is the most gainful employment in livestock. However, poor accessibility to external inputs (cotton seed cake, groundnut cake, molasses, etc.) because of their high cost and of their low availability on local markets, limits the intensive expansion of fattening practice in their environment. To adapt to this situation, farmers feed their animals by using more and more local feed resources and sometimes supplement with small quantity of concentrate. Therefore, smallholder farmers derive profit from the crop residues and from the natural tanniniferous forages to fatten at lower cost a small number of animals. It has been shown that the incorporation of the pods of *Piliostigma reticulatum* considerably improves the ingestion of coarse fodder diets such as sorghum stover, cowpea haulms and tree pods (Zoundi et al., 2006).

According to Dan Gomma (1998), thousands of animals fattened in Niger are exported or sacrificed each year in religious ceremonies such as baptisms and feasts. Many studies have shown that the fattening of sheep based on legume haulms and hays gave good performances on animal growth rate and slaughter weights (Niango et al., 1995, 1997; Dan-Gomma, 1998). The use of legume haulms allows a reduction of the use of agro-industrial by-products and the duration of fattening. In the West of Niger, the cowpea haulms are used as a basic ration in the fattening of sheep (Sido, 2001). According to Karimou (1996), in the zone of Toukounous, concerning the fattening of sheep, women distributed the cowpea haulms and the *Acacia radiana* pods at will with a supplement of sorghum grain and millet bran without measuring the level supplied. Other studies in Western Niger (at Toukounous) on fattening sheep about the technical and economical performances have been done by using cowpea haulms, bush legumes hays, *Acacia raddiana* pods, bush straw and millet bran (Issa et al., 2006). It was seen that it is possible to locally develop an efficient fattening of sheep and the rate of profitability could be higher if farmers pay more attention to the collection and crushing of pod. On the other hand, the profit would be higher if the optimum rate of utilisation of legume haulms and pods was found instead of being used *ad libitum*, as these supplements become expensive (Issa et al., 2006). The use of multi-nutritional blocks or mineral blocks as supplements could increase the sheep production.

2.13 Conclusion

In Sahelian countries of Africa, the most important feeds used in animal feeding by smallholder farmers in the dry season are crop residues, namely cereal crop residues and legume crop residues. The cereal crop residues are commonly known by their characteristic as poor quality forages due to their low content of crude protein and their high fibre levels. Therefore, when offered to animals, both dry matter intake and digestibility are low. However, the legumes crop residues have a good nutritive value. In the dry season, smallholder farmers have a serious problem to feed their animals in order to gain weight and make profit. They use their own farm residues to feed animals during the dry season. Farmers attempt to supplement these poor quality residues with agro-industrial by-products; but the access of these products is very difficult. So, in this study, the best combination of supplementation should be carried out by using the farm residues and agro-industrial by-products in order to increase the rate of profitability in livestock farm activity. Thus, adequate supplementation is required for efficient utilisation of feed supplement in Sahelian countries.

In this particular area, the feeding strategies need to be developed to ensure the improvement of livestock production. To develop effective feeding systems with crop residues and agro-industrial by-products, a more appropriate method is strategic supplementation with or without chemical/physical treatment of the basal resource. However, the use of chemical treatment is low due to their high cost in developing countries. In this case, feed supplementation of tropical crop residues would be more useful to improve their quality by providing the deficient nutrients. This could allow smallholders to enhance their farming income by sheep fattening which especially is their most important activity during the dry season.

According to their importance in the crop-livestock system in Sahelian countries particularly in Centre-Southern Niger, millet stovers and the groundnut haulms are the main crop residues produced and used in livestock farming systems to feed animals. This study focuses thus on increasing the feeding value of millet stovers as basal diets with the supplementation of groundnut haulms in order to substantially improve both sheep fattening and the income of smallholder farmers.

Chapter 3

Effect of chopping sizes on millet stover intake and degradability *in sacco* of millet stover, groundnut haulms, millet bran and wheat bran

Abstract

The study evaluated the effect of chopping millet stover (*Pennisetum glaucum L.* R. Br.) in sheep feeding and the degradability *in sacco* of feeds. Two Holstein cows were used to determine the degradability *in sacco* of feeds. The potential dry matter degradability (g/kg) were 846, 809, 730, 410, 550 and 370 for millet bran (MB), wheat bran (WB), groundnut haulms (GH), millet stover, leaves plus sheath and stems of MS respectively. The potential nitrogen degradability (g/kg) of MB, WB and GH were 865, 908 and 817 respectively. The nitrogen content was 7.4, 15.1, 22.0 and 26.2 g/kg for MS, GH, millet bran and wheat bran respectively. The effects of chopping millet stover (MS) on dry matter intake in Oudah bicolor sheep were studied in Maradi, Niger. Four treatments were T0 (unchopped MS), T1 (MS chopped, 50 cm), T2 (MS chopped, 25 cm) and T3 (MS chopped, 10 cm). A randomized block design was applied on 36 sheep, implying 9 sheep per treatment (T0, T1, T2 and T3). The treatment T2 or 25 cm size gave the best MS intake of 560 g/day. The results indicated that groundnut haulms, millet bran and wheat bran had good nutritive value whereas millet stover had low nutritive value. The 25 cm chopping size was the one to propose to smallholder farmers.

Key words: Millet stover; chopping; intake; degradability; Oudah bicolor sheep

3.1 Introduction

The dry season is the particular period of livestock feed shortage in Sahelian countries. However, crop residues are plentiful after harvesting for just three months from December to February. In Niger, the chronic livestock feed shortage occurs from April to June (Williams et al., 1997). Animals lose weight and body conditions decrease during this period of feed shortage. It is crucial to develop strategies to mitigate the feed shortages during the dry season.

Millet is a staple food in Niger (Obilana, 2003). A national survey by INRAN (1996) showed that over 50 % of millet stover in Niger is used for feeding livestock, mostly in the dry season. Unfortunately, the feeding value of millet stover is extremely low. Thus, improving its nutritive value is indispensable for livestock feeding. Despite its importance in the dry season, the millet stover is offered in bulk, without chopping, causing a lot of feed wastage because there is no popularized technology showing the importance of chopping millet stover. Osafo et al. (1993, 1997) showed that chopping sorghum stover increased intake in sheep. Osama and Mohammed (2009) showed that chopping sorghum stover to 1-2 cm length also had a significant effect on intake in goats. Chopping also reduced the amount of feed wasted (Osafo et al., 1993). However, these technologies were based on mechanical chopping and it is not obvious whether this is worthwhile with smallholder farmers because of their feeble purchasing power to buy the machine-chopper. To reduce wastage and increase the millet stover intake and utilization, farmers could use manual chopping with a machete instead of using the machine-chopper which is not affordable to them.

Millet stover is rich in fibre and low in protein (Chenost and Kayouli, 1997; Jayasuriya, 2002). Male lambs generally select against the stems. After chopping, the animals are expected to increase feed intake by also consuming the stems. The degradability of these stems although not known, is likely to be low. Understanding the degradability of different components of the plant is useful to predict the nutritive value and intake of millet stover by sheep. Estimates of degradability can be used to predict the nutritive value of livestock feeds (Orskov et al., 1988).

The maintenance requirements could be met by millet stover supplemented with low levels of protein or non-protein nitrogen. However, to raise production above maintenance, digestibility and protein supplementation would need to be increased. Thus, smallholder farmers use supplements such as groundnut haulms, millet bran and wheat bran to improve animal performance. Groundnut is commonly grown in southern Niger and the haulms are used in livestock feeding. Millet bran is obtained from the processing of millet grain for household food and is generally available with smallholder farmers. Wheat bran is an agro-industrial by-product, which is easily accessible and can be purchased at affordable prices in the local market.

The objectives of the current study are to determine the optimum chopping size of millet stover and to characterise the feeding value of millet stover, groundnut haulms, millet bran and wheat bran by the technique of degradability. The hypotheses to be tested are that the chopping of millet stover would increase the intake and reduce feed wastage; stems would be less degradable than leaves and whole millet stover.

3.2 Material and Methods

The study was conducted in two experiments.

3.2.1 Experiment 1

Experiment 1 was conducted in 20 days of which 10 days were used for adaption followed by 10 days of data collection. It consisted of testing different chopping levels on millet stover intake for the purpose of choosing the best one for subsequent experiments.

3.2.1.1 Study site

The experiment was conducted in the dry season in an animal production station (Zootechnic station) located at the regional centre for agricultural research (CERRA) of

Maradi, Central South of Niger. This site lies at 13^{o} 27’ 71’’ N and 07^{o} 06’ 47’’ E. It is at an altitude of 347 m and is situated in the Sudano-Sahelian zone with an annual rainfall of 400-600 mm between June and September. The temperature and rainfall distributions follow a seasonal pattern. The relative humidities from October to June and July to September are < 20% and > 80% respectively. The mean temperature min/max is 22/36 ^{o}C. It can get up to 40^{o} C in April-May.

The natural vegetation is Sudano-Sahelian woodland with thorny tree species, regenerating shrubs and perennial or annual grasses. In natural depressions, river valleys and around seasonal ponds larger trees benefit from shallow groundwater and form small areas of dense woodland.

3.2.1.2 Millet stover and groundnut haulms

Millet stover residues obtained from the CERRA at Maradi were stored at the Animal Production Station. The groundnut haulms were purchased from smallholder farmers of Tarna, a village situated 2 km from the station. The millet stover and groundnut haulms were dried naturally in the sunshine. The millet stover was chopped manually with a machete. The groundnut haulms were obtained as crushed matter after the process of separating the haulms from the cloves.

3.2.1.3 Animals and housing

Thirty six one-year old Oudah bicolour male lambs of about 25.8 kg live weight (SD = 3.10), were purchased from the local market. This breed has two variant colours (black-white and red-white). The animal age was estimated by teeth (incisors) observation. They were housed in a shed in individual pens (2m x 1.5m) at the animal production station of CERRA-Maradi, made of local materials, namely sorghum stover and tree poles. The inside of enclosure was daubed with cattle faeces to avoid being eaten by lambs. The animals were ear-tagged and weighed at the beginning of the experiment. All animals were vaccinated with Pestovax against Small ruminant plague (or Rinderpest) and were dewormed with Ivermectin immediately after purchase. Thirty six feed troughs were made of barrels. Ten days for an adaptation period were allowed before the commencement of the experiment.

3.2.1.4 Experimental design

Four chopping sizes were used; namely, T0 (no chopping), T1 (chopped at 50 cm), T2 (chopped at 25 cm), and T3 (chopped at 10 cm). Before starting the study, the animals were weighed, and sorted by weight into nine groups of four animals each. Within each group, the four animals were randomly placed in the four treatments. Thus, we constituted nine animals for each of the four treatments.

3.2.1.5 Feeding management

The first day the animals were given 2.5 kg millet stover per day, 1.5 kg in the morning and 1 kg in the afternoon. However, on the subsequent afternoon the level of 1 kg was adjusted to 1.5 kg. Thus, the level of millet stover was 3 kg per day of which 1.5 kg was given in the morning and 1.5 kg in the afternoon during the experiment. This allowed the animals to eat *ad libitum*. The lambs received 150 g of groundnut haulms in the individual feed trough once a day at 0800h. The groundnut haulms were consumed within ten minutes of being given to animals. Immediately after finishing eating the groundnut haulms, they were given 1.5 kg of millet stover *ad libitum* as the basal diet. At 1800h, all animals were given 1.5 kg of millet stover only. A mineral block and water were offered *ad libitum.*

3.2.1.6 Measurements

The feed offered was measured with the electronic weight scale called Westboao OCS-2 (accuracy ± 0.1%, Shenzhen West-boao Science & Technology Co., LTD. Guang Dong-China, www.west-boao.com) the previous day just to avoid any delay in feeding. Millet stover refusals of each lamb were collected each morning (at 0730h) and each afternoon (at 1730h) before the feed offer. The refusals were weighed with the same electronic balance to determine daily intake. The millet stover intake (MSI) for each lamb was calculated by subtracting the millet stover refusal (MSR) from the millet stover offered (MSO). The initial (25.8 SD = 3.10 kg) and final (27.0 SD = 2.88 kg) live weights were taken after depriving animals of food and water for 14 hours. The electronic balance called Eziweigh 2 (accuracy ± 1 %, Tru-Test Limited, New Zealand, www.tru-test.com**)** was used to weigh the animals.

3.2.2 Experiment 2: Degradability of millet stover, groundnut haulms and cereal brans

3.2.2.1 Study site

Experiment 2 was conducted at Ukulinga Research Farm, the University of KwaZulu-Natal, Pietermaritzburg in a subtropical hinterland, which is approximately 700 m above sea level. The climate is characterized by an annual rainfall of 735 mm, which falls mostly in summer between October and April. The mean annual maximum and minimum temperatures are 25.7 ^{0}C and 8.9 ^{0}C, respectively. Light to moderate frost occurs occasionally in winter.

