INFLUENCE OF AGE AND BODY CONDITION ON SEMEN QUALITY, TESTICULAR AND BODY DIMENSIONS IN RED SOKOTO GOATS OF TWO HAIR TYPES

By

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DEPARTMENT OF ANIMAL SCIENCE,
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MARCH, 2014

DECLARATION

I hereby declare that the work in this thesis titled **"INFLUENCE OF AGE AND BODY CONDITION ON SEMEN QUALITY, TESTICULAR AND BODY DIMENSIONS IN RED SOKOTO GOATS OF TWO HAIR TYPES"** was performed by me at the Experimental and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University Zaria, under the supervision of Prof. G.N. Akpa and Prof. A.I. Adeyinka. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented in any previous application for another degree or diploma at any institution.

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CERTIFICATION

This thesis titled **"INFLUENCE OF AGE AND BODY CONDITION ON SEMEN QUALITY, TESTICULAR AND BODY DIMENSIONS IN RED SOKOTO GOATS OF TWO HAIR TYPES"** by Abdulfatai Lekan AMBALI meets the regulations governing the award of the degree of Master of Science Degree of Ahmadu Bello University, Zaria and is approved for its literary presentation and contribution to scientific knowledge.

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DEDICATION

With deep sense of gratitude, I dedicate this work to Almighty Allah and to my entire family for their undying love, support and prayers throughout the period of study.

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ABSTRACT

The study was conducted (July, 2011 – June, 2012) to determine the influence of age and body condition on semen quality, testicular and body dimensions in Red Sokoto goats of two hair types using 31 Red Sokoto bucks. The ages of the bucks were categorized into four; 9 -12, 13-16, 17-20 and 21-24 months. The hair types were categorized into short-smooth (SS) and long-curly (LC). The body condition was scored and categorized as score 3 and 4. Weight records and linear body measurements were obtained. Testicular length and testicular circumference were measured using flexible tape while testicular width and testicular weight were estimated using the appropriate formulae. The semen trait, sperm morphological defects and semen cation concentrations were evaluated accordingly. The results showed that the mean BW, HG, ST, CW, WH, BD, BL, RW, TL, TC, TW and TWT were 15.02 Kg, 59.9 cm, 54.95 cm, 8.37 cm, 53.41 cm, 32.86 cm, 57.35 cm, 17.03 cm, 12.00 cm, 17.38 cm, 5.53 cm and 203.04 g; while 0.52, 0.64, 0.52, 1.03, 0.61, 94.90, 67.79, 2.62, 5.42 were for DMT, MPD, DH, CBT, ACR, Na, K, Ca and PO_4, respectively. Semen volume, sperm motility, semen pH, sperm concentration and live & dead ratio were 0.42 ml, 79.52 %, 8.85, 701.13 x 10^6/ml and 0.82 %, respectively. Age and BCS significantly ($P<0.01$) influenced BW, body conformation and testicular traits, but had a variable influence on semen traits. DMT, MPD and CBT were more frequent in younger-matured bucks of between 13 and 20 months of age than bucks of later ages while DH and ACR occurred in the younger (9 – 12 months) and older bucks (21 – 24 months of age). Semen cation concentrations were relatively higher in the older bucks of 21 – 24 months than the younger bucks except for Na^+ which was also high in younger bucks of 9 – 16 months. Hair type had influence ($P<0.01$) on some testicular traits. Long-curly haired bucks had the highest DMT and CBT, while the short-smooth haired bucks had the highest DH. Bucks with lower BCS showed higher DH than bucks with higher body condition. Body measurements correlated positively and significantly with testicular measurements (0.25 – 0.61). Body (0.27 – 0.45) and testicular (0.25 – 0.39) measurements were positively correlated to some semen traits. Relationship between semen cations and sperm morphological traits were generally negative and significant ($r = -0.28$ to -0.40) except ACR which was positively and significantly correlated with Ca^{2+} ($r = 0.37$). Semen volume was positively and significantly correlated with K^+ and Ca^{2+} ($P<0.05$; $r = 0.27$ – 0.31). Sperm motility was positively and significantly correlated with Na^+ and K^+ ($P<0.05$; $r = 0.26$ – 0.33). Ca^{2+} was positively and significantly correlated with testicular measurements ($P<0.05$; $r = 0.34$ – 0.39). Bucks with BCS 4 were bigger in size (HG, ST, WH, BL, RW) and weighed more (BW) and had scrotum that were longer (TL), broader (TC), wider (TW) and heavier (TWT); hence produced more semen (SV) with higher concentration of Na than those with BCS 3. Bucks aged 21-24 months with short-smooth hair and higher body condition gave better testicular dimensions and exhibited less occurrence of sperm abnormality than the young, long-curly haired and lower body condition bucks. Therefore, bucks aged 21-24 months with larger body and testicular size can be exploited for optimum breeding performance. When considering hair type as an

indicator of semen quality, short-smooth haired bucks could be used as selection criteria in Red Sokoto goats.

TABLE OF CONTENTS

TITLE PAGE.....i

DECLARATION..... ii

CERTIFICATION..... iii

DEDICATION.....iv

ACKNOWLEDGEMENTS v

ABSTRACT.....vi

TABLE OF CONTENTS..... vii

LIST OF TABLES..... xi

LIST OF ABBREVIATIONS.....xiii

CHAPTER ONE

1.0 INTRODUCTION.....1

1.1 Background Information.....1

1.2 Justification of Research.....4

1.3 Statement of Research Hypothesis.....5

1.4 Objectives of the Study.....5

CHAPTER TWO

2.0 LITERATURE REVIEW.....6

2.1 Goat Population and Distribution.....6

2.1.1 Red Sokoto Goats.....7

2.2 Qualitative Characteristics.....9

2.2.1 Hair type in goats 9

2.3 Body Weights in Goats.....10

2.4 Body Condition Score (BCS).....14

2.5 Body Linear Measurement (BLM).....17
2.5.1 Heart girth.....18
2.5.2 Height at withers.....20
2.5.3 Body length.....23
2.6 Predicting Body Weight Using Linear Measurements..... 25
2.7 Testicular Biometry in Bucks..... 28
2.8 Fixed Factor Effects on Measured Characteristics..... 31
2.8.1 Effect of age..... 31
2.8.2 Effect of sex.....33
2.8.3 Effect of breed……..... 34
2.8.4 Effect of season..... 35
2.9 Factors Affecting Fertility in Bucks..... 35
2.9.1 Male associated factors..... 35
2.9.2 Season..... 37
2.9.3 Nutrition..... 37
2.10 Semen Characteristics..... 38
2.10.1 Semen collection frequency..... 38
2.10.2 Semen evaluation..... 38
2.10.2.1Semen colour..... 38
2.10.2.2Semen volume..... 39
2.10.2.3Semen pH..... 40
2.10.2.4Sperm motility..... 41
2.10.2.5Sperm concentration..... 41
2.10.2.6Sperm morphology..... 42
2.11 Biochemical Parameters of Semen..... 43

CHAPTER THREE

3.0 MATERIALS AND METHODS..... 45

3.1 Experimental site..... 45

3.2 Experimental Animals and their Management..... 45

3.3 Data Collection..... 46

3.3.1 Body weight measurement..... 46

3.3.2 Body linear measurement..... 46

3.3.3 Testicular measurement..... 47

3.3.4 Semen collection and evaluation..... 48

3.3.4.1 Semen collection..... 48

3.3.4.2 Semen evaluation..... 48

3.4 Determination of Factors..... 50

3.4.1 Age determination..... 50

3.4.2 Hair type..... 51

3.4.3 Body condition score (BCS)..... 51

3.5 Statistical Analysis..... 52

CHAPTER FOUR

4.0 RESULTS..... 54

4.1 Body Conformation, Testicular and Semen Characteristics..... 54

4.2 Sperm Morphological Characteristics and Semen Cation Concentrations..... 63

4.3 Correlated Relationships Between Body Conformation, Testicular and Semen Characteristics in Bucks..... 69

4.4 Correlated Relationships Between Sperm Morphological

Characteristics and Semen Cation Concentrations in Bucks..... 79

CHAPTER FIVE

5.0 DISCUSSION..... 91

5.1 Body Conformation, Testicular and Semen Characteristics..... 91

5.2 Sperm Morphological Characteristics and Semen Cation Concentration..... 100

5.3 Relationships Between Body Dimensions, Testicular and Semen Characteristics in the Bucks..... 106

5.4 Relationships Between Sperm Morphological Characteristics and Semen Cation Concentrations in Bucks..... 112

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS..... 118

6.1 Summary.....118

6.2 Conclusions.....121

6.3 Recommendations.....122

References.....123

LIST OF TABLES

TABLE PAGE

Table 2.1 Live body weight of some goat breeds of the world…… 12

Table 2.2 Heart girth (cm) of some goat breed of the world…… 19

Table 2.3 Body height at withers (cm) of some goat breed of the world……. 21

Table 2.4 Body length (cm) of some goat breed of the world…….. 24

Table 2.5: Composition of seminal plasma in ruminant
(Values are mg/dL unless otherwise stated)..... 45

Table 4.1: Summary statistics for body and testicular measurements
and semen characteristics in Red Sokoto buck..... 56

Table 4.2: Effect of age, hair type and body condition score on body
weight and body conformation traits in Red Sokoto bucks..... 59

Table 4.3: Effect of age, hair type and body condition score on
testicular measurement in Red Sokoto bucks..... 61

Table 4.4: Effect of age, hair type and body condition score on semen
characteristics in Red Sokoto bucks..... 63

Table 4.5: Summary statistics for sperm morphology and cation
concentration in Red Sokoto bucks..... 65

Table 4.6: Effect of age, hair type and body condition score on sperm
morphology in Red Sokoto bucks..... 67

Table 4.7: Effect of age, hair type and body condition score on
semen cation concentration in Red Sokoto bucks..... 69

Table 4.8: Correlated relationships among body conformation traits in
Red Sokoto bucks..... 71

Table 4.9: Correlated relationships among testicular characteristics

in Red Sokoto bucks..... 72
Table 4.10: Correlated relationships among semen characteristics in Red Sokoto bucks..... 73
Table 4.11: Correlated relationships between body and testicular Conformation trait in Red Sokoto bucks..... 75
Table 4.12: Correlated relationships between body conformations and semen characteristics in Red Sokoto bucks..... 77
Table 4.13: Correlated relationships between testicular measurements and semen characteristics in Red Sokoto bucks..... 79
Table 4.14: Correlated relationships among sperm morphological traits in Red Sokoto bucks..... 81
Table 4.15: Correlated relationships among semen cation concentrations in Red Sokoto bucks..... 82
Table 4.16: Correlated relationships between sperm morphology and semen cation concentrations in Red Sokoto bucks..... 83
Table 4.17: Correlated relationships between semen and sperm morphological characteristics in Red Sokoto bucks..... 85
Table 4.18: Correlated relationships between testicular measurements and sperm morphological traits in Red Sokoto bucks…..... 86
Table 4.19: Correlated relationships between body conformations and sperm morphological traits in Red Sokoto bucks..... 87
Table 4.20: Correlated relationships between semen characteristics and semen cation concentrations in Red Sokoto bucks..... 89
Table 4.21: Correlated relationships between testicular measurements and semen cation concentrations in Red Sokoto bucks..... 90
Table 4.22: Correlated relationships between body conformation and semen cation concentrations in Red Sokoto bucks..... 91

LIST OF ABBREVATIONS

ACR	Acrosome
AI	Artificial insemination
BCS	Body condition score
BD	Body depth
BL	Body length
BLM	Body linear measurement
BSE	Breeding soundness examination
BW	Body weight
Ca	Calcium
CBT	Coiled and bent tail
CW	Chest width
DH	Detached head
DMT	Detached midpiece and tail
HG	Heart girth
HW	Height at wither
K	Potassium
LC	Long-curly
MPD	Midpiece droplet
Na	Sodium
PO_4	Phosphate
RSG	Red Sokoto Goat
RW	Rump width
SP	Seminal plasma
SS	Short-smooth
ST	Stature
SV	Semen volume
TC	Testicular circumference
TL	Testicular length
TW	Testicular width
TWT	Testicular weight
WAD	West African Dwarf

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Livestock of different species fulfill different functions in the household economy and poor families often keep a diversity of species for this reason (Anderson, 2003). Domestic goats (*Capra hircus, L.*) are important and adaptable domesticated animals (Abdel-Aziz, 2010). They provide a full range of useful products to humans including meat, milk, skin and hair. They efficiently survive on available shrubs and trees in harsh environment and in low fertility lands where no other crops can be grown in Nigeria. Goat production over the years has been one of the major means of improving the livelihoods of poor livestock keepers, reducing poverty and attaining sustainable agriculture and universal food security (Abdel-Aziz, 2010). The population of goats in Nigeria is estimated at 53.8 million (FAOSTAT, 2011) of which traditionally reared stock contributes 99.97%, while 0.03% of the stock is commercially managed. Based on morphology, the two most important goat breeds traditionally recognized in Nigeria are the Red Sokoto (RS) and the West African Dwarf (WAD) goats (Ebozoje and Ikeobi, 1998).

In order to develop a very good model for the genetic improvement of goats, it is important to measure the traits of interest with some high level of accuracy. Since goats are mostly kept for their meat, the most important trait of interest for genetic improvement is the body weight. Body weight is often the most common and informative measure of animal performance (Adeyinka and Mohammed, 2006).

It has been found to be very effective in assessing the reproductive efficiency and performance in goats (Bongso *et al*., 1984) and provide readily obtainable and informative measure for selection, feeding and health care (Thiruvenkandan, 2005). Numerous studies have been carried out on the linear measurements of Nigerian breeds of goats and their relationship with economic characteristics, reproductive performance and possible use for estimating the animals' live weight (Akpa *et al*., 2010; Adeyinka and Mohammed, 2006), but very few have explored the use of testicular measurements for the same purpose. Bongso *et al*. (1984) reported that males with higher values of testicular parameters had higher body weight.

Body size and testicular traits of domestic animals are important parameters in breeding soundness evaluations. The extent of growth in body and testicular sizes determines the production of viable spermatozoa and the ultimate number of progeny. The testicular size has been shown to be a reliable measurement of the reproductive growth status, spermatogenic capacity and seminal characteristics (Keith *et al*., 2009). Body size, as expressed via body weight and physical linear measurements, is closely associated with testicular mass, a phenomenon which explains why testicular growth occurs in parallel to increase in body size (Ahmad *et al.,* 1996; Mekasha *et al*., 2007a).

In environment with high ambient temperature and intense solar radiation, characteristics like coat pigment and hair type may play a vital role in adaptation. Importance of hair type had also been stressed for heat absorption and heat loss and thus, for adaptability of animals (Banerji, 1984). Animals with a wooly coat type are less adaptable to hot climates (Peters *et al*., 1982). Bucks show lower reproductive activity during high ambient temperatures (Roca *et al*., 1992).

Sperm morphology is used as one of the most important criteria in the evaluation of semen quality (Bearden and Fuquay, 1997). In artificial insemination, the genetic impact of a superior buck is determined by the number of does inseminated and this is limited by the number of sperm and quality of semen. However, before considering the sequences of events at insemination, an understanding of good quality semen is desirable (Hunter, 1985). The quality of semen in relation to fertility is determined by the volume of ejaculate, sperm concentration and motility, percent of live sperm and the sperm morphology. The knowledge on correlations of male reproductive traits among themselves and with other variables such as age, weight, and body condition and testis size might have important bearings to indicate the real producing ability of a male for sperm output and quality of semen. Poor sperm morphology is an indicator of decreased fertility in many species, including goats (Chandler *et al*., 1988). An accurate morphological examination of spermatozoa thus enables the elimination of males with potentially low fertility prior to the preservation of their semen (Rodriguez-Martinez and Barth, 2007).

Mineral concentrations in the seminal plasma provide the congenial milieu for the survival of sperms (Kalita *et al*., 2006). The concentrations of different elements in seminal plasma also reflect the quality of semen and physiological status of reproductive accessory gland (Kalita *et al*., 2006). It is known that the seminal plasma contains substances that support the sperm cells. Sodium (Na+) and Potassium (K+) cations in the seminal plasma establish the osmotic balance (Zamiri and Khodaei, 2005), also calcium (Ca^{2+}) is needed for stimulation of steriodogenesis in leydig cells of the testis (Henricks, 1991). A large number of reports on the biochemical composition of cattle semen have been published (Rattan, 1990).

But there is scarcity of parallel information about the semen of the Red Sokoto bucks maintained in the northern part of Nigeria. Abnormal levels of Ca, Na, K, Zn, and Cu in seminal plasma have been reported to be correlated with infertility in humans (Nasrin, 2003). Calcium is the trigger for the acrosome reaction in mammalian spermatozoa and there is substantial evidence that Ca is differentially involved in sperm motility, depending on the stage of sperm maturation. However, Magnus *et al*. (1990) reported no association between ionized calcium concentrations and the proportion of spermatozoa displaying progressive movement. In ram, increasing potassium level is negatively correlated to progressive motility, while the reverse is true for sodium and chloride (Abdel-Rahman *et al*., 2000).

1.2 Justification of Research

By using bucks with a high concentration of spermatozoa in their testes, more does per buck can be successfully bred (Gherardi *et al*., 1980). However, evidence of a relationship between testicular size and sperm characteristics is inconclusive. While some researchers suggested that testicular size provided a good index of testicular sperm output in rams (Lino, 1972), others reported that biweekly scrotal measurements were poorly correlated with semen quality in adult rams (Langford *et al*., 1998). Fernandez *et al*. (1990) did not record a relationship between testicular size and sperm production. These conflicting data justify the need for further studies on the relationship between testicular measurements and semen characteristics in bucks. Very few researchers have explored the use of testicular measurements in conjunction with linear measurements for the possible estimation of animals' live weight in Nigerian breeds such as Red Sokoto Goat. Comparative information on this aspect is scarce regarding indigenous bucks in general.

Establishment of measureable criteria for judging breeding soundness and guiding selection of male goats for breeding, have not been fully documented. Breeding soundness examination (BSE) is a valuable, practical tool for the selection of the best breeding bucks in a flock. For Red Sokoto bucks, information is almost non-existent with regards to the relationships between body conformation, testicular traits and reproductive performance under tropical conditions. Paucity of information or lack of systematic research regarding when bucks should be used for breeding or an age range within which semen production attributes are optimal, make it difficult to determine the optimum age range for efficient breeding and semen collection.

1.3 Statement of Research Hypothesis

The study was designed to evaluate the following hypothesis:

Ho: Reproductive performance of Red Sokoto buck is not influenced by body conformation, testicular traits, age, body condition and hair type.

Ha: Reproductive performance of Red Sokoto buck is influenced by body conformation, testicular traits, age, body condition and hair type.

1.4 Objectives of the Study

The objectives of this research were to:

- Determine the effect of hair type, body condition and age on the measured reproductive traits in Red Sokoto bucks
- Investigate the semen quality of the bucks.
- Determine the relationship between body and testicular traits; semen traits, age, hair type and body condition in a bid to predict their association with fertility.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Goat Population and Distribution

Goats are among the earliest animals to be domesticated about 9,000 years ago and rank among important livestock species used for meat production around the world (Galal, 2005). Although goats are found worldwide, this small ruminant specie has been neglected in the livestock sector (Dubeuf *et al.*, 2004). It is estimated that there are 570 goat breeds distributed across the world, of which 89% are found in Africa. Although goats are found in all types of ecological zones, they are concentrated in the tropics, in dry zones and in developing countries (Galal, 2005). Due to their ability to adapt to different environments, goats exhibit large diversity as a result of natural selection under different conditions (Morand-Fehr *et al*., 2004).

The goat population has increased worldwide during the last three decades and is presently estimated at approximately 840 million head (Simela and Merkel, 2008), of which 95% are meat goats (Thompson, 2006). In 2005, approximately 95.8% of the total world goat population was found in developing countries; of these, 43.6% were in Asia, 29.2% in Africa, 21.7% in China and 1.3% in Central America (Olivier *et al*., 2005). Goats are important for both commercial and subsistent farming systems. Commercial farmers keep goats primarily for meat and fibre production, whereas subsistent farmers who cannot afford to keep cattle use them as a source of meat and milk, as well as cash for other expenses (Casey and Van Niekerk, 1988). It has been documented that sheep and goats are the principal domesticated small ruminants in terms of total numbers and production of food and fibre products (Winrock, 1983).

This attribute may partly be due to their lower feed requirements compared to cattle, and because of their body size (Okunlola *et al*., 2010). The goat population in Nigeria makes it the second most important livestock specie. Three main breeds of goats are recognized in Nigeria, the Sahel desert or West African long-legged goat, the Red Sokoto goat and the West African Dwarf goat.

2.1.1 Red Sokoto Goats

The Sokoto Red, Kano Brown or Maradi goat (Maradi is a *Département* of the Niger Republic) is probably the most widespread and well-known type in Nigeria (Haumesser, 1975). It is the usual village goat in the northern two-thirds of the country although it is less common with transhumant pastoralists. The goat is distributed in Southern Niger and Northern Nigeria between latitude 12^0N and 13^oN and longitudes 4^oEand 5^oE. In Nigeria, their main stronghold is in Sokoto and Kano States. The highest population of goat of about 2.7 million heads has been recorded for Kano and lowest with 2.0 million heads for Zamfara State. The South-West zone had about 4.2 million heads with Oyo State having the highest population of 2.9 million goats (FMARD, 2002).

The goat is uniformly dark glossy red in colour. The skin is light, thin and supple due to very fine pattern of hair follicles. Skin has coarse, thinly-spaced outer hairs and small sweat and waxy glands lacking fats. Female body weight influences birth weight of the young. They are not heavy milkers with average daily milk yield of 0.47-0.66 kg (Akpa *et al*., 2002a, 2004), and may increase in case of multiple births or heavy body weight. The sex ratio is 29% males and 70.3% females. Horn are present in both sexes, ears are short, medium width and usually carried horizontally.

The mature average live weight is 25 kg (23-30 kg) (Ngere, 1985). Height at withers averages 62 cm (Yakubu and Mohammed, 2012). The average flock size is 19.2 (range of 2-70). Ngere *et al*. (1984) argue that populations of the Sokoto Red spread south and east from Sokoto through the savanna belts giving rise to the Kano Brown and, further east, to the Sahel types of Borno State. This type of historical speculation is difficult to accept without more detailed evidence. The most complete overview of the breed is Robinet's (1967) comprehensive survey which integrates data from Nigeria and Niger. The Sokoto Red is the only Nigerian breed for which there is a record of systematic attempts to stabilize a particular type. Henderson (1929), reviewing the work of the Veterinary Service in Sokoto Province, described how, in 5 years, 219,688 non-red male goats were castrated resulting in the replacement of non-red skins by the more valuable red in the local markets.

