University of KwaZulu-Natal

Effect of roughage processing and feeding level on production, reproduction, and growth performance of the Red Maradi goat

NOUROU ABDOU

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By

NOUROU ABDOU

MSc. Animal Science, University of KwaZulu-Natal

Eng. Zootechnician, IPR/IFRA, University of Bamako, Mali

BSc Hons Agric. & Livestock Extension, ESA Kef, University of Tunisia

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Declaration

The experimental work presented in this thesis was carried out at the University of KwaZulu-Natal, Pietermaritzburg, South Africa and at Caprine Centre of Maradi in Niger. The work was supervised by Professor Ignatius V. Nsahlai and Co-supervised by Professor Abdoulaye S. Gouro.

This is to declare that this thesis represents original work done by myself and has not been submitted in any previous application for a degree. All sources of information are shown in the text and listed in the reference and all assistance by others has been duly acknowledged.

Nourou Abdou

University of KwaZulu-Natal

Pietermaritzburg Campus

Signed……………………. Date…………………………..

I declare that the above statement is correct.

Supervisor: Prof. Ignatius V. Nsahlai

Signed…………………………. Date………………………….

Co-supervisor: Prof. Abdoulaye S. Gouro

Signed…………………………. Date…………………………

Dedication

This thesis is dedicated to my beloved wife, ***Habsatou Salifou*** *and my precious children,* ***Mahaman Mansour, Abdoulaye, Amina and Moctar***

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General Abstract

In Sahelian countries, feeds and feeding strategies are the main constraints to livestock production. To solve problems of under feeding and ensure at least animal maintenance, farmers store crop residues and bush straws which largely have low nutritive value. They have high fibre content which limit digestibility in the rumen thus commanding low intake. Hence, animals fed with these feeds produce and reproduce poorly. Among animal species, attention has been made on Red Maradi goats as dual purpose breed to alleviate poverty in rural area of Niger. To attenuate poverty, many studies have been implemented to improve the milk production of Red Maradi goat breed and the growth performance of kids.

The objectives of the study were to (i) determine the nutritive value of natural straws, by-products residues and commercial feeds available in Maradi area; (ii) determine the effect of level of feeding on post-natal performance of dams and kids before 14 days of age; (iii) determine the effect of previous levels of feeding on post-natal performance of dams and kids before 14 days of age; (iv) determine the effect of level of feeding, crushing of stover, and urea-treatment of stover on production of dams and preweaning growth performance of kids; (v) determine the effect of previous levels of feeding on the performance of does and kids before weaning; and (vi) to determine the effect of level of feeding, crushing of stover, and urea-treatment of stover on production and reproductive performance of lactating does.

To determine the nutritive value of available feed resources in southern agricultural zones of Niger and to develop strategy to improve their quality, cereal straws were treated with urea. Cereal straws, legume crop residues and concentrates were collected from Maradi area in the dry season in Niger and composite samples were used. Cereal straws were millet (*Pennisetum typhoides*) and sorghum (*Sorghum bicolor*) stovers, *Diheteropogon hagerupii*, *Eragrostis tremula* and *Schizachyrium exile,* legume crop residues were groundnut haulms (*Arachis hypogea*), and cowpea (*Vigna unguiculata*) husk and concentrates were millet bran, wheat bran and cottonseed cake. Samples of straws and cowpea husk were treated with 3% urea; then all feed samples were untreated. Chemical composition and *in vitro digestibility* of feeds were done in the laboratory. Dry matter

(DM), organic matter (OM), nitrogen (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and acid detergent insoluble nitrogen (ADIN) were analyzed. Degradability characteristics were determined. Type of straws affected chemical composition whereas urea treatment increased N and ADIN content. Legume crop residues differed in NDF and N content. Urea treatment of cowpea husk increased N but it produced objectionable odors. Concentrates differed in N and fibre.

Similar trends were observed for the degradation of DM and OM *in sacco*. Type of straws had different ($P<0.001$) soluble fraction (wash), effective degradability (ED); urea treated straws had higher ED. Legume crop residues affected solubility and ED, while urea-treating cowpea husk decreased ED. Concentrate affected N degradability and ED. Effective degradation of concentrate DM and OM also varied. The metabolizable energy (ME) value was determined through effective degradability (ED) of organic matter (OM) and gas production after 2400h of incubation. Straws had different apparent degradability (Apdeg), degradation rate (C), halflife to the maximum gas volume ($T_{1/2}$), degradation efficiency factor (DEF) and ME. Urea treated straws had higher C and increased ME. Legumes did not affect *in vitro* parameters, however, urea-treated cowpea husk decreased gas production and ($T_{1/2}$) but increased ME. Concentrate degradation and kinetics parameters varied strongly, while Apdeg and true degradability varied leaving microbial yield (MY) unaffected. Degradation efficiency factor was strongly correlated to ME value. These findings suggest that nutritive value of feeds should be considered when formulating diets for ruminants.

In the first experiment, sixty pregnant Red Maradi goats were used in Caprine Centre of Maradi (Niger) for two subsequent lactations from day 1 to day 14 of lactation to evaluate the effect of feeding levels on production performance of dams and post-natal performances of kids at the first lactation; to determine the effect of previous levels of feeding of dam on production performance of dam and post-natal performances of kids at the second lactation; to determine the effect of urea treatment and crushing of millet stover on dam’s feed intake; and to establish the relationship between ME intakes of kid and dam and their requirements based on AFRC and NRC systems. Three diets were formulated as follows: diet1 (D1) for T1, T2, T3 and T4, diet2 (D2) for T5 using crushed millet stover (CMS); diet3 (D3) for T6 using uncrushed and untreated millet stover. For the whole study, this structure of treatment was applied. For the first kidding, six treatments were constituted, namely, T1, T2, T3, T4, T5 and T6, and formed by four levels of feeding (g/kg DM) where T1 = 842, T2 = 934, T3 = 1079 and T4 = 1300 corresponding to 200g, 400g, 600g and 800g of milk production, respectively. Treatments T5 and T6 had the same level of feeding with T2 and were used to ascertain the effect of urea treatment and the effect of crushing of millet stover. A randomized block design was applied on 60 does according to body weight, parity and type of birth implying 10 does per treatment. Seventy three kids of which 47 and 26 twins born were fed colostrum and milk using feeding bottles during a fortnight study period. During the second kidding, all does were fed on T4 which was the best treatment during the first lactation.

Dry matter intake (DMI) and metabolisable energy intake of dams increased linearly with increasing level of feeding. Kids ME intake (kMEint) increased linearly during the first lactation with increasing level of feeding while there was no variation of kMEint at the 2^{nd} lactation.

In the second experiment the same lactating Red Maradi goats were used during two subsequent lactations from 14 days post kidding to 91 days to evaluate the effect of feeding levels of dams, the effect of urea treatment and crushing of millet stover on production performances of dams and on preweaning growth performance of kids (first lactation), and to determine the effect of previous levels of feeding on production performance of dams and theirs kids (second lactation). For the first lactation, 60 goats were put into six groups of 10, and randomly assigned to six treatments (T1, T2, T3, T4, T5, and T6) with the same four levels of feeding and two other treatments (T5 and T6) to evaluate the effect of urea treatment and crushing of millet stover. At the 1st lactation, a randomized block design was applied to 60 does according to body weight, parity and type of birth. Seventy three kids of which 47 singles and 26 twins were used. During the subsequent lactation, 35 lactating does and 17 kids were used. All does were given one dietary treatment (T4) to determine the effect of previous levels of feeding on preweaning performance of kids and determine the potential milk production of Red Maradi goats. During the 1^{st} lactation, the linear effect of level of feeding dam increased dry matter intake, ME intake and milk yield of dam. At the 2nd lactation the previous levels of feeding did not affect these parameters; however, previous levels of feeding affected final body weight and body weight change of dams.

In the third experiment, the same lactating does were used from weaning to next kidding to determine the effect of levels of feeding of dams, the effect of urea treatment and crushing of millet stover (MS) on production and reproduction performances of dams. To evaluate these effects, data collected from previous kidding to subsequent kidding were used. Sixty goats were sorted into six groups of 10, and randomly assigned to six treatments (T1, T2, T3, T4, T5, and T6); the first four treatments tested the effect of levels of feeding. Millet stover (MS) was crushed and treated with 3% urea, T5 MS was only crushed, and T6 MS was offered whole to evaluate the effects of urea treatment and crushing of MS, respectively. Oestrus synchronization was used to reproduce does after weaning kids at three months of age. The feeding level affected linearly and in a quadratic fashion the dry matter intake (DMI) and milk yield (myd) of doe while dam final body weight (dfwt) was affected in a quadratic fashion. Urea treatment of MS did not affect DMI, myd and dfwt whereas crushing of MS increased dam DMI and dfwt. The post-partum anoestrus period (Panoest), kidding interval (Kinterv), gestation length (Lgest) and lactation length (Llact) were not affected by treatments. The main issue resides on the potential genetic of the breed which may probably have undergone some dilution as the expected milk yields were not obtained in spite of satisfying nutrient requirements for defined levels of production.

Feeds differed in their nutritive values and urea treatment improved nutritive value of straws by increasing N and ME content, and OM digestibility of straws with the exeption of *Diheteropogon* and cowpea husk with little effects. The level of feeding impacted positively on production and reproductive performance of dam and kid growth. However, theses performances seemed to be lower than expected. Further investigations on how to increase intake to satisfy metabolisable energy requirement of goat for successful production are recommended.

Thesis output

Conference Abstracts

1. **Abdou, N, Gouro, A.S. and Nsahlai, I.V., 2016**. Nutritional characteristics of available feed resources in Maradi area of Niger. 48th Annual Congress of The South African Society for Animal Science, 21 – 23 September 2015.

Papers under review

1. **Abdou, N, Gouro, A.S. and Nsahlai, I.V., 2016**. Nutritional characteristics of feeds and effect of urea treatment of roughages. *In Animal Production Science.*
2. **Abdou, N, Basha, N.A.D, Gouro, A.S. and Nsahlai, I.V., 2016.** Nutritive Value of Feeds and the Effect of Urea Treatment of Roughages on Gas Production. *Applied Animal Research.*
3. **Abdou, N, Gouro, A.S. and Nsahlai, I.V., 2016.** The effect of feeding levels of lactating does on post-natal performance of kids. *Tropical Animal Health and Production.*

Article in preparation

1. **Abdou, N, Gouro, A.S. and Nsahlai, I.V., 2016.** The effect of feeding levels of lactating does on preweaning performance of kids. To submit to *Small Ruminant Research.*

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List of Abbreviations

*	Significant (P<0.05)
◦ C	Degrees celcius
A	Gas produce from soluble fraction from in vitro fermentation
ADF	Acid detergent fibre
ADG	Average daily gain
ADL	Acid detergent lignin
AFRC	Agricultural and Food Research Council
AOAC	Association of Official Analytical Chemists
ApDeg	Apparent degradability
apwc	Average periodic weight change
b	Potentially degradable fraction
B	Gas produce from slowly degradable fraction
BCS	Body condition score
Btype	Birth type
BWt	Body weight
C	Gas production rate from *in vitro* fermentation
c	rate constant for the degradation of "b" fraction
c1	Degradation rate of gas for soluble fraction (A) from in vitro fermentation
c2	Degradation rate of gas for insoluble fraction (B) from in vitro fermentation
Cel	Cellulose
CERRA	Regional Centre for Agricultural Research
CF	Crude fibre
Cm1	Conception at 1st mating
Cm2	Conception at 2nd mating
Cm3	Conception at 3rd mating
CMS	Crushed millet stover
CP	Crude protein
CSC	Cottonseed cake
CUTMS	Crushed and urea treated millet stover

D	Diet
dADG	Dam average daily gain
DEF	Degradability efficiency factor
dfwt	Dam final weight
dint	Dam intake
diwt	Dam initial weight
DM	Dry matter
dMEi	Dam metabolisable energy intake
dMEi_AFRC	Dam metabolisable energy intake based on AFRC
dMEi_NRC	Dam metabolisable energy intake based on NRC
dMEr	Dam metabolisable energy requirement
dMEr_AFRC	Dam metabolisable energy requirement based on AFRC
dMEr_NRC	Dam metabolisable energy requirement based on NRC
DMI	Dry matter intake
DP	Digestible protein
dwt	Dam weight
dwtc	Dam weight change
E	Energy
Ev_g	Energy value for gain
FAO	Food and Agriculture Organization
Fcfa	Franc is the currency of communauté financière Africaine
g	Gramme
GDP	Gross domestic product
GH	Groundnut haulms
h	Hour
Hcel	Hemicellulose
ILCA	International Livestock Centre for Africa
INRAN	National Agricultural Research Institute of Niger
Kcal	Kilo calory
kfwt	Kid final weight
k_g	Efficiency with which metabolisable energy is used for production/gain
Kg	Kilogramme

kinterv	Kidding interval
kiwt	Kid initial weight
k_m	Efficiency with which metabolisable energy is used for maintenance
KMEint	Kid metabolisable energy intake
kMEr_AFRC	Kid metabolisable energy requirement based on AFRC
kMEr_NRC	Kid metabolisable energy requirement based on NRC
ksex	Kid sex
Kwt	kid weight
L	liter
Lgest	Gestation length
Llact	Lactation length
Lt	Lag time
m	Metre
m^2	Square metre
MB	Millet bran
ME	Metabolizable energy
MED	Metabolisable energy content of diet
MEint	Metabolisable energy intake
MEm	Metabolisable energy for maintenance
MEmk	Metabolisable energy of milk production
MEmr	Metabolisable energy requirement
MEr	Metabolisable energy requirement
MJ	Mega Joules
ml	Milliliter
MRA	Ministère des ressources animals
MY	microbial yield
myd	Milk yield
N	Nitrogen
NC	Non conception
NDF	Neutral detergent fibre
NDS	Neutral detergent soluble (NDS)
NE	Net energy

NGO	Non-government organisation
NPN	Non protein nitrogen
NRC	US National Research Council
NS	Not significant ($P>0.05$)
OM	Organic matter
OMD	Organic matter degradability
PF	Partitioning factor
pH	Power hydrogen
Panoest	Anoestrus period
PPR	Peste des Petits Ruminants
Preg	Pregnancy
Ptreatment	Previous treatment
R^2	Coefficient of determination
RGAC	Recencement General de l'Agriculture et du Cheptel
RMSE	Root mean square error
SAS	Statistical Analysis System
SD	Standard deviation
SE	Standard error
SMEC	Sum of metabolisable energy derived from colostrum intake
SMEM	Sum of metabolisable energy derived from milk intake
SS	Sorghum stover
$T_{1/2}$	Halflife of the maximum gas volume
TME	Total metabolisable energy requirements
Trdeg	True degradability
Treat	Treatment
Typeb	Type of birth
UKZN	University of KwaZulu-Natal
USD	United States Dollars
UT	Urea treatment
VFA	Volatil fatty acids
$W^{0.75}$	Metabolic weight
WAD	West African dwarf goats

WB	Wheat bran
Wk	Week
Wt	Weight
μ	Maximum rate of gas production at the point of inflection of the gas curve

Chapter 1

General Introduction

1.1 Background

In Niger, livestock contributes between 11 and 35% of the annual national Gross Domestic Product (GDP) and the agricultural GDP, respectively. The 2012 population census was 17129076 with a 3.9% growth rate (INS-Niger, 2013) and 80 to 90% of the population live in rural areas and are smallholder farmers with agriculture and livestock as main source of income (IFAD, 2015).

The South-Eastern part of Niger has the highest human population density in addition to high level of poverty and malnutrition. Tsai (2010) reported a 13.4% malnutrition in two regions of the South-East of Niger namely Maradi and Zinder with children <5 years the most affected. Under-nutrition and micronutrient deficiency are the main causes of chronic malnutrition in Niger leading to retarded growth in children with over 46.3% between age 6-59 months (INS-Niger, 2009). High rate of morbidity, mortality and disability is also associated to nutritional deficiencies in Niger with a child mortality rate of 20% and low life expectancy of 44.7 years (Tsai, 2010).

To alleviate poverty, many programmes such as the Struggle Against Poverty and Rural Development Strategies were implemented by the Goverment. Non Governmental Organisations (NGOs), Government and foreign partners distributed small ruminants, mostly the Red Maradi goats to women. Red Maradi goat is a dualpurpose breed, which is prolific, produces high milk yields and provide meat. Children's growth is dependent on the intake of proteins, lipids, vitamins and minerals which are derived partly from food, milk and other dairy products (Rolland-Cachera *et al.*, 1995; Hoppe *et al.*, 2006).

Despite the importance of milk and dairy products, the consumption has remained low in Niger (36 L/head per year) whereas the United Nations recommends 91 L/head per year (MRA-Niger, 2003). On body weight basis, goats are better milk producers than cows or sheep (Malau-Aduli and Anlade, 2002). In smallholder farming systems devoid of cattle, milking goat constitutes the principal milk source consumed through millet flour, traditionaly called “Fura”. Fura is one of the favourite meal in Niger villages. Goat milk provides children with more nutrients than cow milk (Attfield *et al.*, 1990; Midau, 2012). Goat milk compared to cow milk is a good source of energy, calcium, phosphorus, magnesium and vitamin A for growth, and can be used to overcome nutritional deficit of the rural communities (Attfield *et al.*, 1990; Midau, 2012). Hence, goat milk is used to save orphaned children in rural zones of Niger (Guillermet, 2007).

Although the Red Maradi goat has high importance as a major nutrient source in the Nigerien society, their production characteristics have not been fully investigated. The few available studies report conflicting results. For example, daily milk yield has been reported as 0.6 kg, 0.40 kg, 0.54 kg and 0.39 to 0.45 kg, respectively by Robinet (1967), Gerbaldi (1978), Wilson (1991) and Djibrillou *et al.* (1998). Furthermore, most studies on Red Maradi goat have been done in Nigeria with the same breed called Red Sokoto goat but the environmental conditions are not the same. Therefore, a critical evaluation of growth rate, milk yield and reproductive efficiency of Red Maradi goats is needed in order to characterise this breed.

Red Maradi goat has a great potential to produce milk (Bembelo, 1961; Zangui, 1986). Bembelo (1961) reported that goats’ milk is mainly used by people in rural areas in the absence of cows’ milk. Furthermore, Zangui (1986) indicated that Red Maradi goats produce enough milk for its kids. However, the milk production potential of this breed is not yet known. To determine the effet of milking frequency on milk flow rate, Akpa *et al.* (2003) working on red Sokoto goats in Nigeria which were raised in a semi-intensive system reported an average daily milk yield of 466.9 ± 26.51 g in 120 days. It is important to note that in this study, does received supplementary feed of 300 g/head/day of concentrate mixture of maize (30%), wheat offal (35%) and cottonseed cake (35%) after coming back from grazing in the afternoon.. Notwithstanding the importance of the aboved studies, these authors did not research on the impact of the animal intake on milk production. Djibrillou *et al.* (1998) working on red Maradi goat (32.7 ± 1.9 kg of body weight) in Niger, during the first eight weeks of lactating, reported daily milk yields of 0.39, 0.44 and 0.45 L with respective intakes of 23.9, 24.1 and 46.7 g DM/kg $W^{0.75}$/day of untreated straw, urea-treated straw and untreated straw plus cottonseed cake. By the end of the study, all does lost weights of about 5.85, 2.80 and 2.74 kg corresponding to diets of untreated straw, urea-treated straw and untreated-straw plus cottonseed cake, respectively.

More investigations are needed on how and which supplements can be used as a feeding strategy to enhance milk production and reproduction performance of red Maradi goats. In tropical countries feeding is one of the main constraints of livestock production (Nsahlai *et al.*, 1998; Savadogo *et al.*, 2000) particularly in Niger where the rainy season is short (June to September), and the dry season is long (October to May) with forage shortages occurring from March to June.

To avoid under feeding and ensure at least animal maintenance during the critical period, farmers struggle to feed animals with stored crop residues and bush straws after coming back from pastures (INRAN, 1996). However, cereal crop residues and bush straws have low nutritive value. The high cell wall and low CP characteristic explain the low intake and low digestibility of cereal crop residues (Preston, 1995; Chenost and Kayouli, 1997; Salem and Smith, 2008; Koralagama *et al.*, 2008; Abdou *et al.*, 2011).

Animals when given cereal crop residues and bush straws without concentrate supplementation perform poorly (Ayantunde *et al.*, 2007; Abdou *et al.*, 2011). Several practices have been introduced to improve the feeding value of crop residues among which are physical treatment, chemical treatment, biological treatment and supplementation. Physical treatment (chopping, grinding/milling) of crop residues is the process of reducing the particle size (Chenost and Kayouli, 1997). Biological treatment uses live organisms to increase digestibility (Mahesh and Mohini, 2013). For example, fungi has been used to improve quality of crop residues (Sarnklong *et al.*, 2010) and improve digestibility through delignification and increase protein content, while minimising loss of biomass (Gupta *et al.*, 1993). Other studies (Preston, 1995; Buttery *et al.*, 2005; Smith *et al.*, 2005; Abdou *et al.*, 2011) have supplemented crop residues to reduce their deficiencies of protein, minerals and vitamins. Therefore, with or without treatment, cereal crop residues need supplements to satisfy nutrient requirements of animals.

Research and development projects have accorded more attention on chemical treatment to improve the feeding value of cereal crop residues by increasing intake (50%) and digestibility (10%) (Chenost and Kayouli, 1997; Sarnklong *et al.*, 2010; Owen *et al.*, 2012). Acids, alkalis like sodium hydroxide, potassium hydroxide, calcium hydroxide, ammonia or urea are used for chemical treatment. Among these treatments, urea treatment is the most commonly recommended in developing countries (Schiere and De Wit, 1995; Chenost and Kayouli, 1997; Guo *et al.*, 2002; Elseed *et al.*, 2003a; Owen *et al.*, 2012) due to its advantage of improving nitrogen content thus reducing the use of concentrate. In addition, urea treatment ensures good conservation of treated residues due to alkaline conditions resulting in ammonia release from urea through enzymatic reaction of urease present in crop residues (Mgheni *et al.*, 1993). According to Preston (1995), urea treatment potentially could improve the quality of cereal crop residues by about 5-10%, 1% and 25-50% units of OM digestibility, nitrogen content of DM and *ad libitum* intake, respectively. Furthermore, feeding animal with urea-treated straw increased feed intake by 10 to 15%, growth rate of calves by 100 to 150 g/day and milk yield varying from 0.5 to 1.5 L/day (Owen *et al.*, 2012). Frequently, the effect of urea treatment is shown through increased bacterial synthesis in the rumen and cell wall digestion (Chermiti *et al.*, 1994; Chenost and Kayouli, 1997).

Cereal crop residues (millet and sorghum stovers), bush straws (*Diheteropogon hagerupii*, *Eragrostis tremula* and *Schizachyrium exile)* and legume crop residues (groundnut haulms and cowpea husk) are collected and stored in huge quantity by smallholder farmers for use during the dry season. However, more than 50% of these cereal straws offered to animals is wasted (INRAN, 1996). Thus, roughage processing sush as crushing and urea treatment of cereal crop residues and bush straws were used in the current study. Urea is subsidized to smallholder farmers to reduce the cost of this technology in Niger. The crushing machine of about 900 USD which is believed to be affordable for smallholder farmers' organisations and big farmers was used for crushing.

Digging a hole or building a silo both of which command a huge labour for farmers were popularised for urea treatment. As reported by Walli *et al.* (1988), the duration of urea treatment is between two to three weeks depending of environmental conditions and even lesser in tropical country but higher in cold environments. In relation to dosage, Kayouli (1994) popularised 5% of urea, which has not been attractive to smallholder farmers. Thus, Owen *et al.* (2012) reported that the technology of urea-treatment needs to be promoted and refined so that the treatment by urea solution becomes an easier process. Therefore, in the present study, polyethylene bags, 3% of urea, 50% of water and 40 days as duration of treatment were used.

Among feed resources, cereal crop residues, bush straws, legume crop residues (groundnut haulms, cowpea husk), and agro-industrial by-products are feeds used by smallholder farmers in West and East Africa to fill the feed gaps during the period of acute feeds deficiency (Ayantunde *et al.*, 2007; Koralagama *et al.*, 2008; Abdou *et al.*, 2011). Agro-industrial by-products are rich in nitrogen and metabolisable energy and are used as supplements to improve the utilization of cereal crop residues. Common examples are cottonseed cakes, and wheat bran which are generally subsidized by the Nigerien government, making them affordable to small holder farmers. Another ingredient is millet bran which is obtained from the processing of millet grain for household food, and is generally available to smallholder farmers.

Goats are able to digest a large variety of roughage and their nutrient requirements vary with age, sex, breed, production system (dairy or meat), body size, climate and physiological stage (growth, pregnancy and lactation). Their daily feed intake ranges from 3-4% of body weight (Rashid, 2008). During lactation, does should be given adequate feeds to meet maintenance and production requirements. Otherwise, does will likely lose body weight due to the high demands particularly at peak lactation and an inability to consume an adequate quantity of feed. Inadequate nutrition will decrease body condition, reduce milk production, reduce kid weaning weight and increase kid mortality. In this study, urea, cottonseed cake, wheat bran, millet bran, groundnut haulms and millet stover and mineral lick were used to meet the overall requirements of goats for milk production and improve reproductive performance.

1.2 Objectives

The overall goal of this study is to improve milk production of Red Maradi goats and the growth performance of kids. The specific objectives were to:

1. Determine the nutritive value of some feeds available in Maradi area;
2. Determine the effect of level of feeding, crushing of stover, and urea treatment of stover on post-natal performance of dams and kids before 14 days (first lactation);
3. Determine the effect of roughage processing and previous levels of feeding on post-natal performance of dams and kids (second lactation);
4. Determine the effect of level of feeding, crushing of stover, and urea treatment of stover on dam production and preweaning growth performance of kids (first lactation);
5. Determine the effect of roughage processing and previous levels of feeding on the performance of does and kids before weaning (second lactation);
6. Determine the effect of level of feeding, crushing of stover, and urea-treatment of stover on production and reproductive performance of lactating does.

1.3 Hypotheses

The hypotheses to be tested were:

1. Feeds differ in their nutritive value;
2. Feeding lactating does with different levels of feeding, crushing and urea treatment of stover influence post-natal performance of kids;
3. Previous level of feeding and roughage processing can influence the post-natal performance of dams and kids;
4. Feeding levels of lactating does, crushing and urea treatment of stover influence dam production and preweaning growth performances of kids;
5. Pevious level of feeding and roughage processing do not affect dams and kids performances before weaning;
6. Roughage processing and feeding levels of lactating does influence production and reproductive performance of does.

Chapter 2

Literature review

2.1 Introduction

Many goat breeds have been domesticated worldwide but for dairy goats, breed standards and production records have been kept (Wikipedia, 2012). Selection of domestic goat (*Capra aegagrus hircus*) is generally based on improving production of meat, milk, or skin. Thus, breeds are generally classified based on their primary use, though there are several breeds which are considered dual or multi-purpose goats like the Red Maradi goat for which selection was based on its ability to produce meat, milk and quality skin. The most known breeds of goats are Saanen, Toggenburg, Alpine, Anglo-nubian, Boer, Angora, Cashmere, Nigerian Dwarf, Pygmy, Red Sokoto (Maradi) goat, and Sahelian goats.

Switzerland goat breeds like Saanan, Toggenburg, Overhasli and Alpine, the French goat breed are the world's leaders in milk production. A Saanen nanny produced an average of 3.8 litres per day, the average weights of mature doe and buck are 68 kg and 91 kg, respectively (Wikipedia, 2012). The Anglo-Nubian or simply Nubian, the English goat breeds are dual-purpose for meat and milk production. The Spanish, South African Boer and Somali breeds of goats are best known for meat producing ability. Turkish Angora, Asian Cashmere, and Russian Don goats are kept for mohair and cashmere production. Nigerian Dwarf, Pygmy, Sahelian, and Red Maradi goats from West Africa are considered as multi-purpose goat breeds; they produce meat, milk and skin; they demand increasing interest for research to investigate the potential production of these breeds. Two goat breeds are principally raised in Niger, namely the Sahelian goat with two varieties (Peul goat and Touareg goat) and Red Maradi goat (Rhissa, 2010). Sahelian goat is raised anywhere in Niger whereas Red Maradi goat is confined in Southern-East of the country, in Maradi and Zinder regions as its predilection area.

A recent census on the livestock in Niger recorded about 31 039 041 animals, which were 11 238 268 goats (36.2%), 9 192 017 sheep (29.6%), 7 336 088 cattle (23.6%), 1 565 420 camel (5%), 1 477 073 donkey (4.8%) and 230 174 horses (0.7%) (RGAC-Niger, 2007). Thus, goats occupy the highest fraction of livestock in Niger.

In Niger, breeding activities and distribution of the red goat began in 1945, based on selection in Maradi, the predilection habitat or agro-ecological area of this breed, the reason for its name ‘Red Maradi’ goat. Then, the distribution of Red Maradi goat outside Maradi region, started with the castration of bucks other than the red. A further step was taken in 1963 with the creation of the Centre for Breeding Goat of Maradi covering an area of 1850 ha.

Maradi goat breeding Centre initially allotted 7495 animals to be distributed in different parts of Niger, of which 2287 were females and 5208 males. It appears that bucks represent 70% of animals that were distributed to farmers from 1972 to 1984. The repartition of animals comprised of Dosso (39%), Tahoua (26%) and Tillabery (17%) (Djariri, 2005). However, no goats were allotted to Agadez and Diffa regions which are located in the North and North-East of the country, which suggest that environmental conditions might not have been favourable for red goat (low availability of by-products and crop-residues, long displacements rangeland and pastures and desertification). Nowadays, because of repeated efforts of Government, NGOs and Development Projects, Red Maradi goats are widely distributed in Niger and West Africa. The Red Maradi goat is present in Burkina Faso, Cameroon, Cote d'Ivoire, Mauritania and Senegal (Djariri, 2005).

For two decades of research on the Red Maradi goat in Niger, very little has been published, because the results have been compiled principaly as reports. Unlike in Niger, the Red Maradi goat is called Red Sokoto in Nigeria and has been accorded more attention in order to stabilize and standardize the breed due to its zootechnical aptitudes. Research conducted in Nigeria on the Red Sokoto goat started during British colonisation (Djariri, 2005), and intensified with the independence and the establishment of tertiary and research institutions.

In rural areas of Niger, small ruminants are raised to combat poverty and food shortage, but under nutrition and poverty still exist mostly in South-Eastern sections where the population density is highest. Demands for energy and protein are increasing all the time. Low income and poverty of the household make it difficult to reach a balance diet. Many programmes (e.g. the Struggle Against Poverty and, the Rural Development Strategies) were implemented by Government to support the vulnerable masses, but the problem still persists because of acute poverty and less availability of nutritive foods. Non Government Organisations (NGOs), Developement Projects and Government programmes distributed small ruminants mostly red Maradi goats to women to alleviate this acute crisis. Notably, the Red Maradi goat is a dualpurpose breed which is prolific, provides meat and has a good dairy potential. So a majority of households keep goats mainly for meat and milk production but milk production is insufficient to satisfy the needs of both kids and humans. Although a greater proportion of milk is not consumed fresh, it is consumed with a traditional or local food called "Fura". This is prepared by processing millet grain to flour which is cooked and mixed with fermented milk (lait caillé). However, the milk production potential of Red Maradi goat remains unknown.

Niger has a history of cyclical and severe famine and regular food shortage due to severe recurrent droughts. The last recent droughts were in 1968, 1971-1974, 1981, 1984, 1987, 1989, 1990, 2000 and 2004 (Mamadou, 2010). This state of affairs affected the entire demographic spectrum where children were most vulnerable. About 10% of children younger than 5 years had acute malnutrition and 44% of children had chronic malnutrition (Tsai, 2010). In 2005, food insecurity caused by locust infestation and drought caused a severe shortage of food crops raising acute malnutrition to 13.4% of the population in South-East Niger like Maradi and Zinder regions (Tsai, 2010). According to INS-Niger (2009), under nutrition and micronutrient deficiency were the main causes of chronic malnutrition which led to retarded growth of children in Niger affecting more than 46.3% of children within the age bracket of 6-59 months old. High rate of morbidity, mortality and disability were thus due to nutritional deficiencies in Niger. This situation and other factors like severe poverty, food insecurity, and malaria have resulted in a child mortality rate of 20% and plummeted life expectancy to 44.7 years (Tsai, 2010).

Although alleviating under-nutrition in Niger is a real challenge, there is substantial optimism. It is known that a child's growth and development are related to the intake of nutrients such as protein, lipid, vitamins and minerals derived from food. Milk and other dairy products provide important amount of these nutrients and their intake would improve the overall nutritional quality of children's diet (Johnson *et al.*, 2002). Furthermore, chevron is the main source of meat in these villages although the production is still low.

2.2 Geographical distribution of Red Maradi goat

Red Maradi goat is distributed in Southern Niger and northern Nigeria between 12°N and 14°N and 4°E and 10°E. The traditional habitat in other words the cradle of red Maradi goat in Niger is the Southernpart (in Maradi, Zinder) before being distributed to other regions such as Tahoua, Dosso, and Tillabery (Table 2.1).

Table 2. 1 Repartition of goats in Niger (Djariri, 2005)

Region	Red Maradi goat		Black goat		Sahelian goat		Total
	n	%	n	%	n	%	n
Agadez	0	0.00	0	0.00	332068	4.16	332068
Diffa	0	0.00	0	0.00	1784910	22.36	1784910
Dosso	220902	19.34	77796	14.90	673748	8.44	972480
Maradi	368312	32.25	227400	43.54	486787	6.10	1082575
Tahoua	243930	21.36	151254	28.96	2202700	27.59	2597934
Tillaberi	6836	26.44	62895	12.04	1535902	19.24	1900808
Zinder	301973	26.44	62895	12.04	1535902	19.24	1900808
Total	1141953	100	522275	100	7982981	100	9647409

n: sample size

In Niger the population of Red Maradi goats was about 1.2 million over 10 million goats which is 12% of the national goats (Djariri, 2005). However, Red Maradi goat is largely raised in Nigeria as Red Sokoto goat where the breed is predominant in Sokoto, Kano, Katsina, Kaduna and Zaria states. The population of Red Sokoto (Maradi) goats was estimated in Nigeria at about 17 million over a total of 34.5 million goats which is about 50% of total population of goats (Oni, 2003). The total population of red goats can be estimated at 20 million head of which 80 to 85% is in Nigeria.

2.3 Ecological zones

As described by Wilson (1991), a favourable zone of red Maradi goat is semi-arid areas with a single rainfall season of 4-6 months duration. These areas are cultivated to millet, sorghum, groundnuts and cowpea. Several species of economic trees (Baobab, *Adansonia digitata;* Shea-butter Nut, *Butyrospermum parkii*; Locust Bean, *Parkia biglobosa)* and *Acacia Spp.* form an integral part of the agro-sylvo-pastoral system. In the Maradi region most goats are found in the cultivated valleys of seasonal rivers (rainfall 600 mm) which provide a favourable micro-zone with out-of-season crop residues and browse shrubs.

2.4 Ethnology

2.4.1 Skin coat

The coat is red, this is the phenotype which has been taken into account for selection and diffusion in the Caprine Centre of Maradi since 1945. It is the same criteria with Red Sokoto goats in Nigeria. However, from one environment to another, the skin colour has become more red (brown) from North (Niger) to South (in Nigeria) due to gene-environment interaction.

2.4.2 Physical characteristics

The Red Maradi goat was first described by Wilson (1991). It has relatively small size 60 cm (male 60-65 cm; female 54-65 cm). Adult weight is 27 kg and 25 kg for male and female, respectively. It has a slim head, prominent fore head, profile rather short and straight or slightly dished black mucous membranes. Horns in both sexes are short to medium in length, slightly heavier in males but set close together on the skull. Their horns are rather flattened dorso-ventrally; they grow backwards close to the head and neck. Ears are short, medium width and usually carried horizontally; they are rather longer and semi-pendulous. The beard is made of profuse hair in males but usually often covered with hair which is absent in females. The forehead is longer, bushier and darker in males than in females. Males carry a light mane extending to the shoulders. The neck is short, thin and very mobile. The chest is rounded and well-proportioned and the withers are not prominent. The Red Maradi goat has a medium length back with short croup and both fore and hind legs are rather short and strong but well-muscled. The conformation of the udder is good, well rounded with well-spaced teats.

Hassan and Ciroma (1992) showed that for adult Red Sokoto (Maradi) goats height at withers was between 55 and 69 cm, and the body length ranged between 78 and 98 cm (Table 2.2). On the other hand, heart girth would give the best estimate for predicting body weight at 1-2 years of age, while body length was the most appropriate estimate for aged goats (Table 2.3).