3.2.2.2 Animals and feeding management

For this experiment, two fistulated Holstein cows about 300 kg live weight were kept under natural grazing of kikuyu (*Pennisetum clandenstinum*) pasture and given 2 kg of lucerne per cow per day in the afternoon. The adaption period was two weeks.

3.2.2.3 Feeds

The same feeds described above were used; namely, millet stover, groundnut haulms, millet bran and wheat bran. The leaves and sheath together and the stems of millet stover were also used.

3.2.2.4 Degradability

The degradability of DM and nitrogen for millet stover, millet stover leaves plus sheath, millet stover stems, groundnut haulms, millet bran and wheat bran were measured according to Ørskov and McDonald (1979). This technique measures the disappearance of feed constituents, dry matter and protein from synthetic nylon bags (pore size 41 µm and measuring 9.0 cm x 14.5) after rumen incubation for varying periods of time (0, 3, 6, 9, 12, 24, 48, 72, 96 hours) with duplicate bags (one bag for each of the two cows). The bags containing the feedstuffs were suspended in the rumen through a rumen fistula. Each feed was ground through a 2 mm screen size and weighed into bags at the rate of 4 g of the feed sample. The sequential addition method for samples incubation was used. After withdrawal, the bags containing the residues were immediately rinsed to remove excess ruminal contents and microorganisms on the surface of the bags, and kept in the freeze (4 ^{0}C). The bags for zero time were not incubated. At the end of the experiment, all collected bags were washed in a domestic washing machine with the bags of zero time together until the water was completely clear after 30 min (The water was changed six times, with each cycle lasting 5 min).

After washing, the bags were dried in an oven at 60 ^{o}C for 48h, cooled in a desiccator and weighed. Thus, dry matter loss was calculated and expressed as percentage degradability of the original dry matter incubated. The nitrogen (N) loss was calculated and expressed as percentage degradability of the original feed incubated, by this formula:

N loss (%) = 100*(NOF-NR)/NOF;

Where NOF is the nitrogen in the original feed, NR is the nitrogen in the residue.

3.2.2.5 Chemical analysis

Duplicate analyses of samples of feed offered were done to determine their chemical composition. The dry matter (DM) was determined by using an oven at 60 ^{0}C during 48 h. The ash was determined by combusting in a furnace for four hours at 550^{o}C, AOAC (1990) method. Nitrogen content was determined by using LECO Truspec Nitrogen analyzer based on Dumas Combustion method (AOAC, 16th year edition). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by using ANKOM Fiber Analyzer. The hemicellulose and cellulose were obtained by calculating the difference. After the incubation period, duplicate analyses of samples of groundnut haulms, millet bran and wheat bran were also done to determine nitrogen content. All the analyses were done in the Laboratory of the Discipline of Animal and Poultry Science at the University of KwaZulu-Natal, Pietermaritzburg.

3.2.2.6 Statistical analysis

Data of the effect of chopping size on feed intake was analyzed (SAS: Statistical Analysis System, SAS Institute Inc. 2004) using General Linear Models (GLM) procedure. The basic statistical model was: $Y_{ij} = \mu + chopping_i + Lwt_j + e_{ij}$

Where Y_{ij} is the independent variable (feed intake), μ the overall mean, $chopping_i$ is a chopping size, Lwt_j the live weight used as co-variate and e_{ij} the residual error. The t tests were used to compare the means of millet stover intake (MSI).

The degradability data were fitted (SAS, 2004) using the non-linear formula, $P= w+b(1-e^{-ct})$ of Ørskov and McDonald (1979). Where *P* is the percentage of material degraded after time "*t*", *w* is the washing loss, which also represents the intercept of the degradation curve at time zero, it represents the component of DM degraded rapidly relative to the degradation of the component described by $b(1 - e^{-ct})$, *b* represents the potential degradability of the component which will in time be degraded, *c* = the rate constant for the degradation of "*b*" and w + *b* represents the potential degradability of the sample. The effective degradability (ED) was calculated as ED = w + b*c/(c + k) where k = fractional rate of passage (0.03/h).

3.3 Results

3.3.1 Chemical composition of feeds

The chemical composition of feeds is shown in Table 3.1. The NDF and ADF were superior in wheat bran than in millet bran. Millet stover had higher NDF and ADF than groundnut haulms. The groundnut haulms (14.8 g/kg) had a higher content of nitrogen than millet stover (7.4 g/kg). The nitrogen content of wheat bran (26.2 g/kg) was higher than that of millet bran (22.0 g/kg).

Table 3.1 Chemical composition of feeds used (g/kg DM).

Composition	DM	OM	N	NDF	ADF	ADL	Hem	Cel
Millet stover	938	935	7.4	859	532	197	327	336
Groundnut Haulms	937	924	15.1	565	422	165	142	259
Millet bran	953	939	22.0	383	71	37	312	35
Wheat bran	946	947	26.2	482	140	43	342	96

DM: Dry matter; OM: Organic matter; N: Nitrogen; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; ADL: Acid detergent lignin; Hem: Hemicellulose; Cel: Cellulose

3.3.2 Dry matter degradability

The dry matter degradation parameters are given in Table 3.2. The losses of soluble dry matter and small particles at zero times by washing were substantial for the bran followed by groundnut haulms and low for stover. Among concentrates, the (b) fraction of millet bran was higher than for wheat bran. The potentially degradable fraction (b) of groundnut haulms was higher than for millet stover. The degradation of (b) fraction of millet stover leaves was higher than for millet stover while the stem of millet stover had the lowest (b) fraction. The same trend was observed with the degradation rate (c) which was faster with millet bran than with wheat bran. The DM degradation rate (c) was faster in groundnut haulms than millet stover leaves, stems and the whole millet stover. Millet bran had the highest potential degradability (w + b) followed by wheat bran, groundnut haulms, millet stover leaves, whole millet stover, and then the stems. The same trend was observed with the effective degradability (ED), where millet bran had the highest ED followed by wheat bran, groundnut haulms, leaves, whole millet stover and stems (Table 3.2).

Table 3.2 Dry matter degradability *in sacco* of different types of feeds (g/kg) based on $Y = wash + b (1 - e^{-ct})$

Feed	Wash (SE)	b (SE)	c (SE)	Wash + b	ED	R^2
Millet bran	439 (2.2)	408 (7.0)	0.215 (0.038)	847	798	0.922
Wheat bran	456 (11.2)	353 (10.4)	0.077 (0.021)	809	711	0.880
Groundnut Haulms	319 (17.2)	412 (9.2)	0.156 (0.019)	731	665	0.963
MS leaves & sheath	156 (0.6)	394 (12.2)	0.071 (0.009)	550	423	0.973
Millet stover	152 (10.3)	260 (5.8)	0.058 (0.005)	412	325	0.988
Millet stover stem	217 (9.5)	152 (5.6)	0.063 (0.009)	369	320	0.968

MS: Millet stover; SE: Standard error; ED (Effective degradability) = wash + b*c/(c + kp); kp = 0.03.

3.3.3 Nitrogen degradability

The nitrogen degradation parameters of concentrates and groundnut haulms are shown in Table 3.3. The potentially degradable fraction (b) of millet bran was higher than for wheat bran whereas the rate of degradation (c) of wheat bran was faster than for millet bran. The potential degradability (wash + b) and the effective degradability (ED) of wheat bran were higher than for millet bran. The nitrogen degradation parameters of groundnut haulms were lower than for millet bran and wheat bran (Table 3.3).

Table 3.3 Degradability of nitrogen of feeds (g/kg) based on $Y = wash + b (1 - e^{-ct})$

Feed	Wash (SE)	b (SE)	c (SE)	Wash + b	ED	R^2
Millet bran	402 (19.9)	463 (4.9)	0.243 (0.028)	865	814	0.966
Wheat bran	567 (3.9)	341 (5.1)	0.257 (0.053)	908	872	0.898
Groundnut Haulms	415 (48.3)	402 (8.4)	0.210 (0.027)	817	767	0.954

SE: Standard error; ED (Effective degradability) = wash + b*c/(c + kp); kp = 0.03.

3.3.4 Effect of chopping on millet stover intake

Dry matter intake of millet stover and total dry matter intake of control was higher ($p<0.05$) than for all chopping sizes (Table 3.4). The intake of T3 chopping size was lower than T1 and T2 chopping sizes. However, there was no significant difference between T1 and T2 chopping.

Table 3.4 Effect of chopping on voluntary intake (g DM)

	T0 (control)	T1(50 cm)	T2 (25 cm)	T3 (10 cm)	SED
MSI	696 [a]	545 [b]	560 [b]	496 [c]	7.6
TDMI	846 [a]	695 [b]	710 [b]	646 [c]	7.6

a, b, c values with different superscripts in a row denote significant differences ($p < 0.05$) between means within the same row. MSI: Millet stover dry matter intake; TDMI: Total dry matter intake; DM: Dry matter; SED: Standard error difference.

3.4 Discussion

The unchopped MS (T0) and the least chopped size (10 cm) gave the highest and lowest intake, respectively, which is opposite to what was expected (Osafo et al., 1993, 1997; Asma and Mohammed, 2009). The high intake of unchopped stover could be due to uncontrollable factors, such as consumption by other lambs principally, and feed wastage. Unchopped millet stover is long (> 2 m) (Oumar and Sawsen, 2010) and it would be eaten not only by the lambs to which it was offered but also by lambs in neighbouring pens through the movement of stover from one pen to another. Offering millet stover without chopping may cause a food waste (spoilage by urine, faeces and trampling by the animals). Thus, the intake of unchopped MS may not reflect the true consumption; it is overestimated (see appendix 3).

The lowest intake of the least chopped size (10 cm) could be explained by the selective nature of sheep. The intake of moderate chopping sizes (50 and 25 cm) was higher than of the least chopped size (10 cm). With moderately chopped sizes, the leaves and sheath were not moved from stem and this enable the sheep to select the leaves and sheath which were easier to obtain than when chopped at 10 cm where leaves, sheath and stems were mixed together (see appendix 4, 5 and 6). This is in agreement with FAO (2007) where it was found that male sheep prefer selecting the leaves and sheath in unchopped than chopped sorghum stover.

Excluding the unchopped millet stover and the chopping size of 10 cm, the DM intake response is similar to the results of Osafo et al. (1993, 1997) and Asma and Mohammed (2009) on chopping sorghum stover which showed an increased DMI of sorghum stover with decreasing chopping size in sheep and goats respectively. It contrasts to the studies of Wahed (1987) and Osafo et al. (1997) who reported no intake improvement by chopping barley straw for goats and sorghum stover for cattle respectively.

The physical and chemical characteristic of millet stem might be the main factors which influence its intake. According to Romney and Gill (2003), the nutritive value of feed influences its digestibility and therefore its intake. Moreover, millet stover stem is more slowly degraded in the rumen than the leaves and sheath; this was confirmed in our experiment on degradability *in sacco* which tested whole millet stover, its stems and leaves plus sheath. According to Fernandez-Rivera et al. (1994) and Osafo et al. (1997), the offer of ample amounts of stover enables the animal to select the more palatable or nutritious parts, which increase the quality and intake of feed consumed. This factor would also explain the selective behaviour of lambs in our study which were offered enough quantity of millet stover. It is interesting to note that the refusals which consisted largely of stems were eaten by the cattle in the station at that particular period in the dry season.

The digestibility of a feed is defined by its potential degradability, rate of degradation, and its residence time in the rumen (its effective degradation) plus digestion in the hind gut (Orskov et al., 1980). The effective DM degradability of millet bran (798 g/kg) and wheat bran (711 g/kg) were higher than groundnut haulms (665 g/kg) and millet stover (325 g/kg). The same results were found by Jayasuriya (2002) on degradability of brans (600-800 g/kg), groundnut haulms (500-700 g/kg) and cereal stover (200-400 g/kg). Study on millet stover degradability conducted by Chenost (1993) and Kayouli (1979, 1988, 1994a, b) showed the value of millet stover DM degradability between 320-400 g/kg which is similar to these results. The value of the potential degradability (731 g/kg) of groundnut haulms found in this study corroborates the result of Gognet et al. (1992).

The effective degradability of nitrogen in millet bran (814 g/kg), wheat bran (872 g/kg), and groundnut haulms (767 g/kg), showed good nutritive value for these feeds. According to these results, millet stover is a poor quality roughage; it contains high cell wall content which affects its digestibility. The superior nutritional value of leaves relative to whole millet stover and stems might be due to the lower cell wall content of leaves; this agrees with the studies of Ramasin et al. (1986) and Norton (1998b). The high level of degradation parameters of millet bran, wheat bran and groundnut haulms could be explained by their good chemical composition which has a positive effect on their degradation (Huntington and Givens, 1997; Vitti et al., 1999).