The Sokoto red goat was the source of 'Morocco leather' known in Europe from the medieval period onwards. It acquired this name because it was transported across the Sahara by caravans controlled by Moroccan merchants. The Sokoto Red is still known for its suitability for fine leather. The skin is reputed to be of high quality; therefore, it is used in the leather industry locally and internationally (Akpa *et al*., 1998). Alaku and Moruppa (1983) found that Red Sokoto goats slaughtered in the driest months suffered a 55% reduction in skin weight; making it 4.9% of the total body weight. The milk yield is around 0.5 kg in dry season and up to 1.5 kg in wet season. Kidding normally occurs in three or four times in two years.

2.2 Qualitative Characteristics

Qualitative traits are those that can be categorized like coat colour, hair type, presence/absence of horns and/or beard, facial profile etc. According to Oseni *et al*. (2006), varied expression of qualitative traits may represent some adaptive mechanisms related to adaptation and survival in different ecological zones in the country. This is substantiated by the report of Odubote (1994) on the influence of certain qualitative traits on the genetic potential or adaptability of Nigerian goats. In environments with high ambient temperature and intense solar radiation, characteristics like coat pigment and hair type may play a vital role in adaptability. Importance of hair type had earlier been stressed for heat absorption and heat loss and thus, for adaptability in ruminant animals (Banerji, 1984).

2.2.1 Hair type in goats

Hair is a filamentous biomaterial that grows from follicles found in the dermis (Wikipedia 2007). Each strand of hair is made up of the medulla, cortex, and cuticle (Meyer *et al.*, 2002). Hair is one of the defining characteristics of mammals. Most common interest in hair has been focused on hair growth, hair types and hair care (Yilmaz *et al.*, 2010). The shape of the follicle determines the shape of the cortex, and the shape of the fibre is related to how straight or curly the hair is (Wikipedia 2007).

Hair types in goats have been categorized into coarse and smooth (Yakubu *et al*., 2010a). The authors explained further that, structurally, the hair type of female Red Sokoto and WAD goats (90.81 and 84.44%) were smoother than that of the male (86.08 and 74.01%). Ozoje (2002) investigated some qualitative traits and their relationship with body measurement in West African Dwarf goats. The author found smooth hair to be the

predominant hair type in the goats.

He explained further that body of goats with smooth hair was significantly longer compared to those with wool. Tantia *et al*. (2001) had also categorized goat hair into long, medium, smooth, straight and curly. In relation to production traits, Acharya *et al*. (1995) discovered that long-haired Sirohi goats performed better than their short haired counterparts.

2.3 Body Weight in Goats

Body weight is the measurement used mostly to evaluate body development and carcass characteristics in animals (De Brito Ferreira *et al*., 2000). It is often the most common and informative measure of animal performance (Adeyinka and Mohammed, 2006) and has been found very effective in assessing the reproductive efficiency and performance in goats (Bongso *et al*., 1984). Body size and shape measured objectively could improve selection for growth by enabling the breeder to recognize early maturing and late maturing animals. Knowing the body weight of goat could also be exploited in adequate feeding and health care (treatment doses of antibiotics, anthelmintics, etc) and better estimate of potential profit (Slippers *et al*., 2000; Thiruvenkadan, 2005). Knowing the approximate BW, would allow the producer to make good sound management decision. However, it is not easily measured in the field. This is due to the time and energy expended while determining it; and the non-availability of weighing scales especially in the small scale farming sector (Mani *et al*., 1991; Nesamvuni *et al*., 2000).

The body weight of Red Sokoto goats at various growth stages has been recorded by many authors. Akpa *et al.* (1998) recorded overall mean body weight at 1-6, 7-12, 13-18, 19-24,

25- 30, 31-36 months to be 10.2±0.87, 14.8±1.07, 17.3 ± 0.93, 19.8 ± 0.50, 31.3 ± 1.21 kg respectively.

Hassan and Ciroma (1992) found the average mean bodyweight of 201 male and female goats in three age groups (1-2, 3-4, 5 years and above) to be 16.41, 22.94, 30.02 kg. Nuru (1985) reported body weight at birth that ranged 1.5 – 2.0 kg, while at 3 months was 7 – 12 kg and weight at 12 months was 15 – 17 kg. However, three months body weight of Red Sokoto goat in Niger was reported by Ourmara (1989) to be 9.05 kg. Yakubu and Mohammed (2012) reported that the body weight of Red Sokoto goat averaged 22.32 kg, while Okpeku *et al*. (2011) reported 18.99 kg. Lower body weight of 4.33 and 7.55 kg at 0 - 1 and 1 – 2 age group was recorded for WAD bucks (Fajemilehin and Salako, 2008), which is at variance with the observation of Ojedapo *et al*. (2007) who recorded higher body weight of 18.9 Kg for adult WAD goats.

In addition, Ngere *et al*. (1984) and Osuhor *et al*. (2002) had reported heavier weights for adult bucks compared with doe which is in agreement with the observation of Adeyinka and Mohammed (2006), Khan *et al*. (2006) and Okpeku *et al*. (2011). However, Ojedapo *et al*. (2007) and Fajemilehin and Salako (2008) recorded more weight for does than bucks in WAD goat. Red Sokoto goats had also been shown to have higher body weight (25.99kg) than the Borno White (23.71 kg) (Raji *et al*., 2008). There was a wide variation in body weight of different breeds of goats (Table 1.1). Appreciable weight of 34.9±5.22 kg was recorded for pubertal Boer goats approximately, 8-9 months of age (Keith *et al.*, 2009), while Okere *et al*. (2011) reported BW of 40.7±5.01 kg for Kiko bucks. Egwu *et al*. (1995) reported birth weight of 1.2-2.0 kg in Red Sokoto goats and Sahel goats while the WAD was 1.0-2.0kg. Makun *et al*. (2008) reported birth weight in Red Sokoto and

Sahelian goats kids to be 1.0 Kg and 2.2 Kg, respectively; while they reported their weaning weight to be 18.9 kg.

In another study, the Red Sokoto goat kids were reported to weigh about 1.5-2.0 kg at birth while adults weighed between 20-35 kg (Osuhor *et al*., 2002). The kids of Sahelian goats weighed between 2.1-2.8 kg at birth and mature adults weigh between 31-50 kg (Akinwole *et al*., 1991).

Table 2.1: Live body weight (Kg) of some goat breeds in different countries

Breed	Country	Sex	Mean((±se)	References
Alpine	France	Male	77	Briggs and Briggs (1980)
Alpine	France	Female	61	Briggs and Briggs (1980)
Altai Mountain	Russia	Male	65-70	Mason (1988)
Altai Mountain	Russia	Female	41-44	Mason (1988)
Anglo-Nubians	UK	Male	79	Briggs and Briggs (1980)
Anglo-Nubians	UK	Female	61	Briggs and Briggs (1980)
Angora	Turkey	Male	82-102	Briggs (1969)
Baltistani	Pakistan	-	25-30	Khan *et al.* (2005)
Barbari	India	Male	37.8±1.96	FAO (1982)
Barbari	India	Female	22.6±0.32	FAO (1982)
Bari	Pakistan	-	25-30	Khan *et al*. (2005)
Beetal	India	Male	41.47±1.63	Khan *et al*. (2006)
Beetal	India	Female	33.95±4.97	Khan *et al*. (2006)
Belgian Fawn	Belgium	Male	65	Mason (1996)
Belgian Fawn	Belgium	Female	60	Mason (1996)

Bengal	West Bengal	Male	32.4±2.74	FAO (1982)
Bengal	West Bengal	Female	20.4±0.16	FAO (1982)
Bengal	Assam	Male	15.4±0.58	FAO (1982)

Table 2.1 (Continued): Live body weight (Kg) of some goat breeds in different countries

Breed	**Country**	**Sex**	**Mean((±se)**	**References**
Bengal	Assam	Female	14.3±0.20	FAO (1982)
Black Bengal goat	Bangladesh	Male	21.82 ±0.70	Rahman *et al*. (2008)
Boer	USA	Male	50-61	Mason (1988)
Boer	USA	Female	41-45	Mason (1988)
Borno White	Nigeria	-	23.71	Raji *et al.* (2008)
Brown Shorthair	Czech R.	Male	63-86	Matlova (1998)
Brown Shorthair	Czech R.	Female	54-64	Matlova (1998)
Changthangi	India	Male	29.8±0.3	Misra *et al*. (1998)
Changthangi	India	Female	23.5±0.3	Misra *et al*. (1998)
Damascus	N. Cyprus	Female	50-60	Mason (1996)
Damascus	Turkey	Female	50-60	Mason (1996)
Damascus	Israel	Female	40-60	Devendra (1989)
Damascus	N. Cyprus	Male	60-90	Mason (1996)
Damascus	Turkey	Male	60-90	Mason (1996)
Damascus	Israel	Male	50-60	Devendra (1989)
Desert Black goat	Egypt	Male	31.3	Ahmed *et al*. (2002)
Desert Black goat	Egypt	Female	27.3	Ahmed *et al*. (2002)
Girgentana	Sicily	Male	65	Milerski and Mares(2002)
Girgentana	Sicily	Female	45	Milerski and Mares(2002)
Hair	Turkey	Female	40-45	Yalcin (1986)

Hairy goat	Pakistan	-	25-30	Khan *et al.* (2005)
Jining Grey	China	Male	33.2	Cheng (1986)
Jining Grey	China	Female	25.4	Cheng (1986)

Table 2.1 (Continued): Live body weight (Kg) of some goat breed in different countries

Breed	**Country**	**Sex**	**Mean((±se)**	**References**
Kiko goat	USA	-	40.7	Okere *et al*. (2011)
Mubende	Uganda	-	23.52	Semakula *et al.* (2010
Red Sokoto	Nigeria	Male	24.01	Hassan and Ciroma(1992)
Red Sokoto	Nigeria	Female	21.65	Hassan and Ciroma(1992)
WAD goat	Nigeria	-	15.37	Okpeku *et al*. (2011)
Sahel	Nigeria	-	23.48-32.03	Oyeyemi *et al*. (2011)
Russian White	Russia	Female	50-60	Dmitriez and Ernst (1989)
Russian White	Russia	Male	60-70	Dmitriez and Ernst (1989)
Sahelian	Mali	Male	38.6-56.7	Mason (1996)
Sahelian	Mali	Female	25-34	Mason (1996)
Tapri	Pakistan	-	20-25	Khan *et al*. (2005)
Thuringian	German	Male	55	Mason (1996)
Thuringian	German	Female	48	Mason (1996)
W. Shorthaired	Czech R.	Male	68-86	Matlova (1998)
W. Shorthaired	Czech R.	Female	54-68	Matlova (1998)

WAD = West African Dwarf, N = number of animal

2.4 Body Condition Score (BCS)

Body condition scores are important in determining the nutritional status of animals. Under-nutrition results in lower BCS. The term body condition refers to fleshiness of an animal (Luginbul, 2002; Thompson and Meyer, 1994) and describes the degree of fatness (Mangione, 2002) or an index to the degree of fatness expressed in the anatomy of the animal that can be viewed by the human eye (GAN Lab, 2001).

Condition scoring is a system of describing or classifying animals by differences in relative body fatness (Thomas and Kott, 2002; Skea, 1990). The advantage of a condition score measurement is that it is easy to learn, fast, simple, cheap, does not require specialized equipment and is sufficiently accurate for many research and management situations (Rutter *et al*., 2002). It is useful not only for research scientists but also for farmers and development planners (Nicholson and Butterworth, 1986; Cisse *et al.*, 1990). Steele (1996) stated that the body condition scoring is a method of assessing the body condition. Due to the fact that goats have very little body fat under the skin, this system really gives a good estimate of the goats` muscle cover.

Santucii *et al*. (1991) reported that body condition score of goats is a measurable parameter and was regularly included in the research programmes of several countries. A system for giving a number or score to describe the degree of fatness was first started in Australia and then widely accepted in the UK and other countries (Gatenby, 1995). The purpose of giving numbers to the condition is to allow a statistical analysis of the data and to facilitate codification on computer files (Nicholson and Butterworth, 1986). Several authors and researchers described the methods of allocating a score or index of body

condition.

Lawrence and Fowler (1998) indicated that the body condition scoring can be a very useful management aid in predicting body composition. The relationship between body weight and condition score on the Rasa Arganesa breed was semilogarithmic, and that between carcass fat depots and condition score was logarithmic (Teixeira *et al.,* 1989).

The correlation of the body condition scores with body weight was also reported by Sanson *et al*. (1993) who reported that body weight and condition scores were highly correlated (0.89) and an analysis indicated that each unit increase in condition score resulted in an increase of 5.1 kg in body weight.

The application of body condition score has been reported by many researchers. Thomson and Meyer (1994) reported that body condition scoring can be used to evaluate the status of the animal and a potential tool for producers to increase production efficiency. Thomas and Kott (2002) stated that the use of both body weight and body condition scoring can help producers make important feed management decisions. Otto *et al*. (1991) examined carcass composition in relation to body condition scoring in cows. They found that one unit change in condition was equivalent to 56 kg of body weight in dairy cow. Total carcass dry matter increased 7.23 percent for each unit increase in the body condition score. Their work demonstrated that the body condition score correlated with body composition and was a useful tool in the field to assess carcass composition.

Aumont *et al*. (1994) studies on Creole goats indicated that composition of muscle and adipose tissue was significantly influenced by body condition score. Some studies have shown that BCS can be used in selecting robust and profitable animals due to its moderate genetic relationship with other functional traits such as body weight and feed efficiency (Coffey *et al*., 2001; Berry *et al.*, 2002), fertility traits and energy balance or metabolic stability (Pryce *et al*., 2001; Dechow *et al*., 2002, 2003; Lopez-Gatius *et al*., 2003). Keith *et al.* (2009) obtained mean values of 4.0±0.77 for body condition score in pubertal Boer goats.

The author recorded a correlation coefficient of r = 0.653 between BW and BCS and r= 0.582 between HW and BCS. However, Nsoso *et al.* (2003) recorded no apparent relationship between body weight and condition score. The authors concluded that BCS is a more useful indicator of seasonal nutritional effects in goat than body weight or heart girth.

2.5 Body Linear Measurement (BLM)

Linear measurement is useful in young animals to enable early assessment of animals for selection and to predict mature rating. The linear body measurements in different livestock species have been studied. For instance, Jeffery and Berg (1972) reported that at maturity, linear body measurements are essentially a constant reflecting heritable size of the skeleton. Linear body measurement has also been studied to demonstrate the effect of cross breeding and as a criterion for selecting replacement stock of animals and for evaluating breeds in a controlled environment (Shrestha *et al*., 1984). Yakubu *et al.* (2010b) made a comparative study of the structural variation between Red Sokoto goat

and WAD goat based on linear body measurements. Okpeku *et al.* (2011) observed that Red Sokoto goats had significantly higher conformation traits compared to their WAD goat counterparts.

The authors also recorded higher values for conformation traits in males compared to females. This is in agreement with the observations of Vargas *et al*. (2007) and Yakubu *et al*. (2010b). However, Yakubu (2009) reported that the body conformation traits of male and female goats were similar, although this submission was for kids compared to data reported for relatively mature animals in other studies. Linear measurement is divided into two groups: Skeletal and Tissue measurement.

Skeletal measurement includes all the height and length measurements, while heart girth, chest depth, punch girth and width of hips etc are the tissue measurement. Fajemilehin and Salako (2008) reported body linear measurements for male and female WAD goats to vary between 33.70 and 39.58 cm, 28.98 and 31.50 cm, 25.68 and 30.49 cm, 28.94 and 34.73 cm and 6.47 and 7.72 cm for male goats; and 41.53 and 59.51 cm, 37.07 and 53.55 cm, 31.30 and 45.22 cm, 37.08 and 50.23 cm, 9.06 and 13.08 cm for female goats for heart girth (HTG), body length (BDL), height at wither (HTW), rump height (RPH) and sacral pelvic width (SPW), respectively.

2.5.1 Heart girth (HG)

Heart girth can be defined as the circumference of the chest immediately behind the fore-legs (Katongole *et al*., 1996; Ojedapo *et al*., 2007) or the circumference of the chest just behind the scapula (Pesmen and Yardimci, 2008). Keith *et al*. (2009) and Alphonsus *et al*. (2010) recorded mean values for heart girth of 64.80 cm and 75.92 cm, respectively in

RSG. Comparable value of 69.81 cm and 65.95±0.69 cm has also been reported by Yakubu and Mohammed (2012) and Okpeku *et al*. (2011) in RSG. However, Adeyinka and Mohammed (2006) obtained lower value of 40.44±1.86 cm in RSG. The authors also obtained 43.65±1.76 cm for heart girth in Borno white goat. Value of 58.21±0.60 cm has been observed in WAD goat (Okpeku *et al*. 2011). Ojedapo *et al.* (2007) had earlier reported mean value of 60.70±0.77 cm in WAD goat.

Khan *et al*. (2006) reported heart girth at 4-12, 13-18, 19-24 and 25-36 months of age to be 59.10±0.86, 66.0±3.19, 70.29±1.19 and 79.63±0.96 for male, while 57.60±0.95, 61.29±1.27, 64.00±0.68 and 70.15±1.80 were obtained for female. Heart girth measurement also varies in different breeds (Table 2.2).

Akpa *et al*. (1998) reported mean values of chest girth in Red Sokoto goats at 1 – 6, 7 – 12, 13 – 18, 19 – 24, 25 – 30 and 31 – 36 months to be 44.6 ± 2.18, 57.7 ± 1.86, 60.1±0.92, 70.9±1.4 and 70.7±1.60cm respectively. Mohammed *et al*. (2006) reported mean heart girth in male at 4 – 12, 13 – 18, 19 – 24 and 25 – 36 months as 59.10 ± 0.86, 66.0 ± 3.19, 70.29 ± 1.19, 79.63 ± 0.96cm while that of females at the same age groups as 57.60 ± 0.95, 61.29 ± 1.27, 64.00 ± 0.68 and 70.15 ± 1.80 cm, respectively in Beetal goats.

Table 2.2: Heart girth (cm) of some goat breeds in different countries

Breed	**Country**	**N**	**Sex**	**Mean((±se)**	**Referen**ces
Abergelle	Ethiopia	-	Female	71.2	Nigatu (1994)
Afar	Ethiopia	-	Female	67.4	Nigatu (1994)
Angora	Turkey	-	Female	64.3-68.9	Yalcin (1986)
Barbari	India	11	Male	75.5±1.25	FAO (1982)

Barbari	India	203	Female	64.3±0.40	FAO (1982)
Beetal	India	12	Male	86.0±1.20	FAO (1982)
Beetal	India	132	Female	73.7±0.70	FAO (1982)
Bengal	West Bengal	4	Male	72.0±1.35	FAO (1982)
Bengal	West Bengal	554	Female	63.2±0.16	FAO (1982)
Borno White	Nigeria	-	Male	48.99	Adeyinka and Mohammed (2006)
Borno White	Nigeria	-	Female	38.32	Adeyinka and Mohammed (2006)
Don	Russia	-	Female	81.7	Dmitriez and Ernst (1989)
Hair	Turkey	-	Female	81.6	Yalcin (1986)
Kiko goat	USA	3	Male	81.7 ± 4.72	Okere *et al.* (2011)
Red Sokoto	Nigeria	-	Male	43.33	Adeyinka and Mohammad (2006)

Table 2.2 (Continued): Heart girth (cm) of some goat breeds in different countries

Breed	**Country**	**N**	**Sex**	**Mean((±se)**	**References**
Red Sokoto	Nigeria	-	Female	37.53	Adeyinka and Mohammad (2006)
Sahelian	Mali	-	Female	62-78	Mason (1996)
Sahelian	Mali	-	Male	70-85	Mason (1996)
S.E. Somali	Ethiopia	-	Female	70.4	Nigatu (1994)
WAD	Nigeria	44	Male	39.58	Fajemilehin and Salako (2008)
WAD	Nigeria	45	Female	50.25	Fajemilehin and Salako (2008

WAD = West African Dwarf, N = number of animal

2.5 2 Height at withers (HW)

This is the distance from the surface of a platform to the withers (Hassan and Ciroma, 1992). It can also be the distance between the most dorsal point of the withers and the ground level (Katongole *et al*., 1996; Ojedapo *et al*., 2007). Alphonsus *et al.* (2010) recorded mean value for HW of 55.4 ± 0.40 cm, while Adeyinka and Mohammed (2006) obtained 40.94±1.91 cm in Red Sokoto goat, respectively. Keith *et al.* (2009); Okpeku *et al*. (2011) and Yakubu and Mohammed (2012) obtained comparable mean value of 62.34 cm, 62.65 cm and 61.04 cm in RSG respectively. Okpeku *et al*. (2011) recorded value of 47.88±0.50 cm, while Ojedapo *et al*. (2007) recorded 44.50±0.58 cm in WAD goat.

Value of 43.94±1.80 cm was observed by Adeyinka and Mohammed (2006) in White Borno goat. Khan *et al.* (2006) reported HW at 4-12, 13-18, 19-24 and 25-36 months of age to be 60.30±1.16, 68.25±1.42, 72.14±0.67 and 82.11±1.02 for male while 56.50±1.28, 63.14±0.55, 66.50±1.18 and 71.42±2.31 were obtained for female.

Varied measurements have been recorded in different goat breeds in different locations (Table 2.3). In the same vein, Akpa *et al.* (1998) has earlier recorded mean values for HW in Red Sokoto goats at 1 – 6, 7 – 12, 13 – 18, 19 – 24, 25 – 30 and 31 – 36 months to be 38.1 ± 2.09 cm, 47.5 ± 3.26, 53.3 ± 1.49, 53.5 ± 1.87, 64.1 ± 0.83, 64.1 ± 0.83 cm for males and 39.7 ± 3.29, 51.0 ± 0.89, 52.8 ± 1.37, 52.9 ± 1.25, 59.7 ± 1.41 and 59.8 ± 1.28 cm for females, respectively.