Table 2. 2 Means for bodyweight (kg) and linear body measurements (cm) (Hassan and Ciroma, 1992)

Age (year)	Sex	n	Body weight	Body length	Height at withers	Heart girth
1-2	Male	45	16.67	78.80	56.44	60.76
	Female	47	16.16	79.49	58.49	62.77
3-4	Male	41	24.01	88.90	64.17	69.09
	Female	34	21.65	85.43	61.07	66.38
5	Male	25	30.30	99.66	68.32	77.14
	Female	16	29.75	96.44	65.94	73.63

n: sample size

Table 2. 3 correlation coefficient between bodyweight (kg) and linear body measurements (cm) (Hassan and Ciroma, 1992)

Age (year)	Sex	n	BL	HAW	HG
1-2	M	45	0.58	0.73	0.88
	F	47	0.39	0.81	0.84
	M&F	93	0.45	0.73	0.78
3-4	M	41	0.64	0.55	0.38
	F	34	0.27	-0.03	0.23
	M&F	75	0.53	0.47	0.38
5	M	25	0.99	0.68	0.64
	F	16	0.71	0.41	0.57
	M&F	41	0.75	0.55	0.58

n: sample size; M: male; F: female; BL: body length; HAW: height at withers; HG: heart girth

2.5 Feed intake

Comparing to sheep and cattle, according to their diet, goat species are considered as intermediate feeders (Hofmann, 1989). Goats change their feeding behaviour according to seasonal changes in diet availability (Fedele *et al.*, 1993; Papachristou, 1994). Goats are characterised by high saliva secretion and large absorption surface of the rumen epithelium, which protect them from the risk of acidosis; and by their considerable enlargement of the digestive apparatus when highly fibrous feed is used (Silanikove, 2000). Goats are selective . Indeed, more than other species, goats are able to choose, among the available feedstuffs, parts of plants with the highest protein content and the highest digestibility. They select feed on the basis of prehension ease, sensorial characteristics and post-ingestive effects learnt from their own experience (Provenza *et al.*, 2003).

Feed intake is related to breed, feeding conditions and livestock system. According to Avondo *et al.* (2008), feed intake of Girgentana lactating goats increased (up to 3 kg DM per day) with self-regulating crude protein (16.5%) and neutral detergent fibre (34%). Economides (1998) and Fedele *et al.* (2002) demonstrated that even diets of 60-70% concentrate levels, goats do not alter their productive capacity or their metabolic well-being. According to Abijaoudé *et al.* (2000), when a diet is rich in concentrate and may cause metabolic effects, goats change their feeding behaviour and reduce daily feed intake to avoid dangerous effects of excessive starch in the rumen.

2.5.1 Dry matter intake of goats

The daily feed intake of goats ranges from 3-4% of body weight and is influenced by dry matter of feeds (which range from 12-35% in forages, 86-92% in hays and concentrates), palatability, and physiological stage of the goats (growth, pregnancy, and lactation) (Rashid, 2008). However, to meet the production (milk or meat) purpose, nutrients are required depending of age, sex, breed, body size, climate and physiological stage of the animal. The six classes of nutrients are protein, carbohydrate, fat, vitamins, minerals, and water. Nutrients are often classified as organic (carbon-containing) or inorganic (minerals, water).

2.5.2 Nutrient requirements of goats

To meet energy, protein, mineral, and vitamin requirements of goats, feeding strategies should be used depending on the condition of the goats. Energy is derived from the breakdown of several nutrients, including fat, protein, and both simple and complex carbohydrates. Energy and/or protein deficiencies cause weight loss and low productivity of animals, and oversupply of these nutrients will usually result in excessive fatness, which is also undesirable.

2.5.2.1 Nutrient requirements of lactating does

When feeding goats to meet their maintenance and production requirements, the primary goal is to maintain body weight and subsequently satisfy production. Nutritive elements should satisfy doe requirements in order to reach the expected production. Lactating does need nutrients according to different stages of production and total digestible nutrients are required more than crude protein at any stage (Table 2.4).

Table 2. 4 Nutrient requirements of mature does (Rashid, 2008)

Production stage	Nutrient requirements, dry matter basis		
	DMI, % of BW	% CP	% TDN
Maintenance	1.8 - 2.4	7	53
Early gestation	2.4 - 3.0	9 - 10	53
Late gestation	2.4 - 3.0	13 - 14	53
Lactation	2.8 - 4.6	12 - 17	53 - 66

DMI: Dry matter intake; BW: body weight; CP: crude protein; TDN: total digestible nutrient

2.5.2.2 Nutrient requirements for early to mid-gestation

During this phase of production, the goal is to maintain body condition of mature females and increase condition of young females. Nutrient requirements are only slightly above maintenance; low quality feedstuffs should be utilized. Young females should be fed separately from mature females. Does do not need grain in early pregnancy. Overfeeding can lead to complications such as hypocalcemia and ketosis; pregnant goats can drink up to 16 L of water a day (Cheryl, 2012).

2.5.2.3 Nutrient requirements for late gestation

Late gestation is probably the most critical period for doe nutrition. Energy requirements increase dramatically in late pregnancy (Hart, 2008; Susan, 2008). Does gain body weight during this phase. Seventy percent of foetal growth occurs during this period. Mammary tissue is also developing. Proper nutrition is necessary to prevent pregnancy toxaemia (ketosis) and milk fever (low blood calcium). Nutrition affects the birth weights of kids and a higher mortality among small and large kids occurs when nutrient requirement are unbalanced. On the other hand, when feeding more than the requirements, oversized foetuses increase dystocia incidences.

2.5.2.4 Nutrient requirements for early lactation

Feeding lactating does is related to their genetic potential for milk production and desired level of production. There is a little or no reason to increase the feeding levels of does that have just given birth. Does that have been properly fed in late gestation usually produce more than enough colostrum for their kids. In this phase, it is reasonable to provide does with fresh and clean water permanently and forage only for a few days. When lactation advances, nutritional requirements increase to their highest and especially if they are nursing multiple kids. Feed should be provided according to the number of kids.

2.5.3 Nutrition for kids

It is crucial that kids nurse their mothers (does) in the first 8 hours of their life to consume colostrum at a minimum rate of 10-20% of their body weight, preferably within 2-3 hours after birth (Rashid, 2008). Colostrum contains vitamins and antibodies that will save kids from many diseases including enterotoxaemia and tetanus. Growing kids have the highest protein requirements. Creep feeding may or may not be economical, especially for goats. Energy needs depend largely upon desired growth rates and the animals' genetic potential for growth.

2.5.4 Nutritional complications in goats

2.5.4.1 Pregnancy toxemia (Ketosis or Twins disease)

Does need high energy diets during the last period of pregnancy especially prolific does to cover the needs of foetuses (Rashid, 2008). Malnutrition during the terminal weeks of pregnancy leads to the breakdown of body fat reserves that secrete ketones. Due to lack of energy the glucose concentration in the brain decreases and nervous signs appear. At this stage the doe seldom survives. Autolysis of dead foetuses produces toxins causing toxemia in the doe and eventually death (Rashid, 2008). Treatment is usually unsuccessful. Intravenous injection of 5% dextrose can be helpful in the early stages. However, proper feeding of does during pregnancy can prevent pregnancy toxemia.

2.5.4.2 Acidosis, enterotoxemia, founder and hypocalcemia

A sudden increase or excessive feeding of grains can also cause healthy problems to the doe. Lactic acid content of the rumen can increase to toxic levels (acidosis) due to feeding of starches that exceed need. Acidosis can cause vasoconstriction of blood vessels around hooves (founder). High levels of starch in the diet also speed up the bacterial growth in the intestines (*Enterotoxemia*). The rapid bacterial growth means more endotoxin production and death occurs quickly. This usually happens with rapidly growing kids. Often called milk fever, hypocalcemia is a deficiency of calcium in the blood that arises when a doe does not get enough calcium in her diet to support its needs and the needs of unborn kids.

2.6 Reproduction

In tropical regions local goats can reproduce all year long but the breed and environmental factors linked to season, livestock system, nutrition and availability of feed tend to limit reproduction performances (Delgadillo *et al.*, 1997). Birth weight, growth rate, body weight of kids and parity of doe affect the reproductive performance of goats (Mellado *et al.*, 2006). Other factors such as age at puberty, fecundity, prolificacy, interval between kiddings also affect reproductive performance of goats.

2.6.1 Fecundity

Fecundity is the ability of a doe to reproduce more than on kid. Fecundity rate is defined as the number of kids born divided to the number of does used during mating. It can also be obtained by the product of fecundity rate by the rate of prolificacy. It is a good indicator of flock fertility. The fecundity rate is influenced by genetic aptitude and environmental conditions. Thus, one can observe a high variation between breeds and livestock system. The Red Maradi goat is among the most fertile breeds in West Africa (Table 2.5).

Table 2. 5 Fecundity rate according to the race and livestock type (Charray and Provost, 1980)

Races	Authors	Fecundity rate
Peul goat of Burkina Faso	Dumas and Raymond (1975)	130-152
Sahelian goat (Touared)	Haumesser quoted by Gerbaldi (1978)	157.1
Sahelian goat (Peul)	Haumesser quoted by Gerbaldi (1978)	181.5
Red Maradi goat	Haumesser (1975)	167
Red Maradi goat	Gerbaldi (1978)	153
Red Maradi goat	Gerbaldi (1978)	118.8
Red Maradi goat	Robinet (1967)	165-175

Thus, fertility rates observed in most traditional breeds, showed large variations depending on breeds. To express this rate in the Red Maradi goats, Robinet (1967) suggested that for a good female, kidding twins continues for up to five or six years. It is more common to have six kids from three pregnancies within 20 months. The same author stipulated that in rural areas, an average birth coefficient of 3 kids per female per year which is 300% of fecundity rate, and concluded with an average fecundity rate of 165-175% (Table 2.5). Haumesser (1975) obtained a rate of 167% over 2450 observations which were in agreement with Robinet (1967). However, data in the goat breeding centre of Maradi gave fecundity rates of 80 and 110%, respectively in 1992 and 1993 (Hamidou, 1995) which are less than the results found by Robinet (1967) and Haumesser (1975). This indicated that the fecundity tended to decrease in the Caprine centre of Maradi and may be due to inbreeding or under feeding because the feeding conditions decrease from day to day due to feeble financial support.

2.6.2 Prolificacy

Prolificay or litter size was defined as number of kids born per kidding doe (Alexandre *et al.*, 1999). The red Maradi goat is reputed as a prolific breed. This prolific aptitude depends not only on the breed but also by some factors such as alimentation, season, age, weight and parity (Tables 2.6, 2.7 and 2.8).

Table 2. 6 Prolific aptitude of Red goats in different livestock systems (Djariri, 2005)

Authors	Observations	Single %	Twin %	Triplet %	Quadruple %
Wilson (1991)	Red goats: n=123 Shika/Nigeria	32.60	58.80	7.20	1.80
	Red goats: n=1668 Traditional System in Niger	56.10	40.90	2.80	0.80
	Red goats / Station Niger	48.60	47.50	3.90	0.00
Marichatou et al. (2002)	Traditional System Niger Red goats n=148	63.58	36.48	0.00	0.00
	Black goats n=131	75.52	24.42	0.00	0.00

n: sample size

2.6.2.1 Effect of season and feed availability on reproductive performance

There are differences in the onset and length of the breeding season among the various breeds of goats and even between individual animals within a breed. The normal breeding season for goats occurs when days are shorter and depends on breed, location, nutrition, among other factors. Indeed, geographic location, particularly degree of latitude impacted on timing and length of the breeding season. At locations close to the equator, tropical breeds of goats often breed throughout the year. However, factors such as rainfall, nutrition and status of lactation can also affect breeding season. Other stresses such as transportation or diseases may cause a temporary stoppage of oestrus activity.

Although goat breeds in Niger (a tropical country) are not seasonal breeders contrary to those of temperate countries; they are more reproductive after crop harvest which occurs from September to December when goats are at liberty after being kept at home during the rainy season and have free access to natural grazing. This period coincide with high availability of crop residues and abundant pastures. The reproductive performance is highly affected by feed availability in this particular period when mating occurs. According to Haumesser (1975), in traditional system, more than 50% of kiddings occurred between 15th of February and 15th of April, most of which were conceived in mid-September and mid-November during which there was abundant feed. This may be due to seasonal factor (end of rainy season), goat liberty (no more zero grazing) and availability of feeds (flushing) in this particular period. Amoah *et al.* (1996) indicated that environmental conditions other than photoperiod like availability of feed, variations in rainfall, temperature and humidity may affect the breeding season of goats. Similar observations were made (Webb and Mamabolo, 2004) when working on South African indigenous goats where 96% and 32% of twin births were recorded in autumn and winter, respectively, against 4% and 68% of single births in autumn and winter due to feed availability. According to Hart (2008), nutrition and feed availability through flushing influenced super-ovulation response and lead to a greater proportion of twins and triplets in goats.

Body condition score (BCS) influenced conception rate and prolificay. The BCS for breeding does should be between five to six for meat goats and 3 to 3.5 in dairy goats (McKenzie-Jakes, 2008). Females that are in good condition should have good milk production, good colostrum quality and high pregnancy and twining rates. Animals that are bred in poor condition may have increased incidents of morbidity, weak and unthrifty kids, incidences of abortion, low milk production and kids with low birth weight. Therefore, it is of utmost importance that animals are in optimum condition prior to the start of the breeding season. The same findings were reported by El-Hag *et al.* (2001) that the nutritional limitations under harsh environment (high ambient temperature, scarcity of feed and water) conditions have a negative effect on the reproduction of sheep in semi-arid area. However, McEvoy *et al.* (1995) showed that flushing ewes before mating did not increase ovulation rate, but improved the body condition of ewes. Whereas Idris *et al.* (2010) reported that flushing and steaming-up had increased lambing, fertility, prolificacy, fecundity, pregnancy, weaning rate, and reduced abortion rate.

2.6.2.2 Effect of parity on prolificacy

Litter size is influenced by age which has a repercusion on parity in does (Haumesser, 1975). This author found positive effect of parity on litter size in Creole goats and Red Mardi goats (Table 2.7). It was concluded that Creole goats are more prolific than Red Maradi goats.

Table 2. 7 Increase of average litter size with parity (Haumesser, 1975)

Parity	Creole goats of Guadeloupe		Red Mardi goats	
	Litter size	n	Litter size	n
1	1.67	-	1.08	227
2	2.12	34	1.20	51
3	2.33	30	1.72	483

n = sample size

Crepaldi *et al.* (1999) working on Alpine goats found positive effect of parity on litter size. Similar findings were observed by Mellado *et al.* (1991), Marichatou *et al.* (2002) (Table 2.8) and Yang *et al.* (2011) respectively on crossbred native goats in Mexico, Red Maradi goats in Niger and Boer goats in China where litter size increased with parity, from one to four.

Table 2. 8 Effect of parity and coat on birth type of goats (Marichatou *et al.*, 2002)

Parity	Coat	n	Twin		Single		Kids	Litter size
			n	%	n	%	n	
1	Black	39	3	7.7	36	92.3	42	1.08
	Red	45	5	11.1	40	88.9	50	1.12
2	Black	39	12	30.8	27	69.2	51	1.31
	Red	45	17	37.8	28	62.2	66	1.38
3	Black	34	10	29.4	24	70.6	44	1.29
	Red	40	20	50	20	50	60	1.5
4	Black	19	7	38.8	12	63.2	23	1.37
	Red	18	12	66.7	6	33.3	30	1.67
Total	Black	131	32	24.4	99	75.5	163	1.24
	Red	148	54	36.5	94	63.6	202	1.36

n: sample size

2.6.3 Abortions

Causes of abortion are not well known, but they are associated with production systems, keeping and housing of animals, alimentation, age of does and infectious agents (Charray and Provost, 1980). About 13% of abortion was observed in Caprine Centre of Maradi (Annual report, 2015).

2.6.4 Kid mortality

Mortality of kids before weaning is of a common occurrence in goats' husbandry (Haumesser, 1975; Obudu *et al.*, 1995; Ojo, 1996). According to Haumesser (1975), in 5 mortalities, 4 cases concern kids before weaning.. The birth year, parity and season of birth affected kid mortality rate in red Sokoto goat while birth type and sex of kid had no marked effect (Ojo, 1996). This author stipulated that kid mortality was 32% before four months of life and further examination revealed pneumonia (36.8%), starvation (15.8%), haemonchosis (12.4%) and ectoparasitism (9.4%) as the main causes of kid mortality. According to Obudu *et al.* (1995), kid mortality varied from one breed to another. When these authors recorded during six years kiddings and mortality rates of Red Sokoto goat (RSG), West African Dwarf (WAD) and the crossing does RSG x WAD, they found high mortality rates in kids of RSG followed by WAD and then RSG x WAD. Like Ojo (1996), the main causes were pneumonia (35.6%), helminths (9.7%) and malnutrition (9.7%).

2.6.5 Puberty

Age at first oestrus and first mating, respectively for female and male is variable and depends on the breed, the production system and climate (Delgadillo *et al.*, 1997). According to Wilson (1991), the first oestrus occurs at 157 ± 5.92 days in red goats (n=8). However, Kano Brown was more precocious with first oestrus at 120 days. The weight at first oestrus was between 10.5 and 18.0 kg (Wilson, 1991). The first oestrus of goat breeds from tropical and subtropical countries occur between 8 and 14 months (Delgadillo *et al.*, 1997) and this also confirmed that red Maradi goat is a more precocious breed. However, the age at first oestrus retarded when the feeding condition is low. Although oestrus is not seasonal in does of tropical countries, the age at first oestrus of Creole goats in

Goudeloupe was influenced by birth season even when feeding conditions were good (Delgadillo *et al.*, 1997). Thus, according to these authors, the average age at first oestrus is 172 days but may vary down to 128 days for females born in August and up to 204 days for females born in December. Temperate goats appeared late concerning first oestrus when transferred to tropical areas. Thus, first oestrus occurred between 12-20 months instead of 8-12 month (in temperate country) and this may be due to low growth of these breeds in tropical conditions (Delgadillo *et al.*, 1997).

2.6.6 Age at first kidding

The Red Maradi goat is recognised as a precocious breed. The age at first kidding varies with environmental conditions. It is around 435 ± 35 days (range 243-882) at the experimental farm of Shika / Zaria, Nigeria; the first kidding would be later in the traditional environment in the area of Zaria (Wilson, 1991). Haumesser (1975) reported an age at first kidding of 426.7 ± 13 days in traditional system in Maradi region. The average age at first kidding in the Red Maradi goat observed in traditional farming system on 30 primiparous red Maradi goat and 31 primiparous black goats is 13.57 ± 2.5 and 13.68 ± 2.91 months respectively (Marichatou *et al.*, 2002). However, the age at 1st kidding is 24, 30 and 12-18 months respectively with Afar goats (Djibouti), Boran goats (Kenya) and West African Dwarf goats (Wilson, 1991).

2.6.7 Kidding interval

According to Haumesser (1975), the average interval between kiddings was 332.4 ± 6.2 days in red Maradi goat. The same author observed that the duration of this interval decreases as the period of parturition approaches mid-September to mid-November which is also the period of most intense sexual activity.

Wilson (1991) reported different kidding intervals for red Maradi goat according to livestock systems in Nigeria and Niger (Table 2.9). He noted that the interval between kidding is influenced by abortion, kid deaths and the season of previous birth. Thus, intervals following an abortion (220 ± 16 (n = 59)) and those following kid deaths in the first 15 days of life (269 ± 22 (n = 32)) were shorter than all intervals (332 ± 109 (n =

665)) in the Niger traditional system. The interval is 226 ± 97 (n = 56) days when the precedent parturition occurred in July-August, against 343 ± 164 (n = 552) days when it occurred in the dry season (September to April). This reflects the impact of quality and availability of diet on the frequency of kidding.

Table 2. 9 Kidding interval of Red Maradi goat (Wilson, 1991)

n	System/location	Periodicity	Herd periodicity (%)
51	Shika/Nigeria	240 ± 57.8 days	
665	Traditional/Niger	332 ± 109 days	11% < 240 days 240 < 43.50% < 340 days 45.20% > 340 days
	Research station/Niger		20% < 180 days 180 < 25% < 210 days 210 < 17.5% < 240 days 275 < 12.50% < 305 days 305 < 2.5% < 335 days 5% > 335 days

n: sample size

In villages of Maradi zone, Marichatou *et al.* (2002) recorded in traditional farming conditions an average inter-kidding interval of 386 days in the red goat against 363 days in the black goat. This difference was not statistically significant between red goat and black goat, which is considered phenotypically different to red goat only. Also, according to these same authors, the relative long interval in traditional system may be related to the insufficiency of bucks in villages and the fact that goats were kept at home for a period of about six months during the rainy season (June to November). Other factors such as age, maturity, nutritional status, general health, endocrine balance and normality of sex organs would affect buck fertility. Spermatozoa quality, nutrition, body weight, maturity, stress, disease, mating frequency, seasonal, climatic changes, and level of management also affect male fertility (Carol and William, 1994).

2.6.8 Oestrous cycle

The oestrous cycle for red Maradi goat is between 15-30 days in goat breeding centre of Maradi in Niger; heat lasts 24-120 hours with red goats in Kano where birth is throughout the year (Wilson, 1991). Haumesser (1975) noted, however, over 50% of kiddings took place between February 15 and April 15, due to oestrus from mid-September to mid-November. He argued that this could be related to climatic factors whereby goats are liberated at the end of rainy season for grazing after being kept at home during the whole rainy season.

2.7 Diseases

At Caprine centre of Maradi, respiratory infections were by far the leading causes of morbidity recorded in between 1999 and 2003 with an average of 34% and 32% of cases (Table 2.10). Helminths, ectoparasites, the diarrhea-respiratory syndrome (Pest de Petit Ruminant), foot rot, and bloating are the main causes of mortality in small ruminants in traditional north and south of Nigeria (Mohammed, 2002).

Table 2. 10 Causes of morbidity in red Maradi goats at caprine centre of Maradi (Djariri, 2005)

	1999		2001		2002		2003	
Infections	n	%	n	%	n	%	n	%
Internal parasitism	78	10.2		0		0	24	18.8
External parasitism	2	0.3	14	2.2	21	2.5		0.0
Respiratory infections	276	36.2	215	33.2	239	28.1	49	38.3
Digestives infections	324	42.5	205	31.6	229	26.9	33	25.8
Traumatism	13	1.7	68	10.5	16	1.9	1	0.8
Musculo-skeletal infections	-	0.0	15	2.3	17	2.0	-	0.0
Uro-genital infections	2	0.3	1	0.2	10	1.2	2	1.6
Eye infections	20	2.6	35	5.4	41	4.8	2	1.6
Weight loss	8	1.0	26	4.0	86	10.1	-	0.0
Respiratory-diarrhoea	-	0.0	-	0.0	115	13.5	-	0.0
Abscess	37	4.9	34	5.3	47	5.5	3	2.3
Mastitis	2	0.3	13	2.0	17	2.0	14	10.9
Suspected eczema	-	0.0	17	2.6	-	0.0	-	0.0
Others	0	0.0	5	0.8	14	1.6	-	0.0

Gastro-internal parasitism is the third leading cause of morbidity in the caprine centre of Maradi. Study conducted in Nigeria showed that young subjects are more infected than adults and the rate of infestation is higher in the rainy than dry season (Nwosu *et al.*, 1996). Uro-genital infections and mastitis are not so fatal and frequent in Red Maradi goat.

2.8 The place of goats in milk production

Goats are raised worldwide, but are more adapted to arid, subtropical, or mountainous regions. More than 460 million goats in the world produce over 4.5 million tons of milk and 1.2 million tons of meat annually, besides mohair, skin and dung for fuel and fertilizer (Attfield *et al.*, 1990). The world's dairy goat production has grown partly because of the global quest for increasing food self-sufficiency by people in many countries. More people consume dairy products from goats than from any other animal and goat's milk greatly improves the diet of many households (Silanikove *et al.*, 2010). This importance of milk production gives to certain goat breeds their reputation. Thus, according to Attfield *et al.* (1990), the Saanen breed is best known as the Holstein (a very productive dairy cow) of the goat world, producing a large quantity of milk and the Nubian as the Jersey of the goat world. According to Murdoch (2012), Saanan and Nubian goats produced an average daily milk yield of 3.5 and 2.5 L per day respectively with a lactation period of 10 months.

Goats produce milk more efficiently than cows in view of their management and are inexpensive to keep. Goats eat little and appreciate a varied diet, they eat whatever is available in pastures; they are opportunistic feeders. This characteristic helps by reducing the feeding costs and labour. In addition, goats can maintain themselves on grazing without any supplements; they occupy a small space, and produce enough milk for the average family; whereas the prospect of maintaining a productive cow at home is too high for a homeowner.

2.8.1 Milk yield

Milk yield is affected by breed, body condition score, parity, season, and litter size on partial daily milk yield (Table 2.11). Partial daily milk defined as hand-milking of 12 hours from 1800h to 0600h was recorded weekly during 14 weeks by Zahraddeen *et al.* (2009a) on three goat breeds, namely the Sahel goat, Red Sokoto (Maradi) goat and West African Dwarf goat. Sahel goat had the highest average partial daily milk yield followed by Red Sokoto and West African Dwarf does. Partial daily milk yield increased with increase in body condition score and parity. This agrees with Butswat *et al.* (2002) in

Sahel and Red goats where milk yield increased up to third parity and then declined. Garcia et al. (1976) cited by Zahraddeen *et al.* (2009a) found that the milk yield of Anglo-Nubian, Alpine, Toggenburg and Saanen goats peaked in the third lactation.

Goats had higher partial daily milk yield in the dry than in the wet season (Zahraddeen *et al.*, 2009a). This is in agreement with Iloeje *et al.* (1981) that WAD does kidding from January to March had more milk than those kidding from April to July. This could be due to the availability of crop residues and access to pasture after crop harvest. Indeed, feeds are more available from January to March (crop residues, pastures, shrubs) and herds free during the day whereas the period between April to July coincide to feed scarcity and herds are kept at home from June-July (zero grazing) until October-November. Does with single birth had lower milk yield than does that kidding twins (Zahraddeen *et al.*, 2009a) and agree with Wilson (1991).

Zahraddeen *et al.* (2009a) reported that milk yield increased from the first week, reached a peak in the third week and then declined subsequently up to the fourteenth week (Figure 2.1) which is in agreement with Djibrillou *et al.* (1998). Variable peak milk yields have been observed by various studies according to breeds and environment. Butswat *et al.* (2002) reported a peak milk yield in the fourth week in Red Sokoto Goat and Sahel Goat in Bauchi, a part of Sudan savannah ecological zone of Nigeria. Akpa *et al.* (2003) reported also that milk production increased during early lactation, attaining a peak at 4^{th} week of lactation thereafter declining sharply between 4^{th} and 7^{th} week of lactation. James and Osinowo (2004) reported that the West African Dwarf does in humid environment attained peak milk yield in the third week of lactation with Sahel Goat and Red Sokoto goat in the second week.

Table 2. 11 Mean partial daily milk yield (PDM/ml) in goats as influenced by breed, body condition score, parity, season and litter size (Zahraddeen *et al.*, 2009a)

	n	Partial daily milk yield (ml)
Overall	820	188
Breed		***
Red Sokoto	376	188.
Sahel	247	208
West African Dwarf	197	169
Body condition score		***
2	460	184
3	263	186
4	97	193
Parity		***
1	442	173
2	308	182
3	70	208
Season		***
Dry	486	195
Wet	334	182
Litter size		***
1	764	174
2	56	202

n: sample size; ***; P<0.001.

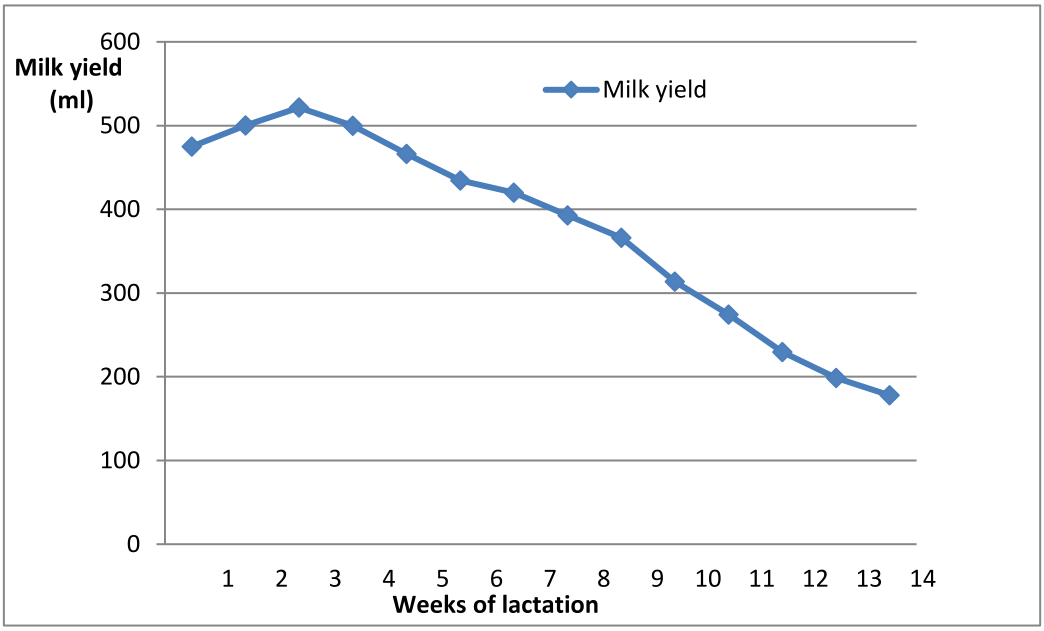


Figure 2.1 Daily milk yield (ml) of goat breeds (Zahraddeen *et al.*, 2009a)

2.8.3 Milk composition

Goat milk composition is influenced by genotype, stage of lactation, season, parity and diets (Table 2.12 and Table 2.13). According to Akinsoyinu *et al.* (1981) the total solids and gross energy declined with advance in lactation in red Sokoto (Maradi) goats and there was a steady fall in milk yield.

Table 2. 12 Milk composition (%) in red Maradi (Sokoto) goat

Authors	n	Protein	Fat	Total solid	Solid non fat	Ash	Lactose
Akinsoyinu et al., 1981	8	4.7	4.6	15.7	-	-	5.25
Djibrillou et al., 1998	30	4.34	3.63	-	-	-	-
Djibrillou et al., 1998	30	4.53	3.62	-	-	-	-
Djibrillou et al., 1998	30	3.91	5.21	-	-	-	-
Malau-Aduli & Anlade, 2002	35	5.49	5.8	15.37	9.57	0.77	3.31
Zahraddeen et al., 2007	15	3.84	4.38	11.3	-	0.84	4.9
Alawa and Oji, 2008	40	5.5	5.7	17.1	11.4	-	-
Midau, 2012	40	-	5.01	16.58	11.79	0.58	-
Mean		4.47	4.74	15.21	10.92	0.73	4.48

n = sample size

2.8.4 Effect of breed on milk composition

Milk composition is influenced by breed. Malau-Aduli and Anlade (2002) reported that goat milk contained the highest percentages of fat (5.80%), total solids (15.37%) and ash (0.77%) while the bovine contained least percentages of fat (4.82%), total solids (12.77) and ash (0.68%). According to Zahraddeen *et al.* (2007), the fat content was highest in the Sahel goat and lowest in Red Sokoto goat. Crude protein was affected by breed (Zahraddeen *et al.*, 2007) and similar results were observed by Beyene and Seifu (2000) in Borama goat milk in Ethiopia. Additionally, Zahraddeen *et al.* (2007) observed that crude protein is highest in Red Sokoto goat, followed by Sahel Goat and lowest in West African Dwarf goat; it also decreased with advancing lactations. The fat content and total solids were affected by breed as well (Table 2.13).

Table 2. 13 Mean of milk composition (%) in goats as influenced by breed (Zahraddeen et al., 2007)

Factor	n	Crude protein	Fat	Total solid	Ash	pH	Lactose
Overall	100	3.52	4.77	11.53	0.87	6.25	4.55
Breed		***	***	*	NS	NS	***
Red Sokoto	40	3.84	4.38	11.30	0.84	6.32	4.90
Sahel goat	32	3.45	5.16	11.67	1.08	6.21	4.46
West African Dwarf	28	3.27	4.74	11.63	0.70	6.21	4.29

n = sample size, NS = Not significant, * $P < 0.05$, *** $P<0.001$, [a, b, c] Mean in the same column within a subset having different superscripts are significantly different.

Egbowon (2004) observed that milk fat is higher in dual purpose breeds (Red Sokoto, West African Dwarf and East African Dwarf goats) than those selected for milk production alone (Finish, Saanen, Alpine or Anglo Nubian). This is certainly due to the negative correlation between milk fat and milk yield in milk goat breed.

2.8.5 Effect of diet and season on milk composition

The protein content in goat milk vary with diet. For example, Djibrillou *et al.* (1998) fed three diets and observed that goats milk protein content was highest in urea-treated straw and lowest for untreated straw plus cottonseed. The same authors reported that diet highly affected milk fat content of red goats. Thus, goats fed a ration of untreated straw plus cottonseed produced milk of which fat content was much higher than that of milk produced by goats fed on diet based on untreated straw or urea-treated straw (Table 2.14).

Table 2. 14 Summary of overall mean values of results of an eight-week experimental period for goats fed untreated straw (UNTS), urea-treated straw (UTS) and untreated straw + cotton seed (UNTS + CS) diets (Djibrillou *et al.*, 1998)

	UNTS	UTS	UNTS + CS
Milk yield (g/day)	389	443	447
Milk fat (%)	3.63	3.62	5.21
Milk protein (%)	4.34	4.53	3.62
Energy value of milk (kcal ME)	443	495	660
DMI (g/kg $W^{0.75}$/day)	39.8	24.1	46.7
DMI (kcal ME/day)	398	511	937
Weight loss over 8 weeks (kg)	5.85	2.80	2.74

Season also had a strong influence on milk composition (Table 2.15). Milk fat content recorded in wet season was higher than in the dry season (Zahraddeen *et al.*, 2007; Zahraddeen *et al.*, 2009a; Midau, 2012). However, Zahraddeen *et al.* (2007) observed that season had no effect on milk crude protein content (Table 2.16).

Table 2. 15 Milk yield/week kg^{-1} and milk composition (%) in wet and dry season (Midau, 2012)

Parameters	Wet season (n=20)	Dry season (n=20)
Milk yield	3.38	2.08
Fat	5.01	4.84
Total solids	16.58	17.86
Solid non fat	11.79	13.42
Cholesterol	0.18	0.17
Calcium	0.29	0.22
Magnesium	0.15	0.14
Phosphorus	0.14	0.13

n = sample size

Table 2. 16 Mean milk composition (%) in goats as influenced by season (Zahraddeen *et al.*, 2007)

Factor: Season	n	Crude protein	Fat	Total solid	Ash	pH	Lactose
Dry	56	3.52	4.49	11.56	0.66	6.26	4.25
Wet	44	3.53	5.04	11.50	1.09	6.23	4.85
Season		NS	***	NS	NS	NS	***

n = sample size; NS = Not significant, *** P<0.001.

2.8.6 Effect of lactation stage on milk composition

The stage of lactation affected milk composition. Fat content of milk decreased as lactation progressed (Wilson, 1991; Djibrillou *et al.*, 1998; Zahraddeen *et al.*, 2007). Wilson (1991) noted that the lipid drops sharply after the fourth week of lactation and all variables, except for lactose, are higher in colostrum than in milk. Crude protein was affected by stage of lactation (Zahraddeen *et al.*, 2007). Similar results were observed by Beyene and Seifu (2000) in Borama goat milk in Ethiopia. According to Zahraddeen *et al.* (2007), crude protein decreased with advancing lactations (Table 2.17).

Table 2. 17 Mean of milk composition (%) in goats as influenced by stage of lactation (Zahraddeen *et al.*, 2007)

Factor: Lactation stage	n	Crude protein	Fat	Total solid	Ash	pH	Lactose
Colostrum	25	3.85	5.35	11.59	0.73	6.18	5.02
Early lactation	25	3.66	4.97	11.43	0.79	6.36	4.72
Mid lactation	25	3.38	4.62	11.51	1.12	6.33	4.40
Late lactation	25	3.20	4.13	11.61	0.79	6.11	4.07
Lactation stage		***	***	NS	NS	NS	***

n = sample size; NS = Not significant; *** P<0.001.

2.8.7 Effect of parity on milk composition

Milk composition is affected by parity**.** According to Zahraddeen *et al.* (2007), the fat content was highest in the third parity followed by the second parity and least in the first parity. However, the parity had no effect on milk crude protein content (Table 2.18).