3.5 Conclusion

Millet bran, wheat bran and groundnut haulms were highly degraded in the rumen while millet stover, millet stover leaves and stems were less degraded. The high effective digestibility and the rate of degradability of groundnut haulms, wheat bran and millet bran showed that these feeds can constitute good supplements for millet stover as a roughage-basal diet in feeding sheep.

Chopping sizes had an effect on millet stover intake in sheep. Unchopped millet stover showed the highest intake which did not reflect the real consumption by lambs. Thus, in practical terms, at smallholder farmers’ scale, the millet stover mean size of 25 cm would be the best useful chopping size. This size was taken as a standard for subsequent experiments.

Chapter 4

The effect of groundnut haulms supplementation on millet stover intake and digestibility and growth performance of lambs

Abstract

Supplementing millet stover (MS) with groundnut haulms (GH), millet bran (MB) and wheat bran (WB) can improve the feed value of MS and promote live weight gain of sheep in the dry season. The purpose of this study was to develop a feeding technology transferable to smallholder farmers by supplementing MS. The study was conducted in two successive phases. The phase 1 of 66 days**,** evaluated the effect of GH, MB and WB supplementations on MS intake and growth performance of sheep, the phase 2 of 14 days, assessed the effect of GH, MB and WB supplementations on intake and digestibility of MS. Six treatments were constituted, namely, 1, 2, 3, 4, 5 and 6 formed by four levels of GH (0, 200, 400, 600g) and two others (600g GH + 100g MB) and (600g GH + 75 g WB) respectively. A randomized block design was applied on 36 Oudah bicolor sheep, implying 6 male lambs per treatment (1, 2, 3, 4, 5 and 6). The GH supplementation levels had a linear effect ($P<0.001$) on dry matter intake (DMI) of MS, cell wall and nitrogen. Millet stover intake (MSI) decreased significantly with increasing level of GH. However the total dry matter intake (TDMI) significantly increased with GH levels. MB increased ($P<0.05$) both TDMI, TOMI and nitrogen intake (NI), ($P<0.001$). WB increased MSI ($P<0.05$), TDMI and TOMI ($P<0.01$), NI ($P<0.001$) and cell wall intakes. GH supplementation had both a linear and quadratic effect on DM digestibility of MS, cell wall and nitrogen digestibility. GH had a linear and significant effect ($P<0.001$) on live weight gain (LWG) and efficiency. The maximum average daily gain (80.5 g/day) was obtained with treatment 6 followed by the treatment 5 (68 g/day). The animals of treatment 1 received MS stover alone and lost their weight (-19.13 g/day). The results indicate that the supplementation of MS as the basal diet with GH and brans enhanced sheep production through improvements in digestibility and intakes of TDM, TOM, cell wall and nitrogen.

Key words: Millet stover; groundnut haulms; millet bran; wheat bran; intake; digestibility; growth performance; Oudah bicolor sheep

4.1 Introduction

Cereal Crop Residues (CCR) are poor quality feeds used mostly in tropical countries. They are low in protein, soluble sugar and starches. Their digestibility is less than 55 % (Leng, 1990). They are rich in crude fiber which decreases their degradability in the rumen. The nitrogen of CCR is often inaccessible due to the lignified cell wall. However, the nutritional value of leaves is higher than that of stems (Osafo, 1996). Cereal crop residues are also low in vitamins and minerals (Preston and Leng, 1987; Chenost and Kayouli, 1997).

In Niger, more than 53 % of crop residues are used in animal feeding (INRAN, 1996). The main crop residues used in livestock feeding are cereal residues, namely, millet stover, sorghum stover and crop legume residues such as groundnut and cowpea haulms. Some research works have shown good performance (growth and carcass) of sheep with legume haulms (Niango et al., 1995; Dan-Gomma, 1998). In Western Niger studies on cowpea haulms as the basal diet which were supplied with cereal grains and cereal bran have given a good performance in fattening sheep (Karimou, 1996; Siddo, 2001; Issa et al., 2006). However, there is competition between men and animals for cereal crops. Indeed, millet and sorghum are the main foods in Niger, which is continuously exposed to food insecurity. As a supplementation technique, the above technologies could not be adopted by the smallholder farmers who need feed self-sufficiency.

Poor nutrition is one of the main constraints of livestock productivity in sub-Saharan Africa (SSA) as the feed resources are limited both in quality and quantity (Nsahlai et al., 1993). Thus, an improved livestock system needs to be developed in order to help smallholder farmers to improve their farming income. In fact, the use of legume haulms as a supplement could reduce the use of agro industrial by-products and the duration of fattening which is generally more than 6 months. Indeed, for smallholder farmers, it is a good opportunity for them to use their own crop residues to improve the livestock productivity. This study focuses on the need to improve the utilisation of millet stover as the basal diet by supplementing with groundnut haulms, concentrates and minerals.

It is expected that these supplements will balance basal diet deficiency and will supplement nutrients needed by animals for production. The use of groundnut haulms, millet bran, wheat bran and mineral block could enhance the activity of rumen microbes. Indeed, these supplements could correct nutritional imbalance for rumen microbes, satisfy the rumen activity and therefore improve the digestibility and intake of dry matter. By adopting this type of supplementation, smallholders could increase the animal production and their farming income.

The purpose of this study is to develop a feeding technology transferable to smallholder farmers by using the local feeds namely millet stover, groundnut haulms, millet bran, wheat bran to improve the livestock productivity and livelihood of smallholder farmers. The objective of this study is to evaluate the effects of groundnut haulms on the intake and digestibility of millet stover and on the growth performance of sheep. It is hypothesized, that increasing levels of groundnut haulms would increase millet stover intake and digestibility; supplying millet bran and wheat bran could bring respectively the necessary energy and protein, thereby improving millet stover digestibility and growth rate of sheep.

4.2 Material and Methods

4.3 Voluntary intake

The experiment took 66 days of which 10 days were for adaptation period and 56 days were for data collection.

4.2.1.1 Study site

The experiment was conducted at the same site of experiment 1 in the dry season in Animal Production Station located at the Regional Centre for Agricultural Research of Maradi described in experiment 1. It consisted of supplementing millet stover with different levels of groundnut haulms and cereal brans to evaluate the intake and digestibility of millet stover.

4.2.1.2 Animals and housing

Thirty six one-year old Oudah bicolour male lambs of about (27.0 SD = 2.88 kg) live weight were used in the experiment. The initial live weight of animals was weighed at the commencement of the experiment in the morning (0800h) after depriving the animals of food for 14 hours. The animals were sorted based on weight into six groups of six animals. Animal within a group were randomly placed into six treatments. The animals were housed in a shed in the same housing as experiment 1 in individual pens. The housing had a natural floor covered with sand.

4.2.1.3 Feeds

The same stock of feeds used at the previous study were used in this experiment namely, millet stover, groundnut haulms, millet bran, wheat bran and mineral blocks. The process of getting millet stover, groundnut haulms and mineral block is described above (page 34) in the experiment 1. Millet bran is commonly produced from the processing of millet grain into flour for household use. Thus, it can easily be found by smallholder farmers. Wheat bran is an agro-industrial by-product sold generally at the market at an affordable price.

4.2.1.4 The experimental design

The treatments 1, 2, 3, 4, 5 and 6 were constituted respectively by the following levels of groundnut haulms 0, 200, 400, 600, 600 g of groundnut haulms plus 100 g of millet bran and 600 g of groundnut haulms plus 75 g of wheat bran. Each lamb in the treatment was given 3 kg of millet stovers (chopped at 25 cm) per day (1.5 kg in the morning and 1.5 kg in the afternoon).

4.2.1.5 Feeding management

The most useful chopping size of millet stover (25 cm) revealed in the experiment 1 was used as chopped millet stover. The time of feed supply was the same than experiment 1. However, once a day 100 g of millet bran and 75 g of wheat bran were supplied in individual plastic bowls to treatments 5 and 6 respectively, at 0800h before groundnut haulms and millet stover. Treatment 1 received in individual feed troughs (described above) only 3 kg of millet stover in two equal meals (1.5 kg) morning (0800h) and afternoon (1800h). The treatments 2, 3, 4, 5 and 6 received in individual plastic bowls 200, 400, 600, 600 and 600 g of groundnut haulms, respectively, in two equal meals offered in the morning and in the afternoon, as soon as the bran offered to treatment 5 and 6 was completely eaten (within 10 min). For treatment 2 which received 200 g of groundnut haulms, the whole amount was offered once a day in the morning. Animals had *ad libitum* access to water given in individual plastic bowls attached to the pen and to a mineral block which was hung in each pen.

4.2.1.6 Measurements

The feeds offered were measured the previous day in order to respect the time of feed supply. The refusals were collected in the afternoon (1700h), and at 0700h before fresh feed was offered. Samples of feed refusal (20 %) were collected each day, and stored in plastic bags. At the end of the study the composite samples were mixed and two full hands taken as a representative refusal sample for each lamb. Thus, 36 composite samples of 36 lambs were collected at the end the study for laboratory analysis.

The same process was used with the groundnut haulms; however, there were very rare frequencies of groundnut haulms refusals. The bran refusals were observed with only three animals during the first four days of the experiment. An electronic balance (Westboao OCS-2, accuracy ± 0.1%, Shenzhen West-boao Science & Technology Co., LTD. Guang Dong-China, www.west-boao.com) was used to measure the feeds offered and the refusals.

Representative feed samples of original millet stover, 5 full hands from the diagonals and middle of the feed stock were collected at the beginning, middle and the end of the study. At the end of the study these samples were mixed and one composite sample (2 full hands) was taken for laboratory analysis. The mineral block was weighed for each lamb at the commencement and end of the experiment, and the mineral intake was obtained by calculating the difference.

Animals were weighed every week at 0800h after depriving them of food and water for 14 hours. At the end of weighing, water and feed were supplied. An electronic balance (Eziweigh 2, accuracy ± 1 %, Tru-Test Limited, New Zealand, www.tru-test.com) was used to weigh the animals.

4.2.1 Digestibility

The voluntary intake and digestibility were consecutives studies. The experiment started after 66 days of voluntary intake and took 14 days of which 7 days were for adaptation and 7 days for data collection.

4.2.2.1 Measurements

The animals were weighed (0800h) at the commencement and end of the study. The only difference in measurement parameters other than intake experiment was the faeces collection. Faeces were collected twice daily (at 0700h and at 1700h) and weighed before feed supply. For each animal sub-samples (10%) of faeces were taken, and dried in the shed and stored. At end of the experiment, faeces dry matter was determined for each animal by using an oven at 65^{o}C for 48 hours. Composite faeces samples (20%) were taken for each animal for laboratory analysis. The apparent digestibility was calculated by using this formula: **Apparent digestibility** (%) = (Ingested feed **–** faeces)/Ingested feed x 100.

4.2.2 Chemical analysis

Duplicate analysis of samples of feed offered, refusal and faeces was done to determine their chemical composition. The DM was determined by using an oven at 65 ^{0}C during 48 h. The Ash was determined by combusting in a furnace for four hours at 550^{o}C, AOAC (1990) method. Crude Protein (Nx6.25) was determined by using LECO Truspec Nitrogen analyzer based on Dumas Combustion method (AOAC, 16th year edition). Neutral

Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were determined by using ANKOM Fiber Analyzer. The hemicellulose and cellulose were obtained by calculating the difference. Minerals (macro and micro elements) were determined by using a Varian 720-ES (www.varianinc.com). All the analyses were done at the Department of Animal and Poultry Science, University KwaZulu-Natal, Pietermaritzburg (UKZN) except mineral analysis which was done at the chemistry laboratory of UKZN.

4.2.3 Calculation and statistical analysis

Data were analyzed using the General Linear Model (GLM) of Statistical Analysis System (SAS, 2004, SAS Institute Inc. Cary, NC, USA) to determine the Least Square Means (LSmeans) and the significance of differences between treatments. Linear and quadratic contrasts were used to compare the effect of the level of groundnut haulms on feed intake and digestibility, live weight and efficiency of gain.

The basic statistical model was: $Yij = \mu + Li + LWTj + eij$

Where *Yij* is the independent variable (feed intake and digestibility, live weight and efficiency), *μ* the overall mean, *Li* the effect of level of groundnut haulms, *LWTj* the effect of live weight as covariate, *eij* the residual error.

The contrast statement was used to specify the effect of millet bran and wheat bran on feed intake and digestibility, live weight and efficiency of gain.

- Contrast : *4 vs 5* is the effect of millet bran
- Contrast : *4 vs 6* is the effect of wheat bran

4.3 Results

4.3.1 Chemical composition of feeds offered and refusals

The chemical composition of feeds offered and refusals are shown in Table 4.1. The animals ate all the amounts of groundnut haulms (GH) and brans offered. The refusals of groundnut haulms were obtained only with animals affected by diarrhoea and fever which were observed rarely during the experiment.