Table 2.3: Body height at withers (cm) of some goat breeds in different countries

Breed	Country	N	Sex	Mean((±se)	References

Abergelle	Ethiopia	-	Female	65.0	Nigatu (1994)
Afar	Ethiopia	-	Female	60.9	Nigatu (1994)
A. Nubians	UK	-	Female	74	Brigss and Briggs (1980)
A. Nubians	UK	-	Male	87	Brigss and Briggs (1980)
A. White	Spain	-	-	73.64±0.24	Herrera *et al*. (1996)
Angora	Turkey	-	Female	51.3-55.2	Yalcin (1986)
Barbari	India	11	Male	70.7±0.74	FAO (1982)
Barbari	India	203	Female	56.2±0.37	FAO (1982)
Beetal	India	12	Male	91.6±1.97	FAO (1982)
Beetal	India	132	Female	77.1±0.46	FAO (1982)
B. Fawn	Belgium	-	Male	81	Mason (1996)
B. Fawn	Belgium	-	Female	71	Mason (1996)
Bengal	West Bengal	4	Male	58.3±3.16	FAO (1982)
Bengal	West Bengal	554	Female	55.4±0.18	FAO (1982)
Bengal	Assam	25	Male	49.5±0.64	FAO (1982)
Bengal	Assam	137	Female	49.3±0.24	FAO (1982)

Table 2.3 (Continued): Body height at withers (cm) of some goat breeds

Breed	**Country**	**N**	**Sex**	**Mean((±se)**	**References**
Borno White	Nigeria	-	Male	49.81	Adeyinka and Mohammed (2006)
Borno White	Nigeria	-	Female	38.08	Adeyinka and Mohammed (2006)
Creole	Mexico	-	Female	62.7±0.4	Vargas *et al.* (2007)
Creole	Mexico	-	Male	70.1±0.8	Vargas *et al.* (2007)
Criollo	Argentina	-	-	64.1±3.3	Lanari *et al*. (2003)
Don	Russia	-	Female	60.3	Dmitriez and Ernst (1989)
Florida	Spain	-	-	77.91±0.29	Herrera *et al*. (1996)

Girgentana	Sicily	-	Male	70	Milerski and Mares(2002)
Kamori	Pakistan	-	Male	60.30±1.16	Khan *et al*. (2006)
Kamori	Pakistan	-	Female	56.50±1.28	Khan *et al*. (2006)
Granada	Spain	-	-	68.22±0.50	Herrera *et al*. (1996)
Hair	Turkey	-	Female	72.4	Yalcin (1986)
Khari	Nepal	-	-	66.9±0.2	Kuwar (2000)
Kiko goat	USA	3	Male	67.1 ± 4.03	Okere *et al*. (2011)
Red Sokoto	Nigeria	-	Male	44.13	Adeyinka and Mohammad (2006)
Red Sokoto	Nigeria	-	Female	37.75	Adeyinka and Mohammad (2006)
Sahelian	Mali	-	Female	65-75	Mason (1996)
Sahelian	Mali	-	Male	65-85	Mason (1996)
Skopelos	Greece	-	Female	68	Pappas *et al*. (1992)
Tswana	Botswana	50	Male	65.1±0.6	Nsoso *et al*. (2004)
Tswana	Botswana	50	Female	56.3±4.5	Nsoso *et al*. (2004)
Thuringian	German	-	Male	78	Mason (1996)
Thuringian	German	-	Female	74	Mason (1996)

Table 2.3 (Continued): Body height at withers (cm) of some goat breeds

Breed	**Country**	**N**	**Sex**	**Mean((±se)**	**Reference**
WAD	Nigeria	44	Male	30.49	Fajemilehin and Salako (2008)
WAD	Nigeria	45	Female	34.72	Fajemilehin and Salako (2008)

WAD = West African Dwarf, N = number of animal

2.5.3: Body length (BL)

Body length is the distance from the external occipital protuberance to the base of tail (Hassan and Ciroma, 1992) or the distance from the anterior point of the shoulder to the

posterior extremity of the pin bone (Katongole *et al.*, 1996; Ojedapo *et al.*, 2007). It is also distance from occipital joint to the first caudal vertebra (Pesmen and Yardimci, 2008). The mean body length in Red Sokoto goat has been reported to be 59.0 ± 0.43 cm (Alphonsus *et al.*, 2010); 64.58 cm (Keith *et al.*, 2009); 51.63 cm (Yakubu and Mohammed, 2012) and 57.89±0.53 cm (Okpeku *et al.*, 2011), respectively. Adeyinka and Mohammed (2006) had also reported 43.73±1.77 cm as mean value for RSG and 46.69±1.80 cm as value for White Borno goat.

Okpeku *et al.* (2011) recorded value of 44.86±0.50 cm, while Ojedapo *et al.* (2007) obtained 44.30±0.70 cm in WAD goat, respectively. Khan *et al.* (2006) reported body length at 4-12, 13-18, 19-24 and 25-36 months of age to be 59.60±0.74, 64.38±1.39, 69.42±0.29 and 78.15±0.60 cm for male while 58.70±0.84, 60.14±0.50, 62.16±0.60 and 69.31±1.85 cm were obtained for female. According to Akpa *et al.* (1998), the mean body length of Red Sokoto goats for age group 1 - 6, 7 – 12, 13 – 18, 19 – 24, 25 – 30 and 31 – 36 months of age were 36.7 ± 2.36, 44.5 ± 0.50, 51.0 ± 0.99, 55.7 ± 2.09 and 63.3 ± 2.20 cm, respectively in males, while the females had 39.7 ± 3.29, 50.8 ± 0.83, 53.7 ± 1.43, 53.8 ± 1.48, 61.5 ± 1.00, and 62.1 ± 0.97cm respectively. Table 2.4 gives value for other breeds of goat across the globe.

Table 2.4 Body length (cm) of some goat breeds

Breed	**Country**	**N**	**Sex**	**Mean((±se)**	**References**
Angora	Turkey	-	Female	53.6-55.7	Yalcin (1986)
Barbari	India	11	Male	70.5±1.43	FAO (1982)
Barbari	India	203	Female	58.7±0.38	FAO (1982)
Beetal	India	12	Male	85.5±1.49	FAO (1982)

Beetal	India	132	Female	70.4±0.88	FAO (1982)
Bengal	West Bengal	5	Male	63.2±2.14	FAO (1982)
Bengal	West Bengal	554	Female	51.2±0.16	FAO (1982)
Bengal	Assam	25	Male	53.8±0.72	FAO (1982)
Bengal	Assam	137	Female	54.8±0.26	FAO (1982)
Borno White	Nigeria	-	Male	51.07	Adeyinka and Mohammed (2006)
Borno White	Nigeria	-	Female	42.31	Adeyinka and Mohammed (2006)
Don	Russia	-	Female	64.5	Dmitriez and Ernst (1989)
Hair	Turkey	-	Female	71.5	Yalcin (1986)
Kiko goat	USA	3	Male	69.5 ± 5.56	Okere *et al*. (2011)
Red Sokoto	Nigeria	-	Male	45.80	Adeyinka and Mohammad (2006)
Red Sokoto	Nigeria	-	Female	41.66	Adeyinka and Mohammad (2006)
Skopelos	Greece	-	Female	56.0	Pappas *et al*. (1992)
WAD	Nigeria	44	Male	31.50	Fajemilehin and Salako. (2008)
WAD	Nigeria	45	Female	44.03	Fajemilehin and Salako. (2008)

WAD = West African Dwarf, N = number of animal

2.6 Predicting Body Weight Using Linear Measurements

Numerous studies have been carried out on the linear measurements of many Nigerian breeds of goats and their possible use for estimating the animals' live weight; Sahel goats of Nigeria (Mohammed and Amin, 1997), Red Sokoto goats (Hassan and Ciroma, 1992; Akpa *et al*., 1998; Adeyinka and Mohammed, 2006; Akpa *et al*., 2009; 2010), West African Dwarf goat (Mayaka *et al.,* 1995). In some other regions of the world similar studies have been carried out (Islam *et al.,* 1991; Slippers *et al.,* 2000; Singh and Mishra, 2004; Hamayun *et al.,* 2006, Khan *et al.,* 2006). Body measurement is important for the prediction of live weight, carcass weight and determination of certain body conformation

traits that can be taken into consideration in selecting animals for genetic improvement (Akpa *et al.,* 2006). Estimating live weight using body measurements is practical, faster, easier, and cheaper in the rural areas where the sources are insufficient for the breeder (Nsoso *et al.*, 2003).

According to Oseni and Ajayi (2008), conformation traits that were highly correlated with body weight include body length, body depth, hearth girth, height at withers and height at rump. Moruppa and Ngere (1986) and Osinowo *et al.* (1989), obtained higher correlation coefficients between linear traits and body weight in the females compared to the males in RSG. The authors explained that body weight could be predicted more accurately in the female than in the male. Otoikhian *et al.* (2008) showed that there is a positive correlation between increase in body parameters measured with weight gain. This means that animals at different age groups have differences in measurement of body parts (Osinowo *et al.,* 1989; Otoikhian *et al.,* 2008).

Yakubu *et al*. (2007) made a comparison of the linear and non-linear models in the estimation of body weights from body measurements in West Africa Dwarf (WAD) goats in North Central Nigeria and confirmed that linear body measurements can be used to assess the live body weights of WAD goats.

Akpa *et al.* (1998) reported that Red Sokoto goats' body weight was significantly and positively correlated with body length (0.74, 0.63, 0.60 and 0.65), height at withers (0.79, 0.60, 0.51, 0.47 and 0.46) and chest girth (0.72, 0.57, 0.76, 0.72, and 0.75) at 1-6 months,

7-12 months, 13-18 months, 19-24 months, 25-36 months, respectively. They concluded that based on the magnitude of the correlations, heart girth and body length could be used to estimate body weights in Red Sokoto goats across all ages. Similarly, Yakubu and Mohammed (2012) revealed that body length had the highest direct effect on body weight, which is closely followed by chest girth in Red Sokoto goats. Mohammed *et al*. (2006) reported that body weight was correlated with body length (r == 0.49, 0.12, 0.70 and 0.78) in beetal goats. Ojedapo *et al*. (2007) reported a high and positive correlation between body length and body weight in West African Dwarf goats.

Alphonsus *et al*. (2010) used a combination of HW, BL, and CG to predict body weight in Red Sokot goat. The authors concluded that combination of linear body measurements can be used with high degree of reliability to estimate body weight in Red Sokoto goats. Adeyinka and Mohammed (2006); Yakubu (2009); Semakula *et al.* (2010) and Fajemilehin and Salako, (2008) also supported the use of two or more linear traits in multiple regression to predict body weight in goats. Studies have also shown that there are high and significant correlations between height at withers, heart girth and body weight at 1-2years of age, suggesting that either of these variables or their combination could provide a good estimate for predicting live weight in Red Sokoto goat at an early age (Hassan and Ciroma, 1992).

Thiruvenkadan (2005) reported a high correlation between height at withers and body weight in males of 6- 9 months and 9 – 12 months and in females of 0 – 3 months. Similar findings have been observed by Eugena (2010) and Attah *et al.* (2004). Hamayun *et al.* (2006) observed high and significant correlation coefficient (r = 0.638 and r = 0.552) between height at withers, heart girth and body weight at 4 to 18 months of age

respectively, in Beetal goats. Suggesting that either of these variables or their combination would provide a good estimate for predicting live body weight in Beetal goat at an early age. Similar trend was also reported in Red Sokoto goats (Moruppa and Ngere, 1986; Akpa *et al.,* 2009).

The highest correlation co-efficient value was found between chest girth and body weight followed by Horn base circumference and body weight (Bello and Adamu, 2012). It was concluded that the two traits could be used to predict the body weight of castrated savannah brown goats. Osinowo *et al.* (1992); and Ozoje and Herbert (1997) observed that measurement of the chest girth was effectively used to estimate live body weight of Yankasa sheep and Red Sokoto goats under field conditions. De Villiers *et al*. (2009) obtained a regression coefficient of heart girth measurement against body weight of 0.895 in goat, which demonstrated a strong relationship between the two variables. A correlation coefficient of r = 0.839 was also established between BW and heart girth in pubertal Boer male goats. Badi *et al*. (2002) proved that heart girth is the best parameter for estimating the body weight in Eritrean goat and that the height at wither can be used as a supplementary variable that can provide additional information.

In another study by Isaac and Ibrahim (2006), chest girth recorded the highest correlation with body weight in both sexes. Their report was an indication that chest girth succeeded in estimating body weight more than any of the other linear body measurement. Giving the impression that heart girth might give the best estimate for predicting live weight in Red Sokoto goats. Isaac and Ibrahim (2006) concluded that although chest girth is the most highly correlated trait to body weight, combining it with other linear body measurement

(height at withers and body length in a stepwise multiple regression) will produce the best predication equation for body weight.

Thiruvenkadan (2005) suggested that the higher association of body weight with chest girth was possible due to relatively larger contribution in body weight by chest girth (consisting of bones, muscles and viscera). Slippers *et al.* (2000) investigated the relationship between heart girth and body weight in 54 Nguni goats and concluded that predicting the body weight of Nguni goats from measurement of their heart girth is easy and accurate. Slippers and co-authors suggested, however, that the method needed to be refined, to allow for possible differences in the body weight-heart girth relationship between heavily pregnant does and other does. Otoikhian *et al.* (2008) revealed that up to 74.4% of body weight can be assessed without having to weigh the goat. This is supported by Ensminger (2002), who developed a BW equation where the heart girth is squared, multiplied by body length and then divided by 300.

2.7 Testicular Biometry in Bucks

Testicular traits are important variables directly associated with sperm features and animal fertility. The shape and content of the scrotum are associated with fertility parameters (Coulter and Foote, 1977).

Scrotal circumference (SC) and testicular consistency (TC) have been extensively used in predicting the reproductive capacity of male domestic animals (Toe, 2000; Ugwu, 2009; Antonio *et al.*, 2011). This is because scrotal circumference is an indirect measurement of testicular weight and a reliable indicator of testicular growth and spermatogenic capacity of the testis (Daudu, 1984). Likewise, testicular weight (TW) is a reliable variable for estimating the sperm production capacity of males. Animal size and traits such as birth

weight (BW) are closely associated with testicular weight (Nsoso *et al*., 2003). Keith *et al.* (2009) reported high and positive correlation between testicular measurement and body conformation traits (HG, HTW and BL) in pubertal Boer goat bucks while Bitto and Egbunike (2006) recorded high correlations between body weight and testicular morphometry in WAD bucks. These finding are in consonance with the observation of Koyuncu *et al.* (2005); Rajuana *et al*. (2008) and Agga *et al*. (2011).

Antonio *et al*. (2011) evaluated scrotal-testicular biometry on Brazilian goats, in the rainy and dry periods of the year. They obtained high values of SC (24.63 cm/ 26.97 cm), SL (16.61 cm/ 18.24 cm), TL (5.32 cm/ 5.93 cm), and TV (173.81 cm^3 / 203.01 cm^3) in dry and rainy periods, respectively. They explained further that the goats demonstrated higher values of scrotal perimeter and testicular length in the dry year period, an observation also made by Almeida *et al*. (2010). Similarly, Villar *et al*. (1993) and Campos *et al*. (2003), suggested an interference of season on the size of the male organs. Moreira *et al*. (2001) observed that the increase in the environmental temperature promote a negative influence correlation on the scrotal circumference and testicular length. However, Bitto and Egbunike (2006) reported that testicular and epididymal morphometry of WAD bucks were unaffected by season ($P<0.05$).

According to Colas *et al*. (1990), age and body weight of Kivircik ram lambs were positively correlated with the five testis measurements investigated ($r = 0.722 – 0.953$). However, body weight was more closely correlated with testis measurements than age. Similarly, Salhab *et al*. (2001) reported high significant correlations between body weight and testis parameters. The authors explained that testicular and scrotal parameters were positively correlated with each other ($r = 0.806 – 0.953$) with testicular length having the

highest correlations with the other testicular measurements. Kabiraj *et al.* (2011) conducted biometrical study of testes in black Bengal bucks of three different age groups, 0.5 to 1.0 years (group A), 1.5 to 2.0 years (group B) and 2.5 to 3.0 years (group C). The author recorded an increase in testicular measurements as age and body weight increased. Age has also been reported to influence testicular traits in Ethiopian bucks (Mekasha *et al*., 2008).

Waheed *et al.* (2011) reported correlation coefficients of testicular length with body length, heart girth, body weight, rump height and withers height to be 0.206, 0.180, 0.304, 0.365 and 0.347, respectively. According to Raji *et al*. (2008), Borno White had longer scrotal length (15.12 cm) than the Red Sokoto goats (12.91 cm) while scrotal circumference and testes weight were significantly higher in the Red Sokoto. The authors also recorded highest correlation coefficient (0.74 and 0.82) between Scrotal length and body weight in both Red Sokoto and Borno White goats, respectively. Alade *et al.* (2007) had reported similar findings in Red Sokoto and Sahel goat, respectively. Salhab *et al*. (2001) and Shoyombo *et al.* (2012) suggested the use of testis length and testicular weight in estimating testicular growth and in selecting bucks for reproductive purposes.

Ugwu (2009), working to determine the relationship between scrotal circumference (SC), *in situ* testicular measurements and sperm reserves in WAD bucks. The author showed that SC had highly significant correlation with testis (0.86). SC was also significantly correlated with TL (0.72) and TW (0.65), while TL and TW *(in situ*) were correlated respectively with testis sperm (0.70 and 0.55). Daudu (1984) had earlier reported similar

relationships between scrotal circumference and sperm reserves of the testes in Red Sokoto bucks.

2.8 Fixed Factor Effects on Measured Characteristics

2.8.1 Effect of age

Fajemilehin and Salako (2008) and Semakula *et al.* (2010) reported that age significantly influenced body weight and all the measured linear traits in all age groups and breed of goat considered. They recorded consistent increase in all the traits as the animals aged. This agreed with the reported of Raji *et al*. (2008) on Red Sokoto and Borno White goats; Ebegbulem *et al.* (2011) and Ojedapo *et al*. (2007) on WAD goat and Rahman *et al*. (2008) on Black Bengal bucks, respectively. Age had also been reported to have a significant effect on the body condition score (BCS), body weight (BW) and testicular measurements (testicular diameter, testicular length, testicular volume and testicular weight) in goat (Agga *et al*., 2011). Positive correlation of age with BCS during all seasons has also been reported (Renquist *et al.*, 2006).

According to Kridli *et al.* (2005), age of buck had a significant influence on scrotal circumference and that mature bucks recorded a scrotal circumference of 28.3 ± 0.9 cm compared with 24.8 ± 0.8 cm for yearling bucks.

The author however revealed that age had no significant influence on semen characteristics even though all variables were numerically better in mature bucks. Koyuncu *et al* (2005) and Colas *et al*. (1990) had also reported similar findings. Singh *et al.* (2007) analyzed data on 3531 Jamunapuri goats and reported that age significantly

affected growth traits and live weights. In the same vein, Kabiraj *et al.* (2011) conducted biometrical study of testes in black Bengal bucks of three different age groups, 0.5 to 1.0 years (group A), 1.5 to 2.0 years (group B) and 2.5 to 3.0 years (group C).

They reported an increase in testicular measurements with the advancement of age and body weight in black Bengal bucks. Similarly, Chandan *et al*. (2005) reported that the testicular length, width, thickness and volume were significantly affected by age in five Beetal X Assam bucks investigated. Souza *et al*. (2011) reported that age correlated with all the semen traits investigated in Anglo-Nubian bucks except semen volume, which is in agreement with the observation by Hassan *et al*. (2009). However, Rajuana *et al.* (2008) reported positive correlation of age with semen volume in Black Bengal bucks. This implies that as the age of bucks increases, sperm production are expected to increase proportionately.

In a research by Bitto and Egbunike (2012) to compare semen characteristics of pubertal and adult WAD bucks. They found that adult bucks were significantly superior to pubertal bucks in all the semen traits measured except semen colour and that incidences of abnormal and dead spermatozoa were higher in pubertal compared to adult bucks. Abd-Allah *et al*. (2007) had earlier recommended 2 years of age as optimal age for bucks expected to be used for either natural service or artificial insemination.

Age of the animal is an important physiological factor that modifies the sperm morphological characteristics of domestic animals. This has been demonstrated by earlier studies, which found abnormal sperm head shape to be more prevalent at younger age, to gradually decrease after sexual maturity, and to become greater again at older age,

provided that the animal is healthy (Amann *et al*., 2000).

2.8.2 Effect of sex

Sex is an important source of variation for live body weight and linear body measurements at all age groups. Goats have been reported to exhibit sexual dimorphism in body weight and other body linear measurements (Adeyinka and Mohammed, 2006; Ojedapo *et al*. 2007). Semakula *et al.* (2010) reported that gender significantly influenced body weight, body length, height at withers and heart girth for different age groups with males being generally heavier than females. This is in consonance with observation by Akpa *et al*. (1998); Hamayun *et al*. (2006) and Adeyinka and Mohammed (2006). Fajemilehin and Salako (2008) while working on West African Dwarf goats on the other hand, reported findings which sharply contradicted the above findings with females being superior in body weight and linear body measurements across all age groups.

The sex-related differences might be partly a function of the between-sex differential hormonal effects on growth. Wenzhong *et al.* (2005) and Ebegbulem *et al.* (2011) reported that sex is one of the major factor influencing body weight and growth rate. They observed that females were also larger than males for all body sizes except withers height.

However, Yakubu (2009) reported that the morphological traits of male and female goats were similar, although this submission was for kids compared to data reported for relatively mature animals in other studies. On the contrary, sex has been shown to have no influence on weight gain in goats (Otoikhian *et al.,* 2008). This is supported by the

findings of Ozoje and Herbert (1997) who observed that sex did not significantly affect body length, heart girth, leg length, and shoulder width either at birth or at any other age up to when the kids are weaned in WAD and Red Sokoto goats, respectively. However, Singh *et al.* (2007) analyzed data on 3531 Jamunapuri goats and reported that sex significantly affected growth traits and live weights. After analyzing data on 30 Baladi, Baladi X Damascus and Baladi X Anglo-Nubian goats, Hassan *et al.* (2001) reported that body weight was significantly affected by sex.