Table 2. 18 Mean of milk composition (%) in goats as influenced parity (Zahraddeen *et al.*, 2007)

Factor: Parity	n	Crude protein	Fat	Total solid	Ash	pH	Lactose
1	60	3.49	4.39	11.58	0.97	6.32	4.03
2	20	3.55	4.73	11.68	1.00	6.28	4.85
3	20	3.57	5.54	11.35	0.65	6.14	5.30
Parity		NS	***	NS	NS	NS	***

n = sample size; NS = Not significant; *** P<0.001.

2.9 Kid performance

2.9.1 Birth weight, weight at 30, 60 and 90 days

Djibrillou (1989) and Wilson (1991) found that kid sex and dam age influenced the birth weight and kids weight at 30 days. Males are born slightly heavier than females (Haumesser, 1975; Djibrillou, 1989). In addition, Marichatou *et al.* (2002) observed that black kids are born slightly heavier than red kids (1.95 ± 0.36 kg vs. 1.82 ± 0.45 kg). At Caprine Centre of Maradi, average weight were 2.05 kg, 3.94 kg and 9.05 kg corresponding to birth, 30 days and 90 days after kidding (Djibrillou, 1989). According to this author, weight of kids after 30 days and 90 days was influenced by the dame age and kids sex. Wilson (1991) observed that male and female twins were heavier than those born single or triplets after 30 days. But by 60 days, Wilson (1991) observed that male and female born single were heavier than twins and triplets, and then female born single and twin were equal but both were heavier than female born triplet (Table 2.19).

Table 2. 19 Birth weight, weight at 30 days and weight at 60 days in Caprine Centre of Maradi (Wilson, 1991)

	Birth weight (kg)		Weight at 30 days (kg)		Weight at 60 days (kg)	
Type	Male	Female	Male	Female	Male	Female
Single	2.1	2.1	3	3.7	6.1	5
Twin	1.8	2.1	3.9	4.4	5.8	5
Triplet	1.5	1.4	3	3	5.4	4.2

2.9.2 Average daily gain (ADG) between 0, 30 and 60 days

The diet of lactating goats strongly influences the development of kids before weaning in Red Maradi goat. Djibrillou (1989) observed ADG of 43 g, 46 g and 50 g during the first 30 days of life and ADG of 19 g, 22 g and 32 g from 30-60 days, in kids born to dams fed untreated straw, urea-treated straw and untreated straw plus cottonseed, respectively. This meant that ADG of kids is related to feed quality; the higher the feed quality, the higher the ADG. The ADG also decreased with kid's age. Contrary to Djibrillou (1989), Marichatou *et al.* (2002) found in traditional system higher ADG in Red Maradi goat within the first 30 days of life (70.7 g) and the period of 30 - 60 days (71 g), thus indicating similarity between the two age groups. For black dams, Marichatou *et al.* (2002) also observed that kids had an average daily gain of 49 g and 81 g within the first 30 days and 30-60 days, respectively. This meant that the ADG of black kids within first 30 days and from 30-60 days were higher than those of red kids in the study of Djibrillou (1989). However, according to Marichatou *et al.* (2002) the ADG of black kids were lower and higher than for red kids at first 30 days and 30 - 60 days, respectively. Relatively, average daily gain of black kids was far higher between 30 - 60 days than that of red kids.

2.10 Carcass yield and meat quality

The red goat of Maradi provides good quality meat which is the main source of animal protein in villages of Maradi region. Meat yield is based on sex and body weight, the best yields are provided by castrated bucks. According to Wilson (1991), the average yield at slaughter is 44 - 50% and 54 - 55% in young castrated male and adults, respectively.

2.11 Skin quality

Qualitatively, the Red Maradi goat is recognised for its skin world wide, which is of exceptional quality. They are sought for making good gloves, luxury shoes, and good skin clothes in Europe mostly in Belgium. That was the reason why the goat breed centre of Maradi has been supported by Belgium Kingdom from 1998 until now in order to improve the livestock conditions of this centre and to popularise this breed in rural areas of Maradi region. According to Wilson (1991), Red Sokoto skins are of exceptional good quality and known as "Morocco" in the tannery trade. They are characterized by deep pronounced grain, dense compact elastic fibres, little grease, and ease of tanning; they are in demand for the fancy goods trade. The average weight of dry skin in Niger and Nigeria is about 420 g with 250 g to 625 g for extra light and heavy. The useful tanning surface is 0.28 to 0.65 m^2.

2.12 Summary

So far little progress has been made in studying the red Maradi (Sokoto) goats and many questions remain unanswered. Some well known characters of the red goat of Maradi are the general profile, linear body measurement, and the exceptional quality of red goat skins. The red goat of Maradi is prolific and its gestation period of five months (150 days) is relatively constant. It is admitted that the traditional habitat of the red goat of Maradi is in the southern regions of Niger. The Red Maradi goat is widely distributed in other regions. Its aptitude for dairying is recognized, however, the potential of milk production under optimum feeding conditions needs to be determined; so also is the growth performance of kids. It is necessary to determined how the nutrition of does would affect reproductive parameters; and how nutrition of does during pregnacy would affect milk production performance and kid growth rate. More work has been done in Nigeria examining the red Sokoto goat but the environmental conditions are different than in Niger. Furthermore, apart from genetic factor, the environment severely influence animal production. This is the reason that further study on lactating goats would be undertaken in Niger in order to reveal the real potential milk production of Red Maradi goat and growth performance of kids.

Chapter 3

Effect of urea treatment of roughages and nutritive value of available feed resources in Maradi area of Niger

Abstract

Feed shortage is a major constraint for livestock production in the tropics. The objective of the current study was to determine the nutritive value of available feed resources in southern agricultural zones of Niger and to determine the effect of urea treatment on roughages. Cereal straws, legume crop residues and concentrates were collected in the dry season. Cereal straws were millet and sorghum stovers, *Diheteropogon hagerupii*, *Eragrostis tremula* and *Schizachyrium exile.* Legume crop residues were groundnut haulms and cowpea husk. Cereal straws and cowpea husk were either untreated or treated with urea. Feeds were analyzed for dry matter (DM), organic matter (OM), nitrogen (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and acid detergent insoluble nitrogen (ADIN). The metabolizable energy (ME) was determined through effective degradability (ED) of organic matter (OM) and gas production after 24h of incubation. Degradability characteristics, *in sacco* and *in vitro* digestibility were determined using two fistulated Jersey cows. Type of cereal straws affected ($P<0.001$) chemical composition variables, whereas urea treatment decreased ($P<0.001$) DM, increased ($P<0.001$) N and ADIN content. Cereal straws interacted with urea treatment (UT) to affect ($P<0.001$) N and ADIN. Legume crop residues highly affected ($P<0.001$) NDF and cellulose (Cel) and affected ($P<0.01$) N but urea treatment of cowpea husk ($P<0.001$) decreased DM and increased ($P<0.001$) N. Concentrates affected ($P<0.001$) N, ADF, hemicellulose (Hcel), Cel and ADL. Contents (g/kg DM) of NDF and ADF ranged from 725 to 880 and 438 to 565, respectively for cereal straws; 495 to 617 and 386 to 428, respectively, for legume crop residues; and from 513 to 570 and 122 to 437, respectively, for concentrates. The N content (g/kg DM) in cereal straws, legume crop residues and concentrates ranged from 3.12 to 6.20, 13.55 to 17.50 and 23.31 to 35.45, respectively. Similar trends were observed for DM and OM degradation *in sacco*. Cereal straws had different ($P<0.001$) soluble fraction (wash), effective degradability (ED), apparent degradability (Apdeg), degradation rate (C), gas volume from fast (A), slowly degradable fraction (B) degradation rate for slowly degradable fraction (c2), lag time (Lt), halflife to the maximum gas volume ($T_{1/2}$), maximum rate of gas production (μ), partitioning factor (PF), degradation efficiency factor (DEF) and metabolisable energy (ME). Whereas, urea treated straws had higher ($P<0.001$) wash, ED, degradation rate (c), the rate of gas production (C), Lt and increased ($P<0.01$) ME and μ. Legume crop residues affected ($P<0.01$) solubility and ED, while treating cowpea husk decreased ($P<0.05$) (c), ED, GP, (c1) and ($T_{1/2}$) but increased ME ($p<0.01$). Concentrate type affected ($P<0.001$) N degradability variables (potential degradability, (c) and ED. *In sacco* effective degradation of concentrate DM and OM, and all concentrate degradation and kinetics varied ($P<0.001$) very much, while Apdeg and true degradability (Trdeg) varied to a lesser extent ($P<0.01$) leaving microbial yield (MY) unaffected. These findings suggest that consideration of nutritive value of feeds should be taken when formulating diets for ruminants in the study areas.

Keywords: Cereal straws, Legume crop residues, Concentrates, urea treatment, Chemical composition, *in sacco* degradation, *in vitro* digestion.

3.1 Introduction

Feed for ruminants is determined by the concentrations of its chemical components, the rate and extent of degradation and digestibility (Chumpawadee *et al.*, 2007; Belachew *et al.*, 2013). High quantity and quality feeds are only available during the rainy season which lasts for four months per annum in Niger. Ruminants largely depend on cereal straws in Niger to cope with the dry period of the year. However, these feeds are low in protein and available energy and are deficient in minerals and vitamins (Preston, 1995; Chenost and Kayouli, 1997; Salem and Smith, 2008; Koralagama *et al.*, 2008; Ouda and Nsahlai, 2009; Abdou *et al.*, 2011).

The high cell wall and low crude protein (CP) of cereal straws lead to low intake and low digestibility and consequently low animal performance after feeding (Ngwa and Tawah, 2002; Ngwa *et al.*, 2003). To improve the quality of these roughages, strategies have been used including chemical treatment or supplementation with protein sources such as legume and/or agro industrial by-products (Nsahlai and Umunna, 1996b; Nsahlai *et al.*, 2000; Smith *et al.*, 2005; Ayantunde *et al.*, 2007; Ajayi *et al.*, 2008; Abdou *et al.*, 2011). However, research for development projects have accorded more attention on chemical treatment to improve nutritional value of cereal crop residues by increasing intake (50%) and digestibility (10%) (Chenost and Kayouli, 1997; Khejornsart and Wanapat, 2010; Cherdthong and Wanapat, 2010; Sarnklong *et al.*, 2010; Cherdthong *et al.*, 2011; Owen *et al.*, 2012). Acids, alkalis like sodium hydroxide, potassium hydroxide, calcium hydroxide, ammonia or urea are used for chemical treatment. Among these treatments, urea treatment is the most commonly recommended in developing countries (Devendra, 1997; Schiere and De Wit, 1995; Chenost and Kayouli, 1997; Elseed *et al.*, 2003a; Owen *et al.*, 2012) due to its advantage of improving nitrogen content and reducing the use of protein concentrate.

In recent years, there has been a considerable interest in the use of agro-industrial by-products and crop residues for feeding ruminants in Niger (Ali *et al.*, 2003). However, little is known about the nutritive values of such feedstuffs in Niger and other West African countries. Measurement of *in sacco* degradability give good estimation of feed quality (Bonsi *et al.*, 1996; Mthiyane *et al.*, 2001; Pop *et al.*, 2006; Chumpawadee *et al.*, 2006; Elseed *et al.*, 2007; Chumpawadee *et al.*, 2011). *In vitro* digestibility has been widely used to assess the nutritional quality of feeds, due to its high correlation with *in vivo* digestibility (Nsahlai and Umunna, 1996a; Bonsi *et al.*, 1996; Aregheore, 2000; Tessema and Baars, 2004; Canbolat *et al.*, 2006; Chumpawadee *et al.*, 2007; Chumpawadee and Pimpa, 2008). These cereal straws were treated with urea in order to assess the effect of urea treatment on the chemical composition, *in sacco* degradability and *in vitro* digestibility parameters. The objective of the current study was to evaluate the nutritive values and to determine the effect of urea treatment of some feeds available in South Eastern Niger.

3.2 Material and Methods

3.2.1 Chemical composition of feeds

3.2.1.1 Feeds

Four feed samples were collected per feed in 2012 in Maradi area located at south eastern agricultural zone of Niger with an annual rain fall between 350 and 600 mm; and a composite sample of each feed was taken for urea treatment and laboratory analyses. Roughages consisted of millet stover (*Pennisetum typhoides*), sorghum (*Sorghum bicolor*) stover (whole sorghum stover, sheath and leaves, stems), groundnut haulms (*Arachis hypogea*), *Eragrostis tremula*, *Schizachyrium exile*, *Diheteropogon hagerupii*, and cowpea (*Vigna unguiculata*) husk; while concentrates were millet bran, wheat bran and cottonseed cake. All roughages were treated with urea (3%) for 40 days in plastic bags (at the Discipline of Animal and Poultry Science, SAEES, UKZN, Rep. South Africa). Concentrates used in this study are the only ones available to smallholder farmers in Southern Niger.

3.2.1.2 Proximate analyses

Proximate analyses were conducted in the Laboratory of the Discipline of Animal and Poultry Science at the University of KwaZulu-Natal, Pietermaritzburg, South Africa. Samples of feed offered were analyzed for chemical composition. Dry matter (DM) of feeds was done immediately following the period of urea treatment. Dry matter was determined by drying samples in oven at 60^0C for 48h until weight became constant. Ash was determined by combusting 1 g of sample per crucible in a muffle furnace for four hours at 550ºC (method-942.05 AOAC, 1990). Nitrogen content was determined using the Leco TruMac CNS/NS (LECO Corporation USA, 2012). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined in duplicates using ANKOM-A200/2220 (2052 O'Neil Road, Macedon NY 14502, www.ankom.com). Hemicellulose and cellulose were obtained by difference. After the incubation period, duplicate residue samples of cowpea husks, millet bran, wheat bran and cottonseed cake were analyzed for nitrogen. Acid detergent insoluble nitrogen

(ADIN) was obtained from the residue of ADF using Leco TruMac CNS/NS technique. The ADIN is calculated as following: ADIN (%) = ADF (%)*ADFn (%)/100.

3.2.2 *In sacco* feed degradability

3.2.2.1 Study sites

Experiment 1 was conducted at Ukulinga Research Farm, Pietermaritzburg Campus of the University of KwaZulu-Natal, South Africa. This area is 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, each of two Jersey cows fitted with a rumen cannula, about 350 kg body weight, were kept under natural grazing of kikuyu (*Pennisetum clandestinum*) pasture and given 2 kg of Lucerne per cow per day in the afternoon and a mineral lick *ad libitum*. The adaptation period was two weeks. Two cows were used at the same time in order to have replications.

3.2.2.3 Feeds

Roughages (either untreated or treated with urea) and concentrates were used to determine the chemical composition and degradability in the rumen.

3.2.2.4 Degradability

The degradability of DM, OM and/or nitrogen for millet stover, sorghum stover, sorghum stover sheath and leaves, sorghum stover stems, groundnut haulms, *Eragrostis tremula*, *Schizachyrium exile*, *Diheteropogon hagerupii*, cowpea husk, millet bran, wheat bran and cottonseed cake were measured according to Mehrez and Ørskov (1977). Each feed was ground through a two mm screen size and weighed into nylon bags at the rate of 4 g per feed. Nylon bags (pore size 41 μm and measuring 9.0 cm x 14.5) were incubated for 0, 3, 6, 9, 12, 24, 36, 48, 72, 96 and 120 hours in duplicate bags (one bag for each of the two cows). Concentrates were incubated for a maximum of 48 hours and roughages for 120. Untreated and treated feeds were incubated separately by suspending bags containing feedstuffs in the rumen. A sequential addition method for sample incubation was used. After withdrawal, bags containing residues were immediately rinsed to remove ruminal contents and microorganisms and to stop further fermentation. Bags for zero time were not incubated. At the end of the incubation, all bags plus ones for zero time were washed together in a domestic washing machine for 30 min (six cycles x 5 min duration). Subsequently, bags were dried in an oven at 60ºC for 48h until constant weight, cooled in a desiccator and weighed. Dry matter loss, organic matter loss and nitrogen loss were calculated and expressed as percentage degradability of the original amount.

3.2.2.5 Computation and statistical analysis

The non-linear model with the formula: $P = wash+b\ (1-e^{-ct})$ of Ørskov and McDonald (1979) was fitted to degradability data using (SAS, 2004); where *P* is the percentage of material degraded after time "*t*", "*wash*" is the washing loss, which represents the intercept of the degradation curve at time zero, and is considered as a component of DM degraded rapidly; *b* represents the slow but potentially degradable fraction, *c* = the rate constant for the degradation of "*b"* and wash + *b* represents the potential degradability of the feed. The effective degradability (ED) of each component was calculated as ED = 0.8*wash + b*c/(c + k); Where k = fractional rate of passage. Three rates of passage were used to calculate ED_1, ED_2 and ED_3 as follows: $k_1 = 0.03$ for maintenance; $k_2 = 0.045$ for growth; $k_3 = 0.065$ for milk production, for all feed components.

3.2.3 *In vitro* digestion

3.2.3.1 Gas production

All roughages (treated with urea and untreated) and concentrates cited above were used to determine gas production following the automated gas production technique described by Pell and Schofield (1993). Ingredients were ground through a 1 mm screen and a total of 1.0±0.0010 g DM of each sample was weighed into a 250 ml Duran bottle for *in vitro* incubation. Roughages and concentrates were incubated separately. During each run, there were three controls of lucerne (*Medicago sativa*) and three blanks (only rumen fluid and buffer). Roughages (treated and untreated) were incubated in 4 runs in a completely randomised block design. Concentrates were incubated in 3 runs in a completely randomised design with 5 replicates per sample. A salivary buffer solution was prepared according to McDougall (1948). A 67 ml solution of the buffer was added to each sample and to each blank bottle. These bottles were kept in the incubator (39°C) for 1 hr to allow soaking of substrate prior to adding rumen fluid. Meanwhile, a mixture of the rumen fluid was collected prior to morning feeding from the two fistulated Jersey cows. The rumen material was then squeezed and filtered through four layers of cheesecloth into a pre-warmed flask container (39ºC) that had been flushed with carbon dioxide (CO_2) and transported to the laboratory. Inoculation was completed by adding 33 ml of the rumen fluid into each bottle under a stream of CO_2 and tightening bottle lids. Duran bottles were incubated in the incubator and channels of pressure sensors were fitted. Pressure was logged at 20 min interval during a 72-hours and 48-hours incubation period for roughages and concentrates, respectively, and was converted to volume using a predetermined calibration equation. The metabolisable energy value was calculated according to Menke *et al.* (1979) as follows: ME (MJ/kg DM) = $2.20 + 0.136G_{24} + 0.057CP + 0.0029\ CP^{2}$; Where CP = crude protein in g per 100 g DM, and G_{24} is the gas volume at 24 h after incubation (ml) of 200 mg. In this study the gas volume after 24 hours was converted from 1000 mg to 200 mg of material incubated. Metabolisable energy was also determined based on the degradation of organic matter in the rumen.

3.2.3.2 Degradability

In vitro degradability of cereal straws, legume crop residues and concentrates was done in the Laboratory of the Discipline of Animal and Poultry Science at the University of KwaZulu-Natal, Pietermaritzburg. At the end of incubation, the pH was measured and samples were centrifuged at 17,700xg for 20 minutes at 4ºC. After centrifugation, the supernatant was poured out, the residue was transferred into a container (with known weight) and placed in the oven (70ºC) for 5-6 days until completely dried (constant weight). Dry residues were corrected for blank incubation which contained only buffer and rumen fluid. The difference in mass between the dry residue and the mass of the incubated material represented apparent degradability (Apdeg). The residue was refluxed with neutral detergent solution using ANKOM fiber analyser. The resulting weight of neutral detergent fiber (after correction) was subtracted from the mass of the incubated material which represented the true degradability (Trdeg) (Van Soest *et al.*, 1991; Blümmel *et al.*, 1997b). The difference between Trdeg and Apdeg represented the microbial yield (MY) (Van Soest, 1994; Blümmel *et al.*, 1997b).

The experimental design was a completely randomised block design (9 feeds x 4 runs) for roughages in Experiment two and (3 feeds x 5 pseudo replications x 5 runs) for concentrates in Experiment two. The model described by Campos *et al.* (2004) was fitted to gas volumes to determine gas production kinetics following a two steps process:

Y = GP/[1+e(2+4C (Lt - t)] (Schofield *et al.*, 1994) and

Y = A/[1+exp [2+4c1 (Lt - t)]] + B/[1+exp [2+4c2(Lt - t)]] (Campos *et al.*, 2000); where Y is the total gas volume (mL) at time t, GP is the maximum gas production, C is the overall rate of gas production, A is the gas volume (mL) from fast (soluble sugars and starch) and B is the GP from slowly (cellulose and hemicellulose) degradable fractions, c1 and c2 are the degradation rates (h^{-1}) for fast and slowly degradable fractions, respectively and Lt is the bacteria colonization or Lag time (h). The cumulative gas production (GP) was used to calculate the maximum rate of GP at the point of inflection (μ) and the time taken to produce half of the gas volume (T½) according to Sahoo *et al.* (2010) as follows:

μ (ml/h) = GP x C and

$T_{1/2}$ (h) = Lt + 1/(2*C)

The partitioning factor (PF) (Blümmel *et al.*, 1994; Blümmel *et al.*, 1997a) and the degradation efficiency factor (DEF) (Ouda and Nsahlai, 2009) were calculated as follows:

PF = Trdeg/GP

DEF = Trdeg/ $T_{1/2}$ x $GP_{1/2}$ = 2PF/ $T_{1/2}$

3.2.3.3 Statistical analyses

These data were subjected to the General Liner Model of SAS to determine the effects of feeds, urea treatment and interaction feed vs urea treatment on gas production parameters, the statistical significance being declared at $P<0.05$. Means were compared by least square means (LSMEANS). The models used were:

$Y_{ijkl} = \mu + f_i + u_j + (fu)_{ij} + run_k + e_{ijkl}$ (Experiment 1);

Where, Y_{ijkl} is the independent variable (GP parameters, *in vitro* degradability), μ is the overall mean, fi is the effect of feed roughages (i=1-9), uj is the urea treatment effect (j=1), (fu)ij is the interaction between feeds and urea treatment, runk is the effect of run (k=1-4) and e_{ijkl} the residual error.

$Y_{ijkl} = \mu + f_i + r_j + run_k + e_{ijkl}$ (Experiment 2);

Where, Yijk is the independent variable (GP parameters), μ is the overall mean, fi is the effect of feed concentrates (3 feeds x 5 pseudo replications) (i=1-3), rj is the effect of replication (j=1-5), runj is the effect of run (j=1-5) and e_{ijkl} the residuel error. A correlation analysis was done between ME and derived factors of GP (PF, DEF, μ, $T_{1/2}$). Metabolisable energy was derived using either gas production at 24 h (see above) or effective degradability of OM based on suggestion by Nsahlai and Apaloo (2007): ED*15.06/0.9, where 15.06 is a factor suggested by Czerkawski (1986).

3.3 Results

3.3.1 Chemical composition of feeds

Classes of feeds did not affect ($P>0.05$) the dry matter (DM) and organic matter (OM) content, but their fibre fraction of cell wall (NDF, ADF, Hcel and Cel) were affected ($P<0.001$) except lignin (Table 3.1 and 3.2). Their nitrogen (N) and acid detergent insoluble nitrogen (ADIN) differed ($P<0.001$) consistently.

Cereal straws and forage legumesdid not affect ($P>0.05$) DM content, but, their DM was reduced ($P<0.001$) by adding water during urea treatment. Cereal straws varied ($P<0.001$) in OM contents, whereas the OM was not affected ($P>0.05$) by urea treatment or its interaction with cereal straws. Legume forages affected ($P<0.05$) OM, but treating cowpea husks with urea had no effect on OM.

Fibre fraction of the cell wall (NDF, ADF, Hcel, Cel and lignin) varied ($P<0.001$) across cereal straws (Table 3.1 and 3.2). Millet stover had higher ($P<0.05$) NDF than sorghum stover. The NDF and ADF were superior in cereal straws than in legume crop residues. There was no effect ($P>0.05$) of treating roughages with urea on these cell wall content, except on cellulose ($P<0.01$). However, cereal straws interacted with urea treatment to affect ($P < 0.05$) NDF, ADF and cellulose. Within cereal straws, *Diheteropogon* had the highest ($P<0.001$) NDF and sorghum stover leaves and sheath had the lowest. Treating with urea (a) increased NDF for *Eragrostis tremula* but decreased NDF in other cereal straws, and (b) decreased ADF in sorghum stover but increased ADF in others except in *Diheteropogon hagerupii* where there was no change.

Fibre fraction (NDF and Cel) were affected ($P<0.001$) by legume crop residues whereas ADF, Hcel and ADL were less affected ($P<0.01$). Treating cowpea husks reduced ($P<0.05$) only cellulose. Among legume crop residues, cowpea husks had higher NDF ($P<0.001$) and ADF ($P<0.01$) than groundnut haulms.

Nitrogen content differed considerably ($P<0.001$) among cereal straws and was increased ($P<0.001$) by urea treatment. Cereal straws interacted with urea treatment to increase ($P<0.001$) nitrogen content. Nitrogen content (g N/kg DM) of treated feeds increased dramatically for *Eragrostis* (3.29 versus 7.53), *Schizachyrium* (3.53 versus 7.85), sorghum stover (3.6 versus 7.72) but increased modestly for *Diheteropogon hagerupii* (3.12 versus 5.8) and millet stover (6.2 versus 7.3). Legume crop residues affected ($P<0.01$) nitrogen content and urea treatment increased ($P<0.001$) nitrogen of cowpea husks (13.55 versus 22.48). Groundnut haulms (17.50) had higher ($P<0.01$) nitrogen than cowpea husks (13.6).

Within concentrates, DM, OM, N, and ADF were ($P < 0.001$) lowest in millet brans, highest in cottonseed, and intermediate in wheat brans. Among concentrates cottonseed cake had ($P<0.001$) the highest ADF, Hcel, Cel and ADL, followed by millet bran and wheat bran, in this order. The nitrogen content of concentrates was higher than that for legume crop residues, and cereal straws.

Type of cereal straws, and their interaction with urea treatment affected ($P<0.001$) acid detergent insoluble nitrogen (ADIN). Urea treatment increased ($P<0.001$) ADIN content in cereal straws. The ADIN content of straws ranged from 0.64 to 1.41 g/kg DM (in *Eragrostis* and millet stover) and when treated with urea, ADIN ranged from 0.98 to 2.43 g/kg DM (in sorghum stover and *Schizachyrium*). The ratio ADIN and N (ADIN:N) is expressed as ADIN (%) content of feed divided by its N (%) content multiply by 100. This ratio was also highly affected ($P<0.001$) by cereal straws. Type of cereal straw interacted with urea treatment to affect ($P<0.05$) ADIN:N. Nevertheless, this ratio decreased ($P<0.01$) with urea treatment, the amount of decrease being negatively correlated to its N content. The ADIN:N ratio in cereal straws ranged from 14.07 to 32.70% (in sorghum stover leaves/sheath and *Diheteropogon*) while the rank changed to 12.70 to 31.29% (in sorghum stover and *Diheteropogon*) when cereal straws were treated with urea.

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

Feeds	UT	DM (SD)	OM (SD)	N (SD)	NDF (SD)	ADF (SD)
Cereal straws class						
Diheteropogon hagerupii	no	970 (3.11)	959 (12.24)	3.12 (0.29)	880 (2.07)	565 (2.75)
Diheteropogon hagerupii	yes	617 (7.07)	968 (11.85)	5.80 (0.36)	876 (7.36)	566 (7.38)
Eragrostis tremula	no	969 (10.96)	976 (8.49)	3.29 (0.31)	796 (1.78)	465 (10.12)
Eragrostis tremula	yes	613 (1.83)	971 (11.00)	7.53 (0.38)	829 (7.87)	485 (9.08)
Schizachyrium exile	no	949 (6.36)	954 (8.45)	3.53 (0.24)	813 (0.99)	518 (5.19)
Schizachyrium exile	yes	626 (4.80)	956 (9.35)	7.85 (0.29)	812 (7.49)	541 (4.31)
Millet stover	no	954 (3.81)	913 (9.20)	6.20 (0.15)	816 (1.60)	518 (5.27)
Millet stover	yes	619 (9.89)	911 (4.17)	7.28 (0.95)	799 (2.98)	523 (8.80)
Sorghum stover (SS)	no	964 (7.07)	845 (9.56)	3.60 (0.04)	791 (9.40)	535 (15.06)
Sorghum stover (SS)	yes	624 (2.57)	843 (7.45)	7.72 (0.02)	773 (21.12)	514 (10.90)
Fractions of cereal straws						
SS Leaves & sheath	no	973 (0.70)	809 (3.36)	6.35 (0.29)	725 (4.99)	440 (2.73)
Sorghum stover stems	no	962 (3.18)	906 (2.34)	3.58 (0.27)	731 (11.42)	438 (3.65)
Legume forages class						
Cowpea husks	no	944 (1.13)	935 (6.85)	13.55 (0.06)	617 (0.06)	428 (2.13)
Cowpea husks	yes	627 (7.49)	928 (8.01)	22.48 (0.61)	615 (1.93)	422 (7.85)
Groundnut haulms	no	932 (0.42)	889 (11.37)	17.50 (0.58)	495 (11.17)	386 (0.26)
Concentrates class						
Millet bran	no	919 (0.35)	897 (7.97)	23.31 (0.09)	513 (23.06)	122 (0.23)
Wheat bran	no	953 (8.62)	951 (6.79)	26.07 (0.8)	477 (7.99)	125 (1.09)
Cottonseed cake	no	980 (3.32)	948 (7.95)	35.45 (0.49)	570 (6.08)	437 (6.78)
Variation sources						
Between classes						
RMSE		157.81	48.69	3.14	48.90	72.83
F Value		1.66	0.21	141.12	111.34	36.52
Class effect		NS	NS	***	***	***
Within cereal straws						
RMSE		7.71	8.70	0.37	8.57	7.97
Feeds effect		NS	***	***	***	***
Treatment effect		***	NS	***	NS	NS
Feeds*treatment		NS	NS	***	*	*
Within legume forages						
RMSE		4.38	8.95	0.49	6.54	4.70
Feeds effect		NS	*	**	***	**
Treatment effect		***	NS	***	NS	NS
Within concentrates						
RMSE		5.34	7.59	0.54	14.52	3.96
Feeds effect		**	**	***	*	***

UT: urea treatment; DM: Dry matter; OM: Organic matter, N: Nitrogen; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; Acid detergent fibre nitrogen; Hcel: hemicellulose; Cel: Cellulose; ADL: Acid detergent lignin; SD: standard deviation; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

Table 3.2 Chemical composition of feeds (g/kg DM)

Feeds	UT	ADIN (SD)	ADIN:N (SD)	Hcel (SD)	Cel (SD)	ADL (SD)
Cereal straws class						
Diheteropogon hagerupii	no	1.02 (0.01)	32.70 (0.31)	316 (0.68)	485 (0.17)	78 (1.54)
Diheteropogon hagerupii	yes	1.81 (0.01)	31.29 (0.16)	310 (0.01)	476 (0.78)	88 (2.91)
Eragrostis tremula	no	0.64 (0.06)	19.70 (1.95)	330 (8.34)	397 (2.20)	67 (2.86)
Eragrostis tremula	yes	1.27 (0.05)	16.90 (0.75)	344 (1.21)	414 (2.77)	72 (1.77)
Schizachyrium exile	no	1.11 (0.14)	31.39 (4.17)	295 (6.18)	447 (0.70)	49 (3.74)
Schizachyrium exile	yes	2.43 (0.08)	30.98 (1.06)	270 (3.18)	450 (1.67)	90 (0.49)
Millet stover	no	1.41 (0.11)	22.80 (1.88)	298 (6.88)	394 (5.72)	130 (3.09)
Millet stover	yes	1.62 (0.05)	22.37 (0.73)	276 (5.81)	406 (1.34)	118 (3.06)
Sorghum stover (SS)	no	0.77 (0.06)	21.55 (1.78)	257 (24.47)	296 (24.92)	198 (22.45)
Sorghum stover (SS)	yes	0.98 (0.11)	12.70 (1.53)	259 (10.23)	331 (6.70)	189 (1.25)
Fractions of cereal straws						
SS Leaves & sheath	no	0.89 (0.01)	14.07 (0.21)	285 (7.72)	289 (3.65)	145 (5.02)
Sorghum stover stems	no	0.85 (0.03)	23.69 (1.03)	293 (7.78)	332 (4.96)	100 (3.13)
Legume forages class						
Cowpea husks	no	2.71 (0.10)	20.01 (0.75)	189 (2.2)	328 (2.52)	102 (1.46)
Cowpea husks	yes	3.59 (0.26)	15.99 (1.17)	193 (5.92)	312 (4.98)	105 (1.06)
Groundnut haulms	no	2.19 (0.001)	12.51 (0.007)	110 (10.92)	265 (3.26)	116 (3.13)
Concentrates class						
Millet bran	no	2.34 (0.32)	10.03 (1.39)	391 (22.84)	61 (1.35)	63 (1.24)
Wheat bran	no	0.79 (0.12)	3.03 (0.48)	352 (6.91)	86 (2.82)	35 (2.28)
Cottonseed cake	no	3.21 (0.30)	9.06 (0.86)	133 (12.86)	339 (4.11)	101 (0.72)
Variation sources						
Between classes						
RMSE		0.65	6.07	56.13	77.76	40.95
F Value		15.97	17.66	13.44	22.06	2.81
Class effect		***	***	***	***	NS
Within cereal straws						
RMSE		0.07	1.68	9.23	7.93	12.88
Feeds effect		***	***	***	***	***
Treatment effect		***	**	NS	**	NS
Feeds*treatment		***	*	NS	*	NS
Within legume forages						
Root MSE		0.16	0.80	7.28	3.73	2.08
Feeds effect		*	**	**	***	**
Treatment effect		*	*	NS	*	NS
Within concentrates						
RMSE		0.26	0.99	15.65	2.98	1.55
Feeds effect		**	*	***	***	***

UT: urea treatment; DM: Dry matter; OM: Organic matter, N: Nitrogen; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; ADIN: Acid detergent insoluble nitrogen; Hcel: hemicellulose; Cel: Cellulose; ADL: Acid detergent lignin; SD: standard deviation; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

Legume forages varied in ADIN ($P<0.05$) and ADIN:N ($P<0.01$) and treating cowpea husks increased ($P<0.05$) ADIN and decreased ($P<0.05$) ADIN:N. Within legume crop residues, cowpea husks had higher ($P<0.05$) ADIN and ADIN:N than groundnut haulms.

The ADIN and the ratio ADIN:N were respectively affected ($P<0.01$ and $P<0.05$) by concentrate type. Within concentrates, cottonseed cake (3.21 g/kg DM) had the highest ($P<0.01$) ADIN and wheat bran (0.79 g/kg DM) had the lowest; while millet bran (10.03) had the highest ($P<0.05$) ADIN:N and wheat bran (3.03) the lowest.

3.3.2 *In sacco* feed degradability

3.3.2.1 Dry matter and organic matter degradability

Dry and organic matter degradation parameters of tropical forages and concentrates are given in Tables 3.3 and 3.4. These classes of feeds had different ($P<0.001$) wash values, b-fraction, rate of degradation (c) and effective degradability (ED).

Type of cereal straws had different ($P<0.001$) wash values, b-fraction ($P<0.01$), potential degradability ($P<0.01$), rate of degradation ($P<0.001$) and effective degradability (ED) ($P<0.001$). Urea treatment increased ($P<0.001$) washing losses and (ED), increased the rate of degradation except for *Eragrostis tremula* that decreased and *Diheteropogon* that did not change but decreased b-fraction except for *Eragrostis tremula* that increased. The interaction feeds x urea treatment was significant ($P<0.001$) for wash-value, rate of degradation and effective degradability. Sorghum stover leaves and sheath had higher ($P<0.001$) wash value, b-fraction ($P<0.01$), rate of degradation ($P<0.001$), potential ($P<0.01$) and effective degradability ($P<0.001$). These trends were consistent in the degradation of dry matter and organic matter.

Within legume crop residues, groundnut haulms had higher ($P<0.05$) wash, wash+b and ($P<0.01$) effective degradability. Feed types had similar ($P>0.05$) b-fraction and degradation rate. Treating cowpea husks with urea decreased ($P<0.05$) the degradation rate (c) and ED but had no effect on wash, (b) fraction, and Wash + b; and these trends were consistent in the degradation of DM and OM.