Table 4.1 Chemical composition of feeds and refusals during the experiment (g/kg DM)

Feeds	Millet stover offered	Millet stover refusal	Groundnut haulms offered	Groundnut haulms refusal	Millet bran	Wheat bran
DM	938	945	937	956	953	946
OM	935	936	924	907	939	947
N	7.4	7.4	15.1	14.8	22.0	26.2
NDF	859	836	566	562	383	482
ADF	532	524	422	433	71	140
ADL	197	190	165	260	37	43
Hemicellulose	327	312	142	1290	312	342
Cellulose	336	334	259	172	35	96
Ca	2.00	-	8.74	-	0.50	10.72
P	0.41	-	0.74	-	6.10	97.00
Na	0.75	-	0.83	-	0.42	1.77

DM: Dry Matter; OM: Organic matter; N: Nitrogen; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre; ADL: Acid Detergent Lignin; Ca: Calcium; P: Phosphorus; Na: Sodium.

The NDF and ADF were superior in wheat bran than in millet bran. Millet stover had higher NDF and ADF than groundnut haulms. Both millet stover offered and refused had similar fibre components. Similar NDF and hemicellulose were obtained with groundnut haulms offered and refused. But the lignin content was higher in refusals than in the offered groundnut haulms. The groundnut haulms (14.8 g/kg) had a higher content of nitrogen than millet stover (7.4 g/kg). The nitrogen content of wheat bran (26.2 g/kg) was higher than for millet bran (22.0 g/kg). The mineral content (macro elements), namely, calcium (Ca), phosphorus (P) and sodium (Na) of groundnut haulms is higher than of millet stover. The wheat bran had higher content of macro elements than millet bran. Wheat bran is rich in Phosphorus (97.00 g/kg). The mineral content (g/kg) of mineral block was 3.5, 0.07, 138.7, and 0.8 for Ca, P, Na and magnesium (Mg) as macro elements respectively. It was 1099.40, 4.81 and 57.02 ppm respectively for iron (Fe), copper (Cu) and manganese (Mn) as trace elements. Mineral block is rich in sodium but poor in the other elements cited above.

4.3.2 Minerals intake

The intake of calcium (Ca), phosphorus (P), sodium (Na) as macro elements linearly increased P<0.001) for both Ca and P, and Na (P<0.01) from diet 1 to 6 (Table 4.2). However, there was no quadratic effect on minerals intake. Only P intake increased significantly (P<0.001) with millet bran intake. Wheat bran increased significantly (P<0,001) the intake of both Ca and P, whereas the intake of Na was not affected.

Table 4.2 Macro elements intake (g/day)

Diet $	Ca	P	Na
1	1.22	0.24	1.39
2	2.91	0.38	2.13
3	4.49	0.49	2.18
4	6.09	0.61	2.34
5	6.15	1.22	2.54
6	7.05	7.7	2.65
SED	0.06	0.06	0.24
Linear	***	***	**
Quadratic	NS	NS	NS
Contrast			
4 vs 5	NS	***	NS
4 vs 6	***	***	NS

GH: Groundnut haulms; MB: Millet bran; WB: Wheat bran; Ca: Calcium; P: Phosphorus; Na: Sodium; ***: P < 0.001; **: P < 0.01; NS: Non significant (p>0.05); 4 vs 5: Effect of millet bran; 4 vs 6: Effect of wheat bran; SD: standard error of difference; $ Diet: 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB; 6 = 600 g GH + 75 WB.

4.3.3 Effect of groundnut haulms supplementation and bran on millet stover intake

All supplements offered were completely consumed. The level of groundnut haulms had a linear effect (P<0.001) on millet stover intake (MSI) (Table 4.3). The MSI decreased consistently with increasing level of groundnut haulms (GH). The quadratic effect of the level of groundnut haulms on intake variables was not significant. The linear effect (P<0.001) of the level of groundnut haulms was observed with total organic matter intake (TOMI), TDMI, and cell wall intake (NDFI, ADFI, CelI).

Table 4.3 Effect of level of groundnut haulms and brans on intake (g/day)

Diet $	MSI	TDMI	TOMI	NI	NDFI	ADFI	HemI	CelI	Mnls
1	601	608	562	4.46	516	320	196	202	7
2	566	777	714	7.22	599	386	213	242	11
3	479	890	817	9.59	638	424	213	264	11
4	435	1039	955	12.19	709	483	226	300	11
5	411	1122	1031	14.28	730	479	269	296	12
6	499	1183	1089	14.64	802	529	273	329	12
SED	22.2	23.1	21.6	0.17	19.5	12.2	7.37	7.6	1.7
Linear	***	***	***	***	***	***	**	***	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrast									
4 vs 5	NS	*	*	***	NS	NS	***	NS	NS
4 vs 6	*	**	**	***	**	**	***	**	NS

MSI: Millet stover dry matter intake; Mnls: minerals; TDMI: Total dry matter intake; NDFI: Neutral detergent fibre intake; ADFI: Acid detergent fibre intake; ADLI: Acid detergent lignin intake; HemI: Hemicellulose intake; CelI: Cellulose intake; SED: Standard error of difference; ***: P < 0.001; **: P < 0.01; *: P < 0.05; NS: Non significant (p>0.05); 4 vs 5: Effect of millet bran; 4 vs 6: Effect of wheat bran;
$ Diets : 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB;
6 = 600 g GH + 75 WB.

Nitrogen intake was increased linearly (P<0.001) with the level of groundnut haulms supplementation (Table 4.3). The intake of mineral block was not affected. The contrast between the treatments 4 versus 5 showed that millet bran increased TDMI, TOMI

(P<0.05), nitrogen intake (P<0.001), and hemicellulose intake (P<0.001). The contrast between treatments 4 versus 6 showed that the intakes of all variables increased significantly by supplying WB, except of minerals; (P<0.001) for nitrogen and hemicellulose intake, (P<0.01) for TDMI, TOMI and intake of all cell wall constituents; MSI was significantly (p<0.05) increased when wheat bran was supplied.

4.3.4 Effects of groundnut haulms supplementation and brans on live weight gain and efficiency

The average daily gain was improved by groundnut haulms supplementation (Table 4.4). The effect of the level of groundnut haulms was positively linear (P<0.001). However, there was no quadratic effect of level of supplementation on LWG. The level of groundnut haulms had a linear (P<0.001) and quadratic (P<0.05) effect on the efficiency. The efficiency was significantly (P<0.001) improved by increasing the GH levels. It is important to notify the shift of efficiency from treatment 3 (40.6 g/kg) to treatment 4 (39.4 g/kg), when increasing level of groundnut haulms from 400 g to 600g.

According to the contrast between the treatments 4 versus 5 (Table 4.4), millet bran stimulated LWG and efficiency non significantly. However, wheat bran significantly stimulated (P<0.05) LWG and efficiency of gain.

Table 4.4 Effect of level of groundnut haulms and brans on live weight gain and efficiency of gain

Diet $	ILWT (kg)	LWG (g/day)	Efficiency (gain/kg)
1	26.3	-19.1	-33.2
2	26.3	11.5	15.2
3	26.4	35.4	40.6
4	26.5	41.2	39.4
5	26.4	68.0	61.5
6	26.6	80.5	67.9
SED	-	11.6	12.5
Linear	-	***	***
Quadratic	-	NS	*
Contrast			
4 vs 5	-	NS	NS
4 vs 6	-	*	*

ILWT: Initial live weight; LWG: Live weight gain; SED: Standard error of difference; ***: P < 0.001; *: P < 0.05; NS: Non significant (p>0.05); 4 vs 5: Effect of millet bran; 4 vs 6: Effect of wheat bran; $ Diet: 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB; 6 = 600 g GH + 75 WB.

4.3.5 Effect of groundnut haulms supplementation and brans on intake during the digestibility trial

The mean of millet stover dry matter intake (MSI) decreased with the increasing level of groundnut haulms supplementation (Table 4.5). However, the TDMI, TOMI, cell wall intakes (except hemicellulose) and nitrogen intake (NI) increased with the level of groundnut haulms supplementation. The linear effect of the level of groundnut haulms supplementation was significant for MSI, TDMI, TOMI, NI, NDFI, CelI, (P<0.001). None of the quadratic effect was significant.

The contrast between treatments 4 versus 5 and between 4 and 6 revealed no effect of millet bran or of wheat bran, except where wheat bran increased nitrogen intake (P<0.05).

Table 4.5 Effect of groundnut haulms and brans on intake during the digestibility trial (g/day)

Diet $	MSI	TDMI	TOMI	NI	NDFI	HemI	CelI	Mnl
1	522	529	493	3.94	449	171	175	7
2	474	685	628	6.53	520	183	211	11
3	366	776	712	8.75	540	176	226	11
4	345	955	877	11.60	635	198	271	11
5	286	976	895	13.04	610	206	249	12
6	403	1090	1003	14.01	722	242	298	12
SED	45.9	50.3	47.0	0.4	41.7	15.5	16.5	1.7
Linear	***	***	***	***	***	NS	***	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
Contrast								
4 vs 5	NS	NS	NS	NS	NS	NS	NS	NS
4 vs 6	NS	NS	NS	**	NS	NS	NS	NS

MSI: Millet stover dry matter intake; Mnls: minerals; TDMI: Total dry matter intake; NDFI: Neutral detergent fibre intake; ADFI: Acid detergent fibre intake; ADLI: Acid detergent lignin intake; HemI: Hemicellulose intake; CelI: Cellulose intake; SED: Standard error of difference; ***: P < 0.001; **: P < 0.01; *: P < 0.05; NS: Non significant (p>0.05); 4 vs 5: Effect of millet bran; 4 vs 6: Effect of wheat bran;
$ Diet: 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB; 6 = 600 g GH + 75 WB.

4.3.6 Effect of level of groundnut haulms and brans on millet stover digestibility

The apparent digestibility of total dry matter, total organic matter, cell wall constituents and nitrogen increased with increasing level of groundnut haulms supplementation (Table 4.6). Both the linear and quadratic effects were observed with apparent digestibility of TDM, TOM, cell wall and N. Millet bran and wheat bran had no effect on digestibility.

Table 4.6 Effect of level of groundnut haulms and brans on digestibility (g/kg)

Diet $	TDMd	TOMD	Nd	NDFd	ADFd	Hemd	Celd
1	360	477	33.5	518	511	528	655
2	560	613	312.7	637	634	643	737
3	620	666	455.6	645	632	670	730
4	649	684	519.0	657	645	681	730
5	648	686	552.1	632	612	672	712
6	626	659	518.9	631	619	656	708
SED	28.5	24.0	38.7	27.8	28.1	28.6	22.5
Linear	***	***	***	***	**	***	**
Quadratic	**	**	**	*	*	*	*
Contrast							
4 vs 5	NS	NS	NS	NS	NS	NS	NS
4 vs 6	NS	NS	NS	NS	NS	NS	NS

TDMd: Total dry matter digestibility; Nd: Nitrogen digestibility; NDFd: Neutral detergent fibre digestibility; ADFd: Acid detergent fibre digestibility; Hemd: Hemicellulose digestibility; Celd: Cellulose digestibility; SED: Standard error of difference; ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; NS: Non significant ($p>0.05$); 4 vs 5: Effect of millet bran; 4 vs 6: Effect of wheat bran; $ Diet: 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB; 6 = 600 g GH + 75 WB.

4.4 Discussion

4.4.1 General

The chemical characteristics of millet stover, groundnut haulms, millet bran, and wheat bran were consistent with the range of Jayasuriya (2002). These values demonstrated that millet stover is a poor quality cereal crop residue; groundnut haulms, millet bran and wheat bran have high protein content. In ruminants fed on crop residues such as millet stover, intake is relatively low due to high lignocellulose and low N content, and will not provide sufficient nutrients for maintenance requirements (Van Eys et al., 1987; Leng, 1990; Savadogo et al., 2000). The maintenance requirements could be met by supplementing millet stover with low-levels of protein or non-protein nitrogen such as was the case with low level of groundnut haulms. However, to increase productivity above maintenance, digestibility and protein supplementation would need to be increased (Preston, 1982; Smith, 1987; Nsahlai et al., 1993; Chenost and Kayouli, 1997; Jayasuriya, 2002).

The chemical composition shows similar nitrogen and cell wall content of millet stover offered and refusals. This could be explained by the high amount (3 kg/day) of millet stover offered such that even if the sheep selected leaves, a substantial amount of leaves was still lost with refusal. The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were similar in offered and refusal groundnut haulms. However, the content of acid detergent lignin (ADL), hemicellulose and nitrogen (N) differs between offered and refusal groundnut haulms. ADL was higher in refusal than in GH offered and the content of hemicellulose and N were higher in GH offered than GH refusal. These results are similar with the study of Ayantunde et al. (2007) who supplemented bush hays with groundnut haulms and showed that hemicellulose and N were higher in GH offered than GH refusal whereas ADL in refusal was higher than GH offered. This could be explained by the selective feeding behaviour of sheep; when given a choice, they select the most palatable and nutritive constituents.