2.8.3 Effect of breed

Aryal and Neopane (1996), Misra *et al.* (1998), Hassan *et al.* (2001), Singh *et al*. (2007) and Ravimurugan *et al*. (2007) had studied body measurements and live weights of different goat breeds and different non-genetic factors affecting these traits. Ozoje and Herbert (1997) revealed that Red Sokoto goat was superior to the WAD goats at maturity in terms of weight and body measurements. Adeyinka and Mohammed (2006) found White Borno goat to be heavier than Red Sokoto goats in both sexes. This is in consonance with the report of Moruppa and Ngere (1986). However, Raji *et al*. (2008) found Red Sokoto goats to be heavier than White Borno goat. Semakula *et al.* (2010) compared three breeds of Ugandan goats and found that Mubende were superior in withers height to other two breeds investigated. Hassan *et al*. (2001) reported that body weight 30 Baladi, Baladi X Damascus and Baladi X Anglo-Nubian goats was significantly affected by breed.

2.8.4 Effect of season

Season has been reported to have significant effect on mean body condition score, body weight and heart girth in goat (Nsoso *et al*., 2003). The authors reported that the body

condition score was significantly higher during the wet than the dry season. Cisse *et al.* (2002) observed a decline in body condition of goat in the dry season and gain it during the wet season. As pointed by Luginbul (2002); and Rae and Tawah (1999), this allows BCS to be used as a management tool in farm animals since it is so sensitive to seasonal change. Ozoje and Herbert (1997) found that season of breeding significantly affected body length, heart girth and leg length at birth. In another study by Maina *et al*. (2006) to investigate the influence of season on semen characteristic in Sahel bucks. They recorded total morphological defective spermatozoa per ejaculate to be 6.48% and 17.69% while the sperm concentration were $3.73x10^9$ ml and $2.67x10^9$ ml in the dry and rainy seasons, respectively. They concluded that ejaculate quality was better during the dry season.

2.9 Factors Affecting Fertility in Bucks

2.9.1 Male associated factors

The bucks may greatly influence fertility results after cervical AI. It has been reported that variation in fertility of buck ejaculates exists independently of the sperm quality (Choudhry *et al*., 1995; Paulenz *et al*., 2002). Variations in the fertility of bucks have been reported after cervical inseminations with fresh semen (Paulenz *et al*., 2002; Anel *et al*., 2005), with frozen semen (Colas, 1979; Windsor, 1997; Soderquist *et al*., 1999; Paulenz *et al*., 2005; 2007) and after laparoscopic inseminations with frozen semen (Maxwell, 1986; Eppleston *et al*., 1986; 1991; Eppleston and Maxwell, 1995).

In a large scale epidemiological study, Anel *et al*. (2005) observed that the male factor significantly influenced fertility. Despite the restrictions in the choice of ejaculates, the authors found important differences in fertility among bucks, particularly when cervical

AI with cooled semen was used. Salamon and Maxwell (1995) proposed that buck differences in fertility could be both genetic and environmental, whereas ejaculate differences are probably due to nutrition, management and previous frequency of ejaculation. However, differences in fertility have been demonstrated among fertile males in different species, the causes of these differences remain unclear (Ostermeier *et al*., 2001).

Saacke *et al*. (1988; 1994) have suggested that factors associated with semen quality which affect fertility can be classified as either compensable or non-compensable. It was suggested that the effects of compensable factors on fertility might be sensitive to the number of sperm inseminated, whereas those of non-compensable factors were not. As the number of sperm inseminated increases, fertility increases until a plateau is reached (den Daas, 1992). At this point, compensable factors no longer have an effect on fertility. It is thus the non-compensable factors that contribute most to the fertility level of a buck.

A non-compensable defect in sperm would be one in which a sperm reaches the fertilization site and initiates the egg activation process, but fails to sustain zygotic, embryonic, or foetal development (Ostermeier *et al*., 2001). Evidence of such defects in sperm has been described in bulls with fertility differences (Eid *et al*., 1994). Likely candidates for non-compensable factors would have incorrectly assembled chromatin or damaged DNA within the sperm nucleus.

2.9.2 Season

Although seasonality is less marked in male than in female, changes in testicular volume,

hormonal profiles, sexual behaviour and semen quality that affect the reproductive performance of rams have been reported (Casao *et al*., 2010a). In this sense, the treatment of bucks with slow release implants of melatonin during the non-breeding season accounted for increased scrotal diameter and improved the reproductive performance of ewes inseminated during anoestrus with semen from these melatonin-implanted males. A direct beneficial action of melatonin on sperm motility (Casao *et al*., 2010c) and on other buck sperm characteristics during the non-breeding season has recently been demonstrated, with decreased apoptotic like changes and modulating capacitation and fertilization rates (Casao *et al.*, 2010b).

2.9.3 Nutrition

Several studies on nutrition in bucks have demonstrated that diet may have an effect on testis size and sperm production (Brown, 1994). It has been described that found components of the diet, such as Vitamin E, may have a positive effect in increasing semen quality and quantity (Yue *et al.*, 2010). The effect of diet of the bucks on the reproductive success of does after AI remains to be determined. Dolatpanah *et al*. (2008) reported that fish oil supplementation with excess vitamin E had a significant effect on measured semen parameters. They concluded that bucks that received fish oil in association with vitamin E, showed the greatest improvement in semen characteristics and reduction in incidences of sperm abnormalities.

2.10 Semen Characteristics

2.10.1 Semen collection frequency

Semen collection frequency may have an impact on sperm quality. Long abstinence (Pascual *et al.*, 1993) and successive ejaculations (Ollero *et al*., 1994) have been associated with membrane alterations of spermatozoa. A decrease in semen volume and sperm concentration with successive ejaculations has been reported in several studies (Ollero *et al*., 1996; Kaya *et al*., 2002). In the study by Ollero *et al*. (1996), the maximum proportion of viable cells was obtained in the second ejaculate after an abstinence period of 3 days. The authors concluded that the use of the second and/or a mixture of second and third ejaculates would improve the results in artificial insemination. Increased semen collection frequency may have an effect on sperm quality and the composition of the seminal plasma (Kaya *et al*., 2002), although it remains to be determined whether this has an impact on field fertility.

2.10.2 Semen evaluation

Semen evaluation is a useful tool in the selection of males and ejaculates for assisted reproduction. Traditional evaluation techniques, based on the subjective assessment of parameters such as sperm motility and morphology, semen volume or concentration, have long been employed in the diagnosis of male subfertility and sterility (Verstegen *et al.*, 2002).

2.10.2.1 Semen colour

The colour of buck semen ranges from a creamy white color to yellow (Osinowo, 2006). Oyeyemi *et al*. (2000) reported milky and creamy in WAD bucks.

These ranges of colour have been reported by many authors and apparently do not have any bearing on the semen quality. Red coloring of the sample indicates the presence of blood. This may be due to trauma that has occurred prior to collection. Yellow watery colors may indicate urine in the ejaculate. A dark sample may indicate debris such as dirt or manure contaminating the sample due to an uncleaned prepuce or the presence of pus.

2.10.2.2 Semen volume

The volume of normal buck ejaculate ranged usually form 0.5 to 2 ml (with an average of 1 ml) (Lynn *et al.*, 2011). Blokhuis (1962) estimated the average volume from a series of collections to range between 0.25 and 5.0 ml with ideal volume not to exceed 2 ml. Mellado *et al.* (2011) obtained 0.51 ± 0.29 vs. 0.55 ± 0.28 ml from Granadina bucks fed increased and standard diet respectively. Smith (1978) reported the average buck semen volume to be between 0.5 and 1.0 ml; however, averages of 0.85, 0.82, and 0.68 ml have been reported by Huat (1975), Patel (1967), and Eaton and Simmons (1952), respectively. Semen volume has also been reported to range between 0.38 ± 0.05 and 0.96 ± 0.04 ml in Anglo-Nubian bucks (Souza *et al.* 2011).

Volume is an important criterion in semen evaluation. The quality of the semen may decrease as the total volume of the ejaculate increases (Huat, 1975). But, generally larger volumes mean more sperm. Older bucks generally have a larger volume of ejaculate than younger bucks. Therefore, age should be considered with respect to this parameter of semen evaluation. Body measurements (BW and BC) has been reported to correlate positively (r = 0.24 - 0.60) with semen volume in bucks (Rajuana *et al.* 2008).

The author also recorded strong and positive correlation (r = 0.53 - 0.61) between testes measurements and semen volume. Oyeyemi *et al.* (2000) observed a decrease in ejaculate volume as the frequency of ejaculations increased, although the decrease was not significant. In a study on three pubertal kiko bucks, Okere *et al*. (2011) obtained semen volume as 1.50 ± 0.5 ml, 1.34 ± 0.93 ml and 0.90 ±0.41 ml with average put as 1.24 ± 0.66 ml. The authors recorded low and negative correlations between BWT, BCS, HTW, HG and semen volume (r = -0.13, 0.13, -0.68, and 0.04), and concluded that semen output is fairly independent of most body conformation traits. Alkass and Ahmed (2011) obtained semen volume of 0.97 and 0.70 ml for black and Meriz bucks, respectively.

2.10.2.3 Semen pH

Patel (1967) reported an average pH of 6.5 while, Huat (1975) estimated the average pH range to be between 6.5 and 7.7. The reaction of freshly ejaculated semen is not far from neutral. Anything that alters the pH of the semen above or below the normal range will cause sperm death. The presence of blood or infection can alter the pH enough to kill the sperm. If the pH of the ejaculate is low (acidic) that may not indicate poor quality since highly active sperm samples produce lactic acid as a metabolic waste product. However, the sperm will be killed if the acidity is not neutralized. All of the common semen extenders (dilutors that "extend" sperm cell life) are buffered. That is, they contain chemicals that tend to prevent pH changes and "force" the pH to remain in a safe range. Since it is a good practice to dilute buck semen as quickly after collection as possible, to prevent loss of viability, the extender will usually correct any pH problem.

2.10.2.4 Sperm motility

The progressive motility of sample is defined as that percentage of the spermatozoa in a sample that swim in a more or less straight-forward direction. Most reports (Huat, 1975; Smith, 1978) indicate an average motility score of 85%. The motility of normal buck ejaculate ranged usually from 70% to 90% (with an average of 80%) (Gimenez, 2007). Semen with an initial motility much below this should probably not be processed any further (Huat, 1975). Souza *et al*. (2011) reported individual motility in Anglo-Nubian bucks to vary from 48.0 ± 10.52% to 82.0 ± 3.74%, at the same age. Oyeyemi *et al*. (2000) also reported motility of range between 88.7±3.10 and 94.54±3.00% suggesting that the viability of the spermatozoa is strong. Alkass and Ahmed (2011) obtained mass motility of 83.07 vs. 71.18 % and individual motility of 89.47 vs. 80.17 % for Black and Meriz bucks, respectively.

2.10.2.5 Sperm concentration

The concentration of the ejaculate is a function of several parameters. They include the degree of sexual preparation of the buck, the age of the buck, the time of year the collection is made, the amount of sexual rest before collection, the health of the buck, its nutritional state, inherent sperm storage, and the production capacity of the buck. The average buck ejaculate usually contains between 2 and 9 billion spermatozoa. Souza *et al.* (2011) obtained sperm concentration in Anglo-Nubian bucks of range between 1.33 ± 0.64 and 3.54 ± 0.14 $x10^9$ /ml. Mellado *et al*. (2011) reported sperm concentration in Granadina bucks fed increased and standard diet as 2210 ± 1139 vs. 2055 ± 656 × 10^6/ml, respectively.

Iheukwumere (2008) determined the effect of different intensities of semen collection on semen characteristics in West African Dwarf bucks and found that the highest semen concentration and volume were obtained when the bucks were ejaculated once per week. The author concluded that once per week semen collection enhances the fertility of West African Dwarf bucks. Maina *et al.* (2006) obtained sperm concentration of $3.73x10^9$ /ml and $2.67x10^9$ /ml in the dry and rainy seasons, respectively. They concluded that ejaculate quality was better during the dry season. Sperm concentration of 113.50 and 81.72 x 10^7/ml has been reported for Black and Meriz bucks, respectively (Alkass and Ahmed, 2011).

2.10.2.6 Sperm morphology

When sperm morphology is evaluated one usually looks for abnormal shapes of the head and tail. Poor sperm morphology is an indicator of decreased fertility in many species, including goats (Chandler *et al*., 1988). Oyeyemi *et al*. (2011) investigated the semen quality and spermatozoa morphology of WAD bucks treated with Aloe vera extract. The authors revealed that continuous administration of Aloe vera extract significantly reduced sperm concentration, motility and percentage livability and resulted in increased sperm abnormalities in the WAD bucks.

However, Dolatpanah *et al.* (2008) reported that fish oil supplementation with excess vitamin E had a significant effect on measured semen parameters. They concluded that bucks that received fish oil in association with vitamin E, showed the greatest

improvement in semen characteristics and reduction in incidences of sperm abnormalities. Oyeyemi *et al.* (2000) also reported a significant increase in abnormal spermatozoa as frequency of ejaculation increased in WAD bucks.

Nur *et al.* (2005) obtained mean percentages of abnormal spermatozoa with defective acrosome as 7.2±2.9% while total morphological defect was 9.7±3.4%, respectively.

2.11 Biochemical Parameters of Semen

Biochemical parameters of semen are of vital importance to its fertility and preservation aspects. Seminal plasma (SP) is the complex fluid portion of semen in which spermatozoa are suspended at the time of ejaculation. It is known that seminal plasma contains substances that support the sperm cells. A summary of the most important constituents of SP of ruminants has been given (Table 2.5). Sperm function is highly dependent on ionic environment (Hamamah and Gatti, 1998). Difference in the dietary mineral level may have a positive effect on the ion concentrations of SP. Sodium (Na^+) and Potassium (K^+) cations in the seminal plasma have been reported to be involved in osmotic balance (Cevik *et al.,* 2007), while the essential trace elements are the components of many important enzymes (Zamiri and Khodaei, 2005); also, calcium (Ca^{2+}) is needed for stimulation of steriodogenesis in leydig cells of the testis (Henricks, 1991).

Na^+ is the principle cation in SP of ruminants, with an exception in bull semen where Ca^{2+} concentration is very high (Setchell and Brooks, 1988). Na^+ ion is also an important element for spermatozoa function (Mosaferi *et al.,* 2005). K^+ is a natural metabolic inhibitor and higher K^+ concentration in SP decreases sperm metabolism thereby, decreasing sperm motility (Massányi *et al*., 2003). Ca^{2+} triggers the acrosome reaction in

mammalian spermatozoa and is also involved with sperm motility (Kaya *et al.*, 2002). Meseguer *et al*. (2004) have reported that Ca^{2+} concentrations in seminal plasma are good predictors of post-thaw semen quality.

Blackshaw (1953) reported that Ca^{2+} at all concentrations in the semen of rams are somewhat deleterious. Assumpção *et al*. (2005) observed a negative correlation of abnormal sperm morphology with P, Ca^{2+} and Na^{+} concentrations and a positive correlation with K^{+} concentration. The high levels of Na^{+} and K^{+} ions has been reported to be associated with low percentages of motile sperm, and such semen was considered to be of lower quality (Asadpour, 2012). Zamiri and Khodaei (2005) showed that low levels of Na^{+} and K^{+} ions were associated with high percentage of motile sperm, which suggest that the cations Na^{+} and K^{+} are generally involved in establishment of osmotic balance, and that seminal plasma osmolality ultimately plays an important role in the activation of the sperm cell.

Table 2.5: Composition of seminal plasma in ruminants (values are mg/dl unless otherwise stated)

Content	Bulls	Rams	Goats	Buffalos

Fructose	150-600	140-600	875	368-815
Glucose	300	0.9-1.6	4.8-8.8	13-52
Citric acid	340-1150	110-260	-	440-444
Total proteins(g/dl)	3.8	2.30-2.50	0.77-1.48	-
Total lipids	29	254-396	-	150-175
Phospholipids	149.1	-	57	6.9-59.4
Cholesterol	312.16	-	-	117.83
Glutamic acid	1.0-8.0	4.5-5.2	-	4.28
Na^{+}	140-280	120-258	60-183	260-278
K^{+}	80-210	50-140	76-255	192-205
Ca^{2+}	35-60	6-15	5-15	30
P^{-}	9	4.8-12.0	-	8-9
Cl^{-}	110-290	86	82-215	303-347
Mg^{2+}	7-12	2-13	1-4	4.3-5.7
Zn^{2+}	2.6-3.7	56-179	-	0.80-1.17
Testosterone (pg/ml)	210-1310	25-375	-	970
Oestrogen (pg/ml)	20-166	-	-	43.67
Prostaglandins (ng/ml)	5-10	500-20000	-	-

Nasrin (2003)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3. I Experimental Site

The study was conducted at the Experimental and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University Zaria, Nigeria. The site is situated between latitude 11^0 and 12^0N and altitude of 640 m above sea level (Google Earth, 2013 PC version). The area falls within the Northern Guinea Savannah Zone having an average annual rainfall of 1100 mm, which falls from late April or early May to mid-October. The peak rainy season is between June and September, followed by the harmattan period of cool and dry weather which lasts from October to January. This is then followed by hot-dry weather from February to April. The mean maximum temperature varies from 26 to 35^0C depending on the season, the mean relative humidity during harmattan period and wet season are 21% and 27%, respectively. Detailed description of Zaria was given elsewhere by Akpa *et al*. (2002b).

3.2 Experimental Animals and their Management

A total of thirty-one Red Sokoto bucks were used for the study. The animals were under the management practice of the Department of Animal Science, Ahmadu Bello University, Zaria. The bucks were reared under semi-intensive system. The animals were released daily for grazing at 8.00am and another shift by 2.00 pm. Supplemental feed (concentrates) was provided. Animals were subjected to dipping against ectoparasites, as well as anti-helminthic drenching (deworming) and vaccination against endemic diseases.

Fresh drinking water was provided *ad libitum.* The experiment commenced when the bucks were 9 – 12 months of age in July 2011 and ended when they were 21 – 24 months, in June, 2012.

3.3 Data Collection

3.3.1 Body weight measurement: The body weight of the bucks was measured in kilograms by following the procedure as described by Akpa *et al*. (1998). The weight of the observer was taken first, and then the body weight of each animal was taken by carrying the animal individually and standing on a weighing scale. The difference between this weight and that of the observer gives the weight of the animal. Weighing was done at the begi of the study and subsequently on monthly basis. A total of 372 records was generated for body weight.

3.3.2 Body linear measurement: Measurement of linear conformation traits were taken on the day of measurements in centimeters cm using flexible tape as described by Alphonsus *et al*. (2009) and Boisot *et al*. (2002). The measurements were taken at the onset and subsequently on monthly basis. A total of 372 records were generated for each of the body linear measurements. The traits are described as follow:

Heart girth (HG): This is the circumference of the body at a point immediately behind the fore limbs and perpendicular to the body axis.

The Stature (ST): This was measured from the top of the spine in between the hips to the ground.

Chest width (CW): This was measured from the inside the surface between the top of the front legs.

The Withers height (WH): This is the highest point over the scapular vertically to the

ground.

Body depth (BD): This is the distance between the top of the spine and the bottom of the barrel at the last rib.

Body length (BL): This was measured from the point of shoulder to the ischium.

Rump width (RW): This is the distance between the most posterior points of pin bones

3.3.3 Testicular measurement

The testicular dimensions were measured at the onset and subsequently on weekly basis before semen collection. A total of 1488 records were generated for each traits as follows:

Testicular length (TL): This was measured in centimeters with a flexible tape as the distance along the caudal surface of the scrotum, from its point of attachment to the tip of the scrotum as described by Bratte *et al*. (1999) and Akpa *et al*. (2012a).

Testicular circumference (TC): This is the maximum dimension around the pendulous scrotum after pushing the testes firmly into the scrotum (Akpa *et al*., 2006). It was measured in centimeters.

Testicular width (TW): This was determined from testicular circumference using a formulae as given below:

$$TW = 2\left(\frac{TC}{2\pi}\right)$$

Where; TW = testicular width

TC = testicular circumference

Testicular weight (TWT): This was determined using Bailey *et al* (1996) formulae as given below;

$$TWT = 0.5533\ x\ TL\ x\ TW2$$

Where; TWT = Testicular weight

TL = Testicular length

TW = Testicular width

3.3.4 Semen collection and evaluation

3.3.4.1 Semen collection: Semen samples were collected from each animal on weekly basis for 52 weeks using an electro-ejaculator and samples were labeled accordingly.

This was done in the morning throughout the duration of the experiment. The sampled semen was evaluated immediately for colour, volume, motility and pH as described by Zemjanis (1970). Sperm concentration, sperm morphology and live/dead ratio were evaluated in the laboratory. A total of 1488 records was generated for each of the observed characteristics**.**

3.3.4.2 Semen evaluation

*Semen colour***:** The colour of each of the semen samples collected was noted visually immediately after collection.

Semen volume: The semen samples were collected into transparent and calibrated plastic test tubes. The volume of each sample was read through the tubes and the figure recorded in millilitres

*Semen pH***:** The hydrogen ion concentration (pH) of individual samples collected was determined using Chemo craft pH paper. This is a pH paper calibrated from 1 to 14 with different colours. One inch of the paper was inserted into the semen for five seconds. Then it was removed and air dried. The colour change was observed after drying and was placed to the colour chart on the pH paper. The corresponding pH number for the colour on the chart was recorded as the pH of the sample

Sperm motility: The motility of the sperm cells (wave pattern of semen) of each sample collected was measured by microscopically evaluating non-diluted semen at 100x magnification power. The wave patterns were recorded in percentage. Mass motility was estimated as percentage score according to the procedure outlined by Melrose and Laing (1970).

Sperm concentration: The concentration of the spermatozoa was determined using the Red Blood Cell counting chamber of a haemocytometer that were crossed with microscopic grids containing 25 large squares with each containing sixteen smaller squares. The total number of smaller squares on the haemocytometer is 400. Sperm cells were counted diagonally from top left to the bottom right and from top right to the bottom left in five large squares or a total of 80 smaller squares (Rekwot *et al*., 1997).

Prior to counting, formaldehyde was used as a dilution reagent. A drop of semen was taken from each sample using a pipette and diluted with formaldehyde solution at 1:100.

The haemocytometer was mounted into the microscope and an absorbable tube and O-no pette was used to pipette a drop of the solution into the haemocytometer chamber. The absorbable tube and the O-no pette were blown before pipetting to avoid air bubbles in the O-no pette. After appropriate counting in the 5 large squares, the number obtained was multiplied with 100 (dilution factor), 16 (the number of smaller squares in a larger square and the volume of the semen sample collected, multiplied by 10^6). The result obtained was recorded as the sperm cell concentration for the sample.