Table 3.3 DM and OM degradability *in sacco* of untreated, treated feeds and concentrate (g/kg DM) based on Y= wash + b (1 - e^{-ct})

Feeds	UT	Wash		b		c		Wash+b	
		DM	OM	DM	OM	DM	OM	DM	OM
Cereal straws class									
Diheteropogon hagerupii	no	99	81	572	600	0.018	0.017	671	681
Diheteropogon hagerupii	yes	129	81	529	568	0.018	0.018	658	649
Eragrostis tremula	no	136	128	521	533	0.021	0.021	657	661
Eragrostis tremula	yes	165	140	538	561	0.015	0.016	703	701
Schizachyrium exile	no	91	79	564	572	0.023	0.022	655	651
Schizachyrium exile	yes	157	160	525	524	0.026	0.025	682	684
Millet stover	no	131	119	552	591	0.011	0.010	683	710
Millet stover	yes	182	141	437	479	0.023	0.021	619	620
Sorghum stover (SS)	no	223	191	507	646	0.017	0.010	730	837
Sorghum stover (SS)	yes	251	342	470	404	0.020	0.026	721	746
Fraction of cereal straws									
SS leaves & sheath	no	217	202	548	632	0.026	0.020	765	834
SS stems	no	206	216	421	452	0.022	0.015	627	668
Legume forages class									
Cowpea husk	no	234	212	466	476	0.145	0.145	700	688
Cowpea husk	yes	236	239	483	474	0.081	0.080	719	713
Groundnut haulms	no	305	311	457	445	0.144	0.135	762	756
Concentrates class									
Cottonseed cake	no	276	260	371	383	0.051	0.048	647	643
Millet bran	no	449	445	374	400	0.294	0.302	823	845
Wheat bran	no	457	458	342	339	0.221	0.217	799	797
Variation sources									
Between classes									
RMSE		56.63	74.42	44.69	69.01	0.458	0.157	52.98	67.94
F Value		40.80	24.27	28.46	27.13	38.20	13.28	5.73	0.12
Class effect		***	***	***	***	***	***	**	NS
Within cereal straws									
RMSE		5.209	5.237	27.877	31.475	0.019	0.001	27.366	30.969
Feeds effect		***	***	**	**	***	**	**	***
Treatment effect		***	***	**	***	*	**	NS	NS
Feeds*treatment		***	***	NS	***	**	***	NS	*
Within legume forages									
RMSE		7.417	7.624	9.850	9.673	0.082	0.009	7.526	7.387
Feeds effect		*	**	NS	NS	NS	NS	*	*
Treatment effect		NS	NS	NS	NS	*	*	NS	NS
Within concentrates									
RMSE		8.22	8.27	9.54	10.27	0.184	0.167	11.77	12.63
Feeds effect		**	**	*NS*	*	*	**	**	**

UT = Urea treatment; Wash: washing loss; b: potentially degradable fraction; c: rate constant for the degradation of "*b*"; Wash+b: potential degradability; DM: dry matter; OM: organic matter; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

Table 3.4 Effective degradability of untreated and treated feeds

Feeds	Treat	ED_1		ED_2		ED_3	
		DM	OM	DM	OM	DM	OM
Cereal straws class							
Diheteropogon hagerupii	no	315	302	264	249	224	208
Diheteropogon hagerupii	yes	333	298	285	247	248	207
Eragrostistremula	no	355	350	306	300	267	260
Eragrostis tremula	yes	351	334	306	286	271	250
Schizachyrium exile	no	336	323	282	268	238	225
Schizachyrium exile	yes	400	399	349	348	307	307
Millet stover	no	284	273	243	232	214	202
Millet stover	yes	373	341	331	296	298	261
Sorghum stover (SS)	no	409	363	364	317	330	284
Sorghum stover	yes	440	530	396	490	362	458
Fraction of cereal straws							
SS leaves & sheath	no	474	459	420	400	376	354
SS stems	no	385	371	345	333	313	304
Legumes forages class							
Cowpea husk	no	620	607	590	576	556	541
Cowpea husk	yes	589	584	547	543	505	501
Groundnut haulms	no	684	676	654	645	621	612
Concentrates class							
Cottonseed cake	no	509	496	473	458	439	423
Millet bran	no	788	809	773	793	755	774
Wheat bran	no	748	756	741	739	722	719
Variation sources							
Between classes							
RMSE		71.50	77.01	74.82	80.71	77.14	83.65
F Value		65.28	48.90	67.80	51.95	67.03	51.73
Class effect		***	***	***	***	***	***
Within cereal straws							
RMSE		7.951	7.967	7.941	7.853	7.610	7.466
Feed effect		***	***	***	***	***	***
Treatment effect		***	***	***	***	***	***
Feed*treatment effect		***	***	***	***	***	***
Within legumes forages							
RMSE		5.866	6.447	5.700	6.527	5.534	6.557
Feed effect		**	**	**	**	**	**
Treatment effect		*	NS	*	*	*	*
Within concentrates							
RMSE		20.04	2.24	0.73	1	0.35	0.34
Feed effect		***	***	***	***	***	***

ED_1 (Effective degradability) = wash + b*c/(c+kp_1) where kp_1=0.03; ED_2 = wash + b*c/(c+ kp_2) where kp_2=0.045; ED_3 = wash + b*c/(c+ kp_3) where kp_3=0.065; kp: passage rate; DM: dry matter; OM: organic matter; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

Within concentrates, millet bran and wheat bran had similar (P>0.05) degradation properties. Both brans had higher wash-value (p<0.01), degradation rate (p<0.05), potential (p<0.01) and effective (p<0.001) degradability. The b-fraction was similar (p>0.05) among concentrates. A similar trend was observed for organic matter degradability with the only difference being that the b-fraction was lower (P<0.05) for wheat bran relative to others.

3.3.2.2 Nitrogen degradability

Feed type affected (P<0.01) wash value, b-fraction, (p<0.001) the potential and effective degradability (Table 3.5). Wheat bran and cowpea husk had similar (b) fraction which was higher than for cottonseed cake. Millet bran had the lowest (b) fraction. The degradation rate and ED followed a descending order: wheat bran, millet bran, cowpea husk and cottonseed cake. Wheat bran had the highest potential degradability (wash + b) followed in order by millet bran, cottonseed cake and cowpea husk.

Table 3.5 Degradability of nitrogen of feeds (g/kg) based on Y = wash + b (1 –e^{-ct})

Feeds	Wash	b	c	Wash+b	ED_1	ED_2	ED_3
Cowpea husk	425	453	0.174	878	812	785	755
Cottonseed cake	450	443	0.104	893	794	759	723
Millet bran	569	347	0.321	916	887	874	858
Wheat bran	492	455	0.424	947	917	903	887
Variation source							
Feed effect	**	**	***	***	***	***	***
RMSE	8.91	8.71	0.114	1.09	0.67	0.65	0.67

Wash: washing loss; b: potentially degradable fraction; c: rate constant for the degradation of "*b*"; Wash+b: potential degradability; ED1 (Effective degradability) = wash + b*c/(c+kp1) where kp1=0.03; ED2 = wash + b*c/(c+ kp2) where kp2=0.045; ED3 = wash + b*c/(c+ kp3) where kp3=0.065; kp: rate of passage; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

3.3.3 Gas production characteristics of feeds fermented *in vitro* using rumen fluid

3.3.3.1 Dry matter degradability and gas production of roughages

The three classes of feeds had different (P<0.001) apparent degradability (Apded), true degradability (Trdeg), microbial yield (MY), rate of gas production (C), and maximum gas production (GP) but had no effect ($P>0.05$) on pH (Table 3.6). These classes had also different ($P<0.001$) metabolisable energy (ME).

Within cereal straws, feed types affected Apdeg ($P<0.001$), C ($P<0.001$), Trdeg ($P<0.01$), MY ($P<0.001$) and GP ($P<0.001$) but had no effect ($P>0.05$) on pH (Table 3.6). Urea treatment increased Trdeg ($P<0.01$), MY ($P<0.05$) and (C) ($P<0.001$). Gas production was highest in *Eragrotis* and lowest in millet sover and was affected by cereal type ($P<0.01$). Cereal straws had different ($P<0.001$) metabolisable energy (ME) where fraction of sorghum stover leaves & sheath (5.17 MJ/kg DM) and stems (4.53 MJ/kg DM) had the highest ME and *Diheteropogon* (3.61 MJ/kg DM) and millet stover (3.55 MJ/kg DM) the lowest ($P<0.001$). Treating cereal straws increased ($P<0.01$) the ME content, with no interaction.

There was no effect ($p>0.05$) of legume crop residues on all gas production parameters. However, treating cowpea husk increased pH ($P<0.05$) and ME ($P<0.01$) but decreased ($P<0.05$) the GP. Groundnut haulms (6.73 MJ/kg DM) and cowpea husk (6.62 MJ/kg DM) had similar ME.

Concentrates affected ($P<0.01$) Apdeg, Trdeg, highly affected ($P<0.001$) pH, maximum gas production (GP), gas production rate (C) and metabolisable energy (ME). However, microbial yield (MY) was similar ($P>0.05$) among concentrates. The true degradability (TrDeg) in wheat bran (873 g/kg DM) was higher ($P<0.01$) than in millet bran (855 g/kg DM) and cottonseed cake (730 g/kg DM). The same trend was observed with the maximum gas production (GP).

Table 3.6 Degradability and gas production factors of roughages fermented in vitro digestibility

Feeds	UT	Apdeg	TrDeg	MY	pH	GP	C	ME
Cereal straws class								
Diheteropogon hagerupii	no	377	623	246	6.83	128	0.021	3.61
Diheteropogon hagerupii	yes	418	592	174	6.7	125	0.024	3.65
Eragrostis tremula	no	461	580	119	6.67	137	0.021	4.18
Eragrostis tremula	yes	480	626	146	6.71	128	0.023	4.23
Schyzachiryum exile	no	410	629	218	6.69	122	0.024	4
Schyzachiryum exile	yes	366	682	317	6.77	129	0.027	4.12
Millet stover	no	382	550	169	6.78	82	0.026	3.55
Millet stover	yes	375	676	301	6.91	103	0.025	3.86
Sorghum stover (SS)	no	532	631	99	6.77	121	0.02	4.09
Sorghum stover (SS)	yes	462	684	222	6.71	120	0.022	4.21
Fraction of cereal straws								
SS leaves sheath	no	597	699	102	6.67	128	0.027	5.17
SS stems	no	508	579	71	6.7	140	0.019	4.53
Legume forages class								
Cowpea husks	no	505	703	198	6.68	156	0.045	6.62
Cowpea husks	yes	553	671	118	6.75	144	0.049	6.97
Groundnut haulms	no	537	761	224	6.72	152	0.042	6.73
Concentrates class								
Cottonseed cake	no	349	730	450	6.83	116	0.018	6.29
Millet bran	no	469	855	430	6.66	156	0.063	7.58
Wheat bran	no	438	873	505	6.64	180	0.073	8.49
Variation sources								
Between classes								
RMSE		87.58	79.87	115.14	0.11	21.044	0.014	0.69
F Value		7.66	48.54	25.27	1.02	20.6	32.8	284
Class effect		***	***	***	NS	***	***	***
Within cereal straws								
RMSE		40.28	53.03	72.42	0.1	11.61	0.0007	0.13
Feed effect		***	**	**	NS	**	***	***
Treatment effect		NS	**	*	NS	NS	***	**
Feed*treatment		NS	NS	*	NS	NS	**	NS
Within forage legume								
RMSE		79.17	44.23	117.98	0.02	4.65	0.002	0.12
Feed effect		NS	NS	NS	NS	NS	NS	NS
Treatment effect		NS	NS	NS	*	*	NS	**
Within concentrates								
RMSE		61.87	46.07	152.5	0.05	15.53	0.007	0.23
Feed effect		**	**	NS	***	***	***	***

Apdeg: the apparent degradability (mg g^{-1} DM); Trdeg: true degradability (mg g^{-1} DM); MY: microbial yield (mg g^{-1} DM); GP: maximum gas production (ml g^{-1} DM); C: constant degradation rate of gas production (h^{-1}); ME: metabolizable energy (MJ/kg DM); RMSE: Root mean square error; NS ($P > 0.05$); * ($P < 0.05$); ** ($P<0.01$); *** ($P<0.001$).

3.3.3.2 Gas production and kinetic factors of roughages and concentrates

Gas production and kinetic parameters varied ($P<0.001$) consistently between cereal straws, forage legume and concentrates (Table 3.7).

Within cereal straws, feeds had different (at least at $P<0.01$) gas volume, fast degradable fraction (A), slowly degradable fraction (B), degradation rate for slowly degradation fraction (c2) and lag time (Lt). However, urea treatment had no effect ($P>0.05$) on (B) and c2 but decreased ($P<0.001$) (A) and increased ($p<0.001$) (Lt). Type of cereal straws interacted with urea treatment ($P<0.05$) on A, c2, c1 and B.

Legume crop residues had similar ($P>0.05$) (A), (B), (c1) (c2) and (Lt). However, treating cowpea husk with urea decreased ($P<0.05$) (c1) and increased ($P<0.001$) (Lt).

Concentrates affected ($P<0.001$) gas volume for fast soluble fraction (A) and slowly degradable fraction (B), degradation rates for fast degradable fraction (c1) and slowly degradable fraction (c2) and lag time (Lt). Wheat bran had also the highest ($P<0.001$) (A), and the lowest ($P<0.001$) (B) and (Lt). Inversely, cottonseed cake had the highest ($P<0.001$) (B) and lowest ($P<0.001$) (A).

Table 3.7 Gas production and kinetic factors of roughages fermented in vitro using rumen fluid

Feeds	Treat	A	c1	B	c2	Lt
Cereal straws class						
Diheteropogon hagerupii	no	19.4	0.085	108.9	0.022	11.7
Diheteropogon hagerupii	yes	22.6	0.114	101.7	0.024	14.7
Eragrostis tremula	no	30.2	0.083	106.5	0.021	6.1
Eragrostis tremula	yes	25.5	0.083	102.6	0.023	8.2
Schyzachiryum exile	no	27.8	0.069	94.7	0.023	8.1
Schyzachiryum exile	yes	29.3	0.067	100.1	0.026	11.2
Millet stover	no	63.5	0.033	18.4	0.031	7.3
Millet stover	yes	29.5	0.078	73.2	0.024	8.4
Sorghum stover (SS)	no	26.1	0.085	94.7	0.020	5.1
Sorghum stover (SS)	yes	22.4	0.068	97.2	0.022	6.6
Fraction of cereal straws						
SS leaves sheath	no	54.4	0.063	73.9	0.027	4.8
SS stems	no	34.32	0.086	105.3	0.019	2.7
Legume crop residues class						
Cowpea husks	no	83.1	0.096	73.2	0.034	2.7
Cowpea husks	yes	83.2	0.087	61.2	0.035	5.0
Groundnut haulms	no	75.4	0.102	76.4	0.034	2.6
Concentrates class						
Cottonseed cake	no	17.5	0.30	98.9	0.020	3.15
Millet bran	no	76.1	0.15	80.4	0.050	4.40
Wheat bran	no	123.9	0.13	56.4	0.043	2.34
Variation sources						
Between classes						
Root MSE		27.11	0.076	19.97	0.008	2.22
F Value		23.92	15.32	7.03	30.59	49.21
Class effect		***	***	***	***	***
Within cereal straws						
RMSE		3.54	0.014	13.69	0.001	1.06
Feed effect		***	**	***	***	***
Treatment effect		***	*	NS	NS	***
Feed*treatment		***	**	*	***	NS
Within legume forages						
RMSE		6.32	0.002	8.06	0.001	0.226
Feed effect		NS	NS	NS	NS	NS
Treatment effect		NS	*	NS	NS	***
Within concentrates						
RMSE		10.3	0.049	20.65	0.002	0.501
Feed effect		***	***	***	***	***

A and B - gas volume (ml) from fast (soluble sugars and starch) and slowly (cellulose and hemicellulose) degradable fractions, respectively; c1 and c2 - degradation rates (h^{-1}) for fast and slowly degradable fractions, respectively; Lt - lag time (h) (for bacteria colonization); RMSE: Root mean square error; NS ($P > 0.05$); * ($P < 0.05$); ** ($P<0.01$); *** ($P<0.001$).

3.3.3.3 Derived factors of gas production of feeds

The three classes of feeds strongly ($P<0.001$) affected halflife to the maximum gas volume ($T_{1/2}$), maximum rate of gas production at the point of inflection of the gas curve (μ) and degradation efficiency factor (DEF). They slightly ($P<0.05$) affected the partitioning factor (PF) (Table 3.7).

Within cereal straws, feed type affected ($P<0.001$) halflife to the maximum gas volume ($T_{1/2}$), maximum rate of gas production at the point of inflection of the gas curve (μ), the partitioning factor (PF) and degradation efficiency factor (DEF). Among cereal straws, *Diheteropogon* (34.9 h and 0.29) had the highest ($P<0.001$) $T_{1/2}$ and lowest DEF respectively whereas sorghum stover leaves & sheath (22.4 h and 4.14 ml/h) had the lowest $T_{1/2}$ and highest ($P<0.001$) (μ) respectively. Millet stover had the lowest μ (2.22 ml/h) and highest PF (6.58), whereas sorghum stover leaves & sheath (0.46) had the highest DEF and sorghum stover stems (0.46) had the lowest PF. However, urea treatment increased ($p<0.05$) (μ) but did not affect any other factor. All these factors were not affected ($P>0.05$) by legume crop residues. Treatment of cowpea husk with urea increased ($T_{1/2}$) but did not affect any other factor.

Concentrates highly ($P<0.001$) affected halflife to the maximum gas volume ($T_{1/2}$), maximum rate of gas production at the point of inflection of the gas curve (μ) and degradation efficiency factor (DEF). They exerted significant ($P<0.01$) effects on partitioning factor (PF). Wheat bran had the highest ($P<0.001$) (μ) and DEF, and the lowest ($P<0.001$) ($T_{1/2}$). Inversely, cottonseed cake had the highest ($P<0.001$) $T_{1/2}$ and PF, and the lowest ($P<0.001$) μ.

Table 3.8 Gas production and kinetic factors of roughages

Feeds	Treat	$T_{1/2}$	μ	PF	DEF
Cereal straws class					
Diheteropogon hagerupii	no	34.9	2.77	4.97	0.29
Diheteropogon hagerupii	yes	35.6	3.03	4.76	0.28
Eragrostis tremula	no	29.3	2.95	4.46	0.30
Eragrostis tremula	yes	30.0	2.95	4.88	0.33
Schizachyrium exile	no	28.8	2.97	4.94	0.33
Schizachyrium exile	yes	29.8	3.49	5.30	0.35
Millet stover	no	25.99	2.22	5.75	0.42
Millet stover	yes	28.23	2.59	6.58	0.47
Sorghum stover (SS)	no	29.6	2.47	5.26	0.36
Sorghum stover (SS)	yes	28.7	2.70	5.72	0.40
Fraction of cereal straws					
SS leaves sheath	no	22.4	4.14	5.44	0.46
SS stems	no	31.0	2.51	4.19	0.29
Legume crop residues class					
Cowpea husks	no	13.8	7.09	4.75	0.65
Cowpea husks	yes	15.1	7.15	4.64	0.62
Groundnut haulms	no	14.5	6.43	5.01	0.69
Concentrates class					
Cottonseed cake	No	31.4	2.05	6.3	0.40
Millet bran	No	12.4	9.83	5.5	0.88
Wheat bran	no	9.5	13.12	4.8	1.02
Variation sources					
Between classes					
Root MSE		5.92	2.74	0.65	0.17
F Value		48.46	33.35	3.53	49.75
Class effect		***	***	*	***
Within cereal straws					
RMSE		1.30	0.34	0.59	0.04
Feed effect		***	***	***	***
Treatment effect		NS	*	NS	NS
Feed*treatment		NS	NS	NS	NS
Within legume crop residues					
RMSE		0.39	0.38	0.42	0.06
Feed effect		NS	NS	NS	NS
Treatment effect		*	NS	NS	NS
Within concentrates					
RMSE		2.73	1.13	1.17	0.21
Feed effect		***	***	**	***

$T_{1/2}$: half time to the maximum gas volume (h); μ: maximum rate of gas production at the point of inflection of the gas curve (ml/h), PF: partitioning factor; DEF: degradation efficiency factor; RMSE: Root mean square error; NS ($P > 0.05$); * ($P < 0.05$); ** ($P<0.01$); *** ($P<0.001$).

3.3.4 Relationship between derived factors of gas production and metabolisable energy

The halflife to the maximum gas volume ($T_{1/2}$), maximum rate of gas production at the point of inflection of the gas curve (μ) and DEF were (P<0.001) correlated to both ME derived from gas production after 24h (MEGP) (Menke *et al.*, 1979) and from effective degradability of organic matter (MEED) (Nsahlai and Apaloo, 2007) for all feeds. However, the relationship was weak and not significant (P>0.05) between PF and MEGP and MEED (Table 3.9). The $T_{1/2}$ correlated negatively to ME. The MEGP and MEED had significant (P<0.001) and strong relationship (r=0.94).

Table 3.9 Correlation coefficients between derived factors of gas production and metabolisable energy

	n	$T_{1/2}$	μ	PF	DEF	MEGP
MEGP (r)	18	-0.88^{***}	0.89^{***}	-0.10^{NS}	0.90^{***}	-
MEED (r)	18	-0.88^{***}	0.87^{***}	-0.02^{NS}	0.91^{***}	0.94^{***}

$T_{1/2}$: halflife to the maximum gas volume (h); μ: maximum rate of gas production at the point of inflection of the gas curve (ml/h), PF: partitioning factor; DEF: degradation efficiency factor; MEGP: metabolizable energy derived from gas production; MEED: metabolizable energy derived from effective degradability of organic matter; r: coefficient of correlation; n: number of observations; ***: P<0.001; NS: P>0.05.

3.4 Discussion

Tropical cereal straws, legume forages and concentrates are generally high in DM content during the dry season due to environmental factors namely high temperature and low humidity. The differences in chemical composition between these classes of feeds are in consistent with other studies (Jayasuriya, 2002a; López *et al.*, 2005; Fulkerson *et al.*, 2007). The ranges of 949 to 973 g/kg DM and 932 to 944 g/kg DM for cereal straws and legume forages respectively, are similar to those reported by Aregheore (2000), Tessema and Baars (2006) and Abdou *et al.* (2011). The similarity of DM among each class of feeds may be due to the harvest time occurring during the dry season. The drastic decrease of DM of urea treated cereal straws after treatment could be explained by the water used for urea treatment. Moreover, samples were taken to evaluate the DM immediately at the end of the treatment. These findings agree with Chermiti *et al.* (1994) who recorded increase change of physical characteristics after treatment, shown by the duration and number on jaw movements to eating untreated and treated straws. Similarly, Wanapat *et al.* (2009) and Gunun *et al.* (2013) reported a decrease of DM after urea treatment of rice straw. The difference in OM content within cereal straws (809 to 975 g/kg DM) and legume forages (889 to 935 g/kg DM) were in conformity with those reported by several studies (Abreu and Bruno-Soares, 1998; Elseed *et al.*, 2007; Abate and Melaku, 2009; Abdou *et al.*, 2011). The variability in OM content among feeds may be due to differences in chemical, physical and thermodynamic properties.

Tropical forages, mostly cereal straws contain high fibre and low protein contents and their degradability is low (Ahmed and El Hag, 2003). In the current study, NDF (g/kg DM) and ADF (g/kg DM) of cereal straws ranged from 725 to 880 and 438 to 565, respectively. In legume crop residues, NDF and ADF ranged from 495 to 617 and 386 to 428, respectively. These results are similar to findings of some studies (Chenost and Kayouli, 1997; Jayasuriya, 2002a; Abdou *et al.*, 2011; Babu *et al.*, 2014). Chenost and Kayouli (1997) reported that the cell wall of tropical forages is between 60 and 80 % of the plant. These authors found that legume crop residues had less fibre content than cereal straws. Jayasuriya (2002a) reported that tropical cereal straws (NDF>800 and ADF>300) and legumes straws (NDF>600 and ADF<300) are characterised by high fibre contents. However, Madibela *et al.* (2002a) found less fibre in chemical composition of sweet sorghum stover (NDF=589 and ADF=285) contrary to cereal straws used in the current study. Furthermore, Fulkerson *et al.* (2007) reported less amount of fibre in grasses (NDF<672 and ADF<327) and legumes (NDF<489 and ADF<404) grown in warm climate of Australia.

To increase feeding value, cereal straws were treated with urea. Treating with urea in the presence of water and warm temperature in hermetic conditions generates gaseous ammonia and carbonic gas, which gradually spreads and treats the forages and ensure good conservation and quality (Makkar and Singh, 1987; Sahnoune *et al.*, 1991; Mgheni *et al.*, 1993; Chenost and Kayouli, 1997; Owen *et al.*, 2012). This leads to break down of chemical bonds formed by lignin, hemicellulose and cellulose, which are respectively indigestible, partially digestible and completely digestible. Our results showed no decrease of cell wall characteristic after urea treatment. However, NDF decreased for all cereal straws except for Eragrostis and ADF decreased only in sorghum stover, which is contrary to Wanapat *et al.* (2009) who reported on rice straw a decrease of NDF and ADF using 5.5% of urea. The difference could be due to lower concentration of urea (3%) used in the current study.

For legume crop residues, NDF (g/kg DM) and ADF (g/kg DM) in cowpea husk were higher than in groundnut haulms and this may be attributed to the difference in their physical characteristic. Indeed, cowpea husk is obtained from cowpea clove residues. However, NDF (542) and ADF (411) values in cowpea husk reported by Oluokun (2005) were lower than those reported in the present study. Abdou *et al.* (2011) observed higher values of NDF (566) and ADF (422) in groundnut haulms than those reported in the current study.

Nitrogen content of cereal straws ranged from 3.12 to 6.2 g/kg DM which is far lower than the minimum required level of 12.8 g/kg DM to stimulate optimal rumen microbial activity (Annison and Bryden, 1998). These results agree with Singh *et al.* (2011) and Abdou *et al.* (2011). The increase of nitrogen by urea treatment could be attributed to the release of ammonia generated by the reaction urea, water, warm temperature and urease. These results were supported by others (Elseed *et al.*, 2003b; Abate and Melaku, 2009; García-Martínez *et al.*, 2009; Gunun *et al.*, 2013) who found increase of crude protein after treating rice straw. For legume crop residues, nitrogen (g/kg DM) content ranged from 13.55 to 17.50 for cowpea husk and groundnut haulms, respectively. After treating cowpea husk, the nitrogen content increased to 22.48 g/kg DM.

The DM, OM, N and ADF content of millet bran were lower than in wheat bran and similar results were reported by Abdou *et al.* (2011). Solomon *et al.* (2008) reported close values of DM, OM, N and ADF in cottonseed cake than those reported in the present study. For concentrates, nitrogen (g/kg DM) content ranged from 23.31, 26.07 and 35.45 for millet bran, wheat bran and cottonseed cake, respectively. These results are also consistent with those reported by Abdou *et al.* (2011). Similar results were observed by Khalaf and Meleigy (2008) on nitrogen (32.74) content of cottonseed cake. The relatively low fibre contents and high protein for groundnut haulms, cowpea husks as legume crop residues and concentrates compared to cereal straws agree with Jayasuriya (2002a), Singh *et al.* (2011) and Abdou *et al.* (2011). Thus, these legume crop residues and concentrates may be considered as good supplements for tropical cereal straws to increase their nutritive values (Abdou *et al.*, 2011).

Estimating ADIN content of feeds improves the understanding on the available amount of protein for ruminants. Tropical forages are known to have high fibre content due to environmental factors like high temperature. Excessive heat, may cause nitrogen to be irreversibly bound to lignin and becomes highly inaccessible (Chenost and Kayouli, 1997). This phenomenon of heat damage can occur during storage or processing of feeds. The feed damage was measured through estimating nitrogen in ADF residue of the feed and the fraction was determined as acid detergent insoluble nitrogen (Mason, 1997). As determination of cell contents, acid detergent insoluble nitrogen (ADIN) is a good predictor to indicate the degradability factor of tropical forages. Additionally, Silva Colomer *et al.* (1989) stipulated that ADIN is a more efficient predictor of organic matter degradability (OMD) than ADF and nitrogen content in tropical roughages. According to Mason (1997) even in absence of heat, 3-8% of total nitrogen will be linked to ADF residue. For excessively heated feeds, nitrogen is usually inaccessible for animals (Van Soest and Sniffen, 1984; Van Soest *et al.*, 1984; Poos-Floyd *et al.*, 1985). This phenomenon may explain our results, where low nitrogen content and high acid detergent insoluble nitrogen (ADIN) were found in cereal straws. The ADIN (g/kg DM) content considerably differed among cereal straws and ranged between 0.77 and 1.41 and increased to 2.43 after being treated with urea. The ADIN as % of total nitrogen content ranged between 12.70 - 32.70% which were higher than values reported by Rothman *et al.* (2008) for herbaceous leaves of the national park of Uganda. However, Fulkerson *et al.* (2007) reported during four seasons, higher amount of ADIN in grasses (1.1-4.2 g/kg DM) grown in warm temperate climate of Australia. The urea treatment increased ADIN content of feed but decreased the ADIN:N ratio and the more the ratio decreased, the less was the ADIN in feed after being treated.

The ADIN (g/kg DM) content in legume crop residues ranged between 2.19 and 2.71. These values overlapped with those reported by Fulkerson *et al.* (2007) in legumes (1.0-4.2). The ADIN:N ratio of legume crop residues ranged from 12.51 to 20.01% which were similar to the findings of Rothman *et al.* (2008) on tree leaves (16.1 ± 6.7%). As for type of cereal straws, the ADIN:N ratio of cowpea husk decreased after being treated by urea.

Concentrates affected ADIN and the ADIN:N ratio. The ADIN as % of total nitrogen in concentrates were 3.03, 9.06 and 10.03% in wheat bran, cottonseed cake and millet bran, respectively. These levels of ADIN in concentrates were acceptable according to Aufrère and Guérin (1996) who reported that ADIN should represent 7 to 9% of total nitrogen, above which feed degradability would be negatively affected. However, Nakamura *et al.* (1994) reported that ADIN of non-forage proteins sources ranged from 1.2 to 36.6%; and from 11.5 to 59.5% when the same feeds were heat damaged. In their study, Nakamura *et al.* (1994) reported 2.6% ADIN:N in cottonseed cake and after heating, this level increased to 11.5% which was close to our results. The relatively high level of ADIN in cottonseed cake may be explained by the processing by milling machine which evolved lots of heats. Furthermore, the technique of ANKOM-A200 Fiber Analyzer for analyzing NDF and ADF generates successive heats which could increase the ADIN.

High variation of *in sacco* degradation parameters between feed and within feed classes may be due to difference in physical characteristics and chemical composition. Similar results were obtained with cereal straws (Huntington and Givens, 1997; Vitti *et al.*, 1999). The fact that urea treatment increased washing losses, rate of degradation (c) and effective degradability (ED) may be due to the increase of nitrogen content, delignification and availability of OM which can stimulate bacteria synthesis in the rumen and cell wall digestion (Chermiti *et al.*, 1994; Chenost and Kayouli, 1997; Smith, 2002; García-Martínez *et al.*, 2009; Abate and Melaku, 2009). The implication of increasing the soluble fraction is that these feeds were easily attached by ruminal microorganisms resulting high microbial yields, and perhaps to higher degradation. By increasing the degradation rate (c), which is one of factors expressing the effective degradability, rumen fill and feed intake (Khazaal *et al.*, 1995), urea treatment increased the ED of cereal straws. Three rates of passage kp_1, kp_2 and kp_3 were assumed to be 0.03, 0.045 and 0.065/h for maintenance, growth and milk production, respectively, to calculate the ED. ED values for cereal straws reported in the current study were lower than those reported by Kamalak *et al.* (2005). The increase in the ED after treatment could be explained by the increase of microbial activity due to increased nutrient availability and favourable rumen environment. Thus, urea treatment could increase microbial protein synthesis in the rumen and therefore increase cell wall degradability and consequently lead to the improvement of nutritive value of feed. This agrees with findings of several authors who stipulated that urea treatment increased digestibility of forages by 8 to 12 points (Rai *et al.*, 1989; Mgheni *et al.*, 1993; Chenost and Kayouli, 1997; Owen *et al.*, 2012).

As response of urea treatment among cereal straws, with respect to ED, millet stover, *Schizachyrium* and sorghum stover responded positively with increases of 89, 64, 31 units respectively compared to other roughages. *Diheteropogon* and *Eragrostis* responded slightly to urea treatment. Among cereal straws, the highest losses of soluble dry and organic matter and small particles (wash) were shown by sorghum stover and its fractions. The wash values in sorghum stover fractions confirmed earlier report of Elseed *et al.* (2007). However, Mgheni *et al.* (1993) reported lower wash value in maize stover and its fractions than for sorghum stovers.

Among legume crop residues, the higher losses of soluble dry and organic matter and effective degradability (ED) in groundnut haulms than in cowpea husk in the present study may be explained by the higher NDF, lower N content in the cowpea husk than in groundnut haulms. This implies that groundnut haulms is more degradable than cowpea husk. These wash and ED values for groundnut haulms were higher than those reported by Larbi *et al.* (1999) on both leaves and stem of groundnut haulms and Kamalak *et al.* (2005) on lucerne hay. Urea treatment had an effect on dry matter and organic matter degradability of cowpea husk. The significant decreases of c and ED after urea treatment suggest that urea treatment could have inhibited microbial activity and increase the retention time in the rumen and therefore decreased cell wall degradability. Furthermore, urea treatment could have led to excessive bacteriostatic agents which would retard the rate of degradation. According to Crampton quoted by Ørskov (1995), "Rate of digestion may be retarded by any one of numerous circumstances which interfere with the numbers or activity of rumen microflora". These include excessive lignification from advanced maturity, practical starvation of flora from nitrogen or specific mineral deficiency or the presence of excessive bacteriostatic agents.

Within concentrates, wheat bran and millet bran had comparable and higher values of wash, degradation rate (c), potential (wash+b) and effective degradability (ED) than cottonseed cake. This could be explained by chemical properties (Chumpawadee *et al.*, 2011). The NDF and ADF in cottonseed cake were higher than in millet bran and wheat bran. Furthermore, cottonseed cake contains gossypol which may decrease its nutritive value (Getachew *et al.*, 2004; Zhang *et al.*, 2006; Khalaf and Meleigy, 2008). Thus, these feeds were easily attacked by ruminal microorganisms and became more degradable. The (c) value of cottonseed cake is similar to that reported by Promkot *et al.* (2007).

The fastest and slowest degradation rate of nitrogen observed in wheat bran and cottonseed, respectively, may be explained by the accessibility of nitrogen to rumen microbial flora. The DM, OM and nitrogen ED in cottonseed cake were higher than those reported by Chumpawadee *et al.* (2011) with similar outflow rate of 0.05/h. These authors reported lower ED in their protein feed sources (e.g. soybean meal) than observed here. The high ED of nitrogen in brans indicated that they provide low amounts of by-pass protein. The relatively low rumen degradability of cottonseed cake may be indicative of being a source of by-pass protein. The relatively low nitrogen degradability of cottonseed cake could be due to relatively high content of ADIN. Furthermore, the low nitrogen degradability of cottonseed cake could also be due to the presence of phenolic compounds that can negatively affect the microbial growth in the rumen (Getachew *et al.*, 2004).

Concerning roughages, the rate of degradation (c) should be combined with wash and (b) fraction for good accuracy of ED. Differences between our results on *in sacco* degradation parameters compared to other studies may be due to different factors such as bag pore size (Vanzant *et al.*, 1998), environment and species of donor animals, sample size, incubation time and washing method (Olivera, 1998).

Type of cereal straws, legume crop residues and concentrate had high effect on *in vitro* digestibility due to differences in physical and chemical composition. Similar findings were observed with cereal straws (Maghsoud *et al.*, 2008). Significant effects of urea treatment on these feeds and their interaction were also observed. Studies on *in vitro* gas production considered wrongly that extent of gas production (GP) was equivalent of substrate degradation (Makkar, 2004). According to Blümmel *et al.* (1997b), GP and microbial yield are inversely related. Makkar (2004) stipulated that selecting a feed according to its high GP is like selecting against maximal microbial yield. Estimating nutritive value of feed may necessitate taking into account some parameters like GP, degradability (Deg), microbial yield (MY) and partitioning factor (PF) (Blümmel *et al.*, 1997b). These authors found that high PF is synonymous of high MY. Makkar (2004) considered that maximizing microbial activity is important in ruminant nutrition, and since that happens at half maximum gas volume, then proposed to take into account in feed evaluation the time that feed attains half gas volume ($T_{1/2}$). According to various and confused results on predicting nutritive value of feeds, Dijkstra *et al.* (2005) proposed integration of kinetics parameters for prediction. Furthermore, Ouda and Nsahlai (2009) recommended to include degradability efficiency factor (DEF) and/or $T_{1/2}$ among evaluation parameters of *in vitro* gas production to improve accuracy in feed evaluation. In the current study, all degradation and kinetics parameters were used to evaluate feed characteristics.