The increased consumption of both calcium (Ca) and phosphorus (P), and sodium (Na) could be due to the increasing level of groundnut haulms. The highest amount of P intake for diet 6 than other diets was due to the supply of wheat bran which is rich in P.

4.4.2 Effect of groundnut haulms

It is known that the best use of poor quality forage is mainly to improve its intake and digestibility by increasing the activity of the rumen ecosystem in order to maximize fibre digestion and optimize microbial protein synthesis. This requires sufficient fermentable nitrogen, energy and minerals to support the rumen microbial population. To satisfy these conditions, groundnut haulms, millet bran, wheat bran and mineral block were supplied to supplement millet stover which is rich in fibre but contains no starch and insignificant amounts of protein. The supplementation was mainly concerned with the need to improve the nitrogen content of diets in order to overcome the nitrogen deficiency in the rumen (Leng, 1987; Smith, 1987; Chenost and Kayouli, 1997) and to provide easily fermentable fibre (Pathirana and Orskov, 1995; Orskov, 1999).

It was observed that the millet stover intake (MSI) decreased linearly with the level of groundnut haulms (GH) supplementation in both phases of the study. These findings were similar to those of Ngwa and Tawah (1992), Savadogo et al. (2000) and Ayantunde et al. (2007). Savadogo et al. (2000) reported that sorghum stover intake declined with even low levels of groundnut haulms supplementation while Koralagama et al. (2008) showed increased maize stover intake with both cowpea haulms supplementation levels (150 and 300g).

The significant linear increase of total dry matter, total organic matter, nitrogen and the cell wall (except hemicellulose) intakes with levels of groundnut haulms supplementation, in both phases of the study, could be due to consumption of the supplements rather than the roughage basal diet (millet stover). This is also in agreement with the studies of Savadogo et al. (2000), Ayantunde et al. (2007), Koralagama et al. (2008).

The drop of DM, N and cell wall intakes observed in the digestibility trial compared to the intake trial might be attributed to the stress due to faeces collection bag and the scorching heat, the mean temperature min/max was 29/42 ^{0}C (DMN Niger, 2010) during the digestibility trial. This is in agreement with Chermiti et al. (1991) who stipulated that the voluntary intake depends on many factors related to animals, feeds and environment; voluntary intake of roughage diet is limited by low digestibility of cell wall and high temperature.

The linear and significant ($P<0.001$) increase of the LWG and efficiency of gain with the level of groundnut haulms supplementation, were similar to studies conducted by Savadogo et al. (2000), Ayantunde et al. (2007) and Koralagama et al. (2008). Ayantunde et al. (2007) observed a high LWG of 40.2 g/day and live weight loss of -18.4 g/day, when animals were fed respectively 450 g of groundnut haulms (GH) and bush hay (alone) as the basal diet.

Despite the mineral block supply, MS could not satisfy the animal maintenance. The minimum supply of 200 g of groundnut haulms ensured the maintenance and increased the LWG (11.5 g/day) while Ayantunde et al. (2007) used a minimum supply of 150 g of groundnut haulms on bush hay as the basal diet and obtained the LWG of 1.4 g/day.

The small change in efficiency of gain for the 600 g of groundnut haulms implied that 400 g GH is the best level of supplementing with GH alone and the energy did not constitute a limiting factor of diets (Figure 1). These results demonstrate that groundnut haulms are a good supplement for poor quality roughage and this corroborates our results on chemical composition and degradability *in sacco* of groundnut haulms.

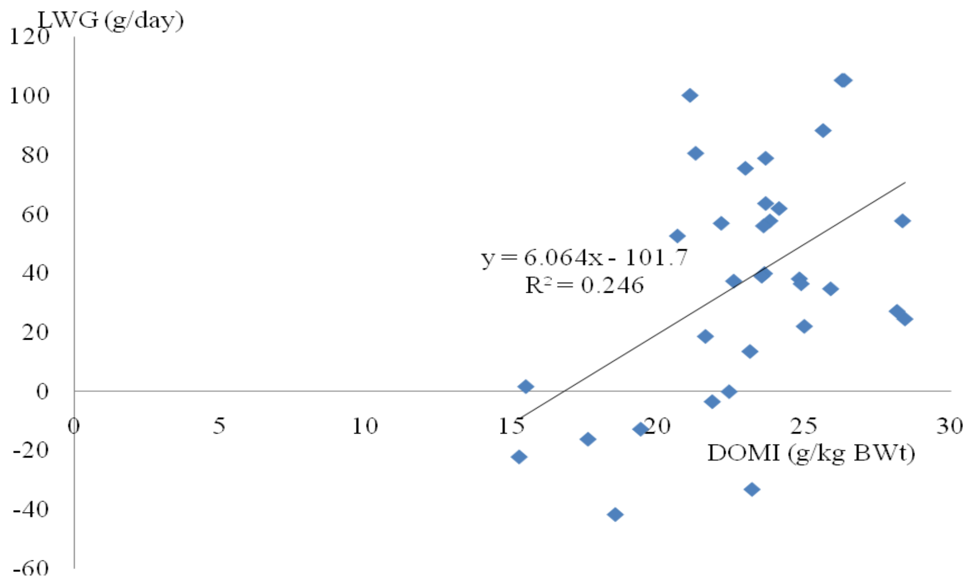

Figure 1 The relationship between live weight gain and the digestible organic matter intake (DOMI)

4.4.3 Effect of brans

The effect of millet bran (MB) was shown by the contrast 4 vs 5. The non-significant effect on millet stover intake when 100 g of millet bran was added on the high level (600 g) of groundnut haulms could be due to the insufficient amount of protein supplied by 100 g of millet bran (Figure 2) to stimulate the microbial activity of the rumen. However, the significant increase of TDM, TOM, N, and hemicellulose intakes were observed with millet bran while there was no significant effect on LWG and efficiency of gain. This could also be explained by the insufficient amount of N supplied by 100 g of millet bran since the nitrogen still constituted a limiting factor (Figure 2).

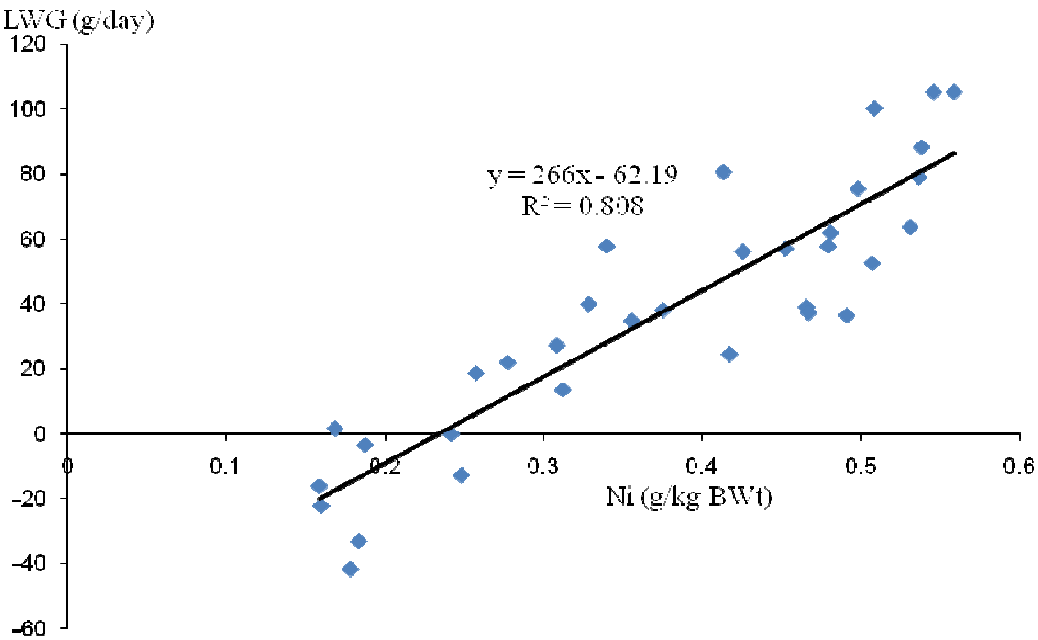

Figure 2 The relationship between live weight gain and nitrogen intake

However, despite the non-significant effect of millet bran (MB), non-negligible increases of LWG and efficiency were observed. This is attributed to the amount of both energy and protein provided by millet bran which would ensure a good balance of fermentation. According to Preston (1984), Leng (1987, 1990) and Chenost and Kayouli (1997), the supplement must provide energy and protein in order to enhance the animal production; this is perhaps the reason why millet bran increased LWG. Secondly, phosphorus (P) supplied by millet bran (Table 4.2) could increase the microbial activity since the P supplied by diet 4 (0.61 g/day) was so far from meeting the daily requirement of 3 g/day of sheep (MTT, 2010). Furthermore, phosphorus is more important than other minerals. It plays an important role in metabolism of glucose, protein and lipid and it is required for correct bone growth. The MB supply could exert a positive effect on LWG by increasing the content of diet to meet the P requirement, although P did not constitute a limiting factor (figure 3).

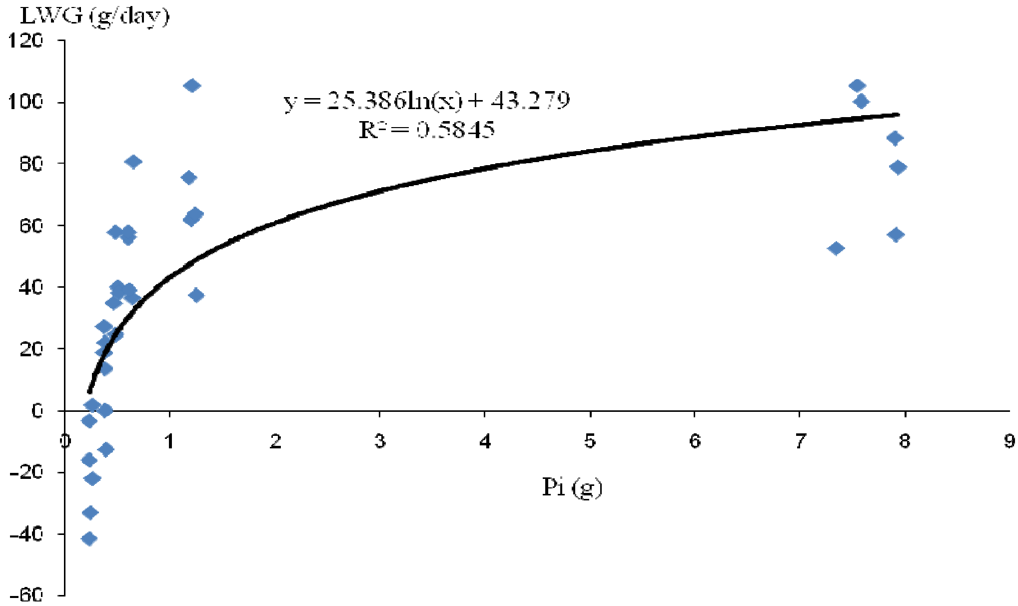

Figure 3 The relationship between live weight gain and phosphorus intake

The effect of wheat bran (WB) was shown by the contrast 4 vs 6. Wheat bran had a significant effect on millet stover intake, TDM, TOM, N, and cell wall intakes at the phase of intake trial. This improvement of intake could be attributed to the protein brought by 75 g of wheat bran which stimulated the rumen activity and improve the live weight gain and efficiency. These improvements in live weight and efficiency could be due to the interaction of N, calcium (Ca) and phosphorus (P) intakes supplied by wheat bran (Table 4.2). In addition to the important role of P described above, calcium supply is also important for the solidification of bones and teeth. Furthermore, the Ca and P supplied by diet 6 satisfied the requirements of sheep which are 5 and 3 g/day for Ca and P respectively (MTT, 2010).

4.5 Conclusion

The groundnut haulms supplementation had an effect on millet stover intake and digestibility. Groundnut haulms had a linear and significant effect on intake and digestibility of total dry matter, total organic matter, nitrogen and cell wall. This translated into a linear and significant effect of the level of groundnut haulms on live weight gain and efficiency of gain.

Millet bran had a significant effect on total dry matter, total organic matter, nitrogen, and hemicellulose intakes; but had no effect on digestibility. The live weight gain and efficiency of gain were non-significantly improved.

Wheat bran significantly improved millet stover, total dry matter, organic matter, nitrogen, and cell wall intakes; but had no effect on digestibility. Wheat bran significantly improved the live weight gain and the efficiency of gain.