Live and dead ratio: The live and dead sperm ratio was estimated by the preparation of a smear of individual semen sample using eosin-nigrosin stain immediately after collection. A drop of semen was diluted and placed on a clean glass slide using automatic pipette. A

drop of the eosin-nigrosin solution was placed alongside the semen on the slide. A gentle circular turning of the slide was done to allow a uniform mixture of the two samples. A quarter of the part of another clean slide was placed on top of the first sample and the two slides were gradually and carefully drawn apart to prepare a thin smear on the first slide. This was allowed to dry and thereafter labeled.

This was done for each sample and they were later mounted on the microscope for counting the live and dead spermatozoa using 400x objective lens. The principle is that the dead sperm cells accept the stain and appear stained while the live sperm cells reject the stain and remain unstained. The procedure above was developed by Hancock (1951)

Sperm morphology: The same slides prepared for live and dead ratio were used for the morphology studies. Live and abnormal spermatozoa percentages were counted using a tally counter. Fifty spermatozoa were examined from each sample. The total number of abnormal spermatozoa was counted and recorded. Types of abnormality observed were: detached mid-piece and tail, detached head, mid-piece droplet, coiled and bent tail, and acrosomal abnormality (acrosome membrane detached, acrosome outlines and acrosome cap defect). Acrosomal abnormalities were determined by using smears made from the raw semen and stained by Giemsa stain according to Watson (1975).

Semen cation concentrations in seminal plasma: Mineral analysis was done with a Coleman 21 Flame Photometer. This instrument is calibrated with five standard stock solutions for concentration of minerals as described by Cragle *et al*. (1958). The semen samples were centrifuged for separation of seminal plasma. Seminal plasma was then processed and different elements: Ca^{2+}, Na^{+}, K^{+}, and PO_4 estimated.

3.4 Determination of Factors

3.4.1 Age determination: The ages of the animals were determined using the dentition estimation method by counting the number of permanent incisors that have erupted on the lower jaw of the mouth as described by Matika *et al.* (1992); and Sastry and Thomas (1980).

This method puts the bucks at 9-12 months of age at the onset of the study. Measurements were made on these bucks at this age group, and subsequently, until after one year of the study. Thereafter, the ages of the bucks were categorized into 9-12, 13-16, 17-20 and 21-24 months.

3.4.2 Hair type: The hair type of the animal was determined through a touch and a feel of the hair. Short-Smooth (SS) and Long-Curly (LC) which was based on length and texture of the hair were used to categorize the animal into two groups.

3.4.3 Body condition score (BCS): The body condition score (1-5) as described by Allen (1990) and Steele (1996) was employed to score the bucks. The buck's backbone, loin and rump areas were palpated and examined and then scored. These areas do not have muscle tissue covering them, hence, combination of skin and fat deposit account for any cover that were felt around these areas. Amount of fat deposit can be determined by the use of fingertip pressure which is exerted on the backbone, pin bone and hip bone, respectively. The scoring as described by Allen (1990) and Steele (1996) is given below:

Score 1 (Very thin): Individual short ribs have a thin covering of flesh. Bones of the chine, loin and rump region are prominent. Hook and pin bones protrude sharply, with a very thin covering of flesh and deep depressions between bones. Bony structure protrude

sharply and ligament prominent.

Score 2 (Thin): Individual short ribs can be felt but are not prominent. Each rib is sharp to touch but have a thicker covering of flesh. Short ribs do not have as distinct an over-hanging shelf effect. Individual bone is the chine, loin and rump regions are not visually distinct but easily distinguishable by touch.

Hook and pin bones are prominent but the depression between them is less severe. Area below tail head and between pin bones is somewhat depressed but the bony structure has some covering of flesh.

Score 3 (Moderate): Short ribs can be felt by applying slight pressure. Altogether, short ribs appear smooth and the over-hanging effect is not so noticeable. The backbone appears as a rounded ridge, firm pressure is necessary to feel individual bones. Hook and pin bones are rounded and smooth. Area between pin bone and around tail head appears smooth without sign of fat deposit.

Score 4 (Fat): Individual short rib is distinguishable only by firm palpation. Short ribs appear flat or rounded, with no overhanging shelf effect. Ridge formed by backbone in spine region is rounded and smooth. Loin and rump region appear flat. Hooks are rounded and the space between them is flat. Area of tail head and pin bones is rounded with evidence of fat deposit

Score 5 (Obese): Bony structures of backbone, short ribs and hook and pin bones are not apparent; subcutaneous fat deposit very evident. Tail head appears to be buried in fat tissue.

3.5 Statistical Analysis

Descriptive statistics were determined for each trait. The effect of age, hair type and body

condition score on body and testicular measurement and semen characteristics were determined using General Linear Model Procedure of SAS (2002). Significant differences in means were separated using Duncan's Multiple Range Test. Correlation analysis procedure of SAS was used to assess the relationship between the measured characteristics.

The monthly data on body weight and body conformation traits were used to determine the relationships between them, giving rise to a total of 372 records for each trait. Also, the weekly data (1488 records) on testicular and seminal traits were used for estimating thier relationships. However, to estimate the relationship of testicular and seminal triats with body weight and body conformation traits, their weekly observations were averaged for each month to get a comparative value to the monthly body measurements.

The model used is as follows:

$Y_{ijkl} = \mu + A_i + H_j + C_k + E_{ijk}$

Where: Y_{ijkl} = estimates of the given measurable characteristics

μ = over all mean

A_i = effect of *i*th age (i: 9-12, 13-16, 17-20 and 21-34)

H_j = effect of *j*th hair type (j: SS and LC)

C_k = effect of *k*th body condition score (k = 3, 4)

E_{ijk} = random error.

CHAPTER FOUR

RESULTS

4.1 Body Conformation, Testicular and Semen Characteristics

The summary statistics for body and testicular measurement and semen characteristics are presented in Table 4.1. The results indicate that the mean body weight was 15.02±0.46 Kg; heart girth 59.95±0.45 cm; stature 54.95±0.82 cm; chest width 8.37±0.19 cm; withers height 53.41±0.58 cm; body depth 32.86±0.43 cm; body length 57.35±0.82 cm; and Rump width 17.03±0.34 cm. The testicular length (cm), testicular circumference (cm), testicular width (cm) and testicular weight (g) were 12.00±0.33, 17.38±0.26, 5.53±0.13, and 203.04±22.25, respectively. The recorded semen volume (ml), motility (%), and semen pH were 0.42±0.05, 79.52±2.31, and 8.58±0.09, respectively while 701.13±70.55 and 0.82±0.12 were recorded for sperm concentration ($x10^6$) and live & dead ratio ($x10^6$), respectively.

The accumulation of semen characteristics in the bucks showed high variability which varied from 5.85 to 69.97. The most variable characteristics were semen volume and sperm concentration (Table 4.1). Similar trend was observed in body conformation traits and testicular measurement, respectively.

Table 4.1: Summary statistics for body and testicular measurements, and semen characteristics in Red Sokoto bucks

Characteristics	N	Mean ± Se	CV (%)	Min	Max
Body weight and Conformation					
Body weight (Kg)	372	15.02 ± 0.46	17.01	10.00	20.00
Heart girth (cm)	372	59.95 ± 0.45	4.22	55.00	65.00
Stature (cm)	372	54.95 ± 0.82	8.35	40.60	63.50
Chest width (cm)	372	8.37 ± 0.19	12.73	6.10	10.20
Withers height (cm)	372	53.41 ± 0.58	6.08	45.70	57.40
Body depth (cm)	372	32.86 ± 0.43	7.35	25.40	36.30
Body Length (cm)	372	57.35 ± 0.82	7.92	50.80	70.50
Rump width (cm)	372	17.03 ± 0.34	11.16	13.70	20.30
Testicular Measurement					
Testicular length (cm)	1488	12.00 ± 0.33	15.33	8.60	16.50
Testicular circumference (cm)	1488	17.38 ± 0.26	8.35	13.90	19.30
Testicular width (cm)	1488	5.53 ± 0.13	8.35	6.95	9.65
Testicular weight (g)	1488	203.04 ± 22.25	24.35	272.60	749.03
Semen Characteristics					
Semen volume (ml)	1488	0.42 ± 0.05	69.97	0.10	1.10
Semen motility (%)	1488	79.52 ± 2.31	16.18	55.00	95.00
Semen pH	1488	8.58 ± 0.09	5.85	8.00	9.00
Sperm concentration ($x10^6$/ml)	1488	701.13 ± 70.55	56.02	209.00	1605.00
Live and Dead ratio ($x10^6$ /ml)	1488	0.82 ± 0.12	11.97	0.60	1.00

N = sample size

The effect of age, hair type and body condition score on body weight and all the body conformation traits are given in Table 4.2. Body weight and conformation traits were significantly ($P<0.01$) influenced by all the age group. Age group 9 – 12 months had the lowest while 17 – 20 was the highest which did not differ significantly from age group 13 – 16 and 21 – 24 months, respectively. There was non-significant effect ($P>0.05$) of hair type on body weight and all the body conformation traits. Body condition score had highly significant effect ($P<0.01$) on body weight, heart girth, withers height, body length and rump width, and a significant effect ($P<0.05$) on stature. However, chest width and body depth were not significantly ($P>0.05$) influenced by Body condition score. Animals with BCS (4) showed superiority over those of BCS (3).

Age effect on body weight showed that age group 9 – 21 had the lowest weight of 13.0 kg than the rest with the highest weight coming from age group 17 – 20 (15.7 kg) which is followed closely by age group 13 – 16 (15.5 kg) and 21 – 24 (15.3 kg), respectively (Table 4.2). The pattern for heart girth and body depth were similar to that of body weight. For age group 9 – 12, withers height and rump width were lower, while the age group 21 – 24 had the highest which is significantly similar to age group 13 – 16. Stature, chest width and body length were lower for age group 9 – 12. However, stature was higher at age group 13 – 16 which did not differ significantly from age group 21 – 24; body length was higher at age group 17 – 20 which was similar with age group 21 – 24; while Chest width was higher at age group 21 – 24 which did not differ statistically from age group 17 – 20. Only chest width increased with age linearly while rump width, wither height and stature

took the sigmoid shape with age.

The effect of body condition score on conformation traits indicated that BCS (4) was superior to BCS (3) for body weight and all the body conformation traits measured except for chest width and body depth where it had no significant effect ($P>0.05$). No significant effect of hair type was observed.

Table 4.2: Effect of age, hair type and body condition score on body weight and body conformation traits in Red Sokoto bucks

Factors	N	Body Weight	Heart Girth	Stature	Chest Width	Wither Height	Body Depth	Body length	Rump Width
		(kg)	cm	cm	cm	cm	cm	cm	cm
Age (months)	372	**	**	**	**	**	**	**	**
9 – 12	93	13.0[b]	58.0[b]	47.2[b]	7.3[b]	47.4[b]	29.9[b]	51.2[b]	14.1[b]
13 – 16	93	15.5[a]	60.4[a]	57.1[a]	8.3[a]	54.8[a]	33.3[a]	58.0[a]	17.4[a]
17 – 20	93	15.7[a]	60.7[a]	55.9[a]	9.1[a]	54.4[a]	35.8[a]	63.6[a]	16.8[a]
21 – 24	93	15.3[a]	60.3[a]	56.4[a]	9.6[a]	55.2[a]	33.0[a]	58.7[a]	19.5[a]
SEM		0.44	0.44	0.47	0.14	0.24	0.34	0.56	0.16
Hair Type	372	ns	ns	ns	ns	ns	ns	ns	ns
Short-smooth	252	15.2	60.1	54.8	8.3	53.5	32.9	57.5	17.0
Long-curly	120	14.5	59.4	55.7	8.5	53.1	32.9	56.7	16.9
SEM		0.46	0.46	0.84	0.19	0.59	0.44	0.83	0.35
Body Condition									
Score	372	**	**	*	ns	**	ns	**	**
BCS (3)	144	12.4[b]	57.4[b]	52.7[b]	8.2	52.1[b]	32.7	55.6[b]	16.0[b]
BCS (4)	228	16.7[a]	61.6[a]	56.4[a]	8.5	54.2[a]	33.0	58.5[a]	17.7[a]
SEM		0.27	0.27	0.77	0.19	0.56	0.44	0.79	0.31

**= P<0.01; *=P<0.05; [a, b, c] Means within the same column and factor with different superscripts differ significantly (P<0.05) N = sample size, ns = not significant

The effects of age, hair type and body condition score on testicular measurement are presented on Table 4.3. The effect of age and body condition score was significant ($P<0.01$) on all the testicular measurements (testicular length, testicular circumference, testicular width and testicular weight). Hair type significantly influenced ($P<0.01$) testicular circumference, testicular width and testicular weight, but had non-significant effect on testicular length.

The effect of age on testicular measurements indicated that age group 21 – 24 performed best for all testicular traits measured. The performance was significantly ($P<0.01$) different from other age groups. However, performance of age group 17 – 20 was not significantly different with those in age group 13 – 16 but with those in 9 – 12 ($P<0.01$) for all traits measured. Hair type effect indicated that bucks with short-smooth hair were significantly ($P<0.01$) superior to long-curly bucks, while bucks with BCS (4) were significantly ($P<0.01$) superior in all the testicular measurements to bucks with BCS (3).

Table 4.3: Effect of age, hair type and body condition score on testicular measurement in Red Sokoto bucks

Factors	N	Testicular Length (cm)	Testicular Circumference (cm)	Testicular Width (cm)	Testicular Weight (g)
Age (months)	1488	**	**	**	**
9 – 12	372	10.9[c]	15.7[c]	5.0[c]	150.8[c]
13 – 16	372	12.2[b]	17.4[b]	5.5[b]	204.2[b]
17 – 20	372	11.3[c]	18.1[b]	5.8[b]	210.3[b]
21 – 24	372	13.2[a]	18.9[a]	6.0[a]	262.9[a]
SEM		0.32	0.20	0.10	17.00
Hair Type	1488	ns	**	**	**
Short-smooth	1008	12.0	17.4[a]	8.8[a]	525.9[a]
Long-curly	480	11.9	16.3[b]	8.2[b]	437.1[b]
SEM		0.34	0.25	0.12	21.67
Body Condition Score	1488	**	**	**	**
BCS (3)	576	11.5[b]	16.9[b]	8.5[b]	465.9[b]
BCS (4)	912	12.3[a]	17.6[a]	8.8[a]	535.7[a]
SEM		0.33	0.26	0.13	21.73

**P<0.01; [a, b, c] Means within the same column and factor with different superscripts differ significantly (P<0.05), N = sample size, ns = not significant

Table 4.4 shows the effect of age, hair type and body condition score on semen characteristics. There was no significant difference (>0.05) in semen characteristics between bucks of different hair types. However, semen volume and sperm concentration were significantly influenced (P<0.01) by age of buck. Age of buck on the other hand had no significant effect on sperm motility, semen pH and Live and dead ratio, respectively. Body condition score significantly influenced (P<0.01) semen volume and semen pH, but had no significant influence on sperm motility, sperm concentration and live and dead ratio.

For semen volume, age group 21 – 24 month performed better (0.6 ml) than the rest (0.2 – 0.5 ml); while for sperm concentration, age group 13 – 16 gave better (764.5 x 10^6/ml) result than the rest group (459.8 – 674.0 x 10^6/ml). Body condition score BCS (4) was superior in semen volume to BCS (3).

Table 4.4: Effect of age, hair type and body condition score on semen characteristics in Red Sokoto bucks

Factors	N	Semen Vol (ml)	Sperm Motility (%)	Semen pH	Sperm Conc(x10^6/ml)	Live & dead ratio(x10^6/ml)
Age (months)	1488	**	ns	ns	**	ns
9 – 12	372	0.2[b]	80.0	8.8	459.8[b]	0.8
13 – 16	372	0.2[b]	80.3	8.5	764.5[a]	0.9
17 – 20	372	0.5[a]	80.0	8.7	674.0[a]	0.9
21 – 24	372	0.6[a]	76.0	8.4	662.4[a]	0.8
SEM		0.05	2.42	0.09	72.27	0.02
Hair Type	1488	ns	ns	ns	ns	ns
Short-smooth	1008	0.4	78.8	8.6	721.1	0.8
Long-curly	480	0.5	82.5	8.5	618.0	0.8
SEM		0.05	2.34	0.07	71.35	0.02
Body Condition Score	1488	**	ns	**	ns	ns
BCS (3)	576	0.3[b]	79.2	8.4[a]	672.8	0.8
BCS (4)	912	0.5[a]	79.7	8.8[b]	719.0	0.8
SEM		0.05	2.32	0.08	71.63	0.02

**P<0.01; [a, b,] Means within the same column and factor with different superscripts differ significantly (P<0.05) N = sample size, ns = not significant

4.2 Sperm Morphological Characteristics and Semen Cation Concentrations

The summary statistics for sperm morphology and cation concentrations in Red Sokoto bucks are presented in Table 4.5. The results indicated that the mean abnormal morphological characteristics of bucks' sperm were; 0.52, 0.61, 0.52, 1.03 and 0.61, respectively for detached midpiece and tail; midpiece droplet, detached head, coiled and bent tail; and acrosome damage. These characteristics varied widely with the CV ranging from 68.43 to 110.41%. The most variable characteristics were detached midpiece and tail; and detached head. The mean semen cation concentrations were 94.90, 67.79, 2.62 and 5.42 (mmol/litre) for sodium, potassium, calcium and phosphate ion, respectively. The variability was low for calcium ion (4.90%), moderate for sodium ion (19.00%) and high for potassium (43.74%) and phosphate ion (40.04%).

Table 4.5: **Summary statistics for sperm morphology and cation concentration in Red Sokoto bucks (N=1488)**

Characteristics	Mean ± Se	CV (%)	Min	Max
Sperm Morphology				
Detached Midpiece & Tail	0.52 ± 0.10	110.41	0.00	2.00
Midpiece Droplet	0.61 ± 0.11	100.38	0.00	2.00
Detached Head	0.52 ± 0.10	110.41	0.00	2.00
Coiled and Bent Tail	1.03 ± 0.13	68.43	0.00	3.00
Acrosome abnormality	0.61 ± 0.12	108.86	0.00	2.00
Semen Cation concentrations (millimol/litre)				
Sodium	94.90 ± 3.24	19.00	56.00	136.00
Potassium	67.79 ± 5.33	43.74	24.70	129.80
Calcium	2.62 ± 0.02	4.90	2.05	2.77
Phosphate	5.42 ± 0.39	40.04	3.14	10.50

N = sample size

The effects of age, hair type and body condition score on sperm morphology are shown in Table 4.6. Age and hair type had significant ($P<0.05 – 0.01$) effect on sperm morphology except the effect of hair type on MPD and ACR ($P>0.05$). BCS only had significant effect ($P<0.01$) on DH.

There was high prevalence of DMT, MPD and CBT in the young-mature bucks of between 13 and 20 months of age than those of later ages while DH and ACR occurred in the younger (9 – 12 months of age) and older bucks (21 – 24 months of age). With respect to hair type, the long-curly haired bucks had the highest DMT and CBT abnormalities (0.8×10^6), while the short-smooth haired bucks had the highest DH (1.1×10^6) abnormalities. With respect to the body condition score, bucks with lower body condition score showed higher DH (130%) than bucks with higher body condition score (90%).

Table 4.6: **Effect of age, hair type and body condition score on sperm morphology in Red Sokoto bucks**

Factor	N	Detached Midpiece & Tail ($x10^6$/ml)	Midpiece Droplet ($x10^6$/ml)	Detached Head ($x10^6$/ml)	Coiled and Bent tail ($x10^6$/ml)	Acrosome ($x10^6$/ml)
Age (months)	1488	**	**	**	**	**
9 – 12	372	0.2[b]	0.5 [b]	1.2 [a]	0.2 [b]	0.7 [a]
13 – 16	372	0.7 [a]	0.7 [a]	0.9 [b]	0.7 [a]	0.5 [b]
17 – 20	372	0.7 [a]	1.0 [a]	1.0 [b]	0.7 [a]	0.3 [b]
21 – 24	372	0.2 [b]	0.4 [b]	1.4 [a]	0.2 [b]	1.0 [a]
SEM		0.10	0.11	0.13	0.10	0.12
Hair Type	1488	**	ns	*	**	ns
Short-smooth	1008	0.4 [b]	0.5	1.1 [a]	0.4 [b]	0.6
Long-curly	480	0.8 [a]	0.6	0.8 [b]	0.8 [a]	0.7
SEM		0.1	0.11	0.13	0.10	0.12
Body Condition						
Score	1488	ns	ns	**	ns	ns
BCS (3)	576	0.60	0.6	1.3[a]	0.6	0.5
BCS (4)	912	0.5	0.6	0.9 [b]	0.5	0.7
SEM		0.10	0.11	0.13	0.10	0.12

**= P<0.01; *= P<0.05; [a, b,] Means within the same column and factor with different superscripts differ significantly (P<0.05) N = sample size, ns = not significant

The effect of age, hair type and body condition score on semen cation concentration is presented in Table 4.7. Age had significant ($P<0.01$) effect on semen cation concentrations while hair type and body condition score only had significant effect ($P<0.01$) on sodium ion (Na^+). The semen cation concentrations was relatively higher in the older bucks 21 – 24 months than the younger bucks 9 – 16 months of age except for sodium ion (Na^+) which was also high in younger bucks of 9 – 16 months.

However, bucks at 17 – 20 months of age recorded the highest value for Potassium ion (K^+) and Phosphate ion (PO_4), respectively. Observations on the hair type of the bucks showed that the long-curly haired bucks were superior in seminal Na^+ than the short-smooth bucks. With respect to BCS, bucks with higher body condition score were superior in seminal Na^+ than bucks with lower body condition score.