Type of cereal straws affected the *in vitro* apparent degradability (Apdeg), true degradability (Trdeg), microbial yield (MY), maximum gas production (GP) and rate of gas production (C). Urea treatment increased Trdeg, MY and C which are good indicators of nutritive values of feeds. This may be explained by delignification, and the release of ammonia which increased rumen microbial activity, cell wall digestion (Mgheni *et al.*, 1993; Chermiti *et al.*, 1994; Chenost and Kayouli, 1997; Owen *et al.*, 2012) and available energy. Thus, urea treatment improves nutritive value of tropical cereal straws. Effects of cereal straws on gas production parameters may be attributed to variability within feeds due to differences in chemical composition (NDF, ADF and nitrogen) (Maghsoud *et al.*, 2008). The present Trdeg values of cereal straws overlapped values of 608 - 730 mg/g DM reported by Ouda and Nsahlai (2009) on grass hay and maize stover. These same authors reported MY values of 259 - 288 mg/g DM for grass hay and maize stover which were higher than our results on cereal straws. The values of GP reported by Ouda and Nsahlai (2009) on these same feeds were higher than for cereal straws. The gas production was highest in *Eragrostis* (129 ml/g DM) and lowest in millet stover (82 ml/g DM) and conversely millet stover had higher MY (169 mg/g DM) than *Eragrostis* (119 mg/g DM). This showed that feeds with high MY may have low GP. These results agree with of Blümmel *et al.* (1997b) who stipulated that GP and microbial yield are inversely related. The metabolisable energy (ME) differed among cereal straws and ME in the fraction of sorghum stover leaves and sheath was highest and *Diheteropogon* and millet stover had the lowest. This may be attributed to the chemical composition of feeds (NDF, ADF, N), where the fraction of sorghum stover leaves and sheath had moderate amount of NDF and ADF and high nitrogen content. Urea treatment increased ME content by decreasing cell wall content through delignification and increasing nitrogen content of cereal straws.

Legume crop residues had similar gas production parameters. However, treating cowpea husk increased pH and ME but decreased GP in view of delignification, structural fragility, and increased nitrogen which would raise ruminal pH and increase digestibility. These findings were supported by Oduguwa *et al.* (2008) who reported even an act of moistening cowpea husk with water would improve fermentation, increase activity of micro-organisms and ether extract. Supplemental non protein nitrogen is not well utilised in ruminant rations containing relatively large amount of protein or rations which are low in digestible energy. However, overflow of ammonia causes protein wastage when fermentable energy is insufficient to support microbial growth required to utilise the excess degraded protein (Broderick *et al.*, 1992). Moreover, availability of fermentable energy constitutes a constraint of microbial growth in the rumen (Satter and Slyter, 1974; Getachew *et al.*, 1998b). Thus, it could be that the fermentable energy was a limiting factor for microbial growth after treating cowpea husk with urea. MY under these circumstances would be met with a reduction of GP. Additionally, the relation protein/energy (P/E) is an important indicator of feed digestibility, and the microbial fermentation in the rumen, is highly dependent on the P/E relationship (Preston and Leng, 1980; Preston, 1982; Preston and Leng, 1987). Groundnut haulms had lower carbohydrate and higher nitrogen content than cowpea husk and vice versa. The ME (MJ/kg DM) values in cowpea husk and groundnut haulms in the present study were lower than those reported in cowpea husk (8.22) and groundnut haulms (7.93) by Onwuka *et al.* (1997) and Etela and Dung (2011), respectively. The difference between these results may be attributed to environmental factors.

Concentrates affected Apdeg, Trdeg, pH, GP and ME due to differences in chemical composition (NDF, ADF, nitrogen) (Sallam *et al.*, 2007; Maghsoud *et al.*, 2008) and neutral detergent solubles (NDS). Ouda and Nsahlai (2009) reported values on Trdeg (787 mg/g DM) and MY (264 mg/g DM) in sunflower cake which were respectively higher and lower than in cottonseed cake. Both parameters values were, however lower than for millet bran and wheat bran reported in the present study. For concentrates, except cottonseed cake, high level of nitrogen is synonymous of high level of Trdeg, GP and C. Thus, wheat bran with its high nitrogen content had higher Trdeg and GP than millet bran. These results agree with Gasmi-Boubaker *et al.* (2005) and Maghsoud *et al.* (2008) who stipulated that nitrogen content positively influenced degradation parameters. The low Trdeg and GP of cottonseed cake compared to brans despite its high nitrogen content may be due to the presence of gossypol, a phenolic organic compound, which could inhibit microbial activity in the rumen (Getachew *et al.*, 2004; Nsahlai *et al.*, 2011). These findings were supported by Zhang *et al.* (2006), Khalaf and Meleigy (2008) who reported that free gossypol decreased crude protein content and *in vitro* digestibility. Furthermore, Basha *et al.* (2014b) reported that levels of condensed tannins limited *in vitro* gas production. That ME differed significantly within concentrates may be due to variable NDF which enriched in cellulose for CSC, based the fact that cellulose is more crystalline and less digestible than hemicellulose. The variation of gas production from soluble fraction (A) and from fibre fraction (B), the degradation rates of quick degradable fraction (c1) and slow degradable fraction (c2) and lag time (Lt) among concentrates can be explained by their chemical composition (Sallam *et al.*, 2007; Maghsoud *et al.*, 2008).

The gas production from soluble fraction and from fibre fraction, the degradation rate for slowly degradation fraction and lag time differed among cereal straws may be explained by differences in the chemical composition properties (López *et al.*, 2005; Sallam *et al.*, 2007; Maghsoud *et al.*, 2008). The lag time was influenced by cell wall content (NDF, ADF) (Basha *et al.*, 2014b). Feed with high cell wall content had the highest lag time among cereal straws. Others contend that the decreased of soluble fraction by urea treatment may be due to the unbalance protein/energy (P/E) which could limit microbial activity to attack to the soluble fraction (Preston and Leng, 1987; Broderick *et al.*, 1992; Getachew *et al.*, 1998a). Additionally, the major limiting factor for ruminant production in the tropics is insufficient extraction of energy by microbes from cell wall-rich crop residues (Getachew *et al.*, 1998b) which may limit the microbial activity and this could have repercussions on lag time and may be the reason of slow bacteria colonization after urea treatment. It is our contention that in the process of delignification some microbial inhibitors are produced with either bactericidal or bacteriostatic consequences thus decreasing the A-fraction. This argument lends credence to the observation that urea treatment of cowpea husk decreased ‘c2’ and increased the ‘Lt’ and half time to the maximum gas volume.

The similarity of A, B, c1, c2 and Lt within legume crop residues could be due to their similarity in ME content (López *et al.*, 2005; Sallam *et al.*, 2007; Maghsoud *et al.*, 2008). The decrease of c2 and increase of Lt by urea treatment may be also explained by the unbalance P/E and/or unavailability of ME after excess releasing of ammonia to support microbial growth to attack to the soluble fraction (Preston and Leng, 1987; Getachew *et al.*, 1998a).

The large variation of kinetic factors, half time to the maximum gas volume ($T_{1/2}$), maximum rate of gas production at the point of inflection of the gas curve (μ), the partitioning factor (PF) and degradation efficiency factor (DEF) within cereal straws may be due to inherent differences in nutritive value (López *et al.*, 2005; Sallam *et al.*, 2007; Maghsoud *et al.*, 2008). Values of $T_{1/2}$ (18.8-26 h) and DEF (0.37-0.53) in grass hay and maize stover reported by Ouda and Nsahlai (2009) were lower and overlapped our findings on cereal straws. According to these results, one can conclude that our cereal straws are low in nutritive values than grass hay and maize stover used by Ouda and Nsahlai (2009). The chemical composition (NDF and nitrogen) influenced $T_{1/2}$ and DEF (Basha *et al.*, 2014a; Basha *et al.*, 2014b). Thus, cereal straws with high NDF and low nitrogen content had the lowest DEF and the highest $T_{1/2}$, and explains why

Diheteropogon had the lowest DEF and the highest $T_{1/2}$ and sorghum stover leaves and sheath had the highest DEF and lowest $T_{1/2}$. As ecpected, urea treatment may be increased 'μ', and rate of degradation perhaps because it increased rumen microbial activity and cell wall digestion (Mgheni *et al.*, 1993; Chermiti *et al.*, 1994; Chenost and Kayouli, 1997; Owen *et al.*, 2012).

The kinetic factors were significantly affected by concentrates due to the significant differences in chemical composition among concentrates (López *et al.*, 2005; Sallam *et al.*, 2007; Maghsoud *et al.*, 2008). Except cottonseed cake, concentrates with low NDF and high nitrogen content had the highest μ and DEF and the lowest $T_{1/2}$. Thus, wheat bran had the highest μ and DEF and the lowest $T_{1/2}$. The highest $T_{1/2}$ and lowest μ and DEF observed in cottonseed cake may be due to its content of gossypol which decreased its degradability (Getachew *et al.*, 2004; Sallam *et al.*, 2009; Nsahlai *et al.*, 2011). However, the partitioning factor PF did not following this trend, and ranged between 4.8 and 6.3. These findings agree with Getachew *et al.* (1998a) who stipulated that PF calculated from many species deviated from conventional values (2.75-4.41). Moreover, Blümmel *et al.* (2005) and Ouda and Nsahlai (2009) reported that PF doubtful and inconsistent, and concluded that PF cannot be a good factor to evaluate the nutritive value of feeds.

In the current study feeds with high Trdeg, C, μ, DEF and low $T_{1/2}$ and Lt may predict good nutritive value and good microbial efficiency in agreement with the works of Ouda and Nsahlai (2007) and Ouda and Nsahlai (2009). Surprisingly, despite the increase in nitrogen by treating cowpea husk, it had a negative effect on degradation rates c, ED, GP, c1, $T_{1/2}$ and Lt. This suggest that either energy or nitrogen was not used efficiently in treated cowpea husk due to unavailability of the other leading to poor microbial yield and effective degradation of OM. Since, cowpea husk by itself constitutes a good source of protein and energy, it is concluded that there is no interest to treat cowpea husk.

Interestingly, sorghum stover, millet stover and *Schyzachyrium* responded more to urea treatment. Nevertheless, sorghum stover may contain polyphenolic compounds which could negatively affect intake and digestion by animal (Cherney *et al.*, 1992). *Schizachyrium* is herbaceous forage available in some areas while millet stover is commonly because it is most abundant cereal residues. Concerning legume forages, groundnut haulms is a residue of groundnut crop and is available with farmers while cowpea husk is less available and expensive. Therefore, millet stover and groundnut haulms were feeds chosen among roughages to formulate diets for the subsequent experiments. Concerning concentrates, all are good sources of protein and energy. By comparing millet bran to wheat bran, wheat bran had higher ED of nitrogen, Trdeg, C, μ, DEF, ME, and lower $T_{1/2}$ and Lt. Moreover, wheat bran is more available and less expensive than millet bran. Thus, wheat bran and cottonseed cake were selected due to its high levels of effective degradable protein and by-pass protein.

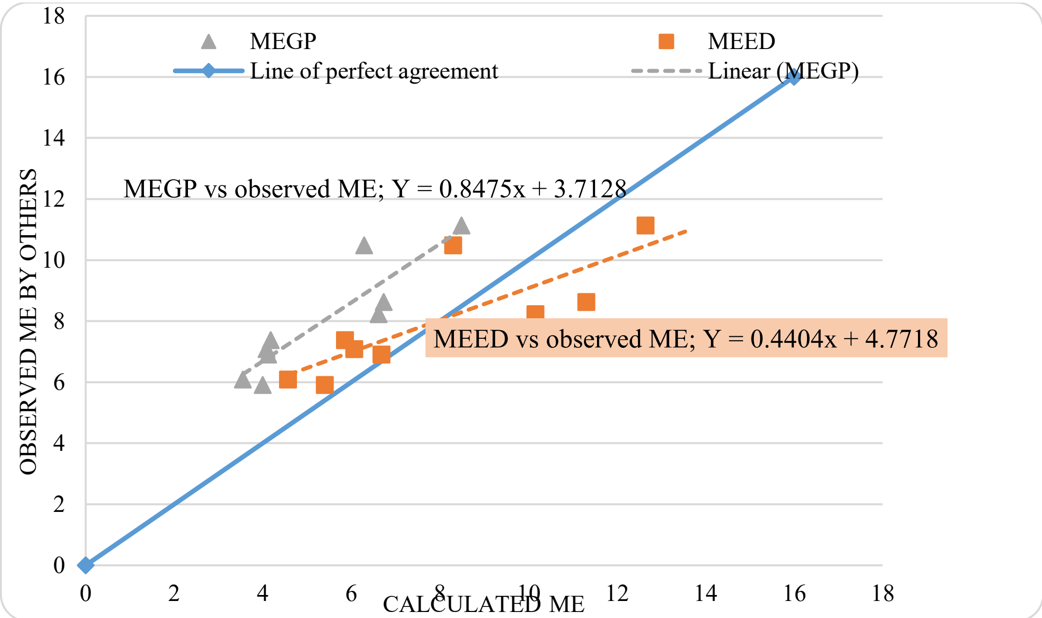


Figure 3.1 Relationship between metabolizable energy content of tropical feeds determined using various methods

The high correlation of $T_{1/2}$, μ and DEF with ME is in agreement with findings of the present study where feeds with high DEF and μ but low $T_{1/2}$ had good nutritive value (López *et al.*, 2005; Sallam *et al.*, 2007; Maghsoud *et al.*, 2008). The non or weak correlation of PF and ME was supported by the findings of Blümmel *et al.* (2005) and Ouda and Nsahlai (2009) who pointed out inconsistency of PF to predict feed value. The positive and strong relationship between MEGP and MEED may indicate that both of them can predict the energy value of feed. However, as indicated in Figure 1, MEGP (Menke *et al.*, 1979) in the present study seemed to be underestimating ME compared to that of various findings (Djibrillou *et al.*, 1998; Mlay *et al.*, 2006; Hamid *et al.*, 2007; Duncan *et al.*, 2010; Nigam and Blummel, 2010; Etela and Dung, 2011; Das *et al.*, 2014) using *in vivo* degradability technique for estimating ME. The MEED based on the effective degradability of organic matter of feeds (Nsahlai and Apaloo, 2007) gave slightly more realistic results compared to the gas production method (Menke *et al.*, 1979). This is clearly shown in Figure 1, where MEED values are scattered at closer proximity to the line of perfect agreement. Thus, MEED values derived directly from animal degradation, that tend to be the more realistic and useful method to evaluate the ME content of feed.

3.5 Conclusions

Type of cereal straws are high in fibre and ADIN, low in nitrogen, low in ME, low in rumen degradation and *in vitro* digestion. Legume crop residues and concentrates are high in nitrogen, high in ME, high rumen degradation and *in vitro* digestion parameters. Urea treatment is a good technology to improve the nutritive value of tropical feeds by increasing nitrogen content, ME content and reducing their ADIN:N ratio. The DM and OM solubility, degradation rate (c) and ED in brans were higher than in legume crop residues and cereal straws. Concentrates with highest 'c' had the highest effective dry and organic matter and nitrogen degradability. Urea treatment reduced the value of cowpea husk and tended to decrease *in vitro* digestion of *Diheteropogon*. To increase the feeding values of tropical forages, mostly dominated by cereal straws with low nutritive values, urea treatment and concentrate supplementation are recommended as good strategies to curb the consequence of the long dry season. When formulating diets for ruminant production, nutritive value of feeds should be taken into account.

Chapter 4

Effect of roughage processing and feeding level on production performance of lactating does and post-natal performance of kids

Abstract

Sixty pregnant Red Maradi goats were used in Caprine Centre of Maradi (Niger) for two subsequent lactations from day one to day 14 of lactation to evaluate the effect of feeding levels of dams on production performance of dams and post-natal performance of kids; determine the effect of urea treatment and crushing of millet stover on feed intake and production performance of dams; to determine the effect of previous levels of feeding dam on production performances of kid and dam; and to investigate the relationship between ME intakes of kid and dam and their requirements based on AFRC and NRC systems. Three diets were formulated as follows: diet 1 (D1) for T1, T2, T3 and T4, formulated with 38% of crushed and urea-treated of millet stover (CUTMS), 32% of groundnut haulms (GH), 22% of wheat bran (WB) and 8% of cottonseed cake (CSC); diet 2 (D2) for T5 with crushed and untreated millet stover (CMS) replacing CUTMS in diet1; diet 3 (D3) for T6 with uncrushed and untreated millet stover (MS) replacing CUTMS in diet1. For the first kidding, six treatments were used, namely, T1, T2, T3, T4, T5 and T6, and formed by four levels of feeding (g/kg DM) where T1=842, T2=934, T3=1079 and T4=1300 corresponding to 200g, 400g, 600g and 800g of milk yield, respectively. Treatments T5 and T6 had the same level of feeding with T2 and were used to ascertain the effect of urea treatment and the effect of crushing of millet stover respectively. A randomized block design was applied on 60 does according to body weight, parity and type of birth implying 10 does per treatment. Seventy three kids of which 47 and 26 twins born were fed colostrum and milk using feeding bottles during a fortnight study period. During the second kidding, all does were fed with T4 of the same diet 1 (D1). Dry matter intake (DMI) and metabolisable energy intake of dams increased linearly ($P<0.001$) with increasing level of feeding. Kids ME intake (kMEint) increased linearly ($P<0.05$) during the first lactation with increasing level of feeding while there was no variation ($P>0.05$) of kMEint at the second lactation. The previous level of feeding, age and birth type

affected (at least $P<0.05$) the final body weight and body weight change of dams. Regressing kid MEint and total metabolisable energy requirements of either AFRC (TME_AFRC) or NRC (TME_NRC) gave regression equations accounting for 38% (AFRC) and 37% (NRC) of the variation. However, kMEint observed were similar to ME requirements of AFRC but lower than that of NRC. ME requirements based on AFRC and NRC of dams had no relationship with dam ME intake.

Keywords: Red Maradi goat, post-natal performance, feeding levels, metabolisable energy, kids.

4.1 Introduction

The Red Maradi (Sokoto) goat is widely represented in southern Niger and is the most important dual purpose goat breed due to its prolificacy and milk production. According to the 2007 statistics, the goat population in Niger was about 11 238 268, which constitutes about 36.2% of the livestock (RGAC-Niger, 2007). Breeding activities of the Red goat began in 1945. This breed has been part of the traditional farming system and has been selected in Maradi since 1963 in the goat breeding centre based on its ability to produce meat and milk. Maradi area constitutes the predilected agro-ecological zone of this breed. Nowadays, by efforts of Government, NGOs and Development Projects, Red Maradi goats are widely distributed in Niger and West African countries. The major constraint limiting the productivity of Red Maradi goat is the nutritional feeding of dams with repercussion on milk production, body weight losses, and low post-natal performances of kids (Obudu *et al.*, 1995; Nnadi *et al.*, 2007; Snyman, 2010; Ukanwoko *et al.*, 2012; Petros *et al.*, 2014).

Djibrillou *et al.* (1998) reported a general weight loss of red Maradi goats fed untreated or urea treated straws supplemented with or without concentrate and attributed this to a negative energy balance. According to Awemu *et al.* (1999) the preweaning mortality of kids of red Sokoto goats isaffected by environmental factors. Husain *et al.* (1995) stipulated that kid survival of Black Bengal goats is influenced by birth weight of kids and milk yield of dams. Similarly, Nnadi *et al.* (2007) and Snyman (2010) included low birth weight, slow growth rate and insufficient milk production as main causes of kid mortality. The growth performance of kids after kidding and survival rates are the most important factors of animal production. However, not much work has been done on Red Maradi goats raised under semi intensive system in Southern Niger. Also, very little is known about the metabolisable energy requirements of kids and dams of this breed in early lactation. The current study was conducted during 14 days post-partum for two subsequent lactations. The objectives of this study were to (1) determine the effect of feeding levels of dams on production performance of dams (first lactation); (2) determine the effect of urea treatment and crushing of millet stover on production performance of dams; (3) determine the effect of level of feeding of dams on post-natal performance of kids (first lactation); (4) determine the effect of previous level of feeding of dams on production performances of dam and kid (second lactation); (5) determine the metabolisable energy requirements for dams and growth of kids; (6) investigate the relationship between kid ME and dam ME intakes and their requirements based on AFRC (1993) and NRC (2007) systems.

4.2 Materials and methods

4.2.1 Study site

The study took place in the Caprine Centre (1850 ha and 893 animals in 2012) located East of Maradi. It is situated in the sahelo-sudanian zone of Niger with a mean annual rain fall of 350-600 mm, latitude 13^{0}30'N, longitude 7^{0}6'E and an altitude of 347 m above sea level. The climate is relatively dry with the rainy season occuring between June and September. The dry season begins in October with dry and cold weather from November to February. The hot weather occurs from March to June. The mean min/max temperature is 22/36ºC with a peak in April-May (>40ºC); heat decreases when rains begin. The relative humidity from October to June and July to September are < 20% and > 80%, respectively. The natural vegetation is Sahelo-Sudanian woodland dominated by various *Acacia* species, with sparse ground regenerating shrubs and perennial or annual grasses.

4.2.2 Animals and housing

Sixty pregnant does were transfered from the flock of Red Maradi goats breeding centre to the feed research unit towards the end of pregnancy (one to two weeks before kidding) were used in this experiment. The average body weight of does was 23 kg (SD = 3.65). After kidding, does were treated against external and internal parasites with Ivermectin (1%), Limoxin (antibiotic) and one week later they were vaccinated against pasteurellosis (pastovac). The following variables were recorded on each doe at the beginning of the study: ear-tag number, body weight, age, parity, date of kidding, litter size and kid sex. Kids were ear-tagged on the second day of life, separated from their dams at the evening of kidding for 14 days. Does were allocated to individual pen (2 m x 1.5 m) in the experimental feed unit with free access to a salt lick and potable drinking water. In this experiment coinciding to the dry season, kid survival rate was 100%.

After weaning kids at 3 months age, does continued on the same diet and oestrus was synchronized to reproduce dams, where 35 out of 58 does conceived giving conception rate of 60 %. A similar experiment which was conducted in the rainy season to determine the effect of previous levels of feeding on the growth performance of kids and milk yield of does; where one treatment (T4) which gave the best milk production response at the previous kidding was applied to all does. In this experiment, 35 does were used with 40 kids and by the end of experiment, kid survival rate was 52.5% due to pasteurellosis (see Appendix A).

4.2.3 Feeds

Feeds were chosen based on nutritive value and availability in the study area, and constituted of raw (only reduced in size to fit into the trough) millet stover (38 %), crushed millet stover with and without urea-treatment (38%), groundnut haulms (32%), cottonseed cake (8%), wheat bran (8%), and mineral lick.

4.2.3.1 Millet stover and groundnut haulms

Millet stover was purchased (0.25 USD/5 kg bundle) from smallholder farmers immediately after harvesting when feed was available and cheap. Groundnut haulms were purchased from smallholder farmers, packaged in 15 kg bags each costing 2.58-5.16 USD (depending on the dry season or period of feed scarcity). Millet stover and groundnut haulms were crushed through a 10 mm sieve (Made Peruzzo, with electric motor single phase 3 HP - 220 Volts - 2.2 Kw, 5-10 Holes mm, model A/5-R/75, Production: 100/500 kg/hour, http://www.peruzzo.it/eng/66-hammer-mill-a-5-r-75.html), and a portion was treated with urea. Some millet stover was chopped at around 25 cm to reduce the length to facilitate placing in the feed trough.

4.2.3.2 Wheat bran, cottonseed cake, mineral lick and urea

These ingredients are available at the local Maradi market and from the regional livestock service at subsidised prices where wheat bran and cotton seedcake would cost 8.60 USD/50 kg bag. Mineral salt block (costing 0.68 USD/stone of 2-2.5 kg) and urea (costing 17.21 USD/50 kg bag) were purchased from local dealers. Cottonseed cake was crushed through a 10 mm sieve with the same crushing machine cited above.

Urea treatment was done by dissolving 4kg of urea in 60 L of water; and the solution was sprinkled onto 100 kg of millet stover, mixed properly, and then stored in polyethylene bags for 40 days in the barn. At the end of treatment, strong smell of ammonia, change in physical characteristics such as brown colour, heat and absence of moulds were observed.

4.2.4 Feeding management

Before entering this experiment, goats were raised on natural grazing based on herbaceous forages dominated by *Schizachyrium exile*, *Eragrostis tremulu*, *Diheteropogon hagerupii*, and shrubs dominated by *Guiera senegalensis*, *Bauhinia rufescens*, and woody plants principally *Acacia nilotica*, *Acacia radianna*, *Acacia albida*, *Piliostigma reticulatum* and *Balanites aegyptiaca*. Feed troughs were made by cutting a barrel in three parts thus 3 feed troughs were made per barrel and pregnant does were transferred to the experimental feed unit. Then an adaptation period of 7-14 days was provided, depending on the pregnancy period in order to familiarise animals to the diet comprising of urea treated millet stover (MS), groundnut haulms (GH), cottonseed cake (CSC) and wheat bran (WB).

During adaptation, does were fed T2 (crushed and urea-treated millet stover) and T5 (crushed and untreated millet stover) alternatively which was supposed to meet the requirement for producing 400 g of milk (known as average milk yield) in red Maradi goats. These treatments were chosen to adapt does with urea treatment and crushed stover. Feed offered was measured with an electronic balance (Sartorius M-Power Toploader Balance, 6100 x 0.1 g) into plastic bags the previous afternoon just to avoid any delays in feeding the following day. Feed was offered in the morning at 8:00 h and refusals were collected the following day between 0700h to 0800h. Mineral lick was hung in individual pens permanently per animal as supplementary ingredient. Water was offered *ad libitum.*

4.2.5 Experimental design

Sixty does were sorted and blocked according to weight, parity, litter size, and age, into 10 groups of six; goats in each group were randomly distributed into six sub-groups of 10, which were randomly allocated to six treatments, making a total of 10 does per treatment. Does were allocated to individual pens in the shed during the experimentation. Six groups (10 lactating does/group) received six dietary treatments from kidding until 14 days post kidding. Six diets given in Table 4.1 were formulated following the AFRC (1993) recommendation and rationed to achieve various milk production targets:
T1: 842g DM of D_1 for 200g of milk production
T2: 934g DM of D1 for 400g of milk production
T3: 1079g DM of D1 for 600 ml of milk production
T4: 1300g DM of D1 for 800 ml of milk production
T5: 934g DM of D2 for 400 ml of milk production
T6: 934g DM of D3 (575 g of mixed GH+WB+CSC + 359 g millet stover) for 400g of milk.

Treatments one to four were rationed to examine the effect of level of feeding; T2 and T5 were compared to determine the effect of urea treatment; and T5 and T6 were compared to determine the effect of crushing millet stover. During the second experiment (lactation), one group of 35 lactating does received one treatment (T4) from kidding to 14 days post kidding to determine the effect of previous treatments on milk production and post-natal growth performance of kids. Groups T2 and T5 were compared to determine the effect of urea treatment while T5 and T6 were compared to determine the effect of crushing millet stover.

4.2.6 Energy requirements for maintenance and growth of kids

The metabolisable energy (ME) intake of dams was derived from proportion of ME in feed intake (of corresponding diet) and ME intake of kids was calculated from ME in milk intake. The ME intake of dams was calculated based of ME content of different ingredients (Table 4.2) derived from degradability of OM based on Nsahlai and Apaloo (2007). The ME intake of kids was calculated as the sum of ME in colostrum plus milk (Akinsoyinu *et al.*, 1981) for Red Maradi goats. It was assumed after considering losses of energy in digestion, absorption and transportation, that seventy per cent (70 %) of milk GE was transformed into ME. The colostral phase was determined for each doe in order to calculate this ME intake derived from colostrum.

$$\text{Metabolizable energy intake of kid (MEint)} = \text{SMEC} + \text{SMEM}$$

Where: SMEC is the sum of ME derived from the quantity of colostrum intake and SMEM is the sum of ME derived from milk intake during the first 14 days of the study. The ME requirement (MEr) was calculated according to the AFRC (1993) and NRC (2007) systems as follows:

$$\text{MEmr (AFRC)} = \text{MEm} + \text{NEg}/k_g$$

Where MEmr = metabolisable energy requirement; MEm (metabolisable energy for maintenance) = $0.315*\text{Kwt}^{0.75}/k_m$; where k_g and k_m are efficiencies with which ME is used for maintenance and production.

$$\text{ME}_g \text{ (Net energy for gain)} = \text{EVg*ADG}/k_g$$

Where: EVg (energy value for gain) = 4.972 +0.3274*Kwt; and ADG = average daily gain; Kwt = kid weight; k_g is efficiency of use of ME for gain.

$$\text{MEmr (NRC)} = 0.521*\text{Kwt}^{0.75} + 13.4*\text{ADG (for suckling male kids) and}$$

$$\text{MEmr (NRC)} = 0.449*\text{Kwt}^{0.75} + 13.4*\text{ADG (for suckling female kids)}$$

Regressions between ME intake of kids and metabolisable energy requirements determined based on AFRC (1993) and NRC (2007) system were used for data of two lactations. The ME intake of dams was calculated based on ME content of diets (Table 4.1) as follows:

$dMEI = (DI/1000)*MED$;

$dMEr\ (AFRC) = 0.315*dwt^{0.75} - 20*dADG + MEmk$;

$dMEr\ (NRC) = 0.462*dwt^{0.75} - 28.5*dADG + MEmk$;

Where dMEI = dam metabolizable energy intake per day; DI = dam intake; MED = metabolisable energy content of diet; dMEr = dam metabolisable energy requirement; dwt = dam weight; dADG = dam average daily body weight change; MEmk = metabolisable energy of milk production.

4.2.7 Measurements

In the current study, feeds offered and orts were measured daily to determine intake. From birth to 14 days age, daily milk production was recorded during both lactations with an electronic balance (Sartorius 6100g d=0.1 g). Kids were temporarily separated from dams flock for the first 14 days to avoid suckling. Colostrum yield was recorded during the first one to four days post-partum and then milk yield during the rest of the 14 days post-partum. Weaned kids of previous lactation were separated from dams flock to avoid suckling their dams, in order to guarantee colostrum production. Does were milked by hand every day from parturition until day 14 and kids were each fed with colostrum and milk using a feeding bottle. After feeding, kids were allowed with their dams for five to ten minutes to enhance dam-kid relationship and avoid rejection of kid(s) by dam. Everyday, measurements of colostrum and milk yield were recorded thrice: in the morning (0800 to 0900h), afternoon (1200 to 1300h) and evening (1800 to 1900h). The total daily milk yield was calculated as the sum of three measurements. Feed offered and refusal were measured daily with an electronic balance (KRN5, max=5kg d=5g) to determine the intake.

Doe weights were measured using an with electronic balance (Kern CH 50 kg, d=50g max=50kg, version 2.7, 2009) during two consecutive days: the day of kidding once the placenta had been expelled and the following morning (0600h) on day 1 of the study. Does weight was recorded once on day seven 7 and twice at the end of the study (i.e. in the evening (1800h) on day 13 and in the morning (0600h) of day 14).

Kids' weight less than 5 kg were measured using an with electronic balance Baxtran KRN5 (max=5kg d=5g) and kids' weight more than 5 kg were recorded with KRN10 (max=10kg d=10g). Kid weight was recorded three times: the day of kidding, seven days and twice at the end of the study, in the evening (1800h) on day 13 and in the morning (06:00h) of day 14.

4.2.8 Chemical analyses

Representative feed samples (10%) of dietary components and refusals were collected daily and at the end of the week, a composite sample (5%) of each was collected and dried (for DM determination) in the oven at 65^0C for 48h. Composite samples of feed offered and orts were analyzed to determine DM, ash, crude protein (Nx6.25), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL). Ash was determined by combusting 1 g of sample per crucible in a muffle furnace for four hours at 550°C (method-942.05 AOAC, 1990). Nitrogen content was determined using the Leco TruMac CNS/NS (LECO Corporation USA, 2012). NDF, ADF and ADL were determined in duplicates using ANKOM-A200/2220 (2052 O'Neil Road, Macedon NY 14502) as described by Van Soest *et al.* (1991). Neutral detergent fibre content was assayed without a heat stable amylase. Both NDF and ADF were expressed inclusive of residual ash. ADL or lignin (sa) was determined by solubilization of cellulose with sulphuric acid. Hemicellulose was obtained by difference of between NDF and ADF and cellulose was calculated as the difference between ADF and lignin (sa). All these analyses were done in the laboratory of the Department of Animal Science of University KwaZulu-Natal, Pietermaritzburg.

4.2.9 Statistical analysis

Data collected during two lactation periods were edited by removing data when kids died particularly during the 2nd experiment, and were analyzed using the General Linear Model of SAS (Statistical Analysis System). Variables included feed intake, milk yield, metabolisable energy intake, body weight change of does, and birth weight, final body weight and body weight gain of kids. The model for analysis was as follows:

$Y_{ijklmno} = \mu + T_m + A_i + B_j + P_k + S_l + L_n + E_{ijklmno}$

Where Yijklmno is the independent variable (feed intake, milk yield, metabolisable energy intake, body weight change of does and body weight gain of kids), μ is the overall mean, Tm is the effect of treatments, Ai is the effect of dam ages, Bj is the effect of birth type, Pk is the effect of parity, Sl is the effect of kid sex, Ln is the effect of initial body weight and Eijklmno is the residual error. The effect of treatment was tested and the means of dam and kid variables were compared between treatments, statistical significance being declared at $P<0.05$. For experiment one, the treatment sums of squares were partitioned to test of the effect of crushing (T5 versus T6), and the effect of treating with urea (T2 versus T5). Then linear and quadratic contrasts were used to determine the effect of the first four treatments. For the second experiment, the effect of the previous level of feeding on these parameters were analysed. Regression relationships were established between ME intake (by dam and kid) and metabolisable energy requirements based on AFRC (1993) and NRC (2007) systems.

4.3 Results

4.3.1 Diets and chemical composition of feed ingredients

The diets and chemical composition of feeds are shown in Table 4.1 and Table 4.2, respectively. It is important to note that the three diets had similar nutritive value (Table 4.1). The DM, OM, NDF and ADF contents in refusals were higher than in feeds offered (Table 4.3).

Table 4.1 Dietary ingredient and chemical composition

Ingredient (g of DM)	Ration	Diet 1				Diet 2	Diet 3
		T1	T2	T3	T4	T5	T6
CUTMS		385	384	385	385	-	-
CMS		-	-	-	-	384	-
MS		-	-	-	-	-	384
GH		308	307	308	308	307	307
WB		230	231	231	231	231	231
CSC		77	77	77	77	77	77
Total		1000	1000	1000	1000	1000	1000
Chemical composition							
N (g/kg DM)		16.93	16.93	16.93	16.93	16.52	16.52
ME of diet (MJ/kg DM)		9.24	9.24	9.24	9.24	8.8	8.8
Rationing							
Target milk production (g)		200	400	600	800	400	400
Rationing level (g/day)		842	934	1079	1300	934	934
Feeding level		0.65	0.72	0.83	1	0.72	0.72

MS: millet stover; CMS: crushed millet stover; CUTMS: crushed and urea treated millet stover; GH: groundnut haulms; WB: wheat bran; CSC: cottonseed cake; ME: metabolisable energy.

Table 4.2 Chemical composition of feeds

Feeds	MS	MS	GH	WB	CSC
Urea treatment	no	yes	no	no	no
Dry matter	954	619	932	953	980
Organic matter	913	911	889	951	948
Nitrogen (N)	6.20	7.28	17.50	26.07	35.45
Neutral detergent fibre (NDF)	816	799	495	477	570
Acid detergent fibre (ADF)	518	523	386	125	437
ME (MJ/kg DM)	4.57	5.71	11.31	12.65	8.30
ADIN	1.4	1.6	2.2	0.8	3.2
ADIN:N	22.8	22.4	12.5	3.0	9.1
Hemicellulose	298	276	110	352	133
Cellulose	394	406	265	86	339
Acid detergent lignin	130	118	116	35	101

ME: Metabolizable energy; ADIN: Acid detergent insoluble nitrogen; ADIN:N: ratio acid detergent insoluble nitrogen in nitogen content of feed; MS: Millet stover; GH: Groundnut haulms; WB: Wheat bran; CSC: Cottonseed cake.

Table 4.3 Chemical composition of feeds offered and refusals (g/kg DM)

		Diet1				Diet2	Diet3
Parameters	Feed	T1	T2	T3	T4	T5	T6
DM	Offered	822	822	822	822	949	949
	refusal	965	965	965	965	970	980
OM	Offered	916	916	916	916	916	916
	refusal	933	947	940	959	945	955
NDF	Offered	613	613	613	613	619	619
	refusal	713	715	672	726	700	823
ADF	Offered	385	385	385	385	383	383
	refusal	510	519	480	531	479	576

DM: Dry matter; OM: Organic matter, NDF: Neutral detergent fibre; ADF: Acid detergent fibre.