It is suggested that in the dry season, when the availability of groundnut haulms were limited, it may be economical to supplement with low level (200g) of groundnut haulms and a low level of bran to avoid the loss of animal weight and therefore to produce moderate LWG. When the feed is plentiful, it would be more economical to supplement with the optimum amount of groundnut haulms (600g) in association with moderate levels of bran (100g) to generate good growth performance (>80 g/day) of male lambs. Thus, it would be better to add the number of lambs to fatten than to increase the amount of food. Further studies are needed to determine the performance of Oudah bicolor male lambs with increasing level of protein.

Chapter 5

General Discussion and Conclusions

In Sahelian countries, the most important constraints of livestock production are poor animal nutrition and productivity due to inadequate feed supply (Nsahlai et al., 1993). Crop residues constitute an important feed resource for animal production. However, cereal crop residues have low nutritive value, low contents of metabolizable energy and crude protein whereas legume crop residues have good nutritive value. Thus, there is a need to develop more efficient way of utilizing these available feed resources.

The smallholder farmers store crop residues to feed their animals mostly during the period of feed shortage in the dry season. In Niger, millet stover is widely used by ruminants as millet remains the staple food. The legume crop residues such as cowpea and groundnut haulms are the main feeds used in animal feeding. However, they are inadequately used; thus, strategies are needed to maximize their utilization in sheep feeding systems.

Millet stover is characterized as low quality roughage based on its NDF (859 g/kg), N (7.4 g/kg), and potential degradability (412 g/kg). Its digestibility is limited particularly for small ruminants. As the basal diet for small ruminants, the use of millet stover should be maximized since small ruminants such as sheep have limited gastro intestinal capacity. In order to increase animal performance there is a need to supplement millet stover, otherwise performance will be held to near or below maintenance levels (Demment, M.W, Van Soest, P.J., 1983; Preston, 1984; Reed et al., 1987; Smith, 1987; Leng, 1987, 1990; Chenost and Kayouli, 1997). In this study unsupplemented animal loss weight (-19 g/day).

High quality supplements such as agro-industrial by-products (cottonseed cake, groundnut cake etc.) are appropriate to improve the nutritive value of millet stover but are beyond the economical situation of small holder farmers. Consequently, ample amounts of millet stover would be used. Millet stover is a long (> 2 m) (Oumar and Sawsen, 2010) cereal crop residue. Smallholder farmers use millet stover in feeding animals without chopping and offer it on the floor, not in the trough. This practice causes a lot of wastage due to the animals tramping and contamination with urine and faeces which reduces its intake.

Secondly, chopping millet stover in small size (10 cm) may reduce its intake due to the difficulty in selecting the most palatable parts, namely the leaves and sheath. The chopping of millet stover can increase the intake and reduce the feed wastage. Chopped millet stover can be easily offered in the trough to sheep. Sheep prefer to select millet stover leaves and sheath than stems which are not palatable and less degradable in the rumen due to the chemical characteristics. However, the small chopping size hinders sheep from selecting appropriately, which explains why the intake of small chopping (10 cm) was lower compared to the moderate chopping sizes. The chopping size of 25 cm was chosen in this study as a standard level which can be easily handled by smallholder farmers due both to its higher intake and less feed wastage. The advantage of this is that refusals can be used to feed cattle whereas the refusals of unchopped millet stover are not recycled in feeding animals due to the contamination with urine and faeces.

Legume crop residues such as groundnut haulms are potentially available to small ruminant holders. Groundnut haulms contain intermediate concentration of N (15.1 g/kg) and NDF (566 g/kg), thus, it is a good source of both energy and protein. The use of groundnut haulms as supplement can improve the rumen ecosystem for maximal utilization of millet stover as the basal diet. Supplementation with groundnut haulms improved total dry matter intake and can maintain or enhance sheep performance depending on supplementation levels. Furthermore, the animal production is higher when adding millet bran or wheat bran on groundnut haulms supplementation.

Besides the role in increasing dietary protein and energy, legume supplementation may have shifted volatile fatty acid production in favour of propionate (known as original precursor of glucose) and stimulated microbial protein production (Van Eys et al. 1986). Legume supplementation of roughage accelerates rumen turnover, and consequently, increases the efficiency of microbial protein production (Bhatti et al., 2008). The inclusion of groundnut haulms as a supplement of millet stover may increase the rate of passage, the proportion of protein which escapes rumen fermentation (Table 5.1) and the efficiency of microbial protein production, therefore the increase of DM digested.

Table 5.1 Nitrogen bypass of groundnut haulms, millet bran and wheat bran (g/day)

Diet $	1	2	3	4	5	6
Total bypass N	0	0.34	0.68	1.02	1.12	1.04

N: Nitrogen; $ Diet: 1 = 0 g GH; 2 = 200 g GH; 3 = 400 g GH; 4 = 600 g GH; 5 = 600 g GH + 100 g MB; 6 = 600 g GH + 75 WB; GH: Groundnut haulms; MB: Millet bran; WB: Wheat bran.

Supplementation on high-fibre diets with a feed of high quality invariably results in an increase in the total DM intake. Changes in intake of the basal diet, however, will be influenced by the composition and physical form of the supplement. Thus, a legume supplement or supplement with high level of NDF usually decreases the intake of the basal diet. However, supplementing with legumes at very low levels (10-15% of DM intake) may stimulate intake of the basal diet although this response is generally smaller than with the concentrate supplement (Demment and Van Soest, 1983; Koralagama et al., 2008). With legume supplements, the effect of fibre digestibility is normally smaller than of concentrates supplements and the depression in intake of the basal diet with legume occurs mainly because of substitution effect. The results of our study matched this theory of the substitution effect with the levels of groundnut haulms supplementation.

An appropriate level of concentrate (20-30% of total DM intake) such as cottonseed cake or groundnut cake increase roughage intake. A large amount of good quality legume residue is required to create the same effect, because of the difference in nutrient density between concentrates and legumes. Nevertheless, because of economic reasons, forage legume remains the supplement of choice for many small ruminant producers.

According to Allden (1981), 2.5 g feed N / 100 g digestible organic matter will ensure adequate levels for fiber digestion, and thereby, reduce the effect of rumen fibre fill on intake. On this basis a diet of 50 % digestibility would require a feed N concentration of 1.25 %. Many fibrous crop residues are deficient in N. Thus, a N supplement is necessary (Leng, 1987; Smith, 1987; Nsahlai et al. 1993; Chenost and Kayouli, 1997). The use of millet bran and wheat bran as supplements in our study was in response to this matter. However, the amount of millet bran (100 g daily) used in our study was not sufficient to increase significantly the digestibility of dry matter.

The order of feed distribution is an important factor which could stimulate the ruminal activity for fibre digestion. The practice of giving bran first, followed by groundnut haulms and millet stover could create a good ruminal ecosystem, increase digestibility and intake.

A supplementation strategy is a main practical option to increase sheep production systems through the improvement of intake and digestibility of diet. Legume crop residues, brans and minerals may be used to develop more efficient feeding systems for sheep.

Conclusions and future Research

It is concluded that chopping millet stover can increase the intake and reduce the feed wastage.

The degradability of millet stover stems is slower than for whole millet stover and millet stover leaves.

Groundnut haulms is good supplements for sheep fed on millet stover. The live weight gain of sheep increased with increasing level of groundnut haulms. The efficiency of gain increased up to 400 g of groundnut haulms, beyond which there was no increase.

Millet bran and wheat bran improve rumen activity, total intakes and live weight gain of sheep but they have no effect on digestibility of diet probably due their insufficient amount. Wheat bran has more effect on millet stover intake, total intakes, nitrogen intake and live weight gain. Both brans radically increase the efficiency of gain.

Further studies are needed on supplementing millet stover with groundnut haulms, brans and multi-nutritional blocks to correct the nitrogen deficiency recorded in this study in order to reach the optimum growth performance of male lambs. For the same target, groundnut haulms can be used as the basal diet with brans and multi-nutritional blocks.

References

Abdou, N. (2004). Pratiques de gestion des biomasses participant aux relations agriculture élevage dans les systèmes agro-pastoraux de l'Ouest du Burkina Faso (le cas du village de Koro). Mémoire de fin d'étude pour l'obtention du diplôme d'Ingénieur de Conception. Option Zootechnie. IPR/IFRA Bamako, Mali. 87 p.

Al-Jassim R.A.M., Ereijfej K.I., Shibli R.A and Abudabos A. (1998). Utilisation of concentrate diets containing a corns (*Quercus aegilops* and *Quercus coccifera*) and urea by growing Awassi lambs. *Small Ruminant research* 29(3):289-293.

Allden, W.G. (1981). Energy and protein supplements for grazing livestock. In Morley, F.H.W., ed., Grazing animais. Elsevier Scientific Publishing Co., Amsterdam, Netherlands. pp. 289-307.

Asma H. M. and Mohammed E. E. (2009). Effects of chopping on utilisation of sorghum stover by Nubian goats. In Pakistan Journal of Nutrition 8 (10): 1567-1569.

Ayantunde, A. A., Delfosse, P., Fernandez-Rivera, S., Gerard, B., and Dan-Gomma, A. (2007). Supplementation with groundnut haulms for sheep fattening in the West African Sahel. In Trop Anim Health Prod 39:207-216.

Ben Salem, H. and Smith, T. (2008). Feeding strategies to increase small ruminant production in dry environnemnt. *Science Direct, Small Ruminant Research* 77:174-194.

Ben Salem, H. and Nefzaoui, A. (2003). Feed blocks as alternative supplements for sheep and goats. In *Small Ruminant Research,* Volume 49, Number 3, pp. 275-288(14).

Bhatti S. A., Bowman J. G. P., Firkins, J. L. , Grove, A. V. and Hunt, C. W. (2008). Effect of intake level and alfalfa substitution for grass hay on ruminal kinetics of fiber digestion and particle passage in beef cattle. In *J. Animal Science* 86:134-145.

Boudet, G. (1971). Esquisse pastorale et esquisse de transhumance de la région du Gourma, le Mali. IEMVT, Maisons-Alfort, 131p.

Boudet, G. (1991). Manuel sur les pâturages tropicaux et les cultures fourragères. IEMVT/Ministère de la Coopération, Paris, 266p.

Boudet, G. and Riviere, R. (1968). Emploi pratique des analyses fourragères pour l'appréciation des pâturages tropicaux. *Rev. Elev. Med. Pays Trop*. 21, (2): 227–226.

Boukary, A.R. (1999). Utilisation des techniques de la production de gaz in vitro, in sacco et de la spectrométrie dans le proche infrarouge pour l'évaluation de la valeur alimentaire des aliments du bétail au Niger. Thèse de fin de fin de cycle de spécialisation Production Animale, *option*: Alimentation-Nutrition. Institut National Agronomique de Tunis.

Boutonnet, J.P., Michel Griffon, M. and Viallet, D. (2000). Compétitivité des productions animals en Afrique subsaharienne et à Madagascar. *Synthèse générale*, CIRAD/EMVT - INRA/SAD.

Buldgen, A. and Dieng, A. (1997). Andropogon gayanus *var. ' bisquamulatus '*. Une culture fourragère pour les régions tropicales. Gembloux, Belgique: Les Presses agronomiques de Gembloux.

César J. and Gouro A. (2004). L'importance des ligneux à usage pastoral. Bobo-Dioulasso, Burkina-Faso, CIRDES, Fiche Technique n°6, 8 p.

Chenost, M. and Kayouli, C. (1997). Utilisation des fourrages grossiers en régions chaudes. Etude FAO Production et Santé Animales no. 135. Rome, Italie. 226 p.

Chenost, M. and Besle, J.M. (1993). Ammonia treatment of crop residues via ureolysis: some reflection on the success of the treatment and on the utilization of the treated material. Proceed, of the International Conf. on Increasing Livestock Production Through Utilization of Farm and Local Resources, Beijing, China, 18-22 October 1993, pp 153-171.

Chenost, M., Royer, V., Centres, J.M., Gaillard, F. and Davis, J. (1993). Traitement des tiges de maïs à l'urée et utilisation pour la production laitière en région productrice de café et de banane en Tanzanie. Rev. Elev. Méd. Vét. Pays Trop*.*, 46, 4, 597-608.

Chermiti, A., Nefzaoui A., Teller E. and Vanbelle M. (1991). Variation de l'ingestion volontaire des lignocelluloses chez les ruminants (cas des pailles de riz). In *CIHEAM-IAMZ*, Options Méditerranéennes - Série Séminaires - no16 - 1991: 61-65.

CILSS (2002). Les ressources naturelles, clés du développement. Ouagadougou, Burkina Faso. CILSS. 29 p.

CILSS (2004). Les actes de la Conférence au sommet des Chefs d'Etats et de Gouvernement du CILSS. Ouagadougou, Burkina Faso : CILSS. 47 p.

