GENETIC ANALYSIS OF GROWTH AND SOME REPRODUCTIVE TRAITS OF SHEEP OF NORTHERN NIGERIA AND THEIR CROSSES

BY

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DECLARATION

I declare that the work in this thesis entitled ‘‘**GENETIC ANALYSIS OF GROWTH AND SOME REPRODUCTIVE TRAITS OF SHEEP OF NORTHERN NIGERIA AND THEIR CROSSES’’** has been performed by me in the Department of Animal Science under the supervision of Prof. G.N. Akpa, Prof. B.I. Nwagu and Prof. I.A. Adeyinka. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

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CERTIFICATION

This thesis titled **''GENETIC ANALYSIS OF GROWTH AND SOME REPRODUCTIVE TRAITS OF SHEEP OF NORTHERN NIGERIA AND THEIR CROSSES''**meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

A total of 65 Yankasa, 23 Uda and 16 Balami ewes were mated to 4 Yankasa, 3 Uda and 3 Balami rams in a diallel breeding pattern to produce 192 lambs that were used to genetically analyse growth and some reproductive traits. Weight records and linear body measurements were obtained from lambs at birth, 90-Day (weaning weight), 180-Day and 360-Day (yearling weight). Blood samples (5 ml) were collected from all the ewes and rams used for the study. The blood samples were subjected to cellulose acetate electrophoresis to obtain distinct bands of haemoglobin genotypes (AA, BB and AB). Daily growth of the lambs was calculated using average daily gain (ADG) and relative growth rate (RGR). The haemoglobin type HbAB was the most predominant in the studied population and allele A of the haemoglobin type was the most numerous. Breed and haemoglobin types had significant ($P<0.05$) effect on lamb weight. Crossbred lambs of Yankasa rams and Uda ewes (YK X UD) were the heaviest at birth. Pure Balami lambs were superior to all other lamb genotypes in body weight at 90 and 180-Day. The heaviest 360-Day weight (18.73±1.53 kg) was recorded for lambs of HbBB. The ADG and RGR of lambs were affected ($P<0.05$) by dam's haemoglobin type, lamb genotype, type of birth and sex of lambs. Yankasa rams and ewes produced lambs with the shortest gestation lengths (151.84±0.23 days and 151.85±0.20 days, respectively). The highest litter size was recorded in UD X YK or BL X UD crosses. All the lamb genotypes had very high mortality from 180 to 360 days. However, there was no mortality recorded for BL X BL lambs from birth to 180 days. The HbBB genotype however had the highest percent mortality from 90 to 180-Day. The coefficients of phenotypic correlations between body weight and linear body measurements increased in proportion as Yankasa lambs grew from birth to 360-Day.Heritability estimates for body weight and some linear body measurements for Yankasa lambs were high at 180-Day (0.765±0.514) and 360-Day(0.805±0.961) indicating low effect of the environment on the traits in the studied population. Linear body measurements that considered volume of animal in terms of circumference (chest girth and loin girth) and body length (back length, neck length and height at wither) tended to give better accuracy of prediction of liveweight of lambs. Balami sheep (used as either sire or dam) expressed its superior genetic potential in terms of faster growth rate than Uda and Yankasa in the Northern Guinea Savannah agro-ecological zone. Selection for improved growth traits in the population of Yankasa sheep should be based on individual records of the lambs at 180-Day because of high heritability for 180-Day body weight of Yankasa lambs. Weighing chart and bands should be produced for all the sheep breeds considered on the basis of prediction equations.

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CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND INFORMATION

Genotypic variations between and within breeds are great resource for improvement of animals (Akpa *et al*., 2010). Variations in the ability of one breed of domestic animals to perform better than the other in productive and reproductive traits arise from the combined effects of genetic components and adaptation to the prevailing environmental conditions in which such animals are being raised (Adebambo, 2003). Adaptation enables individual animals to survive in the environment in which they are managed (Willmer *et al*., 2005; Van der Werf *et al*., 2009). Sheep breeds in various tropical agro-ecological zones have adapted to the prevailing climates having survived in such environment over many generations. Wilson (1991) stated that there aresome reasons in Africa to attempt an improvement of sheep by utilizing non-African breeds. However, the use of non-African breeds of sheep should be under ideal climatic or management conditions for such breeds.

Sheep are kept all over Nigeria (Akpa *et al*., 2002b), with a broad distinction between their importance and ubiquity in the north and the more dispersed populations of the humid zone. Improvement of productivity in Nigerian indigenous sheep is important because of the demand for this species (Adu and Ngere, 1979). Farm animals are improved through health, feeding, breeding, reproductive management and crossbreeding (Akpa *et al*., 1994a; Akpa, 2001 and Tibbo *et al*., 2006). Many crossbreeding schemes, some highly complex, have been developed to meet particular needs. The main objective in crossbreeding programmes is to exploit non-additive

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genetic variance (heterosis or hybrid vigour). Crossbreeding can also be used as a supplement to a programme for additive genetic improvement (Gjedrem, 2005).