4.3.2 Effect of feeding levels on feed intake and production performance of dams

Feed intake varied ($P<0.001$) among treatments (Table 4.4). Feed intake increased linearly ($P<0.001$) with increasing feeding levels. Dams with twins had higher ($P<0.05$) DMI than dams with singles (731 versus 617, $P<0.05$). The metabolizable energy intake of dams (dMEi) had the same trend like DMI and varied ($P<0.001$) among treatments (Table 4.4). Birth type had an influence on dMEi where dams with twins consumed higher ME (6.68 versus 5.60, $P<0.05$) than with single. Kids' variables did not affect ($P>0.05$) DMI of dams.

Milk yield did not vary ($P>0.05$) among treatments (Table 4.4), though it increased ($P<0.01$) linearly. The dam initial body weight affected ($P<0.05$) milk yield while other dam and kid variables had no effect. Milk production would increase by 9.42 ml (SE=3.63, $P<0.5$) per day per unit change (1 kg) in body weight. Dam final body weight (dfwt) and dam weight change (dwtc) were not affected by treatments (Table 4.4). All kid and dam variables except dam initial weight did not affect ($P>0.05$) dfwt and dwtc.

4.3.3. Effect of urea treatment and crushing of millet stover on feed intake and production performance of dams

Urea treatment increased feed intake ($P<0.05$) whereas crushing decreased ($P<0.05$) feed intake (Table 4.4). Both urea treatment and crushing of millet stover had no effect

(P>0.05) on milk yield (Table 4.4) and kid milk intake (Table 4.5) during the first fortnight of lactation.

Table 4.4 Effect of level of feeding dams and roughage processing on production performance of lactating does

Treatment	n	Dam initial weight	DM intake MI (g)	ME intake (MJ/day)	Daily milk yield (g)	Final weight (kg)	Daily weight change (g)
T1	10	22.09	501c	4.63b	332a	20.81	-168
T2	10	23.30	606bc	5.59b	376a	21.41	-125
T3	10	23.02	731ab	6.75a	447a	21.51	-118
T4	10	25.75	824a	7.61a	510a	21.34	-130
T5	10	22.55	542	4.77	373	21.55	-115
T6	10	21.59	647	5.70	425	20.45	-194
Variation sources							
RMSE			116.07	1.06	172.39	1.17	84.20
Treatment			***	***	NS	NS	NS
Age			NS	NS	NS	NS	NS
Parity			NS	NS	NS	NS	NS
Typeb			*	*	NS	NS	NS
diwt			NS	NS	*	***	***
kiwt			NS	NS	NS	NS	NS
ksex			NS	NS	NS	NS	NS
Linear			***	***	**	NS	NS
Quadratic			NS	NS	NS	NS	NS
Contrast							
T2 vs T5			*	*	NS	NS	NS
T5 vs T6			*	*	NS	*	*

Typeb: birth type; diwt: dam initial weight; change; kiwt: kid initial weight; ksex; kid sex; DM: dry matter; ME: metabolizable energy; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

4.3.4 Effect of feeding levels of dams on milk and metabolisable energy intakes and production performances of kids

Milk intake did not vary (P>0.05) among treatments while the metabolisable energy (ME) intake differed (P<0.05) (Table 4.5). Age, parity, dam initial weight (diwt) and kid sex (ksex) did not affect (P>0.05) kid milk intake. However, birth type affected (124.3±14.75, P<0.001) kid milk intake (P<0.001) and kid ME intake (P<0.001) where single born consumed higher milk and ME than twins (330.83 versus 206.52 g/day, P<0.001) and

(0.909 versus 0.584 MJ/day, $P<0.001$) respectively. Kid initial weight (kiwt) (73.12 ± 25.24, $P<0.01$) affected also kid milk intake indicating that every 1 kg change in kid weight would increase milk intake by 73 g. Kid's milk and metabolisable energy intakes increased linearly ($P<0.05$) with feeding levels of dams.

Kid final weight was not affected ($P>0.05$) by treatments (Table 4.5), age, parity, dam initial weight (diwt) or kid sex (ksex). However, it was highly affected ($P<0.001$) by birth type (0.38 ± 0.06, $P<0.001$) where single born and twins had final weight of 2.39 kg and 1.88 kg respectively. Similarly, kid initial weight (kiwt) strongly affected kid final weight (0.98 ± 0.10, $P<0.001$).

The kid average daily body weight gain were similar ($P>0.05$) among treatments (Table 4.5) and were not affected ($P>0.05$) by all dam variables and kid variables. However, it was highly affected ($P<0.001$) by type of birth (29.07 ± 4.79, $P<0.001$) where singles gained more weight than twins (54 versus 28 g/d). No other variable affect ($P>0.05$) kid average daily body weight.

Table 4.5 Effect of level of feeding dams and roughage processing on milk and metabolsable energy intakes and on post-natal performance of kids

Treatment	Kid initial wt (kg)	Kid milk intake (g)	Kid ME intake (MJ/day)	Kid final wt (Kg)	Kid wt gain (g)
T1	1.67	242a	0.683b	2.09a	37.40a
T2	1.80	303a	0.846ab	2.42a	51.00a
T3	1.61	307a	0.762ab	2.10a	41.63a
T4	1.76	305a	0.885a	2.29a	51.24a
T5	1.67	282	0.752	2.16	40.43
T6	1.74	288	0.841	2.23	45.38
Variation sources					
RMSE		70.74	0.32	0.37	19.56
Treatment		NS	*	NS	NS
Age		NS	*	NS	NS
Parity		NS	NS	NS	NS
Typeb		***	***	***	***
diwt		NS	NS	NS	NS
kiwt		**	**	***	NS
ksex		NS	NS	NS	NS
Linear		*	*	NS	NS
Quadratic		NS	NS	NS	NS
Contrast					
T2 vs T5		NS	NS	NS	NS
T6 vs T5		NS	NS	NS	NS

T: treatment; n: number of observation; Typeb: birth type; diwt: dam initial weight; change; kiwt: kid initial weight; ksex; kid sex; wt: weight; ME: metabolisable energy; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

4.3.5 Effect of previous feeding levels on production performances of dams

Feed intake, metabolizable energy intake and daily milk yield were not affected (P<0.05) by previous level of feeding (treatments), age, parity and birth type (Table 4.6). However, previous treatments strongly affected (P<0.001) final weight and daily weight change of dam. Age and birth type affected (P<0.05) final body weight of dam whereas body weight change of dam was heavily affected (P<0.001) by age, birth type and parity.

Table 4.6 Effect of previous levels of feeding and roughage processing on production performance of lactating does

Ptreatment	n	Dam initial weight (kg)	DM intake (g/day)	ME intake (MJ/day)	Daily milk yield (g)	Final weight (kg)	Daily weight change (g)
T1	4	22.57	839a	7.75a	408a	21.89c	44a
T2	2	24.31	875a	8.09a	426a	21.74c	-110c
T3	3	29.73	861a	7.96a	371a	26.28a	-160d
T4	8	27.89	837a	7.73a	364a	24.66b	-108c
T5	5	22.73	895a	7.87a	348a	21.37c	-42b
T6	5	22.23	576a	5.07a	367a	21.18c	-92c
Variation sources							
RMSE			203.11	1.87	153.12	1.81	0.04
Ptreatment			NS	NS	NS	***	***
Age			NS	NS	NS	*	***
Parity			NS	NS	NS	NS	***
Typeb			NS	NS	NS	**	***

T: treatment; Typeb: birth type; diwt: dam initial weight; Ptreatment: previous treatment; DM: dry matter; ME: metabolizable energy; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05).

4.3.6 Effect of previous levels of feeding dams on kids' milk and metabolisable energy intakes and post natal performance

The previous levels of feeding did not affect (P>0.05) kids' milk intake whereas the metabolisable energy intake varied (P<0.01; Table 4.7). Kid final weight was affected (P<0.05) by previous treatment while the kid weight gain was not.

Table 4.7 Effect of previous levels of feeding dams and roughage processing on milk and metabolsable energy intake and post-natal performance of kids

Ptreatment	Kid initial wt (Kg)	Kid ME intake (MJ/day)	Kid milk intake (g)	Kid final wt (kg)	Kid wt gain (g)
T1	1.60	1.168a	167a	2.58a	71.87a
T2	1.37	0.392b	133a	1.39b	9.61a
T3	1.68	0.572b	145a	2.07a	27.52a
T4	1.40	1.049a	158a	2.31a	57.53a
T5	1.53	0.643b	138a	1.97a	31.90a
T6	1.09	1.108a	159a	2.21a	59.36a
Variation sources					
RMSE		0.342	100.55	0.144	12.82
Ptreatment		**	NS	*	NS
Age		NS	NS	NS	NS
Parity		NS	NS	NS	NS
Typeb		NS	NS	NS	NS
Sex		NS	NS	NS	NS

T: treatment; n: number of observations; Ptreatment: previous treatment; Typeb: birth type; wt: weight; ME: metabolisable energy; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); *** (P<0.001).

4.3.7 Colostrum phase

The colostral period during two subsequent lactations varied from 1 to 4 days with means of 2.83 (RMSE = 0.54) (Table 4.8). The level of feeding, parity, type of birth and the interactions treatment x type of birth did not affect (P>0.05) the duration of colostral phase. However, age affected (P<0.05) the duration of colostrum where the colostral phase increased from primiparous to aged does. Similarly, the parity interacted with birth type to affect (P<0.05) colostral duration.

Table 4.8 Factors affecting the duration of colostrum phase

Treat	n	Colostrum phase	Age	n	Colostrum phase
T1	15	2.88^{a}	1	5	2.2^{c}
T2	14	2.50^{a}	2	7	2.85^{bc}
T3	16	2.95^{a}	3	19	2.65^{bc}
T4	18	3.00^{a}	4	30	2.83^{bc}
T5	15	2.65^{a}	5	21	3.04^{b}
T6	17	2.85^{a}	6	10	2.78^{bc}
Variation sources			7	3	3.67^{a}
RMSE		0.56			
Mean		2.83			
Treatment		NS			
Age		*			
Parity		NS			
Typeb		NS			
Teatment*Typeb		NS			
Parity*Typeb		*			

n: number of observations; Typeb: birth type; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

4.3.8 Metabolisable energy intake and requirements of dams and kids according to AFRC and NRC systems

The ME intake of dams and kids and their ME requirements for two experimental data set are shown in Table 4.9. The average value of dams' metabolisable energy intake was close to metabolisable energy requirement of AFRC (dMEr_AFRC) but lower than that of NRC (dMEr_NRC). Concerning kids, the average value of metabolisable energy intake was similar to metabolisable energy requirement (MEr) of AFRC but much lower than that of NRC.

Table 4.9 Observed metabolisable energy intakes of dams and kids compared to requirements according to AFRC (1993) and NRC (2007) systems.

Experiments	Kidding 1	Kidding 2	Average
n	60	27	-
dMEi (MJ/d)	6.128	7.518	6.478
dMEr_AFRC (MJ/d)	5.768	6.724	6.009
dMEr_NRC (MJ/d)	7.697	9.022	8.030
kME intake (MJ/d)	0.794	0.822	0.808
kMEr_AFRC (MJ/d)	0.827	0.802	0.814
kMEr_NRC (MJ/d)	1.540	1.500	1.520
kMEint (KJ/kg $BW^{0.75}$)	440	551	495.5

n: number of observations; dMEi: dam meyabolisable energy intake; dMEr_AFRC: dam metabolisable energy requirement according to Agricultural and Food Research Council; dMEr_NRC: dam metabolisable energy requirement according to US National Research Council; kME: kid metabolisable energy; kMEint: kid metabolisable energy intake; kMEr_AFRC: kid metabolisable energy requirement according to Agricultural and Food Research Council; kMEr_NRC: kid metabolisable energy requirement according to US National Research Council.

4.3.9 Energy requirements for maintenance and growth of kids

Regressions relationship of kids ME intake and total metabolisable energy requirements based on AFRC (TME_AFRC) system showed that the intercept was not different ($P>0.05$) from zero but that the slope was greater than unity and the relationship could account for 38% of the variation ($R^2 = 0.38$; $P<0.001$) as shown in Figure 4.1.

kME intake = -0.172 (SE = 0.098) + (1.34 (SE = 0.129) × TME_AFRC) [n = 171; $R^2 = 0.38$].

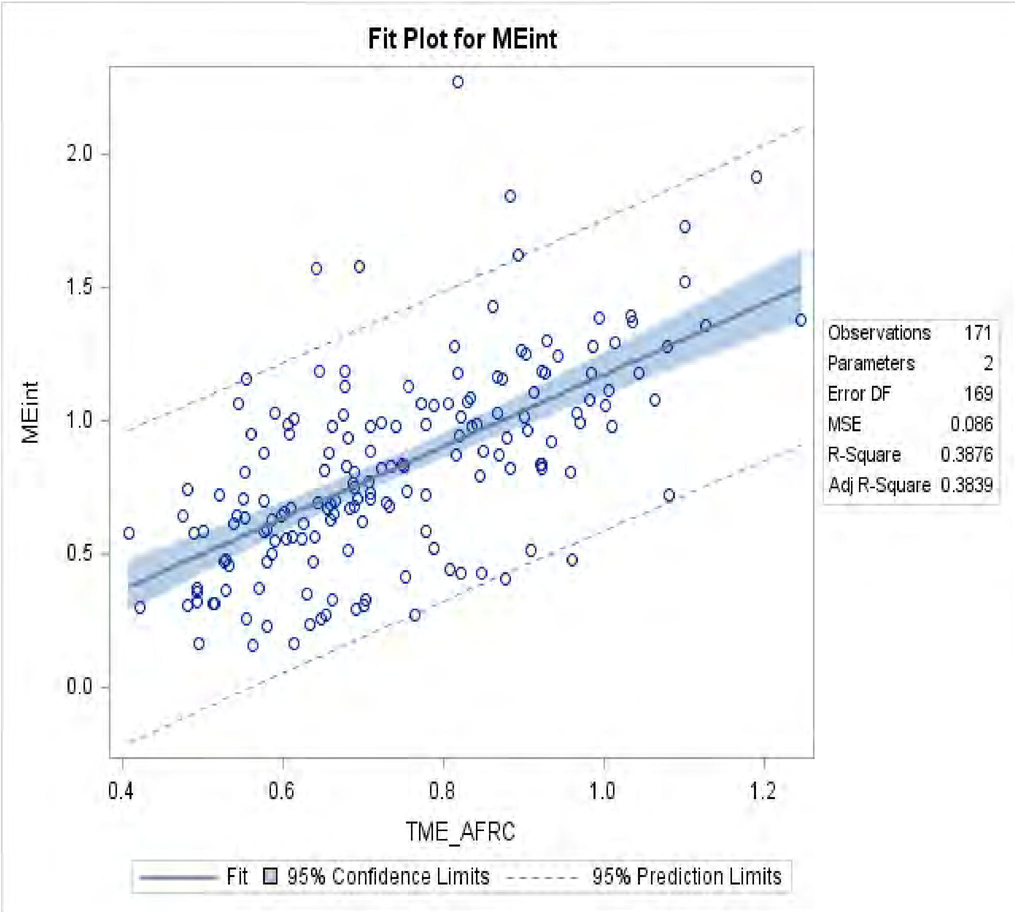


Figure 4.1 Relationship between ME intake (MJ/day) of kids and total metabolisable energy requirement (TME) of AFRC.

Regression relationship between ME intake of kids and total metabolisable energy requirements based on NRC (TME_NRC) system showed that intercept was not difference ($P>0.05$) from zero but that the slope was less ($P<0.001$) than unity ($R^2 = 0.37$; $P<0.001$) as shown in Figure 4.2.

kME intake = 0.005 (SE = 0.084) + (0.604 (SE = 0.059) × TME_NRC) [n = 171; $R^2 = 0.37$].

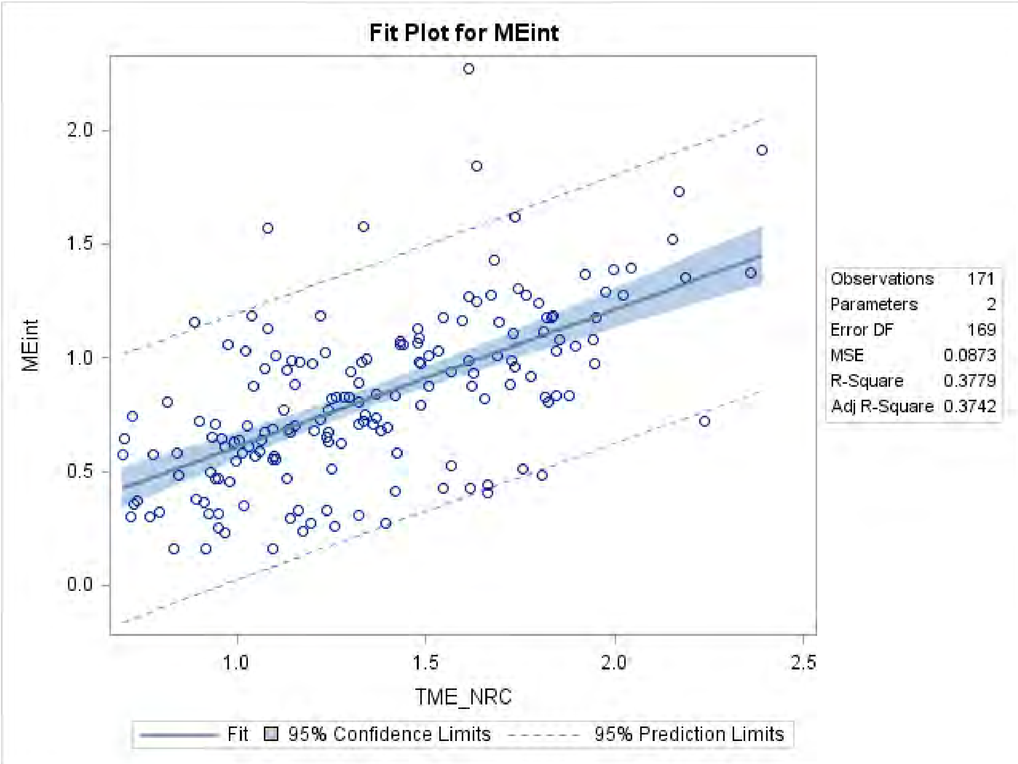


Figure 4.2 Relationship between ME intake (MJ/day) of kids and total metabolisable energy requirement (TME) of NRC

4.3.10 Energy requirements for maintenance, body weight change and milk production of dams

There was no relationship between dam metabolizable energy intake and either values calculated based on AFRC (dMEr_AFRC) or NRC as indicated in the following equation and represented on Figures 4.3 and 4.4.

Dams ME intake = 6.1 (SE = 0.36) + 0.04 (SE = 0.054) x dMEi_AFRC [n = 204; R^2 = 0.003].

Dams ME intake = 6.2 (SE = 0.36) + 0.02 (SE = 0.040) x dMEi_NRC [n = 204; R^2 = 0.001].

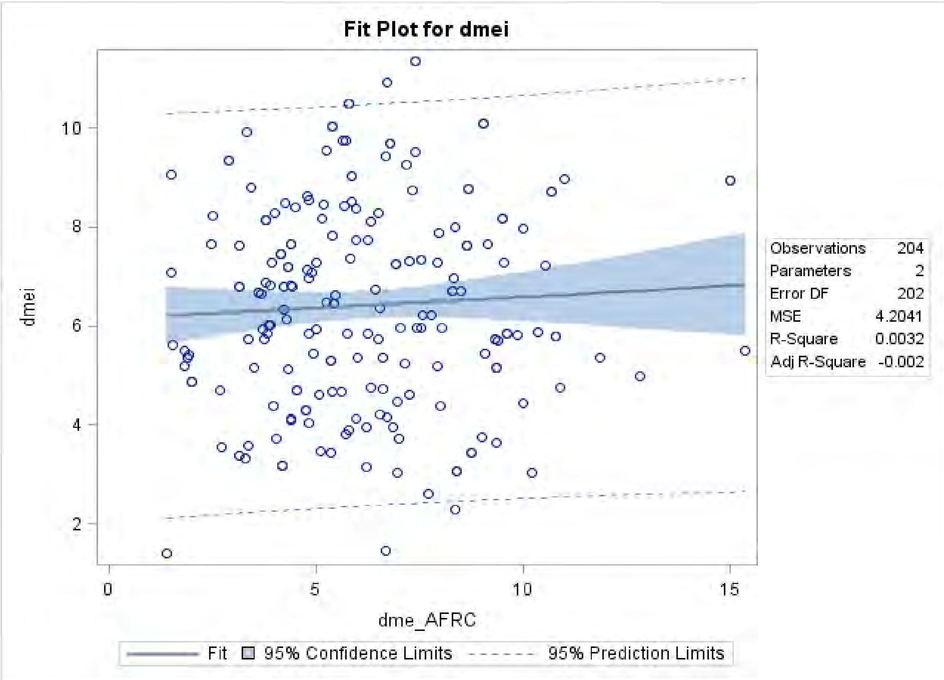


Figure 4.3 Relationship between dam metabolisable energy intake (dMEi) (MJ/day) and dam metabolisable energy requirements of AFRC (dMEi_AFRC)

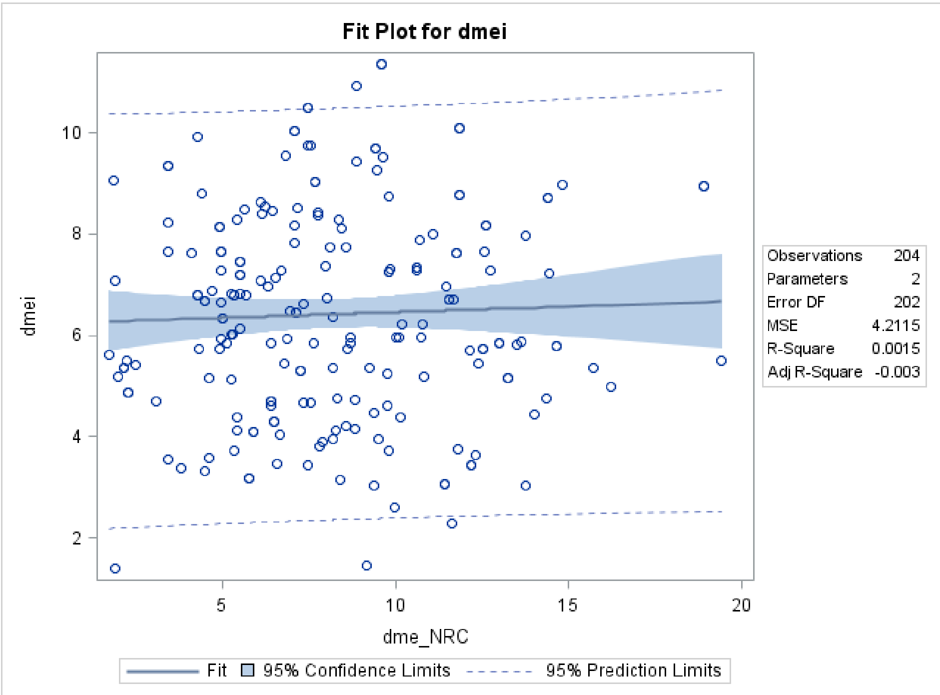


Figure 4.4 Relationship between dam metabolizable energy intake (dMEi) (MJ/day) and dam metabolizable energy requirements of NRC (dMEi_NRC)

4.4 Discussion

The linear increase in dry matter intake of dams for treatments T1 to T4 may be explained by increasing levels of feeding. Similar findings were observed by others (Preston and Leng, 1987; Malau-Aduli *et al.*, 2004; Greyling *et al.*, 2004; Kinuthia *et al.*, 2007) who reported increased dry matter intake (DMI) when goats were offered more feeds. DMI of goats is influenced by several factors, namely feed quality, palatability of feed, roughage concentrate ratio, animal behaviour and physiological stage of goats. The increase of dams' metabolisable energy intake (dMEi) with increasing level of feeding may be attributed to DM intake of dams since the dMEi was related to DM of feeds. This is the reason why the dMEi increased similarly to DMI which is similar to others (Kinuthia *et al.*, 2007). These dMEi were still low but were above the minimum requirement of maintenance estimated at 3.30 MJ/day (AFRC, 1993) and 4.52 MJ/d (Sahlu *et al.*, 2004) for goats weighing 23 kg.

The lack of treatment effect on milk yield despite the linear increase in dry matter and metabolisable energy intakes may be explained both by low dry matter intake and energy mobilized from body tissue for milk production at the early stage of lactation. Macala *et al.* (1993) reported increased milk production of Tswana does supplemented with graded levels of groundnut haulms and Greyling *et al.* (2004) reported effect of level of nutrition on milk production of indigenous and Boer goats in South Africa. Results on milk yield in the present study are similar to those obtained by others (Djibrillou *et al.*, 1998; Zahraddeen *et al.*, 2009a; Otaru *et al.*, 2011) on the same breed. However, Malau-Aduli *et al.* (2004) reported lower (270 g/day) and higher (620 g/day) milk yield values than the present study with non-supplemented and supplemented (with concentrate) treatments, respectively. Additionally, Sangaré and Pandey (2000) reported higher values (700-850 g/day) in early lactation (two first weeks) on Sahelian goats in Mali.

Although only the effect of treatment on kMEint was significant, the linear effect of T1 to T4 was not significant for milk intake. This variation of kMEint can be attributed to both birth type and variation in kid initial weight among treatments which would impact on kid milk intake or the kMEint derived from milk intake in the present study.

The higher DMI of T2 than T5 during two weeks of lactation showed that urea-treating millet stover increased DMI intake compared to the untreated one. This may be explained by the fact that urea treatment on millet stover wetted and perhaps softens the feed and increased its digestibility thereby heightening its appeal and palatability. These findings are in agreement with others (Wanapat *et al.*, 2009; Gunun and Wanapat, 2012; Gunun *et al.*, 2013) who reported increased DMI after treating cereal straws with urea. However, Djibrillou *et al.* (1998) reported no significant effect on DMI during eight weeks of lactation of Red Maradi goats by comparing urea treated and untreated straws and this might be due to increase of dry matter intake with advance of lactation. Thus, change in physiological stage of does with duration of lactation may influence the DMI. Besides that urea treatment increased intake, it did not affect milk yield because metabolisable energy intake were similar. Furthermore, it has been reported that the physico-chemical nature of diet has greater effect with highest productive breeds than medium ones (Morand-Fehr *et al.*, 2000) and moreover than Red Maradi goat as a dualpurpose breed.

The high DMI of group T6 than group T5 showed that crushing millet stover (CMS) did not affect DMI in this short phase (14 days) of study contrary to our expectation. This may be explained by low intake after kidding and by feeding behaviour of goats which selected the most palatable diets offered. Indeed, for treatment T6, all rations formulated based on groundnut haulms, wheat bran and cottonseed cake was completely eaten due to its high nutritive value and in addition leaves and sheath of millet stover were eaten. Thus, as the ratio of roughage to concentrate practically differed between T6 and T5, the difference of DMI may be due to selective behaviour of goats which is in agreement with results reported by several authors (Fedele *et al.*, 2002; Animut *et al.*, 2005; Jørgensen *et al.*, 2007; Basha *et al.*, 2009; Glasser *et al.*, 2012).

The influence of previous levels of feeding on dams' final body weight and body weight change could be explained by the significant effects of previous levels of feeding on feed intake and final body weight of does observed (Chapter six) in the previous experiment where does gained more weight with graded levels of feeding during the last three months of pregnancy. It has been recognized that the body condition scores and stage of lactation influence the energy value of body weight change of lactating animals especially in early and late lactation where body weight change can be large. Thus, during early lactation in accordance with the present study, does might mobilize fat and protein from their body reserves to satisfy milk production and this has repercussions on body weight and body weight changes observed.

The observed metabolisable energy intake of kids in the present study was close to ME requirements of AFRC system whereas the ME requirements of NRC were greater than that observed. Using the NRC requirements will satisfy requirement for more animals in a herd but may overfeed more animals. However, the relationship between kids' ME intake and values predicted using both systems were moderate or weak. Similar results were observed with metabolisable energy requirements for dams, where the ME requirements based on AFRC system were closer to ME values observed compared to NRC system which were greater than ME observed. No relationships were revealed between dams' ME intake and dams' ME requirements of both AFRC and NRC systems. The differences between ME intake and required could be attributed to type of breed, type of production, feeding system, and age or stage of animals. The weak or moderate relationship between the metabolisable energy intake (MEint) of kids and total metabolisable energy requirements based on AFRC and NRC systems may also be explained by the low milk intake of kids during the first two weeks of study. Indeed, kids were fed with feeding bottles which differed to natural suckling and may affect kid milk intake. Observed mean values of ME intake of kids in experiment one (1^{st} kidding of the study) and experiment 2 (the subsequent kidding) were 440 and 551 kJ/kwt$^{0.75}$ respectively, but overlapped results (485 kJ/kwt$^{0.75}$, 13.4 KJ/ADG) of Luo *et al.* (2004) on suckling kids. However, values of MEint observed were lower than those obtained by Sahlu *et al.* (2004) on suckling kids (1.424 MJ/d) of 50g average daily gain (ADG). It is important to note that in some studies, dietary ME was calculated based on feed digestibility through faecal collection whereas others used markers to estimate fecal output. In the present study, ME intake was based on milk intake and feed intake of nursing kids and their dams, respectively. Nonetheless, according to their similarities, to estimate the metabolisable energy requirements of suckling kids and does of Red Maradi goat, it appears rationing based on the NRC system would be more generous than based on AFRC system.

The lack of relationship between dams' metabolisable energy intake and metabolisable energy requirements of both AFRC and NRC systems could be explained by the fact that there was no relationship between body weight change and energy mobilized from body tissue of lactating goats because of their ability to mobilize significant quantity of body fat without change in body weight (AFRC, 1993).

The high DM, OM, NDF and ADF contents of refusals may be explained by differences in physical and chemical characteristics of feeds due to feeding behaviour of goats known to select feeds based on prehension ease, nutrient content and post-ingestive effects. This is in agreement with other works (Provenza *et al.*, 2003; Basha *et al.*, 2009; Glasser *et al.*, 2012). The influence of birth type on DMI could be attributed to high demand of energy by dam with twins compared to those with single to satisfy kids' milk intake and their maintenance. The significant effect of birth type on milk yield is similar to the findings of other researchers (Wahome *et al.*, 1994; Zahraddeen *et al.*, 2009a; Sanogo *et al.*, 2012). However, Akpa *et al.* (2001) reported that birth type did not influence milk yield. The effect of dam initial weight on milk yield is similar to the findings of Wahome *et al.* (1994) and Sangaré and Pandey (2000) on East African goats and Sahelian goats. The variation in milk yield compared to other studies could be due to differences in nutritive value of diets, breed, parity, body weight of does, frequency and milking methods.

All groups of lactating does during the first two weeks postpartum lost body weight in agreement with Greyling *et al.* (2004) using indigenous and Boer goats in South Africa. The significant effect of dam initial weight (diwt) on both dam final weight (dfwt) and dam weight change (dwtc) is in agreement with other studies (Schauff and Clark, 1992; Djibrillou *et al.*, 1998; Fedele *et al.*, 2002; Casals *et al.*, 2006; Otaru *et al.*, 2011). This loss of body weight corrects for the lower feed intake after kidding and therefore does mobilize own energy reserves to satisfy the extra energy requirement for milk production at this particular stage of lactation. Djibrillou *et al.* (1998) attributed body weight loss of lactating does to the unbalanced energy requirement and energy provided in the diet, whereas Schauff and Clark (1992) and Casals *et al.* (2006) attributed this to the decrease of DMI in studies on lactating cows and ewes, respectively.

The significant effect of dam's age on kid metabolisable energy intake (kMEint) could be explained by the duration of colostral phase which differed according to dam's age or the ME in colostrum is higher than that of normal milk. Thus, kids born by aged dam could consume more ME than kids of young does. The influence of birth type on kid milk intake and kMEint may be due to the fact that dam's milk is shared between twins born kids. This was the reason why kid milk and ME intakes of single born were higher than those of twins which would have repercussions on kids' final weight and body weight gain in spite of the superiority of milk yield of dam giving twins. This similarity of trend is due to the fact that kMEint derived from milk intake. Furthermore, single born kids were heavier than twins born kids at kidding, and the present study showed the effect of kid initial weight (kiwt) on kid milk intake. Both of these results are in agreement with other studies (Bajhau and Kennedy, 1990; Sangaré and Pandey, 2000) where kid initial weight affected milk intake and consequently the final body weight. Kids' birth weights in the present study were close to those reported by Muktar *et al.* (2011) on the same breed. However, lower values were obtained by Malau-Aduli *et al.* (2004) on the same breed in Nigeria and higher values by Sangaré and Pandey (2000) on Sahelian goats in Mali, by Mahmoud *et al.* (2012) on Damascus goats' kids in Sudan and by Castro *et al.* (2009) on Majorera goat kids in Spain. This variation in kid birth weight could be attributed to differences in livestock system, diets and breeds. The effect of kid initial weight (kiwt) on kid final weight (kfwt) is in agreement with other works (Bajhau and Kennedy, 1990; Husain *et al.*, 1996; Sangaré and Pandey, 2000). Husain *et al.* (1996) reported in a study on Black Bengal Goat that weight at birth is the most important factor influencing kid growth performance. Furthermore, these authors stipulated that single born maintained higher weight than twins. The influence of birth type on kfwt may be due to the kiwt and kid milk intake (as explained above), where a single born kid was heavier than twins and consumed more milk than twins which had repercussion on kfwt during early lactation. In the present study, single born kid had higher final weight than twins. This is in agreement with Das and Sendalo (1992) who, on Blended goat, reported that birth type influenced body weight at all ages. Similar results were found by Kochapakdee *et al.* (1994) on reproductive performances of Thai goats. The influence of birth type on kwtg corroborates the findings of other studies (Kochapakdee *et al.*, 1994; Zahraddeen, 2009b).

The influence of age and birth type on body weight and body weight change of dam at the subsequent lactation may be explained by the characteristic of Red Maradi goat which is reputed as a prolific breed in West Africa (Djariri, 2005) of which prolificacy is influenced by parity. According to Wilson (1991) and Marichatou *et al.* (2002), respectively 58.8% and 36.5% of twins born were observed with Red Maradi goat. Galina *et al.* (1995) working with Mexican goats found that birth type was partially influenced by age and parity. As parity is highly correlated with age and naturally multiparous does are heavier than young ones. This analogy may be explained by the influence of age and birth type on body weight and body weight change.

The length of colostrum phase (1 to 4 days) is in agreement with some works on other breeds (Fleet *et al.*, 1975; Kracmar *et al.*, 1999; Gajdusek *et al.*, 2001; Kracmar *et al.*, 2002; Kráčmar *et al.*, 2003; Argüello *et al.*, 2004). These authors stipulated that variations in minerals contents of colostrum occurred between 48 and 96 hours. In the present study distinction between colostrum and milk was based on the yellowish colour characteristic of colostrum. However, Akinsoyinu *et al.* (1981) found that colostrum phase in Red Sokoto (Maradi) goat lasted six days after parturition. The influence of age on colostrum duration or production agrees with Płoszaj *et al.* (1997) who reported highly positive relationship between the age and birth type and putrescine concentration in colostrum of Polish White goats and observed that aged goats giving two and three kids, secreted colostrum with a higher concentration of putrescine than young goats giving one kid. In the present study, the parity interacted with birth type to affect colostrum duration/production which is also supported by Płoszaj *et al.* (1997) and Romero *et al.* (2013).

4.5 Conclusions

The levels of feeding dams did not affect the production performance of lactating Red Maradi goat and their kids during the first 14 days postpartum. Urea treatment of millet stover increased feed intake whereas crushing did not. The previous levels of feeding dams impacted on body weight of dams and kids. The metabolisable energy intake of kids was closer to ME requirements based on AFRC compared to NRC system. There was no relationship between ME intake of Red lactating Maradi goat and both ME requirements (AFRC and NRC) of does. To overcome the ME requirements of kids and lactating does of Red Maradi goats, the requirements of NRC system should be used. Kids nurse by does on increasing feeding levels consumed more milk and tended to have a better body weight. Feeding strategy of does may permit to boost the preweaning growth performance of kids which is the most important trait to improve in goat production, but this will be known for the Red Maradi goat in Chapter 5.