Table 4.7: **Effect of age, hair type and body condition score on semen cation concentrations in Red Sokoto bucks**

Factor	N	Sodium (Na) (mmol/litr)	Potassium (K) (mmol/litr)	Calcium (Ca) (mmol/litr)	Phosphorus ($P0_4$) (mmol/litr)
Age (months)	1488	**	**	**	**
9 – 12	372	94.8[a]	42.6[c]	2.6[b]	5.3[b]
13 – 16	372	99.3[a]	72.2[b]	2.6[b]	4.8[b]
17 – 20	372	70.7[b]	83.6[a]	2.6[b]	6.9[a]
21 – 24	372	94.6[a]	73.6[ab]	2.7[a]	6.8[a]
SEM		3.03	5.05	0.02	0.02
Hair Type	1488	**	ns	ns	ns
Short-smooth	1008	93.6[b]	65.9	2.6	5.5
Long-curly	480	100.2[a]	75.5	2.6	4.9
SEM		3.26	5.37	0.02	0.39
Body Condition					
Score	1488	**	ns	ns	ns
BCS (3)	576	90.8[b]	72.8	2.6	5.3
BCS (4)	912	97.5[a]	64.7	2.6	5.5
SEM		3.24	5.37	0.02	0.40

**= P<0.01; [a,b,c] Means within the same column and factor with different superscripts differ

significantly (P<0.05) N = sample size, ns = not significant

4.3 Correlated Relationships Between Body Conformation, Testicular and Semen Characteristics in Bucks

Positive and significant (P<0.01-0.05) correlations (r = 0.3 – 0.99) were found among various conformation traits (Table 4.8). BW had the highest positive correlation with HG (r = 0.99), then followed by WH with ST (r = 0.83). BCS had positive correlation (P<0.01) with BW (r = 0.82) and with HG (r =0.81) respectively.

The correlation analysis among testicular characteristics is presented in Table 4.9. Highly positive and significant (P<0.01) correlations (r = 0.77 – 1.0) were found among the testicular characteristics. Perfect positive correlation was found between TW and TC (r = 1.0). The next positive correlation was found between TWT and TC (r = 0.83) and between TWT and TW (r = 0.83), respectively.

The measured semen characteristics were positively correlated (r = 0.47 – 0.85) with each other (Table 4.10). However negative and significant (P<0.05) correlation (r = -0.37) was observed between semen pH and volume. Other correlations were close to zero or not significant and two of such relationships were negative (live/dead ratio and concentration; and live/dead ratio and pH).

Table 4.8: Correlation coefficients among body conformation traits in Red Sokoto bucks

	BCS	HG	ST	CW	WH	BD	BL	RW
BW	0.82**	0.99**	0.50**	0.31*	0.33*	0.33*	0.49**	0.35*
BCS	-	0.81**	0.41*	0.36*	0.32*	0.36*	0.31*	0.43*
HG	.	-	0.49**	0.31*	0.32*	0.34*	0.49**	0.35*
ST	.	.	-	0.33*	0.83**	0.41*	0.63**	0.71**
CW	.	.	.	-	0.42*	0.33*	0.43*	0.65**
WH	.	.	.	.	-	0.60**	0.64**	0.75**
BD	.	.	.	.	.	-	0.60**	0.41*
BL	.	.	.	.	.	.	-	0.52**

** = P<0.01, * = P<0.05, BW: Body weight, BCS: Body condition score, HG: Heart girth, ST: Stature, CW: Chest width, WH; Withers height, BD: Body depth, BL: Body length, RW: Rump width.

Table 4.9: Correlation coefficients among testicular characteristics in Red Sokoto bucks

	TC	TW	TWT
TL	0.81**	0.81**	0.77**
TC	.	1.0**	0.83**
TW	.	.	0.83**

** = P<0.01, TC: Testicular circumference, TL: Testicular length, TW: Testicular width, TWT: Testicular weight

Table 4.10: Correlation coefficients among semen characteristics in Red Sokoto bucks

	Motility	pH	Concentration	Live/dead ratio
Volume	-0.14	-0.37*	0.47**	0.06
Motility	-	0.01	0.13	0.85**
pH	.	-	0.38*	-0.10
Concentration	.	.	-	-0.03

** = P<0.01, * = P<0.05

The correlation analysis between body and testicular conformations is shown in Table 4.11. Testicular length was positively and significantly correlated with ST, WH, and RW ($P<0.05$; $r = 0.25 – 0.36$) but not with BW, BCS, HG, CW and BD ($P>0.05$; $r = 0.00 – 0.2$). It had negative non-significant correlation with BL ($P>0.05$; $r= -0.05$). Testicular circumference and testicular width respectively were positively and significantly correlated with body measurements ($P<0.05$-0.01; $r = 0.42 – 0.61$) except BW, BCS and HG ($P>0.05$; $r = 0.19 – 0.23$). Testicular weight was also positively and significantly correlated with body measurements ($P<0.05$-0.01; $r = 0.25 – 0.60$) except BW and HG ($P>0.05$; $r = 0.13$). Rump width and withers height recorded the highest correlation with testicular characteristics.

Table 4.11: Correlation coefficients between body and testicular conformations in Red Sokoto bucks

	TL	TC	TW	TWT
BW	0.03	0.19	0.19	0.13
BCS	0.20	0.23	0.23	0.28*
HG	0.04	0.19	0.19	0.13
Stature	0.25*	0.49**	0.49**	0.44*
CW	0.02	0.56**	0.56**	0.39*
WH	0.36*	0.61**	0.61**	0.59**
BD	0.00	0.42*	0.42*	0.25*
BL	-0.05	0.48**	0.48**	0.26*
RW	0.31*	0.61**	0.61**	0.60**

** = P<0.01, * = P<0.05, BW: Body weight, BCS: Body condition score, TC: Testicular circunference, TL: Testicular length, TW: Testicular width, TWT: Testicular weight

The result of the correlation analysis between body conformation and semen characteristics is presented in Table 4.12. Semen volume was positively and significantly correlated with BW, BCS and linear body measurement ($P<0.05 – 0.01$; $r = 0.27 – 0.48$) except BD ($P>0.05$; $r = 0.18$). The semen pH was negatively and significantly correlated with BW, BCS and body measurements ($P<0.05$; $r = -0.29$ to -0.41), except BL, BD and RW where though negative it showed no significant correlation.

Live/dead ratio was positively and significantly correlated with BW, BCS and HG ($P<0.05$; $r = 0.30 – 0.39$) but not significantly correlated with ST, CW, BL and RW ($P>0.05$; $r = 0.03 – 0.13$); and also not positively and significantly correlated with WH and BD ($P>0.05$; $r = -0.02$ to -0.01). Other correlation (sperm motility and concentration) were close to zero or not significantly correlated with BW and linear body measurements and three of such relationships were negative with sperm motility and concentration respectively (BW, HG and BL with sperm motility and BL, BD and RW with sperm concentration).

Table 4.12: Correlation coefficients between body conformation and semen characteristics in Red Sokoto bucks

	Volume	Motility	pH	Concentration	Live & dead ratio
BW	0.28*	-0.01	-0.41*	0.01	0.37*
BSC	0.28*	0.02	-0.41*	0.06	0.30*
HG	0.28*	-0.02	-0.41*	0.01	0.39*
Stature	0.48**	0.05	-0.39*	0.05	0.03
CW	0.27*	0.08	0.09	0.17	0.07
WH	0.36*	0.05	-0.29*	0.07	-0.02
BD	0.18	0.06	-0.02	-0.02	-0.01
BL	0.27*	-0.02	-0.19	-0.05	0.13
RW	0.45**	0.08	-0.23	-0.05	0.04

** = P<0.01, * = P<0.05, BW: Body weight, BCS: Body condition score.

Table 4.13 shows the correlation coefficients between testicular measurements and semen characteristics in Red Sokoto bucks.

The result showed that the semen characteristics were positively and significantly correlated with testicular measurements ($P<0.01$-0.05; $r=0.25$-0.39) except semen pH which was negatively and significantly correlated with testicular measurements ($P<0.05$; $r= -0.31$ to -0.37). Semen volume had the highest positive correlation with TWT ($r = 0.39$); followed by sperm motility with TL ($r = 0.38$), as well as live/dead ratio with TL, TC and TW, respectively.

Table 4.13: Correlation coefficients between testicular measurements and semen characteristics in Red Sokoto bucks

	TL	TC	TW	TWT
Volume	0.31*	0.33*	0.33*	0.39*
Motility	0.38*	0.31*	0.31*	0.37*
pH	-0.37*	-0.31*	-0.31*	-0.36*
Concentration	0.31*	0.25*	0.25*	0.32*
Live/dead ratio	0.38*	0.38*	0.38*	0.31*

* = P<0.05, TC: Testicular circunference, TL: Testicular length, TW: Testicular width, TWT: Testicular weight

4.4 Correlated Relationships Between Sperm Morphological Characteristics and Semen Cation Concentrations in Red Sokoto bucks

The correlations amongst the semen morphological characteristics were generally low and not significant, except the correlation between DH and DMT which was perfectly correlated ($P<0.01$; $r=1.00$) (Table 4.14.). Although not significant ($P>0.05$), the correlated relationships between CBT and all other abnormal morphological characteristics were low and negative ($r= -0.05$ to -0.12).

The result of the correlation analysis among semen cation concentrations is presented in Table 4.15. The correlations amongst the semen cations were generally positive but not-significant except the correlation between Na^+ and K^+ ($r = 0.3$; $P<0.05$) and between Ca^+ and PO_4 ($r = 028$; $P<0.05$) which were significant, respectively.

Table 4.16 shows the correlated relationship between sperm morphology and semen cation concentrations in Red Sokoto bucks. The result showed that the sperm morphological traits were negatively and significantly correlated with semen cations ($P<0.05$; $r = -0.28$ to -0.40) except ACR which was positively and significantly correlated with Calcium ($P<0.05$; $r = 0.37$) and also the only positive and significant correlation recorded. Potassium was found to be negatively and significantly correlated with all the sperm

morphological traits (P<0.05; r = -0.31 to -0.40). In the same vein, MPD was found to be negatively and significantly correlated with all the cation concentrations (P<0.05; r= -0.28 to -0.38).

Table 4.14: Correlated relationships among sperm morphological traits in Red Sokoto bucks

	MPD	DH	CBT	ACR
DMT	0.02	1.0**	-0.12	0.12
MPD	-	0.02	-0.05	0.03
DH	.	-	-0.12	0.12
CBT	.	.	-	-0.03

** =P<0.0, MPD: Midpiece droplet, DMT: Detached midpiece and tail, DH: Detached head, CBT: Coiled and bent tail, ACR: Acrosomal abnormality

Table 4.15: Correlation coefficients among semen cation concentrations in Red Sokoto bucks

	Potassium	Calcium	Phosphate
Sodium	0.3*	0.23 `	0.13
Potassium	-	0.04	-0.17
Calcium	.	-	0.28*

*= P<0.05

Table 4.16: **Correlation coefficients between sperm morphology and semen cation concentrations in Red Sokoto bucks**

	DMT	MPD	DH	CBT	ACR
Sodium	0.02	-0.28*	0.02	0.04	-0.01
Potassium	-0.40*	-0.38*	-0.40*	-0.36*	-0.31*
Calcium	-0.03	-0.30*	-0.31*	0.02	0.37*
Phosphate	-0.19	-0.29*	0.19	0.06	0.09

*= P<0.05, MPD: Midpiece droplet, DMT: Detached midpiece and tail, DH: Detached head, CBT: Coiled and bent tail, ACR: Acrosomal abnormality

The correlations between semen and sperm morphological characteristics were generally negatively and not significant except the correlation between CBT and some semen traits ($P<0.05$; $r = -0.29$ to -0.39) as well as the correlation between semen volume; and some sperm morphological defects ($P<0.05$; $r = -0.26$ to -0.29) which were significant (Table 4.17). However the only positive and significant correlation was observed between ACR and live/dead ratio.

The result of the correlation analysis between testicular measurements and sperm morphological traits is presented in Table 4.18. The correlations between testicular measurements and sperm morphological traits were generally low and not significant except the correlation between TL and MPD which was negative and significant ($P<0.05$; $r = -0.33$). Although not significant ($P>0.05$), the correlated relationships between TWT and morphological traits ($r = -0.00$ to -0.09) as well as the relationship between CBT and testicular traits ($r = -0.02$ to -0.08) were low and negative.

The correlation analysis between body conformation and sperm morphological traits is shown in Table 4.19. DMT was positively and significantly correlated with BD ($P<0.05$; $r = 0.39$) but negatively and significantly correlated with WH ($P<0.05$; $r = -0.25$). MPD was positively and significantly correlated BW, HG and CW ($P<0.05$; $r = 0.25 – 0.28$).

ACR also recorded a positive and significant correlation with CW (P<0.05; r = 0.30). DH only recorded positve and significant correlation with WH and BD (P<0.05; r = 0.25 – 0.39), while CBT was observed to be negatively and significantly correlated with BW, BCS, HG and Stature (P<0.05; r = - 0.25 to - 0.39).

Table 4.17: Correlation coefficients between semen and sperm morphological characteristics in Red Sokoto bucks

	Volume	Motility	pH	Concentration	Live & dead ratio
DMT	-0.26*	-0.24	0.04	-0.17	0.13
MPD	-0.18	-0.11	-0.11	0.06	0.13
DH	-0.26*	-0.24	0.08	-0.17	-0.13
CBT	-0.29*	-0.24	0.13	-0.29*	-0.39*
ACR	0.09	0.04	0.19	-0.15	0.27*

* =P<0.05, MPD: Midpiece droplet, DMT: Detached midpiece and tail, DH: Detached head, CBT: Coiled and bent tail, ACR: Acrosomal abnormality

Table 4.18: Correlation coefficients between testicular measurements and sperm morphological traits in Red Sokoto bucks

	TL	TC	TW	TWT
DMT	0.02	0.02	0.02	-0.00
MPD	-0.33*	0.17	0.17	-0.09
DH	0.02	0.02	0.02	-0.00
CBT	-0.08	-0.02	-0.02	-0.05
ACR	-0.12	0.05	0.08	-0.01

* =P<0.05, MPD: Midpiece droplet, DMT: Detached midpiece and tail, DH: Detached head, CBT: Coiled and bent tail, ACR: Acrosomal abnormality, TL: Testicular length, TC: Testicular circumference, TW: Testicular width, TWT: Testicular weight

Table 4.19: Correlation coefficients between body conformation and sperm morphological traits in Red Sokoto bucks

	DMT	MPD	DH	CBT	ACR
BW	-0.10	0.28*	0.10	-0.39*	0.02
BCS	0.10	0.04	-0.10	-0.25*	0.14
Heart girth	-0.11	0.28*	-0.11	-0.39*	0.03
Stature	0.20	0.09	0.20	-0.26*	-0.18
Chest width	0.11	0.25*	-0.11	0.01	0.30*
Wither height	-0.25*	0.11	0.25*	-0.01	-0.07
Body depth	0.39*	-0.00	0.39*	0.10	-0.11
Body length	0.18	0.23	0.18	-0.21	-0.02
Rump width	0.08	0.00	0.08	-0.03	0.16

* =P<0.05, BW: Body weight, BCS: Body condition score, MPD: Midpiece droplet, DMT: Detached midpiece and tail, DH: Detarched head, CBT: Coiled and bent tail, ACR: Acrosomal abnormality.

The result of the correlation analysis between semen characteristics and semen cation concentrations is presented in Table 4.20. Semen volume was positively and significantly correlated with K^+ and Ca^{2+} ($P<0.05$; r= 0.27 – 0.31) but not with Na^+ and $P0_4$ ($P>0.05$; r= 0.13 – 0.14). Sperm motility was positively and significantly correlated with Na^+ and K^+ ($P<0.05$; r= 0.26 – 0.33). Sperm concentration only recorded positive and significant correlation with K^+ ($P<0.05$; r= 0.37), while live/dead ratio was positively and significantly correlated with only Na^+ ($P<0.05$; r= 0.39) among the cation.

Table 4.21 shows the correlated relationships between testicular measurements and semen cation concentrations. The result showed that Ca^{2+} was positively and significantly correlated with testicular measurements ($P<0.05$; r=0.34 – 0.39), while Na^+ recorded negative and non-significant correlation with testicular measurements ($P>0.05$; r= -0.02 to -0.10). Other correlations were close to zero or not significant.

The correlation analysis between body conformation traits and semen cation concentrations is shown is Table 4.22. Negative but significant ($P<0.05$) correlation was observed between Na^+ and BL (r= -0.26). K^+ was positively and significantly correlated with body conformation traits ($P<0.05$-0.01; r=0.29 – 0.52), except BW, BCS and HG ($P>0.05$; r=-0.09 to -0.14). Ca^{2+} was positively and significantly correlated with CW, WH,

BD and RW (P<0.05; r=0.29-0.42) but was negatively and non-significantly correlated with BW, BCS and HG (P>0.05; r=-0.03 to -0.05). K^+ and Ca^+ had the strongest positive correlation with BD, followed by WH.

Table 4.20: Correlation coefficients between semen characteristics and semen cation concentrations in Red Sokoto buck

	Volume	Motility	pH	Concentration	Live& dead ratio
Sodium	0.14	0.26*	-0.05	0.02	0.39*
Potassium	0.27*	0.33*	0.01	0.37*	0.01
Calcium	0.31*	0.02	0.15	0.00	0.06
Phosphate	0.13	-0.04	-0.13	0.05	-0.08

*= P<0.05

Table 4.21: Correlation coefficients between testicular measurements and semen cation concentrations in Red Sokoto buck

	TL	TC	TW	TWT
Sodium (Na)	-0.02	-0.10	-0.10	-0.10
Potassium (K)	0.11	0.21	0.21	0.20
Calcium (Ca)	0.21	0.39*	0.39*	0.34*
Phosphate (PO_4)	0.16	0.07	0.07	0.15

*= P<0.05, TL: Testicular length, TC: Testicular circumference, TW: Testicular width, TWT: Testicular weight

Table 4.22: Correlation coefficients between body conformation and semen cation concentrations in Red Sokoto Bucks

	Sodium	Potassium	Calcium	Phosphate
BW	0.11	-0.09	-0.03	0.16
BCS	0.19	-0.14	-0.05	0.04
Heart girth	0.09	-0.10	-0.03	0.18
Stature	0.07	0.33*	0.21	0.06
Chest width	-0.07	0.29*	0.33*	0.14
Wither height	-0.03	0.44**	0.31*	-0.03
Body depth	-0.24	0.52**	0.42*	-0.08
Body length	-0.26*	0.29*	0.17	0.05
Rump width	0.01	0.39*	0.29*	0.02

**= P<0.01, * =P<0.05, BW: Body weight, BCS: Body condition score

CHAPTER FIVE

5.0 DISCUSSION

5.1 Body Conformation, Testicular and Semen Characteristics

The mean BWT observed in this study (15.02±0.46 kg) was consistent with 15.47±0.28 kg reported by Otuma (2005) for WAD x RSG crossbred bucks from birth to 2 years of age and close to 16.41 kg reported by Hassan and Ciroma (1992) for 1 – 2 year age group of Red Sokoto goats. Akpa *et al*. (1998) reported mean body weight in Red Sokoto goats at 7 – 12, 12 – 18 and 19 – 24 month of age to be 14.8±1.07, 17.3±0.93, 19.8±0.50 kg, respectively which is slightly higher than what was obtained in this study. Results obtained by Karua and Banda (1992), Okpeku *et al*. (2011) and Yakubu and Mohammed (2012) on Red Sokoto goat were higher than the one obtained in this study. Mean weight of 22.32 kg obtained by Yakubu and Mohammed (2012); and 17.8±1.24 kg by Karua and Banda (1992) in Red Sokoto bucks, respectively were all higher than 15.02 kg obtained in this study.

However, Adeyinka and Mohammed (2006) reported 10.02±0.73 kg for Red Sokoto buck; Ebegbulem *et al*. (2011) reported 13.46±0.54 kg for WAD, while Bello and Adamu (2012) reported 9.6 kg for Savanna brown bucks; these results are lower than the present result. The discrepancies may due to breed and age differences. The results of the present study

also agreed with the report of 15.37 kg mean body weight reported by Okpeku *et al*. (2011) on WAD goat. Yakubu and Mohammed (2012) obtained high variability (19.5%) in body weight which is close to (17.01%) obtained in this study. The high variability in the body weight might not be unconnected with the environmental influences such as temperature and nutrition on this variable. This variation therefore, could serve as a basis for the genetic improvement of body weight.

The mean HG, WH and BL of 81.7 ± 4.72 cm, 67.1 ± 4.03 cm and 69.5 ± 5.56 cm as reported by Okere *et al*. (2011) in Kiko bucks and 75.3 ± 4.87 cm, 62.6 ± 2.88 cm and 64.6 ± 6.2 cm by Keith *et al*. (2009) in Boar bucks, respectively were all higher than the result of the present study. This may be due to differences in breed, climate or breeding goal. The results on body length reported by Yakubu *et al*. (2010b) and Yakubu and Mohammed (2012) as well as the results on rump width and body depth as reported by Yakubu *et al*. (2010b) on Red Sokoto goat, agreed with the present results.

Raji *et al*. (2008) reported 23.17 cm, while Adedeji and Gbadamosi (1999) reported 22.6 cm for testicular circumference in Red Sokoto bucks at 2 years of age. These are higher than that of the present study at similar age group. Higher results had also been reported by Keith *et al*. (2009) and Mekasha *et al*. (2008). However, similar to what was obtained in the present study was the result of Ugwu (2009) who reported a value of 17.25 ± 0.76 cm in WAD. The variability may be due to breed difference, contemporary group level, age, weight and height of bucks (Bourdon and Brinks, 1986).

The strong influence of age on live body weight and linear body measurements in all the traits measured was depicted by the consistent increases in all the measurements as the

animal advanced in age. This is expected since as the animals grow, size and shape are expected to increase with age. The observed values for linear traits in this study were slightly lower to those reported by Hassan and Ciroma (1992) and higher than those reported by Adeyinka and Mohammed (2006) in Red Sokoto goat. Among the four age groups, it was observed that body weight at age group 17 – 20 month was the highest which was statistically higher than 9 – 12 age group, but did not statistically different from age group 13 – 16 and 21 – 24, respectively.

This might be due to the expectation that higher age come with higher body lengths and height until the peak is reached and then followed by decline. The result was similar to the report of Akpa *et al*. (1998) who observed body weight in Red Sokoto bucks at 1 – 6, 7 – 12, 13 – 18, 19 – 24, 25 – 30, and 31 – 36, months of age to be 10.2±0.87, 14.8±1.07, 17.3±0.93, 19.8±0.50, 31.5±1.12 and 31.3±1.21 kg, respectively; and that of Rahman (2007) who observed body weight of black Bengal bucks at 11.5 - 12.0, 14.0 - 16.0 and 17.5 - 19.0 months of age to be 16.62±0.12, 17.62±0.22 and 20.86±0.25 kg, respectively.

The results of the present study also agrees with the reports of Alam (2006) and Herbert *et al*. (2003). However, Adedeji and Gbadamosi (1999) and Raji *et al*. (2008) reported higher body weight of 26 kg and 25.53 kg respectively for Red okoto bucks at 2 years of age which are not consonant with 15.3 kg observed in the present study at similar age group. Higher body weight had also been reported by Hamayun *et al.* (2006); and Fida *et al*. (2006) at comparable age group. It was observed that body weight at age group 17 – 20 was the highest while 21 – 24 was lower. This is in consonance with the results of Akpa *et al*. (1998). This may be due to seasonal effect, physical condition of the animals and higher breeding activities as they mature.