Not many attempts have been made at the improvement of sheep breeds found predominantly in Northern Nigeriausing the genetic resources within and between breeds. This is partially due to genotype-environment interactions, which can be regarded as the adaptation of a breed to its environment. Osinowo and Adu (1985) advised farmers in the different agro-ecological zones to concentrate their efforts in rearing sheep breeds that predominate in their particular agro-ecological zone because the productive capability of such breeds is at its best in such zones.

There are four main breeds of sheep in Nigeria: Balami, Uda, Yankasa and West African Dwarf (WAD). Balami, Uda and Yankasa are predominant breeds in Northern Nigeria while the West African Dwarf (WAD) is adapted to the humid climate of southern Nigeria. These breeds differ considerably in size, coat-colour and other characteristics (Adu and Ngere, 1979). The Balami is the largest in size (live weight) and is confined to the most arid areas of the country (Sudan savannah) while Yankasa, which is the smallest among the three breeds in the Northern part of the country, is adapted to the areas with relatively more rainfall (Northern Guinea Savannah). Thus, any strategy for improving breeds (Yankasa, Uda and Balami) adapted to the semi-arid and arid climate (water and feed scarce areas) needs to consider their unique attributes and focus on improving within breed, with some level of crossbreeding with those that are adapted to such harsh climates (Tibbo *et al*., 2006).

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1.1 STATEMENT OF RESEARCH PROBLEM

Yankasa sheep have been bred and selected by National Animal Production Research Institute (NAPRI) for large litter size, high birth weight, rapid growth rate and good performance of offspring. The same cannot be said for Balami and Uda sheep breeds which are known to grow faster naturally than any other breed in the country. There is paucity of information on detailed genetic diversity and the combining ability (additive and non-additive genetic variation) of Nigerian sheep breeds and their crosses. Concerted efforts at establishing the proficiency of each of the breeds in the country is also lacking. The question that formed the basis of this study tried to find out if it is possible for offsprings of Balami sheep to competefavourably with those of Yankasa and Uda in the Northern Guinea savannah zone of Nigeria.

1.2 JUSTIFICATION OF RESEACH

Growth rate and prolificacy are important traits in most systems of sheep production, since both affect the share of ewe overheads carried by each lamb (Adu and Buvanendran, 1982). Kosgey (2003) concluded that litter size and lambing frequency are the most important traits in a breeding objective for smallholder production. Performance evaluation of these traits is a logistical complement to genetic improvement schemes.

Genetic information available for the assessment of genetic variation has been commonly based on variations at the protein and deoxyribonucleic acid (DNA) levels. These proteins or regions of the genome are treated as genetic markers and variations detected at these loci are assumed to reflect the level of variation that influences adaptation or individual fitness (

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livestock breeds, including the domestic sheep (*Ovis aries*), have been characterized for variations in the major blood proteins and enzymes which are used as genetic markers.Such proteins are albumin (Margetin and Malik, 1982), ceruloplasmins (Graetzer *et al*., 1964; Bhat, 1986), vitamin D-binding protein (Ibeagha-Awemu and Erhardt, 2004), haemoglobin and transferrin (Braend, 1972; Baruah and Bhat, 1980; Margetin and Malik, 1982; Bhat, 1986; Henkes *et al*., 1994; Di Stasio, 1997). Some of the enzymes are amylase (Bhat, 1986), carbonic anhydrase (Margetin and Malik, 1982), malic enzyme, NADH diaphorase and catalase (Tsunoda and Douge, 1990; Henkes *et al*., 1994).

Several studies in sheep have already linked these markers to production traits and environmental adaptation (Dally *et al*., 1980; Vicovan and Rascu, 1989; Charon *et al*., 1996, Salako *et al*., 2007). Information on blood proteins has also been extensively used for parentage control (Francois *et al*., 1992) and to study the genetic relationships among sheep breeds (Buis and Tucker, 1983; Ordas and San Primitivo, 1986; Mwacharo *et al*., 2002). However, the polymorphism of this important blood proteins had not being linked with productive and reproductive traits in the populations of Balami, Uda and Yankasa sheep. Study of the influence of variations in haemoglobin genotype, lamb genotype, breed of sire and dam on growth traits such as birth weight, 90, 180 and 360-Day weight and some reproductive traits can help in selection of sheep on the basis of lambs with the best performing haemoglobin genotype along with other sources of variations.



1.3 GENERAL OBJECTIVE

The general objective of this study was to evaluate the genetic potential for improved growth rate and some reproductive traits in Balami, Uda and Yankasa sheep in the Northern Guinea Savannah zone of Nigeria.

1.4 SPECIFIC OBJECTIVES

The specific objectives are to:

(1.) Evaluate the effect of breed of sire and dam on the growth rate of lambs of Northern Nigeria.

(2.) Evaluate the effect of dam's haemoglobin type on the growth rate and reproductive traits of sheep of Northern Nigeria and their crosses.