Dan-Gomma, A. (1998). Influence de type de fourrage et de différents niveaux de suppléments sur les performances des ovins au Niger. Mémoire de fin d'études pour l'obtention du diplôme d'Ingénieur d'Etat. Option Productions Animales. Institut Agronomique et Vétérinaire Hassan II Maroc. 71 p.

Demment, M.W. and Van Soest, P.J. (1983). Body size, digestive capacity and feeding strategies of herbivores. Winrock International, Morrilton, AK, USA. 80 p.

Deniz, S., Coskun, B. and Kaplan, O. (1995). The possibility of using ammonia-treated wheat straw for fattening yearling lambs. *Hayvancilik Arastirma Dergisi* 5(1-2):18-20.

Devendra, C. (1991). Technologies currently used for the improvement of straw utilisation in ruminant feeding systems in Asia. In Proc. of a Workshop held at the Malaysian Agricultural Research and Development Institute, 7-11 October 1991, "Utilisation of straw in Ruminant Production Systems", pp 1-19.

Dicko, M. S. and Sikena, L. K. (1992a). Fodder trees and shrubs in range and farming systems in dry tropical Africa. In : *Legume trees and other fodder trees as protein sources for livestock, Animal Production and Health,* paper No. 102. FAO, 339 p.

Dicko, M. S. and Sikena, L. K. (1992b). Feeding behaviour, quantitative and qualitative intake of browse by domestic ruminants. Legume trees and other fodder trees as protein sources for livestock, Animal Production and Health, FAO (102): 339 p.

DMN-Niger (2010). Direction de la météorologie nationale du Niger, données de températures de la station météorologique de Maradi.

Dulphy, J.P. (1978). Effet des autres constituants de la ration (glucides, matières azotées) sur la valeur alimentaire des pailles ordinaires ou traitées, In: *«Utilisation des matières premières cellulosiques en particulier la paille en alimentation animale».* C.A.A.A. pp. 121-134.

Fall, S.T. (1991). Arbres et arbustes fourragers dans l'alimentation des ruminants domestiques en zones Sahélienne et Soudanienne; valeur nutritive d'espèces appétées au Sénégal. In: *Actes du quatrième congrès international des terres et parcours*. (2):670 - 673.

Fall, S.T., Samba, A., N'Diaye, S.A. and Traoré, E. (2000). Exploitation des arbres à usages multiples dans les systèmes d'élevage des zones soudanienne et sahélienne. In *Production and Utilization of Multi-purpose Fodder Shrubs and Trees in West Asia, North Africa and the Sahel*. ICARDA (International Center for Agricultural Research in the Dry Areas), ILRI (International Livestock Research Institute, ILRI).

FAO (2007). Use of sorghum stover as dry season fodder. Bird-resistant and non bird-resistant varieties. In *Technology for Agriculture*. http://www.fao.org/teca

FAOSTAT (1999). Food and Agriculture Organization Statistics.

Fernandez-Rivera, S., Midou, A. and Marichatou, H. (1994). Effect of food allowance on diet selectivity and intake of pearl millet (*Pennisetum glaucum*) stover leaves by sheep. In: *Animal Production* 58, 249–256.

Forsberg, N.E., Al-Maqbaly, R., Al-Halhali, A., Ritchie, A. and Srikandakumar, A. (2002). Assessment of molasse-urea blocs for goat and sheep production in the Sultanate of Omam: intake and growth studies. *Tropical Animal Health and Production* 34:231-239.

Francis, A., Gouro, A.S., Ndlovu, L., Nuru, H., Lameta, K. and Judith, F. (2009). Improving Livestock Development in ACP countries: The role of Science, Technology and Innovation in addressing the challenges to food security and economic empowerment. In *CTA*, 2009.

Gihad, E.A. (1979). Value of Dried Poultry Manure and Urea as Protein Supplements for Sheep Consuming Low Quality Tropical Hay. In *J. Anim Sci*. 1979. 48:144-156.

Gognet G.P., Minghey, M. and Brahim, B.O. (1992). Valeur nutritive des residus de recolte et des sous-produits agro-industriels offerts a des moutons peuls du Sahel. In *Small Ruminant Research and Development in Africa*. September 1994.

Grenet, E. and Barry, P. (1990). Microbial degradation in the rumen of wheat straw and anhydrous ammonia treated wheat straw observed by electron microscopy. Reprod. Nutr. Dev., 30:533-540.

Grenet, E. (1997). Aspects microscopiques de la degradation microbienne des tissus végétaux dans le rumen. *INRA Prod. Anim., 10 (3): 241-24.*

Griffith, D.L.V. (1994). A trial to investigate the use of ensiled broiler chicken litter manure in diets for fattening lambs. In: Barbados Society of Technologists in Agriculture (BSTA), Caribbean Developement Bank Barbados. *Proceedings of eleventh annual conference*. pp. 58-71.

Hiernaux, P., Fernandez-Riviera, S., Schlecht, E., Turner, M.B. and William, T.O. (1998). Livestockmediated nutrient transferts in sahelian agro-ecosystems. *In* Soil fertility management in West Africa land use systems. Proceeding of the regional workshop, Univ. of Hohenheim / Icrisat Sahelian Center / INRAN, 4–8 mars 1997, Niamey, Niger.

Huntington, J.A. and Givens, D.I. (1997). Studies on in situ degradation of feeds in the rumen: Effect of species, bag mobility and incubation sequence on dry matter disappearance. Anim Feed Sci Tech 1997; 64: 227-241.

Ickowicz, A., Richard, D. and Manlay, R. (2000). Etude de la valorisation des ressources fourragères par les éleveurs sur les terroirs agro-sylvo-pastoraux soudaniens : pratiques d'élevage et utilisation de l'espace. *In* Dugué P. (éds.), 2000 : Fertilité et relations agriculture–élevage en zone de savane. Acte de l'atelier sur les flux de biomasse et la gestion de la fertilité à l'échelle des terroirs. CIRAD, 5-6 mai 1998, Montpellier, France.

INRAN (1996). Développement des stratégies d'utilisation efficiente des résidus de cultures, des sous-produits agro-industrials dans l'alimentation du bétail au Niger. Document de travail du séminaire de Tahoua 3-5 Janvier 1997. P.32.

Issa, M.B. (2006). Problématique de la gestion durable des resources naturelles et du développemnt agricole en afrique de l'Ouest. Intégration agriculture-élevage : alternance pour une gestion durable des ressources naturelles et une amélioration de l'économie familiale en Afrique de l'Ouest et du Centre. Ouagadougou: INERA, Nairobi : ILRI, Dakar : CORAF/WECARD. pp. 7-22.

Issa, S., Mohammed, A., Ibro, G., Soumailou A. and Sido S. (2006). Amélioration des techniques de valorisation des ressources alimentaires locales pour l'engraissement des ovins dans le Sud-Ouest nigérien. Intégration agriculture-élevage: alternance pour une gestion durable des ressources naturelles et une amélioration de l'économie familiale en Afrique de l'Ouest et du Centre. Ouagadougou : INERA, Nairobi: ILRI, Dakar: CORAF/WECARD. pp. 160-169.

Jahnke, H.E. (1998). Livestock production systems and livestock development in tropical Africa. Kiel, Germany: Wissenschaftsverlag Vauk. 96 p.

Jayasuriya, M.C.N. (2002). Principles of ration formulation for ruminants. www-naweb.iaea.org/nafa/aph/public/review-1.pdf. Consulted the 29/07/2009.

Kafedzhiev, V., Ivanov, I., Uzunov, G. and Gerchev, G. (1998). Results from fattening lambs with ammonia treated hay. Animal Science 35(2):16-19.and Al. 1998.

Kamuanga, M. (2002). Rôle de l'animal et de l'élevage dans les espaces et les systèmes agraires des savanes soudano-sahéliennes. In *Savanes africaines: des espaces en mutation, des acteurs face à de nouveaux défis*. Actes du colloque, mai 2002, Garoua, Cameroun. Prasac, N'Djamena, Tchad - Cirad, Montpellier, France. http://hal.archives-ouvertes.fr/hal-00143518/en/.

Karimou, M. (1996). Evaluation technique et économique de l'embouche ovine pratiquée par les femmes à Toukounous (Filingué). Programme Amélioration des Productions Animales. In: Rapport d'activités INRAN 1996. Niamey, Niger, INRAN. P. 88-90.

Kayouli, C. (1979). Amélioration de la valeur alimentaire de la paille par le traitement à la soude dans les zones méditerranéennes: Exemple Tunisie. Thèse, Institut National Agronomique de Tunisie.

Kayouli, C. (1988). Rapport de Mission. Projet TCP/NER/6758 - Traitement à l'urée des fourrages grossiers en milieu agricole. Niger - Juin 1988.

Kayouli, C. (1994a). Rapport de mission. Projet FAO - PNUD/NER/89/016 Niger: Traitement à l'urée des fourrages grossiers.- Mai 1994.

Kayouli, C. (1994b). Rapport de mission, Projet TCP/CMB/2254 (E): Plan d'urgence pour la sauvegarde du bétail au Cambodge. Avril 1994.

Kayouli, C. (1995). Second Advisory Mission, FAO-TCP/LAO/4451.Increasing utilization of locally feed resources for cattle and buffaloes in LAO, PDR. January, 1995.

Koralagama, K. D. N., Mould, F. L., Fernandez-Rivera, S. and Hanson, J. (2008). The effect of supplementing maize stover with cowpea (Vigna unguiculata) haulms on the intake and growth performance of Ethiopian sheep. In *Animal* (2008), 2:6, pp. 954–961 & *The Animal Consortium 2008*.

Kouonmenioc, J., Lacoste, A. and Guérin, H. (1992). Etude de l'influence de quatre fourrages ligneux sur l'évolution pondérale des ovins de la race naine de l'Afrique de l'Ouest. The Complementarity of Feed Resources for Animal Production in Africa.

Le Houérou, H.N. (1980). Role of browse in the sahelian and sudanian zones. In: *Browse in Africa, the current state of knowledge*. ILCA, Addis Ababa, Ethiopia.

Leng, R.A. (1990). Factors affecting the utilization of poor quality forages by ruminants particularly under tropical conditions. Nutr. Res. reviews, 3:277-303.

Leng, R.A. (1986). Determining the nutritive value of forage. In: Blair, G.J., Ivory, D.A. and Evans, T.R. (eds), *Forages in Southeast Asian and South Pacific Agriculture.* ACIAR Proceedings No. 12, ACIAR, Canberra, pp. 111-123.

Leng, R.A. (1987). Nutritional role of concentrate feeds and perspectives for their substitution based on recent advances in nutritional science. *In Proceedings of the FAO Expert Consultation on the substitution of imported concentrate feeds in animal production systems in developing countries*. FAO Animal Production and Health. Paper 63.

Lowry, J.B., Pehteram, R.J. and Budi, T. (1992). Plants fed to village ruminants in Indonesia. Notes on 136 species, their composition, and significance in village farming systems. ACIAR Technical Reports No. 22, 60 pp.

Manyuchi, B. Hovell, F.D.D., Ndlovu, L.R., Topps, J.H. and Tigere, A. (1997). The use of groundnut hay as a supplement for sheep consuming poor quality naturel pasture hay, *Animal Feed Science and Technology*, 69 (1-3):17-26.

Makkar, H.P.S. (2007). Feed supplementation block technology – past, present and future. In Feed supplementation blocks. FAO Animal Production and Health.

McIntire, J., Bourzat, D. and Pingali, P. (1992). *Crop-Livestock interaction in Sub-Saharian Africa*. World Bank regional and sectorial studies. Washington D.C., USA: The World Bank. 246 p.

MRA (2000). Direction de la production animale et des services vétérinaires, service statistique/commercialisation/documentation. Système d'information sur les marchés à bétail. Conférence sur les perspectives agricoles de l'Afrique de l'Ouest (Bamako du 7 Au 9 février 2000).

MTT (2010), Mineral requirements of sheep. In *MTT Agrifood Research,* 2010. www.mtt.fi/rehutaulukot/english/nutrient_requirements/Ruminants/minerals_sheep.

Murphy, A.M. and Pablo, E.C. (1999). A tropical forage solution to poor quality ruminant diets: A review of *Lablab purpureus. Livestock Research for Rural Development. By line:* http://www.cipav.org.co/lrrd/lrrd11/2/colu.htm.

Ngwa, A. T. and Tawah, C. L. (1992). Effect of legume crop residues and concentrate supplementation on voluntary intake and performance of kirdi sheep fed a basal diet of rice straw. In *FAO ILCA*. The complementarity of feed resources for animal production in Africa.

Ngwa, A.T., Nsahlai, I.V. and Bonsi, M.L.K. (2000). The potential of legume pods as supplements to low quality roughages. *Short paper and poster abstracts: 38th Congress of the South African Society of Animal Science*. In South African Journal of Animal Science 2000, 30 (Supplement 1). The South African Journal of Animal Science is available online at http://www.sasas.co.za/Sajas.html.