There was no wide variability in body measurements as the age of the animals increased, especially in live body weight. This is not in agreement with the earlier reports (Hamayun *et al*., 2006; Fajemilehin and Salako 2008) in goat who reported wide variations.

The effect of age on body linear measurements in Red Sokoto bucks was strong as there were consistent increases in all the traits as the animals aged. Akpa *et al*. (1998) had reported overall mean values for height at withers for Red Sokoto bucks at 7 – 12, 13 – 18, and 19 – 24 months of age to be 47.5±3.26, 53.3±1.49, and 53.5±1.87 cm, respectively while Fida *et al*. (2006) reported 60.30, 68.25 and 72.14 cm at similar age group for Pakistani bucks. These results are not consistent with the result on height at withers obtained in this study. The same trend was also observed in heart girth reported by Akpa *et al*. (1998) and Fida *et al*. (2006) respectively. Hamayun *et al*. (2006) reported the body length of bucks at 4 – 12, 18 – 13 and 19 – 24 months age groups to be 59.60±0.74, 64.38±1.39, and 69.42±0.29 cm respectively.

This is close to 51.2, 58.0, and 63.6 cm recorded in this study in the similar age groups.
The same trend was also observed in heart girth. Rahman *et al*. (2008) reported 59.08±0.87 and 63.25±1.07 cm for HG; and 47.92±0.76 and 51.21±0.93 cm for HW at 9 and 15 months of age respectively. These results are similar to the result of the present study at similar age group. However, the body length reported by Akpa *et al*. (1998) was slightly lower to the one obtained in the present study at similar age group. The observed linear body measurements in the present study also conformed to those reported by Moruppa and Ngere (1986) for Red Sokoto goats in similar age groups.

The significant effect of age on all the testicular measurements in Red Sokoto goats has also been reported by other authors (Ogwuegbu *et al*., (1985); Shamsuddin *et al*., (2000); and Rahman, 2007). Age group 21 – 24 months was observed to be superior in testicular circumference than other age groups. This might be due to differences in age, body weight and height of bucks.

A large TC is associated with good semen quality and a high daily sperm production in bucks (Mekasha *et al*., 2007a) and in bulls (Cook *et al*., 1994). Changes in testicular circumference after reaching sexual maturity can occur in goats due to the influence of photoperiod, nutritional status and temperature (Coelho *et al*., 2006; Almeida *et al*., 2007; Delgadillo *et al*., 2007). However, even though SC increases with age, its growth increment is curvilinear with age in bucks compared to increases in BW (Bongso *et al*., 1982). Earlier studies have demonstrated that SC increases rapidly in young bulls, only gradually in mature bulls and can even decrease as bulls aged (Brito *et al*., 2002a).

In the present study, the size of the testes varied in different age groups. The length and width of testes were also observed to increase with the advancement of age of animals which agreed with the findings of Islam (2001) and Gofur *et al*. (2007). Higher testes weight in age group 21 – 24 month might be due to their higher body weight and size. Raji *et al*. (2008) reported the average testicular weight at 1.0, 2.0, and 3.0 years of age to be 55.00±2.87, 77.28±1.88 and 103.01±2.23 gm respectively in Red Sokoto goats, while Kabiraj *et al.* (2011) reported 77.17, 126.58, and 131.53 gm respectively at similar age group in black Bengal bucks. These results are much lower to the present result. This might be due to physical condition of the selected animals, agro-climatic condition, nutritional level, housing, disease control and other management procedure.

Since TW is highly related to sperm production, selection of bucks with larger testes would enable the insemination of more females in any AI programme (Coulter *et al*., 1975). Testicular weight has been shown to be sensitive to nutrition, and animals on a better dietary regime had heavier testes than those on a lower-quality dietary regime (Mekasha *et al*., 2007a).

Adedeji and Gbadamosi (1999); and Raji *et al.* (2008) reported testicular length of 13.6 cm and 13.26 cm at 2 years of age in Red Sokoto bucks respectively. These are similar to 13.2 cm obtained in this study at similar age group.

The effect of age on semen characteristics was variable and was only observed for semen volume and sperm concentration. Higher semen volume in age group 21 – 24 month might be due to older age with higher scrotal circumference of the animals.

The semen volume obtained in the present study ranged from 0.2±0.05 to 0.6±0.05 ml with mean 0.42± 0.05 (Tables 1 and 4) which strongly supports the findings of other researchers (Karim, 2008; Villar *et al*., 1993; Singh *et al*., 1985). Kabiraj *et al.* (2011) reported 0.32±0.04 and 0.55±0.05 ml at 0.5 – 1 and 1.5 – 2 years of age respectively. This result is in consonance with the present study.

Furstoss *et al.* (2009) reported 0.48±0.10 ml of semen produced from Alpine bucks at 7 months of age which was slightly higher than the result of the present study (0.2±0.05 ml at 9 – 12 months of age). These might be due to breed and nutritional differences, seasonal variation, collection methods and time of collection. Das *et al*. (2006) reported volume range of 0.16 to 0.51 ml in Black Bengal buck, which is lower than the values of this study. Variation in semen volume reported by different workers might be due to

differences in genetics, reproductive health status of bucks, age of bucks, frequency of collection, pooled volume, nutrition, season and management (Soderquist *et al*., 1992). Variations can also be due to skill of semen collector/attendant and temperature of AV.
The superiority of age group 13 – 16 in sperm concentration may be due to the confounding effect of season.

Findings on sperm concentration in this study were not in agreement with the findings of Karim (2008) who reported the average sperm concentration range of 2.75±0.28 to 3.24±0.37 billion/ml in Black Bengal buck; and Khan (1999) who reported the average sperm concentration of 3777.93±142.76 million/ml respectively. These are higher than the result of the present study. Leon *et al*. (1991) and Sharma *et al*. (1991) reported that sperm concentration might vary according to variation in age, breed, collection frequency, feeding regime and climatic condition. According to Afroz (2005) and Apu (2007), the average sperm concentrations of buck semen were 2678.33±30.59 to 2913.33±46.23 and 2434.00±52.81 to 2853.00±90.12 million/ml, respectively. These are higher than the present results.

It is known that the morphological characteristics of spermatozoa are influenced by several factors including the genetic-make up, the physiological stage of the animal, nutrition, climatic factors and disease (Dowsett and Knott, 1996; and Dana *et al*., 2000). Also, Greyling and Grobbelaar (1983) indicated that the percentage of live sperm yielded by the technique of the artificial vagina was significantly higher than those of semen collected by electro-ejaculator. These might be the reasons for lower sperm concentration as observed in the present study.

On the other hand, Javed *et al*. (2000) reported 1.00±0.50 × 10^6/µl; while Raizada *et al*. (1988) and Terezinha *et al*. (1991) had reported sperm concentration of 2.90 and 1.33 ×10^6/µl) in buffalo bulls. These results are lower than the results of the present study. These variations may be attributed to breed and age differences. It can be observed in the present study that sperm concentration was higher in adult bucks (13 – 20 month) than the young (9 – 12 month) and old bucks (21 - 24 month).

This may be attributed to pattern of reproductive advancement in bucks, particularly testicle size and thermo-regulatory mechanisms which are still developing in the young buck, but have reached maturity level in the adult buck. As bucks advance in age, testicular tissues may be broken down faster than being replaced (King, 1993). This may result in testicular degeneration, hence lesser semen production in the older bucks.

The results of the present study indicated an inverse proportional relationship between hair type and body measurement, suggestting that performance is much determined by body weight and not by hair type (Peters *et al*., 1982). While hair characteristics may be of limited value in selection of meat goats to improve thermal adaptation, hair type can however play a role in avoiding ecto-parasitic infestation as long wooly or rough hair type has been reported to result into a lower body weight than a short coat (Peters *et al*., 1982). The significant effect of hair type on all testicular measurements except testicular length as observed in short-smooth haired bucks showing more superiority to long curly might be connected to adaptation. Short-smooth hair has advantage over long-curly as it provides a medium for convectional heat loss from the animal surface. This is supported by the assertion that hair structures have an important role to play in the adaptability of animals to different ecological zones (Banerji, 1984).

It can be observed that the scrotum of short haired bucks were relatively broader (TC) wider (TW) and heavier (TWT) than the long curly haired bucks. The non-effect of hair type on semen characteristics in the present study may be explained by the fact that ambient temperature is considered as a secondary factor (after day length) affecting reproductive capacity in male small ruminants (Thimonier *et al*., 1986).

With animals on a good plane of nutrition as in the present study, all reproductive processes that are dependent on or related to male organ weights like sperm production and the efficiency of sperm production; sperm storage capacity and semen characteristics would therefore be expected to be stable in the buck all year round.

Body weight affects BCS, while, body condition had significant effect on all the conformation traits except chest width and body depth. This signified that bucks with good body weight and healthy body parts are expected to have a good body score and composition and vice versa. The correlation of the BCS with body weight was reported by Sanson *et al*. (1993) who reported that body weight and condition scores were highly correlated (0.89) and an analysis indicated that each unit increase in condition score resulted in an increase of 5.1 kg in body weight. Hence, bucks with BCS (4) as observed in the present study were relatively bigger in size and weighed more than those with BCS (3). Results of Aumont *et al*. (1994) on Creole goats indicated that composition of muscle and adipose tissue was significantly influenced by body condition scoring. Ozoje and Mgbere (2002) also reported on the use of skeletal dimensions such as heart girth and wither height as good indicators of live weight and condition score.

In this study, all the testicular traits were significantly affected by BCS which suggest that

bucks with larger body size and good body score might possess larger scrotal size which may invariably result into a good reproductive capability and improve the fertility of the animal (Akpa *et al.*, 2012a). Better body conformation as observed in bucks with BCS (4) than bucks with BCS (3) signified that bucks with BCS 4 may be expected to have a scrotum that is longer (TL), broader (TC), wider (TW) and heavier (TWT) than those with BCS of 3.

BCS only had effect on semen volume and semen pH. This suggests that buck with better body condition may be expected to produce more semen per ejaculate. This is attributed to larger testicular size expected from bucks with good body score, hence the production of higher semen volume. Akpa *et al*. (2012a) reported significant correlation between body condition score and testicular circumference as well as testicular weight. Live weight and body condition score are important variables influencing the reproductive capacity of domestic animals. Bucks with BCS (4) in the present study were relatively bigger with larger scrotum, hence the reason for increased volume of semen as observed in BCS (4) than what was observed in bucks with BCS (3).

5.2 Sperm Morphological Characteristics and Semen Cation Concentration

The mean values obtained in the present study for sperm morphological defects are supported by the report of Elwishy and Elsawaf (1971) and Mekasha *et al.* (2007b) who observed similar trend. Bitto and Egbunike (2012) reported mean values of 3.01±0.29 and 1.78±0.26 for detached head, in pubertal and adult WAD goats, respectively. These are relatively higher than the result of the present study. Akpa *et al*. (2012b) reported mean 0.7±0.07 for DH in Yankasa ram, which is slightly higher than the value obtained in the present study. The differences may be due to variations in breed, age, secretory activities of the accessory sex glands. Moreover, collection frequency, pre-collection sexual

stimulation, semen collection methods and feeding regime can also influence the sperm abnormality (Kaya *et al*., 2002).

However, it is worthy to observe that the total abnormal spermatozoa in the Red Sokoto buck obtained in this study is 3.3% which is within the acceptable range of not more than 20% of the semen acceptable for use in Artificial Insemination (AI) (Hafez, 1993). Observation from this study demonstrated that cations in semen vary in concentration due to the influence of age, hair type and body condition score. Among the cations, it was observed that the concentration of sodium was the highest, followed by potassium while the calcium content was the lowest. Similar observation/trend has been reported by other authors (Kanwal *et al.,* 2000; Akpa *et al*., 2012b).

Average calcium of (2.62 $\pm$ 0.02 mmol/l) obtained in the present study is comparable or similar to (2.5±0.03 mmol/l) obtained by Akpa *et al.* (2012b) on Yankasa ram; and 10.3±1.0 mg/dl (2.57 mmol/l), 11.20±1.25 mg/dl (2.80 mmol/l) and 9.95±0.35 (2.49 mmol/l) obtained by Asadpour, (2012) on Merino x Moghani, Ghezel x Merino and Ghezel x Baluchi cross bred rams respectively, but lower to 25.3$\pm$2.5 mg/dl (6.33 mmol/l) obtained by Kanwal *et al.* (2000) in bull; and 43.5 $\pm$ 2.8 mg/dl (10.88 mmol/l) obtained by Banerjee and Ganguli *(*1973) in Zebu bull. Abdel-Rahman *et al.* (2000) reported higher value of 22.2$\pm$2.3 mg/dl (5.55 mmol/l) on Barbari ram; 24.3$\pm$2.9 mg/dl (6.08 mmol/l) on Merino ram and 26.9$\pm$2.8 mg/dl (6.73 mmol/l) on Naemi ram, respectively.

Higher Ca content in semen has been reported to have a depressing effect on sperm metabolism (Mann and Lutwak-Mann, 1981) and exaggerated the detrimental effects of K (Abdel-Rahman *et al.,* 2000). Ca triggers the acrosome reaction in mammalian

spermatozoa and is also involved with sperm motility (Kaya *et al*., 2002). Meseguer *et al*. (2004) have reported that Ca^{2+} concentration in seminal plasma is good predictor of post-thaw semen quality. It is to be noted that Ca^{2+} level of 2.62 mmol/l observed in the seminal fluid in this study is of advantage because it is within the recommended level of 5-15 mg/dl (1.25-3.75 mmol/l) for quality semen.

Na is an extracellular element while K is intracellular in nature. There are opinion that normal ionic equilibrium and osmotic pressure are maintained by these ions (Hawk *et al*., 1964). The average K and Na content of 67.79 $\pm$ 5.33 and 94.90±3.24 (mmol/l) obtained in this study was comparable to the findings of Akpa *et al.* (2012b) who reported 68.3±2.84 and 92.6±2.05 (mmol/l) for K and Na, respectively in Yankasa ram. They are however lower than 101.60 $\pm$ 4.45 and 186.89$\pm$10.90 mmol/l obtained by Singh *et al.* (1969) and 156.3±15.9 and 109.1±11.2 obtained by Abdel-Rahman *et al*. (2000) for potassium and sodium, respectively in Merino ram. On the other hand, Asadpour (2012) reported a lower value of 42.00±2.25 and 12.70±0.25 mg/dl for Ghezel x Merino ram; and 37.66±6.56 and 11.10±1.92 mg/dl for Merino x Mogbani crossbred rams respectively. The differences may be due to breed and age differences nutrition and environmental conditions.

High levels of Na^+ and K^+ has been reported to be associated with low percentages of motile sperm, and such semen was considered to be of lower quality (Asadpour, 2012). Na ion is an important element for spermatozoa function (Mosaferi *et al*., 2005). K^+ is a natural metabolic inhibitor and higher K^+ concentration in seminal plasma decreases sperm metabolism thereby, decreasing sperm motility (Massányi *et al*., 2003). Zamiri and Khodaei (2005) showed that low levels of Na^+ and K^+ ions were associated with high

percentage of motile sperm, which suggest that the cations Na^+ and K^+ are generally involved in establishment of osmotic balance, and that seminal plasma osmolality ultimately plays an important role in the activation of sperm cell. The lower values for Na^+ and K^+ as obtained in the present study might be responsible for appreciable sperm motility percentage (76-80.3%) obtained in this study which suggests that semen from the bucks may be of high quality.

It is to be noted that the level of Na^+ and K^+ concentration in this study: 94.90 and 67.79 (mmol/l) respectively, are within the recommended range of 60-183 and 76-255 (mg/dl) for Na^+ and K^+ respectively which is expected to give optimal reproductive performance of the buck. The concentration of inorganic phosphorus (5.42 $\pm$0.39) in the current study was similar to the previous reports of 6.4 $\pm$ 0.6 by Roy *et al.* (1960); and 7.56 $\pm$ 0.42 by Singh *et al.* (1969) whereas an even higher concentration of 12.28 $\pm$ 0.37 by Dhami and Sahni (1993) has also been reported. The phospholipid is required for the preservation of the sperm membrane integrity (Singh *et al*., 1969).

The significant influence of age on sperm morphology indicates that age is an important determinant of sperm morphology. Although sperm abnormalities were present in all the age categories, it was however more prevalent in the younger than the older bucks except for DH and ACR. The presence of sperm abnormalities in all the age categories may probably indicate that sperm abnormalities of any kind could be present in semen irrespective of age category. Occurrence of more normal semen morphology in mature bucks compared to younger and older bucks as observed in this study may probably be due to variation in scrotal circumference, age, body size, secretory activities of their sex glands (Brito *et al*. 2002b; Leon *et al*. 1991) and the heat regulation mechanisms

(McDowell, 1972), which increases with age and then decline at later age.

Age of the animal is an important physiological factor that modifies the sperm morphological characteristics of domestic animals. This has been demonstrated by some studies, which found abnormal sperm head shape to be more prevalent at younger age, to gradually decrease after sexual maturity, and to become greater again at older age, provided that the animal is healthy (Soderquist *et al*., 1991; Amann *et al*., 2000).

This trend was observed in the present study as detached head and acrosome were first seen to be prevalent in the younger bucks (9 – 12 month) and then decrease at maturity age (13 – 20 month) and become greater again at old age (21 – 24 month). The same trend was also observed by Mekasha *et al*. (2007b) on indigenous Ethiopian bucks; Abd-Allah *et al*. (2007) on Native Egyptian bucks; and Vilakazi.

Earlier studies had shown that scrotal circumference was positively correlated with sperm morphology (Barth and Oko, 1989; Vale Filho *et al*., 1997) and that sperm abnormality increases rapidly in younger bucks, gradually in mature bucks and tended to decrease in older bucks (Coulter and Foote, 1977). Bucks often reach puberty at the age of 5 – 7 months and maturity at the age of 1 to 2 years (Chandler *et al.*, 1988). Prior to maturity, the reproductive system in bucks, particularly testicle size (Coulter and Foote, 1977) and thermo-regulatory mechanisms (McDowell, 1972) are still developing. As a consequence, a higher proportion of sperm defects may appear in the ejaculate of bucks prior to maturity (Bearden and Fuquay, 1997) than in older bucks. As bucks advance in age, testicular tissues may be broken down faster than being replaced (King, 1993). This may result in testicular degeneration and abnormal scrotal thermograms, and hence poor sperm morphology in older bucks.

According to Barth and Oko (1989), sperm tail pathologies (bent or coiled) may result from failures in thermoregulation, testicular degeneration, hypo-osmotic conditions or failures in epididymal transit. Just like what was observed by Folhadella *et al*. (2006) in the bovine species, the high prevalence of tail pathologies in this study, such as the detached midpiece and tail; midpiece droplet and coiled and bent tail as observed in the pubertal age category can be associated with sexual immaturity.

Under normal conditions, sperm tail defects decrease against the increasing age gradient, which indicates sexual maturity of domestic animals (Mekasha *et al.* (2007b). The same trend was observed by Akpa *et al*. (2012b). Age had significant effect on all the cations investigated with bucks with 21 -24 month showing superiority over the rest age group. This is expected because metabolic activities such as the secretion and utilisation of cations such as Na^{+}, K^{+}, and Ca^{2+} are known to be more intensified at adult age than at young age in animal.

The variation of the sperm abnormalities with hair type is probably due to the temperature absorbing capacity of the hair, and Hansen *et al*. (2001) reported that a rise in body temperature affects the viability of spermatozoa. This implies that hair types indirectly affect sperm viability by influencing the body temperature. In this study, the short smooth haired bucks had fewer abnormalities than the others. This is in line with the earlier reports (Tumpenny *et al*., 2000) that short, sleek, thin hair coat improved heat and water vapour conductance through the coat layer in stressful hot and humid environments. Short rough hair also had fewer sperm abnormalities in rams than the other hair type (Akpa *et al*., 2012b).

Concentration of Na in the semen of the bucks is relatively higher in long curly haired than short-smooth haired bucks. This might be attributed to increased body temperature always exhibited by long curly haired bucks due to their less heat radiating capability (Peters *et al*., 1982). High body temperature encourages increased metabolic activities hence the production of higher concentration of seminal Na^+. This study is contrary to the report by Akpa *et al.* (2012b) who reported lower concentration of Na^+ in long curly haired rams than the other hair type.

Bucks with BCS (4) had lower detached head and more concentration of Na^+ in the semen compared to BCS (3). Therefore, it seems that bucks with lower body condition score tends to have higher sperm morphological abnormalities and less semen cation concentration. As has been reported earlier (Hossain *et al*., 1990), abnormalities of the spermatozoa could occur due to disorder of the seminiferous tubules or germinal epithelium, which is directly or indirectly related to the body conditions of the bucks, the present results appear to fall within the normal variation range.

5.3 Relationships Between Body Dimensions, Testicular and Semen Characteristics in the Bucks

Positive and highly significant ($P<0.01$) correlations ($r = 0.3 – 0.99$) as observed among various conformation traits indicated that the traits were linked. A highly significant correlation ($r = 0.99$) was established between body weight and chest girth; and ($r = 0.82$) between body weight and body condition score respectively, indicating strong relationships or degree of association between these variables. Ford *et al*. (2009) reported correlation of r = 0.98 and 0.60 in Kiko bucks, while Keith *et al*. (2009) reported lower correlation of r = 0.84 and 0.653 in pubertal Boer buck, respectively for body weight and

heart girth; and for body weight and BCS. These results indicate that the degree of fleshiness is an important consideration when evaluating the weights of goat.

Okpeku *et al*. (2011) reported correlation of r = 0.91 for body weight and heart girth in Red Sokoto buck while Rahman *et al*. (2008); and Yakubu and Mohammed (2012) reported the same value (r = 0.91) for body weight and heart girth correlation in black Bengal buck and Red Sokoto goats, respectively.