Chapter 5

Effect of roughage processing and level of feeding on production performance of lactating does and preweaning kids

Abstract

Red Maradi goats from Caprine Centre of Maradi in South of Niger were used during two subsequent lactations from two weeks post kidding to 91 days to assess the effect of feeding levels of dams, the effect of urea treatment and crushing of millet stover on production performances of dams and on preweaning growth performance of kids, and to determine the effect of previous level of feeding on production performance of dams and their kids. For the first lactation, sixty goats were placed into six groups of 10, and randomly assigned to six treatments (T1, T2, T3, T4, T5, and T6) with four levels of feeding (g/kg DM): T1 = 842, T2 = T5 = T6 = 934, T3 = 1079 and T4 = 1300 corresponding to 200 g, 400g, 600g and 800g of milk production, respectively. Treatment T1 to T4, millet stover (MS) was crushed and treated with 3% urea, T5 MS was only crushed, and T6 was offered whole. Comparison between T2 versus T5, and T6 versus T5 evaluated the effects of urea treatment and crushing of millet stover (MS), respectively. At the 1st lactation, a randomized block design was applied to 60 does according to body weight, parity and type of birth. Seventy three kids of which 47/singles and 26/twins were used. During the subsequent lactation, 35 lactating does and 17 kids were used. All does were given one dietary treatment (T4) to determine the effect of previous levels of feeding on preweaning performance of kids and determine the potential milk production of Red Maradi goat. At the 1st lactation, the linear effect of level of feeding increased ($P<0.001$) dry matter intake, ME intake and milk yield of dams. During the 2nd lactation the previous levels of feeding did not affect these parameters; however, previous levels of feeding affected ($P<0.001$) final body weight and body weight change of dams. During 1st kids' ME intakes increased ($P<0.001$) linearly with levels of feeding and kids' final weight also increased linearly with feeding level of does. During the 2nd lactation, the daily ME intake of dams, and daily milk yield (mean milk yield of 367 g/day) were not affected by previous level of feeding.

Keywords: Red Maradi goat, preweaning performance, feeding levels, milk yield, metabolisable energy, kids.

5.1 Introduction

The Red Maradi (Sokoto) goat is a multipurpose breed which produces meat, milk and good quality skin throughout West Africa. Goats play an important role in generating income, capital storage and improving household nutrition (Kosgey and Okeyo, 2007). Being small in size, they do not require large housing space per head compared to cattle and can easily be handled and managed by women and children. Goats play an important role in the national economy of Niger where they contribute about 51.61% of live animal exports and 59.38% of total hide and skin (INS-Niger, 2011). Red Maradi goat is more dominant in Southern Niger and represent the most important goat breed reared by smallholder farmers due to its prolificacy and milk production (Djariri, 2005). In the semi-arid areas, goats are the most important livestock species for milk production next to cows for smallholder farmers. On body weight basis, the goat is a more efficient milk producer than the cattle and sheep (Malau-Aduli and Anlade, 2002). It was also reported that 61% of households raise at least 1 to 5 goats and goats are the most common animals sold by rural households for immediate cash income used to purchase food items (Wane *et al.*, 2005). However, the livestock system in this area is characterised by an acute shortage of feeds where animals graze only poor natural pastures in the dry season and were offered cut-and-carry grass and shrubs in the rainy season. Nowadays, it appears that Red Maradi goat has undergone a dilution which influences negatively some production attributes namely birth and weaning weights, growth rate and body condition.

According to Smith and Akinbamijo (2000), among numerous productions constraints, the nutritional factor constitutes the most crucial as most of the others can be manipulated by their improvement. Furthermore, Ademosun (1994) pointed dietary protein deficiency, as a major limiting factor to small ruminant production in tropical Africa and suggested the use of agro-industrial by-products as feed supplements to alleviate this constraint. Thus, adequate nutrition and the improvement of dietary protein and energy intake may influence does to express their genetic potential for self-production and production performance of its kids. The preweaning performance of kids is the most important trait for successful animal production but very little is known about this trait for Red Maradi goat. Therefore, the present study intended to (1) determine the effect of level of feeding dam and effects of urea treatment and crushing of millet stover on production performance of dam, (2) to determine the effect of feeding level of dams on preweaning growth performance kids, (3) and to determine the effect of previous levels of feeding dams on production performance of dams and kids during three months post kidding corresponding to weaning period.

5.2 Materials and methods

5.2.1 Study site

Details are given in section 4.2.1 (Chapter 4)

5.2.2 Animal and housing

Sixty lactating does with their 73 kids were used in this experiment from 14 days post kidding until weaning (at 3 months) at the first kidding while 35 lactating does with 17 kids were used at the second kidding. Kids were kept together with dams in individual pens where they ate the same diets and suckled their dams until weaned at 3 months of age. Kid survival rate was 78% at the first kidding and 47% at the second kidding. Kids' mortality was due to lack of milk yield and pasteurollosis (see Appendix A).

5.2.3 Feeds and feeding management

Feed troughs were made by cutting a barrel in three parts each of which became a feed trough. Untreated and urea treated millet stover, groundnut haulms, wheat bran and cottonseed cake were used as feed ingredients. During the 1st lactation, diets were formulated using milled (10mm) urea treated or untreated and uncrushed millet stover (MS), crushed groundnut haulms (GH), cottonseed cake (CSC) and wheat bran (WB). The ingredient and chemical composition of experimental diets were given in Table 4.1. During the 2nd experiment (lactation), only T4 was offered to all does to determine the effect of previous levels of feeding. Every day, diet offered and orts in plastic bags were measured with an electronic balance (Santorin 6100g d = 0.1 g) the previous day in the afternoon just to facilitate the feeding process and measuring intake. Diets were offered in the morning at 0800h and refusals were collected the following day between 0700 to 0800h. Mineral lick was hung in individual pen permanently per animal as supplementary ingredient. Tap water was offered *ad libitum* in a 10 L basin. Representative diets and refusals were collected daily and dried (for DM determination) in an oven at 65^0C for 48h. An electronic balance and a scale were used for measurements. At the end of the week a composite sample (5%) of diets and refusals were taken and stored and at the end of the experiment, representative samples (5%) of diets offered and refusals were collected for chemical analyses.

5.2.4 Experimental design

The six treatments (T1, T2, T3, T4, T5 and T6) allocated to dams were also available to their kids. Sixty animals were blocked according to weight, parity and litter size into groups of 10 animals each, which were randomly allocated to six dietary treatments, making a total of 10 animals per treatment. The six dietary treatments were offered to lactating does from 14 days to 3 months post kidding. After weaning, these animals continued on the same diet until the next kidding. After the 2^{nd} kidding, all animal were fed one dietary treatment (T4) to determine the effect of previous feeding levels. Each dams and its kid(s) stayed together in the same pen, except during test days. On a test day, a dam and its kids were separated and milk yield measured from 1800 to 1800h the next day.

5.2.5 Measurements

At the beginning and end of each experiment, body weights of kids and dams were taken during two consecutive days after starvation for 12 hours from 1800 to 0600h. The body weight of each dam or its kid(s) corresponded to an empty body weight. Empty kids' body weights were recorded weekly from 14 days after kidding until weaning (91 days after kidding). Empty body weights of dams were recorded every two weeks from 14 days after kidding.

Milk intake of kids was recorded weekly until weaning. From 14 days post-partum, milk yield was collected weekly until at the end of the experiment after week 13. Feed offered to dams and refusals were measured daily in order to determine the feed intake. A method of weigh-suckle-weigh followed by hand milking were used to record the milk yield. Thus, measurements were recorded thrice during the test day; in the morning (0600h), afternoon (1200h) and evening (1800h); this was followed by hand milking immediately after the last weighing at 1800h. If a kid urinated during the period of suckling its day's record was cancelled but the measurement was repeated during the following day. The total daily milk yield was the sum of four measurements (3 from kid weight after suckling and 1 from milking hand). During the previous day of milking, kids were separated from dams from evening (1800h) to following evening (1800h) after finishing milk recording.

5.2.6 Chemical analyses

This section is decribed in Chapter 4 (section 4.2.8).

5.2.7 Statistical analyses

Does which were sick, infected with mastitis pathogens or lost their kids before the end of the experiment were removed before analysing data. Variables were feeds intake of dams, metabolisable energy (ME) intake, milk yield, milk intake, initial body weight, body weight gain, and final body weight of kids; starting weight, final weight and body weight change of dams. Data were analyzed using the General Linear Model of SAS (Statistical Analysis System) to determine the Least Square Means (LSmeans), means and the level of differences between treatments. The model of analysis was as follows:

$$Y_{ijklmn} = \mu + A_i + B_j + P_k + T_l + L_m + E_{ijkklmno}$$

Where: Yijklmn is the independent variable (feed intake, ME intake, milk yield, milk intake, final body weight of dam and kid, body weight change of dam and kid body weight gain). μ is the overall mean; Ai is the effect of dam ages; Bj is the effect of birth type; Pk is the effect of parity; Tl is the effect of treatments; Lm is the effect of initial body weight of kids; Eijklmno is the residual error. The treatment sum of square was partition to test of the effect of treating with urea (T2 versus T5) and the effect of crushing (T5 versus T6). Linear and quadratic contrasts were used to compare the effect of level of feeding diet 1. For the second lactation, the effects of previous treatments on the same parameters cited above were tested.

5.3 Results

5.3.1 Chemical composition of feeds and diets

Diet formulation, chemical composition of feeds and diets are shown in Table 4.1, Table 4.2 and Table 4.3 respectively (see Chapter 4).

5.3.2 Effect of feeding levels on feed intake and production performances of dams

Feed intake varied ($P<0.001$) among treatments (Table 5.1). Feed intake increased linearly ($P<0.001$) with increasing levels of feeding dams without any quadratic effect. None of dam variables or kid variables affected dam intake. The metabolisable energy intake of dams (dMEi) increased linearly ($P<0.001$) with increasing levels of feeding (Table 5.1) without the quadratic effect. Neither age, nor parity nor birth type of dams affected dMEi. Milk yield varied ($P<0.001$) among treatments (Table 5.1).

Milk yield increased either linearly ($P<0.001$) or in a decreasing rate ($P<0.01$) with increasing feeding level of dams. The age, parity and birth type did not affected ($P>0.05$) milk yield. Weekly milk yield of different treatments were relatively stable from week 3 to week 9; thence they tended to decrease from week 9 to week 13 except for treatment 4 (Figure 5.1). For the whole period of study milk yield of treatment 4 (T4) was the highest compared to other treatments.

Dam final body weight (dfwt) and dam weight change (dwtc) were not affected by treatments (Table 5.1). All dependent variables of dam did not affect ($p>0.05$) dfwt and dwtc. The body weight change of lactating does tended to increase ($P<0.05$) linearly and positively with increasing levels of feeding until weaning.

5.3.3. Effect of urea treatment and crushing of millet stover on feed intake and production performance of dams

The contrast between treatments 2 versus 5 and between treatments 6 versus 5 showed that both urea treatment and crushing of millet stover did not affect (P>0.05) feed intake, dMEi or milk yield of lactating does before weaning (Table 5.1).

Table 5. 1 Effect of level of feeding and roughage processing on production performance of lactating does

Treatment	Initial weight (kg)	DMI (g)	dMEi (MJ)	Daily milk yield (g)	Dam final weight (kg)	Daily weight change (g)
T1	20.51	742	6.85	237	21.3	3.9
T2	21.57	800	7.4	236	21.5	1.3
T3	22.1	901	8.33	271	22	13.2
T4	23.72	978	9.04	354	22.4	19.2
T5	21.7	799	7.05	230	21.6	3.2
T6	20	764	6.75	246	21.6	2.5
Variation sources						
RMSE		49.34	0.45	40.99	1.25	15.67
Treatment		***	***	***	NS	NS
Age		NS	NS	NS	NS	NS
Parity		NS	NS	NS	NS	NS
Typeb		NS	NS	NS	NS	NS
Linear		***	***	***	NS	*
Quadratic		NS	NS	**	NS	NS
Contrast						
T2 vs T5		NS	NS	NS	NS	NS
T6 vs T5		NS	NS	NS	NS	NS

T: treatment; Typeb: birth type; dMEi: dam metabolisable energy intake; DMI: dry matter intake; RMSE: root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

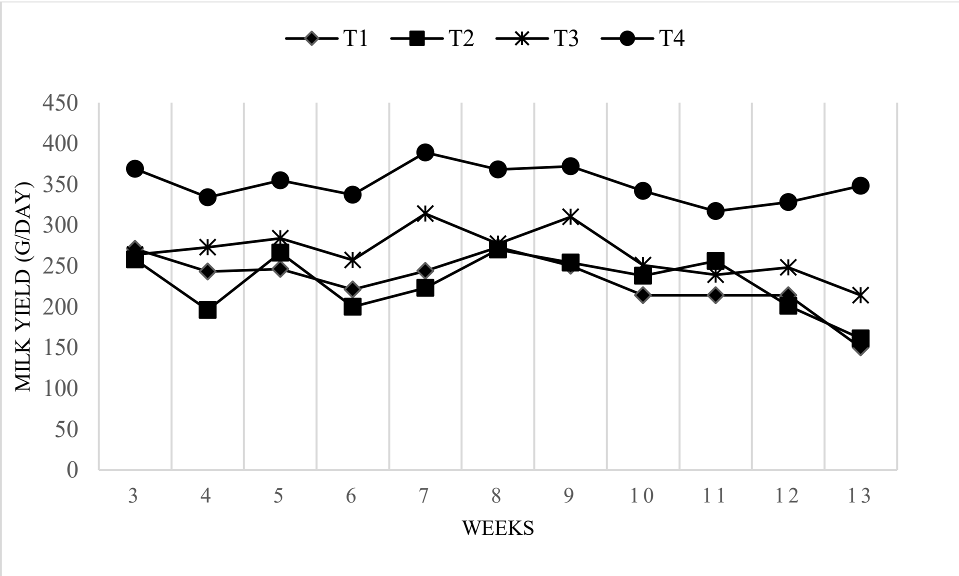


Figure 5.1 Effect of level of feeding on weekly milk yield of lactating does

5.3.4 Effect of feeding levels of dams on metabolisable energy intake and growth performance of kids before weaning

The level of feeding dams increased linearly ($P<0.001$) metabolisable energy intake of kids before weaning (Table 5.2). The type of birth (0.173 ± 0.031, $P<0.001$) and kid initial weight (kiwt) (0.154 ± 0.029, $P<0.001$) strongly increased ($P<0.001$) kids' metabolisable energy intake while the age and parity of dam did not exert any effect. Kids would have an increase consumption of 0.154 MJ ME /kg per day for an extra change of 1 kg of kid initial weight.

The kid final weight (kfwt) and kid weight gain (kwtg) increased ($P<0.001$) linearly with increasing feeding level of dams without any quadratic effect (Table 5.2). The kfwt and kwtg were not affected ($P>0.05$) by all dam and kid variables except that with a 1 kg increased in kiwt the kfwt increased ($P<0.001$) by 0.862 ± 0.227 kg.

5.3.5 Effect of urea treatment and crushing of millet stover on feed intake and production performances of kids

Urea treatment of millet stover did not affect ($P>0.05$) the ME intake, final weight and body weight change of kids but crushing negatively influenced ($P<0.01$) final weight and body weight change of kids (Table 5.2).

Table 5. 2 Effect of level of feeding dams and roughage processing on preweaning growth performance (kg) and metabolisable energy intake (MJ) of kids

Treatment	Kiwt (kg)	KMEint (MJ/day)	Kfwt (kg)	Kwtg (g)
T1	2.37	0.696	2.84	7.22
T2	2.46	0.766	3.16	11.49
T3	2.49	0.91	3.39	14.81
T4	2.52	1.066	4.37	27.16
T5	2.41	0.747	2.81	7.15
T6	2.35	0.737	3.69	18.31
Variation sources				
RMSE		0.262	0.48	6.27
Treatment		***	***	***
Age		NS	NS	NS
Parity		NS	NS	NS
Typeb		***	NS	NS
kiwt		***	***	NS
ksex		NS	NS	NS
Linear		***	***	***
Quadratic		NS	NS	NS
Contrast				
T2 vs T5		NS	NS	NS
T6 vs T5		NS	**	**

T: treatment; Typeb: birth type; kiwt: kid initial weight; ksex; kid sex; Kiwt: kid initial weight; KMEint: kid metabolisable energy intake; Kfwt: kid final weight; Kwtg: kid weight gain; RMSE: root mean square error; NS: not significant (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

5.3.6 Effect of previous feeding levels on feed intake, metabolisable energy intake and milk yield of dams

Feed intake, metabolisable energy intake and milk yield of dam were not affected (P<0.05) by previous levels of feeding (Table 5.3). However, previous levels of feeding, age and parity affected (at least P<0.05) final body weight and body weight change of dams. Birth type affected only final body weight of dams.

Table 5. 3 Effect of previous levels of feeding and roughage processing on production performance of lactating does

Ptreatment	Dam initial weight (kg)	Dry matter intake (kg)	dMEi (MJ/day)	Daily milk yield (g)	Dam final weight (kg)	Dam weight change (g)
T1	23.52	818	7.55	219	21.28	-2.15
T2	23.5	1060	9.8	332	24.65	29.32
T3	25.26	708	6.54	142	23.53	-10.13
T4	25.13	910	8.41	369	22.84	3.13
T5	22.15	898	8.29	229	22.22	3.64
T6	21.8	890	8.22	308	23.6	14.37
Variation sources						
RMSE		95.05	0.87	81.54	0.7	8.64
Ptreatment		NS	NS	NS	***	*
Age		NS	NS	NS	***	***
Parity		NS	NS	*	*	*
Typeb		NS	NS	NS	**	NS

Ptreatment: previous treatment; T: treatment; Typeb: birth type; dMEi: dam metabolisable energy intake; RMSE: root mean square error; NS: Not significant ($P > 0.05$).

5.4 Discussion

The linear increase of feed intake from T1 to T4 may be due to increasing levels of feeding which is in agreement with other reports (Greyling *et al.*, 2004; Morand-Fehr *et al.*, 2007; Sultana *et al.*, 2012; Luka and Kibon, 2014). Kabir *et al.* (2002) and Rashid (2008) reporting that DM intake of goats varied from 3 to 4% of body weight. When converted to DM intake/kg metabolic weight ($BW^{0.75}$), feed intake in the current study ranged between 76.98 to 92.37 g which was relatively high compared to results of Adenuga *et al.* (1991) who reported 60 g/kg metabolic weight in lactating West African Dwarf goats as small breed. However, DM intake in the present study was lower than that of 102 to 116 g/kg $BW^{0.75}$/day and 119.6 g/kg $BW^{0.75}$/day reported by AFRC (1998) and Chowdhury *et al.* (2002) respectively. In fact, dMEi increased also linearly as it was derived from dry matter. The dMEi in the present study was expected to satisfy the ME requirement (7.1 to 9.9 MJ/day) for targeted milk production of 200 to 800 ml/day which seemed to be low. Furthermore, the dMEi ranged from 0.7012 to 0.8410 MJ/kg $BW^{0.75}$

which is so far higher than ME_m required of 0.5013 and 0.462 MJ/kg $BW^{0.75}$ by Luo *et al.* (2004) and Nsahlai *et al.* (2004), respectively.

The linear increase of milk yield with increasing feeding levels of dam corroborated earlier reports (Sibanda *et al.*, 1997; Greyling *et al.*, 2004; Morand-Fehr *et al.*, 2007; Luka and Kibon, 2014) that milk production is related to the quantity of feed offered to lactating goats. The daily milk yield in the present study was lower than that observed in other studies with Red Maradi (Sokoto) goat (Djibrillou *et al.*, 1998; Luka and Kibon, 2014) and Sahelian goat (Sangaré and Pandey, 2000). The milk yield varied weekly among dietary treatments (Fig. 5.1) and the weekly milk yield during three months post kidding was lower than that observed on Red Maradi and West African Dwarf goats (Ahamefule *et al.*, 2012). The highest milk yield of T4 may be due to high metabolisable energy intake compared to other treatments and this is in agreement with other works (Hadjipanayiotou and Morand-Fehr, 1991; Montaldo *et al.*, 1997; Min *et al.*, 2005). It has been postulated that milk yield increased with increasing ME intake (Hadjipanayiotou and Morand-Fehr, 1991). However, these dMEi did not satisfy the expected milk production mentioned above and this could be attributed both to dry matter inatake and genetic potential of Red Maradi goat which would be considered as very low. Nowadays, Red Maradi goat is subjected to genetic dilution in Caprine Centre of Maradi due to inbreeding and low feeding allowances. The environment was too hot and dry perhaps due to global warming. Differences in milk yield compared to other studies may be attributed to feeding system, breed and livestock management systems (Stelwagen, 2001; Ahamefule *et al.*, 2012).

An increase in body weight change of dams is expected due to the increase in DMI and ME intake of dams with advancing lactation compared to early lactation where lactating does had low appetite. Nevertheless, mean body weight change of all treatments stayed positive which is in agreement with Chowdhury *et al.* (2002) who reported body weight gain in german fawn goat. However, other workers (Bajhau and Kennedy, 1990; Djibrillou *et al.*, 1998; Greyling *et al.*, 2004) observed negative body weight change in their studies.

The linear increase of kid metabolisable energy intake (kMEint) may be explained by kids' milk intake which corresponded with daily milk yield of dam. Kids MEint ranged from 277 to 364 kJ/kg $BW^{0.75}$ which is far lower than values of 485 and 521 kJ/kg$BW^{0.75}$ recommended by Sahlu *et al.* (2004) and NRC (2007), respectively, for suckling or preweaning kids. These differences might be due to low milk intake which agrees with Sangaré and Pandey (2000) who found that kid growth in the first three months is largely determined by milk production of their dams. In addition, these differences might be partially attributable to breed and experimental conditions, because the ME derived from feed intake of kids was practically impossible to measure since kids stayed together with their dams.

Urea treatment increases feed intake because it reduces lignification and increases the rate of digestion. However, after kidding intake of lactating does is low but increases thence. That is why there appeared to be an increase in feed intake with stage of lactation compared to the previous experiment where DM intake of dams before 14 days post-partum was low due to the physiological changes of does (Fedele *et al.*, 2002). Secondly, the environment was dry and hot with low humidity, so feed dried out quite rapidly. Thus, at this phase of study, there was no difference in DM intake between T2 and T5 implying that urea treatment of millet stover did not affect dam intake which could be explained by the increase in does' intake as the lactation period progressed while body weights of does were improving. Furthermore, at this phase of lactation does were able to eat enough feeds to meet the ME requirements to attain the goal of 400 g of milk yield. In fact, treatments T2 and T5 had the same level of feeding and the improvement of DM intake may explain the no-effect of urea treatment which is in agreement with work of Djibrillou *et al.* (1998) with Red Maradi goats when comparing intake of urea treated and untreated straws during three months of study.

Crushing millet stover did not affect doe's intake. Similar findings were observed by Wahed (1987) and Osafo *et al.* (1997) who reported no intake improvement by crushing barley straw for goats and sorghum stover for cattle respectively. However, crushing of millet tended to increase DM intake (799 versus 764) of doe due to physiological changes of doe which increased doe's appetite in order to satisfy ME requirements of 400 g of milk production which is in agreement with Fedele *et al.* (2002).Based on NDF (g/ kg DM) of feed offer (619) and orts (813), goats offered long millet stover were able to select only what they ate for example leaves and sheaths, that is why intake of T5 tended to be higher than T6. The thought is that if more feed were offered the effect of crushing could be seen with stage of lactation.The fact that final body weight and body weight gain of kids on T6 (3.69 kg and 18.31 g) were higher than those on T5 (2.81 kg and 7.15 g) in spite of similarity of metabolisable energy intake of milk showed that crushing of millet stover influenced negatively final weight and body weight gain of kids. This could be due probably to superiority in dry matter intake of kids (T6) which easily ate mixed diet (groundnut haulms, wheat bran and cottonseed cake) but reject millet stover offered alone compared to kids (T5) for which diet palatability was low. Indeed, kids (T5) may not have prehension ease of diet based on crushed millet stover which could have influenced on the intake of feed and ME. These differences on kid DM intake may be explained by selective behaviour of goats which is in agreement with results reported by several authors (Fedele *et al.*, 2002; Animut *et al.*, 2005; Jørgensen *et al.*, 2007; Basha *et al.*, 2009; Glasser *et al.*, 2012). Furthermore, similarity of metabolisable energy intake between kids (T5) and kids (T6) may be due to the fact that it was not practically possible to measure DM intake of kid deriving from diet since kid and dam were together in the same pen. Only kid's ME intake (derived from milk intake) was calculated (Table 5.2).

The influence of previous levels of feeding on dams' final weight and body weight change could be due to the significant effect of feed and metabolisable energy intakes of dams when allocated to different feeding levels where does' weight varied with graded levels of feeding during the interval of two subsequent kiddings. This is in agreement with Sibanda *et al.* (1999) who found that Matebele does previously given different levels of ME gained differently in a subsequent lactation. The variation of dam final weight could be due to physiological changes before kidding where the type of pregnancy would differ among treatments and this is shown by the influence of birth type on body weight of dam in the present study. In fact, age, parity and birth type exerted effect on body weight which may be explained by the characteristic of Red Maradi goat which is reputed as a prolific breed in West Africa (Djariri, 2005) of which prolificacy is influenced by age/parity and the recurring pregnancies increased body size of dam (Mioč *et al.*, 2008).

The significant effect of birth type on kid metabolisable energy intake is a reflection of milk production and the fact that twin kids shared their milk. This is the reason why kids born as singles have higher ME intake than twins. Similar findings were observed by Sangaré and Pandey (2000) in their study on Sahelian goats. Kids weaning weight in the present study overlapped results of Makun *et al.* (2008) working on Sahelian and Red Sokoto goats found weaning weights after three months of 5.6 and 3.9 kg, respectively. However, results in the present study were even lower than observed (9.05 kg) by Djibrillou (1989) during 90 days on the same breed in caprine center of Maradi. Marichatou *et al.* (2002) observed 6.06 kg of kid weight only at 60 days of age on the same breed under village conditions. Similarly, higher weaning weight of 5.41-7.41 kg, 10.46-12.02 kg and 14.41-23.25 kg were reported, respectively, by Sangaré and Pandey (2000) at 3 months of age on Sahelian goat, Shaker Momani *et al.* (2012) at 4 months of age on Sahelian crossed with Anglo-Nubian goats and Mahmoud *et al.* (2012) at 3 months of age on Damascus goats in Sudan. The significant influence of kid initial weight on kid final weight is in agreement with Djibrillou (1989) on the same breed and Sodiq (2004) in his study on Kacang and Peranakan Etawah goats in Indonesia. The average daily weight gain (ADG) in the present study were also lower than those observed by Djibrillou (1989) and Marichatou *et al.* (2002) on the same breed. Similarity, Madibela *et al.* (2002b) and Makun *et al.* (2008) reported higher ADG of 88-92 and 66.9 g/day on Tswana goats in Botswana and Red Sokoto goat in Nigeria, respectively. These differences on weaning weight and body weight gain before weaning compared to other studies might be attributed to experimental conditions, kids' energy intake, perhaps to genotype and genetic dilution of red Maradi goats at Caprine Centre of Maradi.

5.5 Conclusions

The level of feeding affected linearly milk yield, feed intake and ME intake of lactating Red Maradi goats with an increase of body weight change before weaning. Urea treatment did not affect feed intake while crushing of millet stover tended to increase feed intake of lactating does. The effect of previous levels of feeding had effect on final body weight of lactating does. Levels of feeding had positive effect on ME intake, final weight and average daily gain of kids. In the present study, the targeted milk yield was not attained in spite of ME supplied by diet corresponding to the requirements, and kid's growth was very low compared to studies with the same or other breeds. It could well be that the feed intake is low and the genetic potential of Red Maradi goats is limited or even degenerated. Further investigations should be made on how to improve feed intake and the genotype of the breed in Caprine Centre of Maradi.

Chapter 6

Effect of roughage processing and feeding level on production and reproductive performances of does

Abstract

Red Maradi goats from Caprine Centre of Maradi in South of Niger were used from weaning to next kidding to determine the effect of levels of feeding of dams, the effect of urea treatment and crushing of millet stover (MS) on production and reproductive performances of dams. To evaluate these effects, data from previous kidding to subsequent kidding were used. Sixty goats were sorting into six groups of 10, and randomly assigned to six treatments (T1, T2, T3, T4, T5, and T6) with four levels of feeding (g/kg DM): T1 = 842, T2 = T5 = T6 = 934, T3 = 1079 and T4 = 1300 corresponding to 200 g, 400g, 600g and 800g of milk production, respectively. Treatment T1 to T4, millet stover (MS) was crushed and treated with 3% urea, T5 MS was only crushed, and T6 MS was offered whole. Comparison between T2 versus T5, and T6 versus T5 evaluated the effects of urea treatment and crushing of MS, respectively. Heat synchronization was used to reproduce does after weaning kids at three months aged. The feeding level affected ($P<0.001$) linearly and in a quadratic fashion dry matter intake (DMI) and milk yield (myd) of doe while dam final weight (dfwt) was affected ($P<0.001$) in a quadratic fashion. Urea treatment of MS did not affect DMI, myd and dfwt whereas crushing of MS increased ($P<0.001$) dam DMI and dfwt. Pregnancy reduced myd ($P<0.05$) and shortened lactation length (Llact) ($P<0.001$), increased dfwt ($P<0.001$) and average periodic weight change (apwc) ($P<0.001$) of does at the last period of pregnancy. The period of lactation, age, parity, birth type (btype) and dam initial weight (diwt) affected ($P<0.001$) DMI whereas myd and dfwt were affected ($P<0.001$) by period, btype and diwt. The post-partum anoestrus period (Panoest), kidding interval (Kinterv), gestation length (Lgest) and lactation length (Llact) ranged from 66 to 93, 236 to 254, 145 to 150 and 155 to 185 days, respectively. Production and reproduction performances were improved with feeding level.

Keywords: Goat, feeding, milk, reproduction, urea treatment, crushing stover.

6.1 Introduction

The Red Maradi goat is raised in Southern-East of Niger, in Maradi and Zinder regions as its predilection area. Nowadays, this breed is diffused to other regions due to efforts of Government, NGOs and Development agencies. However, the environmental conditions of these zones are different in terms of agro-ecology, production system compared to the predilection habitat of Red Maradi goat. Indeed, the prevailing conditions of other zones are low availability of by-products and crop-residues, long movements in search of pastures, desertification, scarcity of feed, high ambient temperature, and water availability. Red Maradi goat, under extensive system of livestock, are subjected to environmental stresses mostly during the dry season which is characterised by low availability of feeds and water leading mainly to inadequate nutrition and consequently to low production and reproductive performances. According to Chaiyabutr *et al.* (1980), starvation may lead to marked decrease of cardiac output, stroke volume, mammary blood flow, blood volume and the rate of milk secretion. Moreover, Maltz *et al.* (1984) found water deprivation caused body losses of 32 and 23% and plasma volume losses of 30 and 34% in lactating and non-lactating goats, respectively whereas Hossaini-Hilali *et al.* (1994) reported 9 and 6% of body weight loss with lacatating and non-lactating black Maroccan goat, respectively, and a drop of 28% of milk yield.

A recent report from Caprine Centre of Maradi (2014), stated that more than 40% of kiddings each year was obtained in December and 25% in March/April. This is linked to availability of generous pasture in August and crop residues in November/December corresponding to period when high quality feed is available in adequate quantity to support mating. This phenomenon resulted to successful fecundity which agrees with Gordon (1997) who observed that super-ovulation was a response of environmental conditions and good nutrition. Additionally, El-Hag *et al.* (2007) and Idris *et al.* (2010) found that supplementing diet gave high conception and lambing rate. According to Zahraddeen *et al.* (2009a), dietary supplementation improved performance of local goats in semi-intensive system under Sudan Savanah ecological zone of Nigeria. However, harsh conditions had negative impact of reproductive performance (El-Hag *et al.*, 2001). Very little is known about performance of Red Maradi goat under various feeding managements. The objectives of the study were to determine the effects of roughage processing and feeding level of Red Maradi goat on reproductive performances during the interval of two kiddings.

6.2 Materials and methods

6.2.1 Study site

Details of the study site have been given in section 4.2.1. (Chapter 4).

6.2.2 Animals and housing

Sixty lactating does were used. Does were treated against external and internal parasites with Ivermectin (1%). Does were housed in individual pen (2 m x 1.5 m) in the experimental feed unit with free access to a salt lick and potable drinking water. After weaning kids at 3 months age, heat was synchronized to reproduce dams by exposing males after a period of isolation (at one mile away) of one month. In this way oestrus was synchronised in goats. Does typically exhibit oestrus or heat for 24 - 120 hours, suddenly, naturel mating occurs for breeding. This method had good result to less seasonal breeds like Red Maradi goat which can reproduce all year long. All bucks were taking to another herd far away (about 2 km) from the experimental group. The ratio 1 buck/10 does was used of which 35 over 58 does conceived giving conception rate of 60% after three consecutive matings of 18 days periods. Does stayed for six days with bucks in order to cover the entire period of 120 hours of oestrus exhibition. Two does were removed from this study for reasons related to ill-health or sickness prior to synchronisation.

6.2.3 Feeds and feeding management

Feeds and feeding management are the same as described in Chapter 4 and Chapter 5. Untreated and urea treated millet stover, groundnut haulms, wheat bran and cottonseed cake were used as feed ingredients. Diets were formulated using milled (10mm) urea treated or untreated and uncrushed millet stover (MS), crushed groundnut haulms (GH), cottonseed cake (CSC) and wheat bran (WB). Everyday, feed offered and orts in plastic bags were measured with an electronic balance (Santorin 6100 g d = 0.1 g) the previous day in the afternoon just to facilitate the feeding process and measuring intake. An electronic balance and a scale were used for measurements. At the end of the week a composite sample (5%) of diets and refusals were taken and stored and at the end of the experiment, representative samples (5%) of diets offered and refusals were collected for chemical analyses.

6.2.4 Experimental design

Sixty lactating does were blocked according to weight, parity and litter size were block and randomly placned into six groups of 10 animals each (see section 4.2.5), which were randomly allocated to six dietary treatments, making a total of 10 does per treatment. These six dietary treatments were offered to lactating does from 3 months post kidding until the subsequent kidding.

6.2.5 Measurements

At the beginning (evening of day 90 and morning of day 91) and end (last measurement before kidding) of experiment, body weights of dams were taken during two consecutive days after starvation for 12 hours from 1800 to 0600h. The body weight of each dam corresponded to an empty body weight. Empty body weights of dams were recorded every two weeks from weaning until kidding. Feed offered and refusals were measured daily in order to determine feed intake. Milk yield was recorded every two days from weaning until dry period when milk yield decreases to 1/5th (100 g) of maximum yield or at a level when farmers stop milking their does. The onset of post-partum oestrus was recorded from day of kidding to the first oestrum of doe. The gestation length was from mating/conception to kidding; and lactation length was from kidding until milk yield dropped to below 100 g considered as dry period for smallholder farmers.

6.2.6 Chemical analyses

This section is decribed in Chapter 4 (section 4.2.8).

6.2.7 Statistical analysis

Data were analyzed using the General Linear Model of SAS (Statistical Analysis System) to determine the Least Square Means (LSmeans), means and the level of differences between treatments using the following model for analysis:

$Y_{ijklmn} = \mu + A_i + B_j + L_k + P_l + T_m + G_n + E_{ijklmno}$

Where: Yijklmn is the independent variable (feed intake, milk yield, body weight gain, gestation length, lactation length, kidding interval and oestrus post-natal period); μ is the overall mean; Ai is the effect of dam ages; Bj is the effect of birth type; Lk is the effect of initial body weight; Pl is the effect of parity; Tm is the effect of treatments; Gn is the effect of pregnancy and Eijklmno is the residual error. Linear and quadratic contrasts were used to compare the effect of treatment on feed intake, milk yield, lactation length, final body weight and body weight change during five periods after weaning: P1 (1-3 week), P2 (4-7 weeks), P3 (8-13 weeks), P4 (14-18 week) and P5 (>19 weeks). Categorical data (conception during 1st mating, cumulative mating, kidding interval, and anoestrus period) were analyzed using Chi Square test and the significance differences between treatments on conception rate and kidding rate and to evaluate the kidding intervals of does.

6.3 Results

6.3.1 Chemical composition of feeds and diets

The chemical composition of feeds is shown in Table 4.2 (Chapter 4) and for diets offered and refusals in Table 6.1. Diets had similar chemical composition; however, the NDF and ADF contents in refusals were higher than in feeds offered (Table 6.1).

Table 6. 1 Chemical composition of feeds offered and refusals (g/kg DM)

		Diet1				Diet2	Diet3
Parameters	Feed	T1	T2	T3	T4	T5	T6
DM	Offered	822	822	822	822	949	949
	refusal	965	965	965	965	970	980
OM	Offered	916	916	916	916	916	916
	refusal	951	947	959	952	950	955
NDF	Offered	613	613	613	613	619	619
	refusal	704	708	760	748	752	823
ADF	Offered	385	385	385	385	383	383
	refusal	516	517	568	565	525	576

DM: Dry matter; OM: Organic matter, NDF: Neutral detergent fibre; ADF: Acid detergent fibre.