Nianogo, A.J., Soma, L., Bonkougou, G.F.X., Nassa, S. and Zoundi, J.S. (1995). Utilisation optimale de la graine de coton et de fourrages locaux pour l'engraissement des ovins Djallonké type Mossi. Revue du Réseau pour l'amélioration de la productivité agricole en milieu aride 7.

Norton, B.W. (1998a). The Nutritive Value of Tree Legumes. In Forage Tree Legumes in Tropical Agriculture. The Tropical Grassland Society of Australia Inc.

Norton, B.W. (1998b). Tree Legumes as Dietary Supplements for Ruminants. In Forage Tree Legumes in Tropical Agriculture. The Tropical Grassland Society of Australia.

Nsahlai, I.V., Osuji, P.O. and Khalili, H. (1993). Feed evaluation. In ILCA Manual 5.

Obilana, A.B. (2003). Overview: Importance of millets in Africa. www.afripro.org.uk .

Ørskov, E. R. and McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural Science, Cambridge, 92:499-503.

Ørskov, E. R, DeB Hovell, F. D., and Mould, F. (1980). The use of the nylon bag technique for the evaluation of feedstuffs. In: *Trop Anim Prod 5:3.*

Ørskov, E. R, Reid, G. W, and Kay, M. (1988). Prediction of intake by cattle from degradation characteristics of roughages. Animal Production. 46: 29 - 34.

Osafo, E.L.K., Owen, E., Said, A.N., Gill, E.M. and McAllan, A.B. (1993). Feeding sorghum stover to Ethiopian sheep and cattle: effect of chopping and amount offered on intake and selection. In: Animal Production in Developing Countries.

Osafo, E.L.K, Owen, E., Said, A.N., Gill, M., and Sherington, J. (1996). The effect of variety and amount offered of chopped sorghum stover on the performance of sheep. In Small Ruminant Research and Development in Africa.

Osafo, E.L.K., Owen, E., Methu, J., Abate, A., Tanner, J.C. and Aboud A.A.O. (1997). Excess Feeding of Stovers from Sorghum and Maize for Small Ruminants and Cattle in Cereal-based Integrated Farming Systems in Africa. www.fao.org/ag/AGAInfo/resources/documents/frg/conf96pdf/osafo.pdf.

Oumar, I. and Sawsen, A. O. (2010). Evaluation morphologique de cultivars de mil (Pennisetum glaucum (L.) R. Br.) collectés en Tunisie et en Afrique de l'Ouest. In FAO-biodiversité, 2010. No.133, pp 35 - 40.

Owen, E. and Jayasuriya, M.C.N. (1989). Use of residues as animal feeds in developing countries. *Research and Development in Agriculture* 6: 129-138.

Paya H., Akbar, T., Hossein, J. and Ali, M.G. (2007). Nutrient Digestibility and Gas Production of Some Tropical Feeds Used in Ruminant Diets. Estimated by the *in vivo* and *in vitro* Gas Production Techniques. *American Journal of Animal and Veterinary Sciences* 2 (4): 108-113.

Picard, J. (2000). Espaces et pratiques paysannes : les relations élevage-agriculture dans deux terroirs cotonniers du Nord Cameroun. In Dugué P. (éds.), 2000: Fertilité et relations agriculture–élevage en zone de savane. Acte de l'atelier sur les flux de biomasse et la gestion de la fertilité à l'échelle des terroirs. Cirad, 5-6 mai 1998, Montpellier, France.

Preston, T.R. (1982). A strategy for the efficient utilization of crop residues and agro-industrial by-products in animal production based on their nutritional constraints.

In: Proceedings of FAO/ILCA Workshop on crop residues and agro-industrial by-products in animal feeding. Dakar, Senegal.

Preston, T.R. (1984). Validity of feeding standards and development of feeding systems based on crop residues and agro-industrial by-products. *In FAO-ILCA***,** *Better utilization of crop residues and by-products in animal feeding: research guidelines.*

Preston, T.R., and Leng, R.A. (1980). Utilization of tropical feeds by ruminants. In: *Ruckebush Y. and Thivend P., eds, "Digestive Physiology and metabolism in Ruminants"*. M.T.P. Press Ltd., Lancaster, 640–641.

Preston, T.R. (1987). Associated effects and interactions among feed ingredients. In: Proceedings of the FAO Expert Consultation on the substitution of imported concentrate feeds in animal production systems in developing countries. FAO Animal Production and Health, paper 63.

Preston, T. R. and Leng, R. A. (1987). Matching ruminant production systems with available resources in the tropics and subtropics. Technical Center for Agricultural and Rural Cooperation. Pernambul Books, Armidale pp. 245.

Provenza, F.D., Burritt, E.A., Clausen, T.P., Bryant, J.P., Reichardt, P.B. and Distel, R.A. (1990). Conditioned flavor aversion: a mechanism for goats to avoid condensed tannins in Blackbrush. *Am. Nat.* 136, pp. 810–828.

Ramazin, M., Ørskov, E. R. and Tuah, A. K. (1986). Rumen degradation of straw. 2. Botanical fractions of straw from barley cultivars. *Animal Production* 43:271-278.

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J. L., Cole, D. C., Demment, M. W., Omore, A., Zinsstag, J. and Ruel, M. (2006). Role of livestock in human nutrition and health for poverty reduction in developing countries. In: *J. Anim Sci*. 2007. 85:2788-2800.

Reed, J.D. and Soller, H. (1987). Phenolics and nitrogen utilisation in sheep fed browse. In: *Herbivore Nutrition Research.* Research papers presented at the Second International Symposium on the Nutrition of Herbivores. Australian Society of Animal Production occasional publication, p. 47.

Reed, J.D., Yilma Kebede and Fussell Les K. (1987). Factors affecting the nutritive value of sorghum and millet crop residues. *In* Plant breeding and the nutritive value of crop residues. ILCA, Addis Ababa, Ethiopia.

Reed, J.D. and Van Soest, P.J. (1984). Estimating the Nutritive Value of crop residue and agro-industrial by-products by chemical methods. In *Better utilization of crop residues and by-products in animal feeding: research guidelines.* FAO, Rome.

RELMA (2007). Feeding sustainability: Tree forage for enriched diets in zero-grazing systems. In RELMA Review Series, Sustainable Livestock Production. Issue 4, http://www.relma.org.

RGAC-Niger, (2007). Recensement General de l'Agriculture et du Cheptel. *Productivité du Cheptel, Enclaves Pastorales et Transect*. Volume 5. Ministère du Développement Agricole et Ministère de Production Animale.

Rivière, R. (1978). Manuel d'alimentation des ruminants domestiques en milieu tropical. Paris, Min. Coop, Manuels et Précis d'Elevage N°9: 472-481.

Romney, D.L. and Gill, M. (2003). Intake of Forages. In CAB International. Forage Evaluation in Ruminant Nutrition. .http://kogi.udea.edu.co.

Sanchez, C. (1998). Manuel d'Alimentation des ruminants domestiques en milieu tropical. Paris, France: La documentation française. 529 p.

Sangaré, M., Thys, E. and Gouro, A. S. (2005). Alimentation des ovins de race locale: techniques d'embouche ovine, choix de l'animal et durée. Synthèse du Centre International de Recherche-Développement sur l'Elevage en zone Subhumide (CIRDES), Burkina Faso, fiche n° 13, 8p.

Sansoucy, R. and Hassoun, P. (2007). The block story. *In Feed supplementation blocks*. FAO Animal Production and Health Paper.

SAS (2004). SAS 9.1 Copyright (c) 2004 by SAS Institute Inc., Cary, NC, USA. Licensed to University of KwaZulu Natal.

Savadogo, M., Zemmelink, G. and Nianogo, A.J. (2000). Effect of selective consumption on voluntary intake and digestibility of sorghum (Sorghum bicolor L. Moench) stover, cowpea (Vigna unguiculata L. Walp.) and groundnut (Arachis hypogaea L.) haulms by sheep. In Animal Feed Science and Technology 84 (2000) 265-277.

Scoones, I. (1995). New Directions in pastoral development in Africa: in living with uncertainty. Ed Ian Scoones, IT publications, London.

SDR (2010). Stratégie de developpement rural au Niger. 65 p. www.gtz.de/de/dokumente.

Sido, S. (2001). Supplémentation en fanes de niébé des rations d'embouche à base de la paille de sorgho. Mémoire de fin d'études pour l'obtention du diplôme d'Ingénieur des Techniques d'Elevage. Niamey, Niger : UMA. 51 p.

Smith, O.B. (1987). Utilization of crop residues in the nutrition of sheep and goats in the humid tropics of West Africa. In La production de viande ovine et caprine dans les régions tropicales, humides de l'Afrique de l'Ouest Sheep and goat meat production in the humid tropics of West Africa, FAO Animal production and health. Paper 70.

Steinfeld, H., de Haane, C. and Blackburn, H. (1996a). Livestock-environment interaction: issues and options. Rome, Italy: FAO. 56 p.

Steinfeld, H., de Haane, C. and Blackburn, H. (1996b). Livestock-environment interaction: finding a balance. Rome, Italy: FAO. 115 p.

Thompson, N.S. (1983). Hemicellulose. In "Kirk-Othmer Encyclopedia of Chemical Technology." http://mrw.interscience.wiley.com. Consulted the 15/07/09.

Van Eys, J.E., Rangkuti, M. and Johnson, W.L. (1986). Feed resources and feeding systems for small ruminants in south and southeast Asia. In Small Ruminant Production Systems in South and Southeast Asia. Proceedings of a workshop held in Bogor, Indonesia, 6 10 October 1986.

Van Soest, P.J., 1987. Effect of environment and quality of fibre on the nutritive value of crop residues. In Plant breeding Plant breeding and the nutritive value ofcrop residues. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia. 7-10 December 1987.

Vitti, D.M., Abdalla, A.L., Silva, J.C., Filho, N., del Mastro, L., Mauricio, R., Oven, E. and Mould, F. (1999). Misleading relationships between in situ rumen dry mater disappearance, chemical analyzed and in vitro gas production and digestibility, of sugarcane baggage treated with varying levels of electron irradiation and ammonia. *Anim Feed Sci Tech* 1999; 79: 145-53.

Wahed, R.A. (1987). Stall-feeding barley to goats: The effect of refusal-rate allowance on voluntary intake and selection. PhD, thesis, The University of Reading.

Williams, T.O., Fernàndez-Rivera, S. and Kelley, T.G. (1997). The influence of socio-economic factors on the availability and utilization of crop residues as animal feeds. In: Crop Residues in Sustainable Mixed Crop/Livestock Farming Systems, (CAB International, Wallingford), 25–39.

Zoundi, J.S., Sawadogo, L. and Nianogo, A.J. (2006). Utilisation de blocs alimentaires en substitution au concentré pour l'engraissement des ovins dans le plateau central du Burkina faso. Intégration Agriculture-Elevage. pp. 132-150.

Zoundi, J.S., Tiendrébéogo, J.P., Traoré, S. and Lalba, A. (2006). Embouche ovine en zone soudano-sahélienne du Burkina Faso: une alternance pour une amélioration de la sécurité alimentaire. Intégration agriculture-élevage: Alternance pour une gestion durable des ressources naturelles et une amélioration de l'économie familiale en Afrique de l'Ouest et du Centre. Ouagadougou: INERA, Nairobi: ILRI, Dakar: CORAF/WECARD. pp. 151-159.

Zoungrana, K.C.Y. (1995). Composition chimique et valeur nutritive des herbacées et ligneux des pâturages naturels soudaniens et des sous-produits du Burkina Faso. Thèse d'état. Université de Ouagadougou, Burkina Faso, 224 p.

Zoungrana, K.C.Y., Toguyeni, A. and Sana, Y. (1999). Ingestibilité et digestibilité chez le mouton des foins de cinq graminées tropicales. Revue Élev. Méd. vét. Pays trop., 1999, 52 (2): 147-153 http://remvt.cirad.fr/cd/EMVT99_2.PDF.

Appendices

Appendix 1: Stock of millet stover

Appendix 2: Chopping millet stover (25 cm)

Appendix 3: Unchopped millet stover offered to lamb

Appendix 4: Refusal of chopped millet stover (50 cm). Only the stems left, the leaves have been selected.

Appendix 5: Chopped millet stover (25 cm), leaves and stems together

Appendix 6: Chopped Millet stover (10 cm), leaves separated from stems by action of chopping in small size

Appendix 7: Lambs with faeces collection bag in digestibility trial

Appendix 8: Weighing lamb with electronic balance Eziweigh 2

Appendix 9: Electronic balance Eziweigh 2

Appendix 10: Electronic balance Westboao OCS-2 for weighing feeds and faeces