These findings are similar to the present study. The highest correlation coefficient reported between BW and HG (r = 0.99) in this study is also consistent with r = 0.99 observed by Adeyinka and Mohammed (2006) in Red Sokoto goats and r = 0.98 observed by Ford *et al.* (2009) in Kiko bucks as well as r = 0.93 observed by Ojedapo *et al*. (2007) in WAD. The relationship between body weight and heart girth can be explained by intimate association between body weight and growth of muscles, bones and visceral organs (Prasad *et al*., 1981), thus indicating that heart girth may be used as a predictor of body weight. The results of the present study were higher than the findings of Khan *et al*. (2006) who observed positive correlation of (r = 0.64) between body weight and heart girth.

The significant correlations between body weight and linear traits showed that various conformation traits could be used as alternatives to body weight as indicators of growth. It also indicates that an increase in any one body measurement would result in a corresponding increase in live body weight, thereby suggesting that either or the combination of these linear traits could be used to estimate live weight in goats fairly well in the situation where scales are not available. The association may also be useful as

selection criterion since positive correlations of traits suggest that the traits may be under the same genetic influence.

Testicular characteristics were positively correlated with each other ($r = 0.81 – 1.0$; $P < 0.01$). Testicular circumference could provide a useful estimate of testicular growth since its correlations with other testicular measurements were the highest. Meeting or exceeding minimal scrotal circumference values based upon buck's age may serve as a requirement for selection of bucks for breeding.

The present results are in accordance with the findings of Salhab *et al*. (2001); and Koyuncu *et al*. (2000; 2005). The highest correlation observed in this study ($r = 1.0$) between the TC and TW is consistent with $r = 0.97$ reported by Oyeyemi and Ubiogoro (2005) in Nigeria large white boars; and $r = 0.90$ reported by Osinowo *et al*. (1977) in bull as well as close to $r = 0.65$ as reported by Ugwu (2009) in WAD buck.

In the same vein, the correlation coefficient between testicular circumference and testicular weight ($r = 0.83$) as reported in this study is similar to the value of $r = 0.79$ reported by Raji *et al*. (2008) and same value by Keith *et al.* (2009) in Red Sokoto buck and pubertal Boer goat, respectively. Koyuncu *et al*. (2005) reported correlation of $r = 0.84$ in Kivircik ram, while Ugwu (2009) reported $r = 0.72$ in WAD buck for testicular circumference and length which are in consonance with $r = 0.81$ observed in the present study. However, Raji *et al*. (2008) reported higher value of $r = 0.94$ for the same traits in Red Sokoto bucks. This suggests that the testicular length is an indicator of testicular circumference. Moreover, $r = 0.77$ observed between TL and TWT in the present study is

slightly higher than r = 0.67 reported by Kabiraj *et al.* (2011) in black Bengal bucks. The difference could be due to the effect of genotype or breed.

There appear to be interaction between testicular circumference as well as testicular size in relation to the appearance of spermatozoa in the ejaculate. Rege *et al*. (2000) and Keith *et al*. (2009) suggested the use of scrotal size and testicular measurements to select for improved sperm production in breeding males. It seemed that not only is there a certain degree of scrotal circumference and testicular size required before sperm could be produced, but also a limit of chronological age below which puberty cannot be attained irrespective of the nutrient management regime applied.

Hence, advantages would accrue from selecting bucks of higher than-average scrotal circumference, even if it were unrelated to the fertility of the buck themselves. Yet whether or not it is justifiable to set acceptable standard scrotal circumference (testis size) for meat goat breeds is open to debate, and requires further investigation.

Volume of semen showed no significant correlation with live & dead ratio (r = 0.06), but showed positive and significant correlation with sperm concentration indicating that the higher the semen volume the more will be the concentration of spermatozoa. This is supported by Webb *et al*. (2004) who observed similar trend. Kabiraj *et al*. (2011) reported correlation of r = 0.77 between semen volume and sperm concentration in black Bengal bucks, which is higher than the value obtained in the present study. However a negative but significant correlation was observed between semen volume and pH (r = -0.37) in the bucks. This is supported by Alkass and Ahmed (2011) who reported correlation of r = -0.36 between semen volume and pH in black goat and Meriz bucks.

Semen pH in the present study showed a negative non-significant correlation with live/dead ratio (r = -0.10), but a positive and significant correlation with sperm concentration (r=0.38), indicating that pH of the semen is a good indicator of sperm concentration. It has been observed that pH depends upon sperm concentration and that a good sperm concentration has an acidic pH (Barnabe *et al*. 1992; Younis, 1996). The observed positive and significant correlation between sperm motility and live & dead ratio indicates that the number of live or dead spermatozoa observed in the semen of the bucks depends on the progressive active movement of the sperm. This agreed with Alkass and Ahmed (2011) on black goat and Meriz bucks.

The positive and significant correlation between testicular dimensions and some of the body measurements suggest that males with larger testicular size might possess larger body size and good reproductive ability. Testicular length and circumference are measures of testicular size which had been found to be significantly correlated with body weight (Adedeji and Gbadamosi, 1999; Bratte *et al* 1999). However, Adedeji and Gbadamosi (1999) reported higher association value (70%) between body and testicular measurements, but this study reported up to (61%). The difference are not significant. A significant correlation between testis weight and wither height as well as between testis weight and rump width could be used in selection of animals for breeding program such as when AI is required. The present result is consistent with the report of Waheed *et al*. (2011) who reported a correlation of r = 0.347 between testicular length and withers height; and r = 0.36 between testicular length and rump width, in Pakistani Beetal male goats, which is consistent with r = 0.36 and 0.31 obtained in this study

In the same vein, Waheed *et al*. (2011) also reported r = 0.52 and 0.43 between testicular

circumference and wither height; and between testicular circumference and rump width respectively, which is similar to r = 0.61 obtained for both relationships in the present study. Ford *et al*. (2009) also reported r = 0.76 between testicular circumference and withers height which is consistent with r =0.61 reported in the present study. Maintaining a high fertility by genetically superior bucks producing large numbers of high quality spermatozoa, is important for the improvement of overall flock fertility (Rege *et al*., 2000). Information on body measurement and semen characteristics helps in the possibility of improving fertility of animals generally (Akpa *et al*., 2012a).

By using bucks with a high concentration of spermatozoa in their testes, more does per buck can be employed; conception rates would increase and the percentage of non-pregnant does would be reduced (Gherardi *et al*., 1980). The present study showed a positive and significant relationship between semen volume and body measurements except body length. This signified that bucks with good body size may have higher semen volume. The positive and significant correlation between WH and semen volume as well as non-significant correlation of semen volume with body length is supported by Okere *et al*. (2011) who reported the similar trend.

The use of an electro-ejaculator has been reported to yield larger ejaculate volume and lower concentration of spermatozoa than using an artificial vagina but the total sperm/ejaculate and the fertility of spermatozoa are similar using both techniques (Kridli *et al.,* 2007; Bearden and Fuquay, 1997). This may be attributed to lower sperm concentration as observed in the present study.

The positive relationship observed between semen quality attributes and testicular dimension indicates that an improvement in one would lead to improvement in the other. However, semen pH related negatively with testicular dimension; thus indicating that larger dimensions would probably lead to lower pH of semen in bucks. This study confirms that testicular weight and sperm concentration were positively correlated (r = 0.32) which supports the reports by Akpa *et al*. (2012a) who reported r = 0.35 in rams and Kabiraj *et al*. (2011) who reported r = 0.84 on black Bengal bucks. In the same vein, testicular traits were significantly correlated with semen volume and sperm concentration which were to some extent similar to observations of other researchers (Rajuana *et al.*, 2008 in Black Bengal buck; Elmaz *et al*. (2007) in Kivircik ram.

The present result is also consistent with r = 0.27 obtained between semen volume and TC as reported by Noran and Mukherjee (1997) in Malaysian local Katjang bucks. Observed correlation values in this study between testicular measurements and sperm concentration (0.25-0.32) indicated that testicular size is a good indicator of sperm production capability. However, the negative but significant correlation of pH with the testicular measurement as observed in the present study suggests that as testicular size increases, a decrease in seminal pH may be encountered in the bucks. This is supported by Akpa *et al*. (2012a) and Noran and Mukherjee (1997) who reported the same trend. Scrotal circumference is an indirect measurement of testicular weight and a reliable indicator of testicular growth and spermatogenic capacity of the testis (Daudu, 1984). Likewise, testicular weight (TW) is a reliable variable for estimating the sperm production capacity of males. Together with the other variables, it can be used to select males for testicular size at puberty (Coulter *et al*., 1975).

5.4 Relationships Between Sperm Morphological Characteristics and Semen Cation

Concentrations in Bucks

Most of the sperm morphological abnormalities were hardly correlated; however DMT was perfectly correlated with DH. This signified that all the abnormal spermatozoa showing DMT also showed DH, thus increase in the number of DMT spermatozoa will lead to direct correlated increase in the number of DH spermatozoa. This is consistent with Akpa *et al*. (2012b) who also reported perfect correlation (r = 1.0) in Yankasa rams and Cevik *et al*. (2007) who reported r = 0.45 in bull, though lower but highly significant as the present study.

The moderate, positive and significant relationship between sodium ion and potassium ion confirmed the responsibility of the two ions in maintaining osmolarity and metabolic activities of the spermatozoa. This finding agrees with Akpa *et al*. (2012b) who reported r = 0.37 in Yankasa rams and Quinn *et al*. (1965) who reported r = 0.51 in rams respectively. Nath (1988) also reported a positive and significant correlation between sodium and potassium content in buffalo semen.

Sperm morphology related negatively and significantly with most semen cations as observed generally in this study but specifically in relationship between potassium and morphological traits; and in MPD with semen cations. This indicates that an increase in potassium ion in the seminal fluid will lead to a corresponding decrease in occurrence of sperm defect in the bucks. This is contrary to the report that K^+ is a natural metabolic inhibitor and higher K^+ concentration in seminal plasma decreases sperm metabolism thereby, decreasing sperm motility and contributing to sperm defects (Massányi *et al*., 2003).

Zamiri and Khodaei (2005) showed that low levels of Na^+ and K^+ ions were associated with high percentage of motile sperm, which suggest that the cations Na^+ and K^+ are generally involved in establishment of osmotic balance, and that seminal plasma osmolality ultimately plays an important role in the activation of sperm cell which consequently influence the occurrence of spermatozoa abnormality in animals. It is to be noted that the level of Na^+ and K^+ concentration in this study given as 94.90 and 67.79 mmol/l respectively, are within the recommended range of 60-183 and 76-255 mg/dl for Na^+ and K^+, respectively which is expected to give optimal reproductive performance of the buck.

It was also observed in the present study that Ca^{2+} related positively and moderately with acrosome abnormality. This is expected as Ca^{2+} is known to trigger the acrosome reaction in mammalian spermatozoa and is also involved with sperm motility (Kaya *et al*., 2002). This signified that an increase in the seminal concentration of Ca^{2+} will lead to corresponding increase in occurrence of acrosome defect in spermatozoa. Meseguer *et al*. (2004) have reported that Ca^{2+} concentrations in seminal plasma are good predictors of post-thaw semen quality. Blackshaw (1953) reported that Ca^{2+} at all concentrations in the semen of rams are somewhat deleterious. The Ca^{2+} level of 2.62 mmol/l as observed in the seminal fluid of this study is of advantage, because it is within the recommended level of 5-15 mg/dl (1.25-3.75mmol/l) for an optimal quality semen that will give optimal performance in the buck.

Semen volume showed a negative but significant correlation with DMT, DH and CBT indicating that the higher the semen volume the lower the level of these abnormalities in

spermatozoa. The present results are in accordance with the findings of Kealey *et al*. (2006) who reported negative correlation of (r= -0.38) between semen volume and abnormal midpiece and (r=-0.05) between semen volume and CBT respectively in Hereford bulls. The negative but significant correlations between some semen characteristics and CBT indicate that, CBT is also not an indicator of sperm concentration and sperm live/dead ratio. Sperm morphological traits are hardly correlated with testicular measurement. However MPD was observed to be negatively correlated with testicular length. This signified that an increase in the length of testis will lead to a decrease in the occurence of midpiece droplet and vice versa.

As has been reported earlier (Hossain *et al*., 1990), abnormalities of the spermatozoa could occur due to disorder of the seminiferous tubules or germinal epithelium, which is directly or indirectly related to the body conditions of the bucks. A negative correlation was observed between CBT and BCS which suggest that bucks with good BCS may likely not record appreciable cases of CBT abnormality in spermatozoa. CBT was also observed to be negatively related to BW, HG and Stature. This indicates that bucks with good body size may show less abnormality relating to CBT in the spermatozoa of the bucks.

According to Barth and Oko (1989), sperm tail pathologies (bent or coiled) may result from failures in thermoregulation, testicular degeneration, hypo-osmotic conditions or failures in epididymal transit. Under normal conditions, sperm tail defects decrease against the increasing age gradient, which indicates sexual maturity of domestic animals (Mekasha *et al.,* 2007b). However, positive and significant relationship recorded between MPD; and BW, HG and CW may not be unconnected to high ambient and scrotal

temperatures. Occurrence of the mid piece spermatozoa abnormality has been traced to the period of storage in the epididymis (Oyeyemi and Babalola, 2006). The positive and significant correlation between BW and MPD was also supported by the Jalal (2008) who reported the same trend.

Semen volume showed a positive and significant correlation with Ca^{+} (r = 0.31) and K^{+} (r = 0.27) but non-significant correlation with Na^{+} and PO_4 indicating that the higher the volume of semen the more will be the concentration of Ca^{+} and PO_4 in the seminal fluid. This finding agrees with Kanwal *et al.* (2000) who reported correlation of r = 0.36 between Ca^{2+} and semen volume in bull.

Abdel-Rahman *et al* (2000) also reported a positve correlation between K^{+} and semen volume. In the same vein, Na^{+} and K^{+} also showed positive and significant correlations with sperm motility. This suggests that the progressive active movement of spermatozoa may be improved or increased by higher concentration of Na^{+} and K^{+} in the seminal fluid of the bucks. This is contrary to the report by Kaya *et al.* (2002) who observed a negative correlation between sperm motility and Na^{+} and K^{+} concentrations in ram semen. However, a positive but non-significant correlation of r = 0.17 was reported by Kanwal *et al.* (2000) between K^{+} and sperm motility in bull. In rams, increasing potassium levels has been reported to be negatively correlated with progressive motility, while the reverse is true for sodium (Abdel-Rahman *et al*., 2000). Hence a positive and significant correlation as recorded in the present study between Na^{+} and sperm motility was supported by the finding of Abdel-Rahman *et al*. (2000).

The observed positive and significant correlation of K^{+} with sperm concentration was not

in accordance with the report by Massanyi *et al.* (2003) that K^+ is a natural metabolic inhibitor and higher concentration in seminal plasma decreases sperm metabolism thereby, decreasing sperm motility. However positive and significant correlation of r = 0.37 between sperm concentration and K^+ as recorded in the present study was in accordance with Abdel-Rahman *et al*. (2000) who reported correlation of r = 0.74 in ram semen. The observed positive and significant correlation between Ca^{2+} and testicular measurements indicates that, as testicular dimension increases, a corresponding increase in Ca^{2+} concentration in the seminal plasma may be expected.

However negative but non-significant correlation as recorded between Na^+ and testicular traits suggests that Na^+ is not a good indicator of testicular growth and development in the bucks**.** The positive and significant correlations of K^+ and Ca^{2+} with some conformation traits suggest that bucks with higher concentration of K^+ and Ca^+ might possess larger body size. It was observed that these conformation traits do not involve three important traits such as BW, BCS and HG. These three traits showed negative but non-significant correlation with K^+ and Ca^{2+} respectively. Body length was also observed to be negatively and significantly correlated with Na^+ suggesting that Na^+ is not an indicator of BL in the bucks.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The study was conducted to determine the influence of age and body condition on semen quality, testicular and body dimensions in Red Sokoto goats of two hair types using 31 Red Sokoto bucks. The ages of the bucks were categorized into four; 9 -12, 13-16, 17-20 and 21-24 months during analysis. The hair types were categorized short-smooth and long-curly. The body condition was scored on a scale of 1 to 5 and then used to categorize the bucks into score 3 and 4. The linear body measurements; heart girth, stature, chest width, withers height, body depth, body length and rump width; and the testicular measurements; testicular length, testicular circumference, were measured in centimeters using flexible tape while testicular width and testicular weight were estimated using the appropriate formulae.

The semen characteristics; semen volume, sperm motility, semen pH, sperm concentration and live and dead ratio were all determined accordingly. Sperm morphological defects; detached mid-piece and tail, detached head, mid-piece droplet, coiled and bent tail, and acrosomal abnormality were also determined. Semen cation concentrations; sodium, potassium, calcium and phosphate were equally determined. The study lasted for one year (July, 2011 – June, 2012). Descriptive statistics were determined for each trait. The effect of age, hair type and body condition on body and testicular measurement and semen characteristics were determined using General Linear Model Procedure of SAS (2002). Significant differences in means were separated using Duncan's Multiple Range Test. Correlation analysis procedure of SAS was used to assess the relationship between the measured characteristics.

The results showed that the mean BW, HG, ST, CW, WH, BD, BL, RW, TL, TC, TW and TWT were 15.02 Kg, 59.9 cm, 54.95 cm, 8.37 cm, 53.41 cm, 32.86 cm, 57.35 cm, 17.03 cm, 12.00 cm, 17.38 cm, 5.53 cm and 203.04 g; while 0.52, 0.64, 0.52, 1.03, 0.61, 94.90, 67.79, 2.62, 5.42 were for DMT, MPD, DH, CBT, ACR, Na, K, Ca and $PO_{4,}$ respectively. Semen volume, sperm motility, semen pH, sperm concentration and live & dead ratio had 0.42 ml, 79.52 %, 8.85, 701.13 x 10^6/ml and 0.82 %, respectively. Age and BCS significantly ($P<0.01$) influenced body weight, body conformation and testicular traits, but had a variable influence on semen characteristics. DMT, MPD and CBT were more frequent in bucks (13 - 20 months) than bucks of later ages while DH and ACR occurred in the younger (9 – 12 months) and older bucks (21 – 24 months of age). Semen cation concentration was relatively higher in the older bucks of 21 – 24 months than the younger bucks of 9 – 16 months of age except for sodium ion (Na^+) which was also high in younger bucks of 9 – 16 months.

Hair type had influence ($P<0.01$) on some testicular traits. Long-curly haired bucks had the highest DMT and CBT abnormalities (0.8 x 10^6/ml), while the short-smooth haired bucks had the highest DH abnormalities (1.1 x 10^6/ml). Bucks with lower body condition score showed higher DH than bucks with higher body condition score. Body measurements correlated positively with testicular measurements ($r = 0.25 – 0.61$). Body ($r = 0.27 – 0.45$) and testicular ($r = 0.25 – 0.39$) measurements were positively correlated to semen characteristics. Relationship between semen cations and sperm morphological traits were generally negative and significant ($r = -0.28$ to -0.40) except ACR which was positively and significantly correlated with Calcium ($r = 0.37$).

Semen volume was positively and significantly correlated with K^+ and Ca^{2+} ($P<0.05$; r = 0.27 – 0.31). Sperm motility was positively and significantly correlated with Na^+ and K^+ ($P<0.05$; r = 0.26 – 0.33). Sperm concentration only recorded positive and significant correlation with K^+ ($P<0.05$; r = 0.37), while live/dead ratio was observed to be positively and significantly correlated with only Na^+ ($P<0.05$; r = 0.39) among the cations.

The Ca^{2+} was positively and significantly correlated with testicular measurements ($P<0.05$; r = 0.34 – 0.39). The K^+ was positively and significantly correlated with body conformation traits ($P<0.05$-0.01; r = 0.29 – 0.52), except BW, BCS and HG ($P>0.05$; r = -0.09 to -0.14). The BW, body conformation and testicular traits increased with increase in age of the bucks. Bucks with BCS 4 were bigger in size (HG, ST, WH, BL, RW) and weighed more (BW) and had scrotum that are longer (TL), broader (TC), wider (TW) and heavier (TWT); hence produced more semen (SV) with higher concentration of Na than those with BCS 3.

Bucks aged 21-24 months with short-smooth hair and higher body condition gave better testicular dimensions and exhibited less occurrence of sperm abnormality than the young, long-curly haired and lower body condition bucks. Therefore, bucks aged 21-24 months of age with larger body and testicular size can be exploited for optimum breeding performance. When considering hair type as an indicator of semen quality, short-smooth haired bucks could be used as selection criteria in Red Sokoto goats.

6.2 Conclusions

The following conclusions were deduced from this study:

- Age and body condition score had strong influences on body weight, body and testicular measurements as there were consistent improvement in the traits as animal aged and body score increased from BCS 3 to BCS 4.

- Bucks with BCS 4 were bigger in size (HG, ST, WH, BL, RW) and weighed more (BW) and had scrotum that were longer (TL), broader (TC), wider (TW) and heavier (TWT); hence produced more semen (SV) with higher concentration of Na than those with BCS 3.

- Bucks aged 21-24 months with short-smooth hair type gave a better testicular dimension and exhibited less sperm morphological defects than the long-curly haired bucks. This suggests that, short-smooth haired bucks aged 21 – 24 month would be better selected for semen quality.

- Semen characteristics in this study exhibited high variability which ranged from 5.85 to 69.97%. The most variable characteristics were semen volume (69.97%) and sperm concentration (56.02%). Therefore these two characteristics constitute major sources of variation for semen evaluation in Red Sokoto bucks.

- The negative and significant relationship between morphological traits and cation concentrations, as observed in the present study suggests that the level of morphological defects of spermatozoa can be determined based on information on semen cations of the

bucks.

- Hearth girth had the strongest correlation with BW while HW was the strongest predictor of testicular dimension in Red Sokoto bucks.

- Better seminal concentration of Na and K would improve sperm motility of Red Sokoto bucks; and bucks with adequate concentration of Ca would exhibit better testicular dimension. Therefore, the mineral status of the seminal fluid is an essential index in evaluating semen quality of bucks

6.3 Recommendations

The following are hereby recommended:

- Bucks at 21-24 months of age with larger body are hereby recommended to goat farmers when selecting breeding bucks for optimum performance. These bucks are expected to show larger testicular size and less sperm morphological defects.

- In selecting bucks for semen quality, it is recommended that breeders should consider bucks with higher semen volume, higher sperm motility and concentration as well as bucks with semen that contain higher concentration of Na^{+} and lower concentration of Ca^{2+} and K^{+}.

- Short-smooth haired bucks are recommended when considering hair type as an indicator of semen quality. These bucks tend to give better testicular dimension and exhibit less sperm abnormalities.

- Heart girth could be used in predicting BW, while HW could be used in predicting testicular dimension in bucks.

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