6.3.2 Effect of feeding levels on feed intake and production performance of dams

The level of feeding affected ($P<0.001$) linearly and in a quadratic fashion dam DM intake (dint) and milk yield (myd) while dam final weight (dfwt) was affected ($P<0.001$) linearly by feeding level (Table 6.2). Pregnancy affected myd ($P<0.05$) and dfwt ($P<0.001$); non-pregnant does had higher myd than pregnant (250 versus 180 g) but had lower dfwt (21.25 versus 24.40 kg) than pregnant ones.

Period of lactation highly affected ($P<0.001$) dint, myd and dfwt. Also treatment interacted with period to affect ($P<0.001$) dint without any effect on myd and dfwt, while the interaction of pregnancy and period affected ($P<0.001$) only dwt but did not exert any effect on dint and myd. Moreover, the three way interaction (treatment x pregnancy x period) had no effect ($P>0.05$) on dint, myd and dfwt.

Table 6. 2 Effect of level of feeding and roughage processing on production performances of dams

Treatment	Dam initial weight (kg)	DM intake (g)	Milk yield (g)	Dam final weight (kg)
T1	20.95	706	198	20.70
T2	22.25	759	216	22.00
T3	22.15	876	241	23.15
T4	24.05	980	332	25.10
T5	22.00	759	206	21.50
T6	20.00	708	200	20.20
Variation sources				
RMSE		88.12	87.51	1.61
Treatment		***	***	***
Pregnancy		NS	*	***
Period		***	***	***
Treat* Period		***	NS	NS
Preg* Period		NS	NS	***
Treat*Preg* Period		NS	NS	NS
Age		***	NS	NS
Parity		***	NS	**
Btype		***	***	***
diwt		***	***	***
Linear		***	***	***
Quadratic		***	***	NS
Contrast				
T2 vs T5		NS	NS	NS
T6 vs T5		***	NS	***

Diwt: dam initial weight; DM: dry matter; Treat: treatment; Preg: pregnancy; Wk: week; Btype: birth type; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

Both age and parity affected (P<0.001) dint but not myd. The birth type (btype) or type of kidding and dam initial weight (diwt) affected (P<0.001) dint, myd and dfwt. Consequently, dams with twins had higher dint (904 versus 778 g, P<0.001), myd (289 versus 222 g, P<0.001) and dfwt (25.00 versus 21.50 kg, P<0.001). Also a change of 1 kg in diwt would elicit an increase of 0.660 ± 0.022 kg on dfwt (P<0.001), 9.3 ± 0.94 g of feed intake (P<0.001) and 7.38 ± 1.05 g of myd (P<0.001).

6.3.3. Effect of urea treatment and crushing of millet stover on feed intake and production performance of dams

The contrast between treatments 2 versus 5 and between treatments 6 versus 5 showed that urea treatment did not affect ($P>0.05$) dam intake (dint), milk yield (myd) and dam final weight (dfwt) but crushing of millet stover increased ($P<0.001$) dint and dfwt but not myd (Table 6.2).

6.3.4 Effect of level of feeding on average periodic weight change of dams

Feeding level of dams and pregnancy did not affect ($P>0.05$) average periodic body weight change (apwc) (Table 6.3) except during gestation (period 5) corresponding to the period from 2^{nd} month to 5^{th} month of pregnancy in which apwc was affected linearly (at least $P<0.01$) by treatment and pregnancy; consequently, pregnant does gained more (383 versus 118 g) than non-pregnant. However, the interaction between treatment and pregnancy did not affect apwc. All parameters related to dams except diwt and age of dam had no influence ($P>0.05$) on apwc. The apwc was highly affected ($P<0.001$) by diwt during the 1^{st} month post-kidding; and it was affected ($P<0.05$) by the age of doe by the end of gestation.

6.3.5 Effect of urea treatment and crushing of millet stover on average periodic weight change of dams

The contrast between treatments 2 versus 5 and between treatments 6 versus 5 showed that both urea treatment and crushing of millet stover did not affect ($P>0.05$) average periodic body weight change (Table 6.3).

Table 6. 3 Effect of level of feeding and roughage processing on average periodic weight change (g/day) of dams

Treatment	Period 1	Period 2	Period 3	Period 4	Period 5
T1	-619	122	60	-84	159
T2	-647	-144	14	44	154
T3	-379	107	78	-189	353
T4	-653	300	44	-15	456
T5	-303	113	-61	-22	106
T6	-441	-41	-10	-66	251
Variation sources					
RMSE	590.22	371.80	132.96	406.42	140.27
Treatment	NS	NS	NS	NS	**
Pregnancy	-	-	-	NS	***
Treat*Preg	-	-	-	NS	NS
Age	NS	NS	NS	NS	*
Parity	NS	NS	NS	NS	NS
Btype	NS	NS	NS	NS	NS
diwt	***	NS	NS	NS	NS
Linear	NS	NS	NS	NS	**
Quadratic	NS	NS	NS	NS	NS
Contrast					
T2 vs T5	NS	NS	NS	NS	NS
T6 vs T5	NS	NS	NS	NS	NS

Treat: treatment; Preg: pregnancy; diwt: dam initial weight; Btype: birth type; Means in the column with the same lowercase letter are not significantly different at P<0.05; RMSE: Root mean square error; NS (P > 0.05); * (P < 0.05); ** (P<0.01); *** (P<0.001).

6.3.6 Effect of level of feeding on reproductive performance of dams

Feeding levels of dams did not affect (P>0.05) kidding interval (Kinter), gestation length (Lgest), and lactation length (Llact), whereas the anoestrus period (Panoest) was quadratically affected by feeding level (Table 6.4). The age, parity and birth type had no effect on Kinter, Lgest, Panoest and Llact. However, pregnancy shortened (P<0.001) the lactation length of does relative to non-pregnant does (152 versus 197 days).

The contrast between treatments 2 versus 5 and between treatments 6 versus 5 showed that both urea treatment and crushing of millet stover did not affect (P>0.05) kinter, Lgest, and Llact, however Panoest was surprisingly lengthen (P<0.05) by urea treatment (T2 versus T5) (Table 6.4).

Table 6. 4 Effect of level of feeding and roughage processing on kidding interval, gestation length, anoestrus period and lactation length (days)

Treatment	Kinterv	Lgest	Panoest	Llact
T1	237	145	64	175
T2	240	150	93	185
T3	238	147	70	168
T4	236	148	66	171
T5	254	148	73	168
T6	240	147	72	155
Variation sources				
RMSE	13.36	3.46	19.49	25.28
Treatment	NS	NS	NS	NS
Pregnancy	-	-	-	***
Age	NS	NS	NS	NS
Parity	NS	NS	NS	NS
Typeb	NS	NS	*	NS
Linear	NS	NS	NS	NS
Quadratic	NS	NS	*	NS
Contrast				
T2 vs T5	NS	NS	*	NS
T6 vs T5	NS	NS	NS	NS

Kinterv: kidding interval; Lgest: length of gestation; Panoest: anoestrus period; Llact: lactation length; Typeb: type of birth; ND: no determined, RMSE: Root mean square error; Means in the column with the same lowercase letter are not significantly different at P<0.05; NS (P > 0.05); * (P < 0.05).

6.3.6.1 The conception rate and kidding rate

Levels of feeding had no effect (P>0.05) on the rate of conception of does in this study (Figure 6.1), however, the rate of conception tended to increase with feeding levels of dams. Once does were confirmed pregnant, they all kidded, hence the kidding rate was similar to conception rate. The pregnancy status of does was confirmed by the three oestrus synchronisations applied in this study. Naturally, a buck would not mate conceived does. This helped to indicate pregnant does subsequently after oestrus synchronisations.

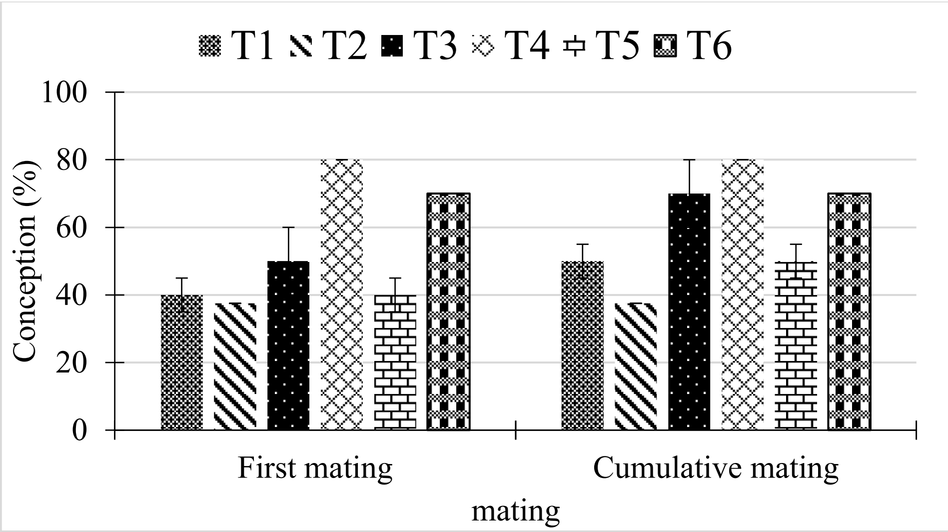
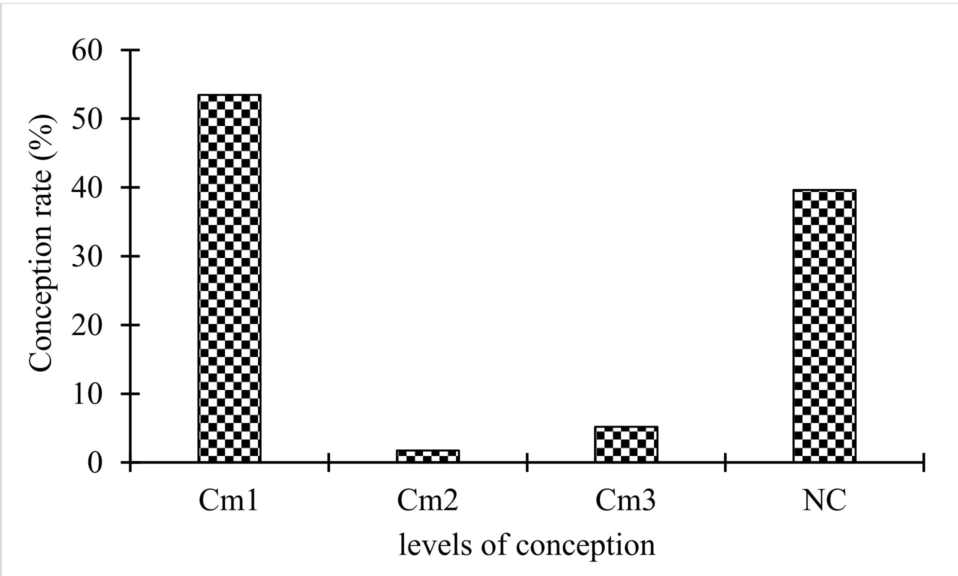


Figure 6.1 Effect of dietary treatment on conception rate of does

The conception rate of the experimental herd differed (P<0.001) among the three mating sessions; first mating had the highest conception rate (54% of the herd) and the second had the lowest. Forty percent of does failed to conceive after third mating (Figure 6.2) and were removed when the pregnant ones started giving birth.



Cm1: conception rate at the 1st mating; Cm2: conception rate at the 2nd mating; Cm3: conception rate at the 3rd mating; NC: non conception after three mating.

Figure 6.2 Conception rate of the herd

6.3.6.2 The kidding intervals

Greater number of does (54%) had kidding intervals between 211-241 days whereas 40% of does did not conceive (Figure 6.3).

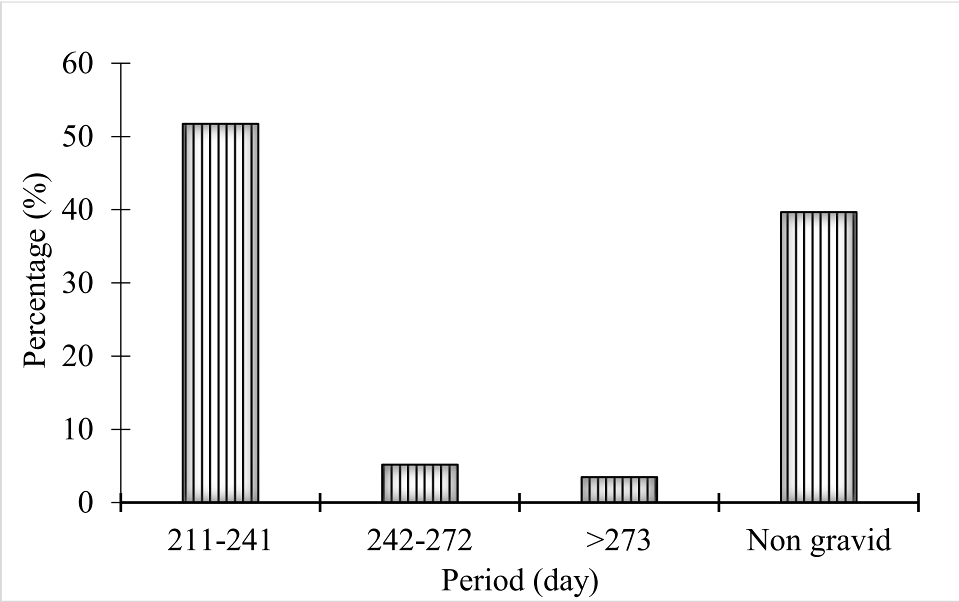


Figure 6.3 Kidding interval of does

6.3.3.3 Anoestrus period

Greater proportion of does (50%) had anoestrus period between 75 to 105 days (Figure 6.4).

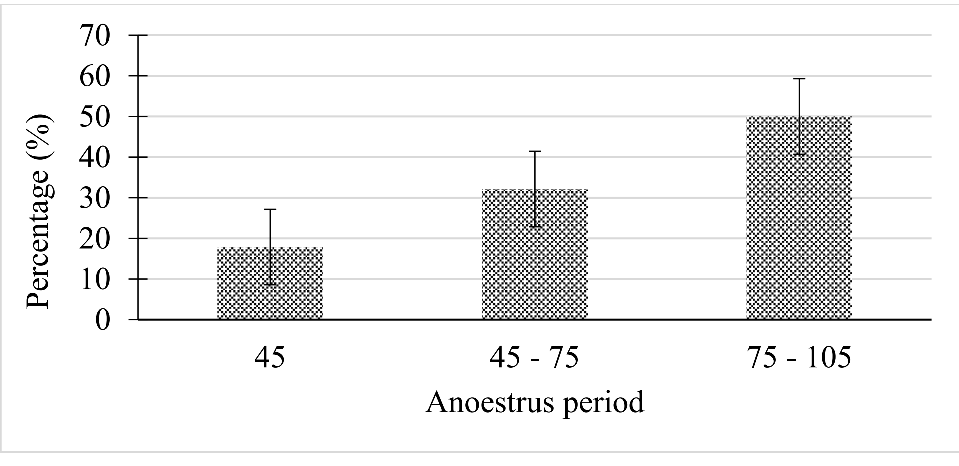


Figure 6.4 Anoestrus periods of does

6.4. Discussion

The levels of feeding affected dam intake and milk yield in agreement with Luka and Kibon (2014) who found that feed intake and milk yield of Red Sokoto goats increased with concentrates supplementation. Similarly, Chobtang *et al.* (2009) reported that increasing level of feeding resulted in a linear increase of final body weight of goat. However, Goetsch *et al.* (2001) reported a non-significant effect of graded levels of feeding on feed intake and milk yield in Alpine dairy goat. Milk yield values in the present study are lower than those reported by Robinet (1967) on Red Maradi goat (600 g for 200 to 220 days of lactation), Mioč *et al.* (2008) on Saanen (2.63 kg/day) and Alpine (2.08 kg/day) dairy goats. Values of feed intake ranging from 72.10 to 90.24 g/kg $W^{0.75}$/d in the present study were relatively similar to those reported by Fedele *et al.* (2002) on Maltese goats during dry to gestation periods (74.68 to 89.03 g/kg $W^{0.75}$/d) but lower than for lactation period (96.084 to 120.59 g/kg $W^{0.75}$/d) of same species (Fedele *et al.* (2002) . However, our values of feed intake were higher that values of 60 g/kg $W^{0.75}$ /d for on West African Dwarf goats (Adenuga *et al.* (1991)) and 27.74 to 48.75 g/kg $W^{0.75}$ /d for Matebele goats (Sibanda *et al.* (1999) but lower than values (102-116 g/kg $W^{0.75}$/day) obtained by Chowdhury *et al.* (2002) with German Fawn goats and recommended values of 119.6g /kg $W^{0.75}$ /d (AFRC, 1998). The significant effect of levels of feeding on dam final weight (dfwt) is in agreement with work of Goetsch *et al.* (2001). This may be due to an increase in dry matter intake and nutrient intake with increasing feeding levels of dams attributable to feed utilisation in order to meet requirements of host body and those of development of foetus and milk production.

The relative increase of conception rate with increasing levels of feeding is in agreement with others (Amoah *et al.*, 1996; Gordon, 1997; Webb and Mamabolo, 2004; Mellado *et al.*, 2006; Hart, 2008; McKenzie-Jakes, 2008) and this may be due to higher nutrient intakes of T3 and T4 and the good quality of T6 where does selected the more palatable parts of the diet. In fact, favourable season with feeds availability in quantity and quality may influence positively the conception rate.

Urea treatment is known to increase feed intake because it reduces lignification and increases the rate of digestion. However, after kidding the intake of lactating does was low but increased thence. That is why there appears to be an increase of feed intake with stage of lactation due to the physiological changes of does (Fedele *et al.*, 2002). Secondly, the environment was dry and hot with low humidity, so treated feed dried out quite rapidly as shown by DM of refusals; thus, there was no difference in DM intake between T2 and T5. Furthermore, at this phase of lactation does were able to eat enough feed to meet the ME requirements for maintenance and milk yield. In fact, treatments T2 and T5 had the same level of feeding and similar weight, suggesting an intake capacity 3-4% of body weight (Rashid, 2008) which is still not reached; so the improvement of DM intake with physiological changes may explain the no-effect of urea treatment in agreement with Djibrillou *et al.* (1998) for Red Maradi goats. The increase of anoestrus period by urea treatment is difficult to explain as other does were also fed on the same diet with urea treatment.

Goats change their feeding behaviour according to diet availability (Fedele *et al.*, 1993; Papachristou, 1994). Goats, more than other species, are selective animals and are able to choose among the available feedstuffs parts of plants with the highest protein content and the highest digestibility. They select feed on the basis of prehension ease, sensorial characteristics and post-ingestive effects learnt from their own experience (Provenza *et al.*, 2003). Goat behabiours would explain why DM intake was higher with T5 than T6 diet. Crushing (T5) of millet stover reduced particle size and made it easy to be ingested in diet formulated with palatable ingredients according to physiological change of lactating does (Fedele *et al.*, 2002). Based on NDF (g/ kg DM) of feed offered and orts refused, goats offered long millet stover were able to select only what they ate for example leaves and sheaths, and goats offered crushing millet stover were able to ingest various parts justifying higher intakes with T5 than T6.

Pregnant does had lower milk yield than non-pregnant ones in accordance with work of Salama *et al.* (2005) who found in Murciano-Granadina dairy goats that pregnancy reduced milk yield. According to Irshad (2015), pregnancy has an inhibitory effect on milk production and the increase in estrogen and progesterone level during pregnancy inhibits milk secretion. In fact, final body weights of pregnant does were higher than that of non-pregnant does which could be explained by increased body size and development of the foetus. Periodic variation of dam intake and milk yield may be due to physiological changes of body weight with advancing lactation and pregnancy as shown by the present results where periodic average weight change significantly increased with increasing levels of feeding and pregnancy at the end of gestation.

That increasing parity and age of dam increased dam's intake could be explained by physiological changes of dam with age/parity which increased dam's body weight (Mioč *et al.*, 2008) and consequently, increased feed intake since body weight is correlated to DM intake (Rashid, 2008). Twinning relative to single birth increased DM intake and milk yield agree with Chowdhury *et al.* (2002) using German Fawn goats. Similarly, Hassan *et al.* (2010) reported for Jamunapari goats that dams had higher milk yield with twin than with single kids. Similar findings were observed by Zahraddeen *et al.* (2009a) in their study with Red Sokoto goat that does kidding single had lower milk yield than does kidding twins. The influence of dam initial weight on loss of body weight at the beginning of lactation agrees with earlier reports (Djibrillou *et al.*, 1998; Casals *et al.*, 2006; Otaru *et al.*, 2011) and this could be explained by loss of appetite at the post kidding period when does mobilises body energy to satisfy requirements of milk production for new born kid.

A greater proportion of does had kidding interval between 211 and 241 days which is similar to the work of Webb and Mamabolo (2004) who found average kidding interval of 238 days but lower than that observed by Ndlovu and Simela (1996). However, Marichatou *et al.* (2002) observed in traditional farming conditions of Maradi area, higher average values of 386 and 363 days with Red Maradi goat and its relative Black goat, respectively, and explained that the relatively long interval in traditional system may be due to few bucks in villages particularly when goats are kept at home for a period of about six months during the rainy season (June to November). Wilson (1991) reported various values, 240 ± 57.8 (n = 51) days at Shika (Nigeria) and 332 ± 109 (n = 665) days in Niger traditional system and noted that the kidding interval is influenced by abortion, kid deaths and the season of previous kidding. Thus, intervals following an abortion (220 ± 16 (n = 59)) and those following kid deaths in the first 15 days of life (269 ± 22 (n = 32)) were shorter than all intervals. Kidding interval obtained in this study were higher than 204 days reported by Sodiq (2004) with Kecang goats of Indonesia. The relatively high kidding interval in the present study may be explained by experimental conditions where oestrus synchronisation was started later after weaning kids (at 91 days).

The gestation length and anoestrus period in the present study were higher than those (135.4 - 143.9 days and 51 days) reported by Hassan *et al.* (2010) with Jamunapari goats respectively, but the observed (152.8 ± 17.6 days) gestation length by the same authors with Jamunapari goats was similar to our observation. The higher lactation length of non-pregnant does than the pregnant is in agreement with Salama *et al.* (2005) reporting that lactation can last for long without kidding. The lactation length in the present study is higher than 120 days observed by Akpa *et al.* (2001) with Red Sokoto goats. The persistency of lactation length of 152 and 197 days for pregnant and non-pregnant does respectively was high and demonstrates the ability of Red Maradi goat to maintain milk production throughout the year with non-pregnant does.

6.5 Conclusions

Levels of feeding affected linearly dry matter intake, milk yield, and final body weight of lactating Red Maradi goats during interval of two kiddings. Urea treatment did not affect feed intake and milk yield, whereas crushing of millet stover increased intake and final body weight of doe. There was linear increased in live weight change with increasing feeding level during late pregnancy.The expected milk yield was not obtained due to low feed intake despite that the rationed diets met nutrients requirements to attain our goals. Further investigation is required based on production system, nutritional status and selection aspects to improve the breed.

Chapter 7

General discussion, Conclusions and Recommendations

7.1 General discussion

In tropical countries, feeds and feeding strategies are the main constraints of livestock production (Nsahlai *et al.*, 1998; Savadogo *et al.*, 2000; Abdou *et al.*, 2011) particularly in Niger where rainy season is too short (three to four months) with often a decreasing rainfall, and the dry season is too long (eight to nine months) with acute forage shortages occurring from March to June. To avoid under feeding and ensure at least animal maintenance, farmers store crops residues and bush straws largely of low nutritive value, they have high fibre content which limit their degradability in the rumen and therefore their low intake; hence, animals fed with these feeds performed poorly (Ayantunde *et al.*, 2007; Abdou *et al.*, 2011). Thus, there is a need to develop more efficient ways of utilizing these available feed resources.

The overall goal of this study was to improve the milk production of Red Maradi goat breed and the growth performance of its kids by efficient use of feeds available in the study area. Specifics hypotheses were: (1) feeds differ according to their nutritive value; (2) feeding lactating does with different levels of feeding, crushing and urea-treatment of stover influence post-natal performance of kids; (3) previous level of feeding and roughage processing influence the post-natal performance of dams and kids; (4) feeding levels of lactating does, crushing and urea-treatment of stover influence dam production and preweaning growth performance of kids; (5) pevious level of feeding and roughage processing do not affect dam and kids performances before weaning; (6) feeding levels of lactating does and roughage processing influence production and reproductive performance of does.

Chapter 3 dealt with the determination of nutrive value of feeds available in Maradi area of Niger. The three type of analyses showed that feed classes (cereal straws, legume crops residues and concentrates) differed in nutritive value; and within each class feeds also had differences. Cereals straws affected fibre fractions of cell wall (NDF, ADF, Hcel, Cel and lignin). Their NDF and ADF were higher than for legume crop residues. Treating roughages with urea did not affect cell wall content except cellulose but increased their N content. Urea-treating cowpea husk also reduced only cellulose but increased strongly its N content. The superiority of cell wall content in cereal straws than in legume crop residues and concentrates is similar to findings of others (Chenost and Kayouli, 1997; Jayasuriya, 2002b; Abdou *et al.*, 2011). The slight decrease in fibre fraction of cell wall with urea treatment is contrary to Wanapat *et al.* (2009) and may be due to a feeble urea dose (3%) used in the current study.

High variation of *in sacco* and *in vitro* degradation parameters between feed and within feed classes may be due to difference in physical characteristics and chemical composition which agree with earlier reports (Vitti *et al.*, 1999; López *et al.*, 2005; Maghsoud *et al.*, 2008).The increase rate of degradation (c) and effective degradability (ED) with cereal straws as a result of urea treatment may be due to increased nitrogen content and availability of OM which can stimulate bacteria synthesis in the rumen and cell wall digestion (García-Martínez *et al.*, 2009; Abate and Melaku, 2009). The fact that urea treatment increased Trdeg, MY and (C) confirms an increase in quality and is associated increased rumen microbial activity, cell wall digestion (Chenost and Kayouli, 1997; Owen *et al.*, 2012) and ME value. Based on the response of urea treatment of roughages, the nutritive value, and availability of feeds, millet stover, groundnut haulms, wheat bran and cottonseed cake were chosen to formulate diets for subsequent experiments. Effects urea treatment on roughages were well observed through *in vivo* and *in vitro* analyses whereas proximate analysis showed an increase of N content but no significant effect on fibre content. It is important to note that proximate analysis alone is not sufficient to determine nutritive value of feeds; *in sacco* and/or *in vitro* analysis should be combined.

Chapter 4 dealt with the effect of feeding levels of lactating does on post-natal performance of kids before 14 days. There was a linear increase of dry matter intake (DMI) and dams' metabolisable energy intake (dMEi) with increasing level of feeding which may be explained by increasing levels of feeding. However, milk yield did not increase significantly despite the linear increase in dry matter and metabolisable energy intakes which may be explained by low DM and ME intakes and the energy mobilized from body tissue for milk production at the early stage of lactation. The variation of kid metabolisable energy intake among treatments may be due to birth type, variation in kid initial weight and probably to colostrum intake which had higher ME than normal milk.

Urea treatment of millet stover increased DMI intake compared to the untreated one. This may be explained by the fact that urea treatment on millet stover wetted and perhaps softens the feed and increased its digestibility thereby heightening its appeal and palatability which is in agreement with others (Wanapat *et al.*, 2009; Gunun and Wanapat, 2012; Gunun *et al.*, 2013) who reported increased DMI after treating cereal straws with urea. The no-effect of crushing millet stover (CMS) on DMI was contrary to our expectation and may be attributable to goats' behaviour.

All group of lactating does during the first two weeks postpartum lost body weight in agreement with Greyling *et al.* (2004) using indigenous and Boer goats in South Africa and Djibrillou *et al.* (1998) with Red Maradi goat. This loss of body weight may be due to lower DM and ME intakes after kidding and therefore does mobilize own energy reserves to satisfy the extra energy requirement for milk production at this particular stage of lactation. Djibrillou *et al.* (1998) attributed body weight loss of lactating does to the unbalanced energy requirement and energy provided in the diet.

Chapter 5 dealt with the effect of level of feeding dams on the preweaning growth performance of kids where the levels of feeding increased DMI, ME and milk yield (myd). The increased dam metabolisable energy intake (dMEi) is due to increased DMI. The increase of myd could be explained by increased dMEi which is in agreement with others (Montaldo *et al.*, 1997; Min *et al.*, 2005; Morand-Fehr *et al.*, 2007; Luka and Kibon, 2014). However, the daily milk yield was still lower than expectation in the present study or observed in other studies with Red Maradi (Sokoto) goat (Djibrillou *et al.*, 1998; Luka and Kibon, 2014) and Sahelian goat (Sangaré and Pandey, 2000). The low milk yield observed in the current study may due to low DMI and therefore low metabolisable energy intake.

Kid metabolisable energy intake (KMEint) increased with level of feeding dams but the KMEint is lower than requirements of Sahlu *et al.* (2004) and NRC (2007). This may be due to the low consumption of milk and ME as milk yield was relatively low, which could explain the low growth rate of kids before weaning. Kid weaning weights in the present study are quite similar to those reported by Makun *et al.* (2008) and lower than those reported by others (Djibrillou, 1989; Sangaré and Pandey, 2000; Marichatou *et al.*, 2002). Differences in weaning weights of kid might be attributed to kids' ME intake and partially to experimental conditions, perhaps to genotype and genetic dilution of red Maradi goats at Caprine Centre.

In Chapter 6, the effect of feeding levels on production and reproductive performance of dams were studied between interval of two kiddings, where DMI, myd and dam final weight (dfwt) increased with levels of feeding in agreement with others (Chobtang *et al.*, 2009; Luka and Kibon, 2014). The relatively low milk yield in the present study could be attributed to lower feed intake and therefore lower ME intake compared to recommended value (AFRC, 1998), and perhaps to genotype and genetic dilution of red Maradi goats at Caprine Centre of Maradi. The relative increase in conception rate with increased feeding level is in agreement with others (Hart, 2008; McKenzie-Jakes, 2008) and may be explained by an increase of nutrients intake with graded levels of feeding.

7.2 Conclusions and recommendations

Cereal straws have low nutritive value and legume crop residues and concentrates have higher nutritive value; therefore the latter two can be used to supplement and improve the nutritive value of cereal straws based diets. Urea treatment of cereal straws improved quality of straws by increasing their N, reducing lignin and fibre, increasing digestible OM and ME content.

However, urea treatment did not affect the values of *Diheteropogon* but reduced the value of cowpea husk. Further study should be undertaken on *Diheteropogon,* cowpea husk and other affected feeds to investigate why *Diheteropogon* did not respond to urea treatment and why urea-treated cowpea husk deteriorated in quality and emitting nauseous smell. It could well be that treat cowpea husk with urea formed bacteriostatic and/or antibiotic substances which reduced *in vitro* gas production. However, treating cowpea with urea is not necessary because on its own it constitute a good source of protein and energy.

The first fourteen days postpartum is a critical period of lactating does characterized by low DM and ME intakes and high body weight loss of dam. Feeding kid with feeding bottle ensured kid's colostrum intake which had positive impact on kid's survival but probably decreased milk intake. At this stage of lactation urea-treated millet stover increased dam's intake whereas crushing did not which was attributed to physiological changes of doe. To avoid or reduce body weight losses of dam, we recommend special feeding based on diet rich in energy and protein to does during the last weeks of pregnancy. Furthermore, strategies to increase feed intake of doe at this stage is needed.

Levels of feeding had positive effect on dry matter intake, metabolisable energy intake, milk yield, and final weight of dams and kids. They also influenced favourably conception and kidding rates and ensured kid survival. However, DMI and ME intakes of dams were still low, and milk yield was low which led to low growth rate of kids before weaning. Crushing of millet stover increased feed intake with advancing lactation. We recommend that further investigations should be made on feed intake, nutrition and genetic selection of the Red Maradi goat in order to improve this breed in Niger.

7.3 Further Research

In this study, herbaceous forages, crop residues and concentrates were identified as the major options to improve livestock production. In Niger, among livestock enterprises, beyond cattle, goats and particularly Red Maradi goat was chosen to increase smallholder farmers' income. However, livestock is confronted with several adversities such as long dry season with scarcity and low nutritive value of available feed resources. Low production performances of Red Maradi goat and kids were observed in this study. To identify reasons and improve production performances of dams and their kids, further studies should be undertaken:

1. Effect of urea and other alkaline doses on nutritive value of feeds;

2. Effect of urea-treated straws on feed intake and milk production of Red Maradi goat and other goat breeds and ruminant species;
3. Effect of supplementing energy sources during last month of pregnancy and beginning of lactation on production performances of dams and kids;
4. Effect of feeding bottle and natural suckling on milk intake on post-natal performance of kids;
5. Selection of Red Maradi goat based on growth of kid, reproductive performance, milk production and other characteristics of Red Maradi goat;
6. Effect of level of feeding on production performance of selected Red Maradi goat and growth performance of kids before weaning.

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Appendices A

Translated version

Republic of Niger *Ministry of Livestock* *Central Laboratory of Livestock*		*LABOCEL* *PO.Box 485* *District Terminus* *Niamey-Niger* *Tel : (227) 20732009*

RESULTS OF ANALYSES

REF. No. 21/08/2014/DDER/LABOCEL

Owner	Nourou Abdou
Sender (address)	Researcher / INRAN / Maradi
Source	Goat Centre of Maradi
Species	Caprine
Number / herd	85
Number of sick animals	30
Number of dead animals	12
Nature of sample	Blood / EDTA + Liver, lung
Clinical signs	Diarrhea, Lack of appetite, standing hair, weakness
Macroscopic lesions	Friable liver, lung emphysema
Date and place of collection	24/08/2014
Samples received on:	26/082014 at diagnosis service
Suspicion:	Pasteurellosis
Examinations : - Hematocrite in hemoparasitology - Isolation in bacteriology	- Variable hematocrit from 18 to 39% - Culture on middle and TCS Kligler helped to isolate bipolar Coccobacillus negative GRAM characteristics of *Pasteurella multocida*
Conclusions	**Presence of Pasteurellosis and surinfestation due to anaplasmosis.**
Recommendations	**Antibiotic treatment (oxy 5 %) + Ivermectin + Fercobsan.**

The General Director

Dr ZANGUI I.M.Sani

Central Laboratory of Livestock (LABOCEL) diagnostic division SDER LABOCEL / Niamey 03/09/2014 13:05:24/GMT

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RESULTATS D'ANALYSES

REF.N°21/08/2014/DDER/ LABOCEL

Propriétaire	Nourou Abdou
Expéditeur (Adresse)	Chercheur / INRAN/Maradi
Localité	Centre Caprin de MARADI
Espèce	Caprine
Effectif /troupeau	85
Nbre de malades	30
Nbre de morts	12
Nature du Prélèvement	Sangs/ EDTA+ Foie, Poumon
Signes Cliniques	Diarrhée, inappetence, poils piqués, faiblesse
Lésions macroscopiques	Foie friable, emphysèmes pulmonaires
Date et lieu prélèvement	Le 24/08/2014
Date d'arrivée prélevt.	Le 26/08/ 2014 au service du diagnostic
Suspicion	Pasteurellose
Examens effectués: - Hématocrite en hémoparasitologie - Isolement en bactériologie	- Hématocrite variable de 18 à 39% - la culture sur milieux TCS et Kligler a permis d'isoler des cocobacilles GRAM négatifs de type bipolaires caractéristiques des Pasteurella multocida
Conclusions	**Il s'agit de la Pasteurellose et d'une surinfestation dûe à l'Anaplasmose.**
Recommandations	**Traitement antibiothérapeutique (oxy5%)+ Ivermectine + Fercobsan.**

Le Directeur Général

Le Directeur Général

Dr ZANGUI I.M.Sani

Laboratoire Central de l'Elevage (LABOCEL) division diagnostic SDER LABOCEL/ Niamey 03/09/201413:05:24 /GMT

Appendices B

Appendix 1: Caprine Centre of Maradi

Appendix 2: Crushing of millet stover (MS) Appendix 3: Urea treatment of millet stover

Appendix 4: Urea treatment of millet stover

Appendix 5: Stored urea-treated MS

Appendix 6: End of urea treatment of M. S

Appendix 7: Diet formulation

Appendix 8: Pregnant doe

Appendix 9: Kidding twins

Appendix 10: Hand milking after kidding

Appendix 11: one of kids’ pen

Appendix 12: Feeding bottle

Appendix 13: Weighing kid

Appendix 14: Weigh-suckle-weigh

Appendix 15: Heat synchronisation

Appendix 16: Water distribution

Appendix 17: Weighing doe

Appendix 18: Two students for traineeship during 3 months