(3.) Measure the level of survivability of lambs of Balami, Uda and Yankasa sheep in the Northern Guinea Savannah zone of Nigeria.

(4.) Estimate genetic parameters (heritability, genetic and phenotypic correlations) of growth traits of sheep of Northern Nigeria.

(5.) Generate prediction equation for body weight of sheep of Northern Nigeria through linear body measurements.

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CHAPTER TWO

LITERATURE REVIEW

2.1 SHEEP IN ANIMAL AGRICULTURE

Sheep are similar to cattle in production cycles. Sheep are among the domestic livestock owned by a lot of production units in African farming systems. They are particularly important for resource-poor households and are often the property of underprivileged groups, such as women and children, because of their lower feed requirements, rapid reproduction cycles and the ease with which they can be handled (Iyiola-Tunji and Issa, 2010).

Sheep are multipurpose animals, as they are a good source of meat and milk, as well as wool and skin. Increase in sheep population and eventual establishment of a sheep industry could provide an inexpensive substitute for beef, pork and poultry products. The latter had been reported (Alcasid, 1988)as becoming short in supply in proportion to human population growth. Among livestock and livestock products, it is projected that by the year 2015 Africa would export only mutton and goat meat while, she would continue to import beef and milk (FAO, 2002).

One sure means of alleviating poverty in rural Nigeria is by encouraging sheep production. This is because sheep are capable of yielding a variety of foods, which are useful for both urban and rural markets. They act as life savings in case farmers have urgent cash requirements (Devendra, 1992, Sarwono *et al*., 1993; Djoharjani, 1996; Budisatria, 2000), and produce manure to fertilize the land. The contribution of sheep to

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the total farm income is relatively high in small farms (Paris, 1992; Soehaji, 1994; Ifar, 1996; Valdivia, 1999).

2.2 SHEEP PRODUCTION IN THE TROPICAL ENVIRONMENT

The tropical region of the world encompasses the area between the 23^{o} 26′ 21′′ N and 23^{0} 26′ 21′′ S (Williamson and Payne, 1978). Holdridge (1966) grouped climate in the tropical region into equatorial or super-humid, humid, sub-humid, semi-arid, arid and highlands. These climate groups were classified based on 'Life Zone Ecology' which combined latitude, altitude, rainfall and mean temperatures (Holdridge, 1965; Holdridge, 1966).

Small ruminants (sheep and goats) are important livestock componentsof all ecological zones and all types of agricultural systems (smallholders mixed farming, agro-pastoral, pastoral, urban, commercial ranching) in tropical Africa (FAO, 2002). Table 2.1 shows the distribution of sheep populations by ecological zone in sub-Saharan Africa. One-sixth of sheep in Africa are found in the tropical region (Wilson, 1991). The majority of sheep in tropical Africa are 'indigenous' types (Epstein, 1971). The development of the tropical African sheep may be considered as an adaptation to the stresses of the environment. Selection over the centuries has been on their ability to adapt to the local ecological conditions (Willmer *et al*., 2005).

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Table 2. 1:Distribution of sheep populations by ecological zone in Sub-Saharan Africa

Zone	Land area (% of SSA)	Sheep (%)
Arid	36	35.7
Semi-arid	18	22.2
Sub-humid	22	13.6
Humid	19	7.9
Higland	5	20.6

Source: Jahnke, 1982;
SSA is Sub-Saharan Africa

Sheep of tropical origin have for long been considered 'unproductive' but it is doubtful if any other type of animal – at least of those currently domesticated – could produce as much in terms of returns for resources utilized. Milford and Minson (1966) stated that the productivity of grazing animals like sheep is limited by a number of factors among which is inadequate nutrition. They further stated that the low feeding value of the pasture is the most important factor limiting the productivity of sheep in many tropical countries.

Sheep tend to thrive best in drier climates (semi-arid and arid) where the feed supply fluctuates both in quantity and quality from the wet to the dry season (Williamson and Payne, 1978). Sheep of the semi-arid zone are generally larger than those of the more humid zone (Blench, 1999). Tropical sheep breeds can be carried through drought periods on hay and supplementary feeding (Wilson *et al*., 1985).

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2.3 DISTRIBUTION AND PRODUCTIVE POTENTIALS OF NIGERIAN SHEEP BREEDS

Detailed description of sheep found predominantly in Nigeria was done by Adu and Ngere (1979). Figures 2.1 - 2.4 show the geographical distribution of Balami, Uda, Yankasa and West African Dwarf (WAD) sheep in Nigeria, respectively. Balami is found in the extreme upper part of the country that cut through Sokoto and Kano States in the North West and Borno State in the North East. Uda breed is found in most parts of the upper Niger and Benue rivers in Nigeria. Both breeds (Balami and Uda) have migratory tendencies (Figures2.1 and 2.2) towards a limited distance South-ward of their homo-climes during the dry season (Blench, 1999).Yankasa breed is the most widely distributed sheep in Nigeria (Figure 2.3) while WAD sheep is predominant in the Southern part of the country (Figure 2.4).

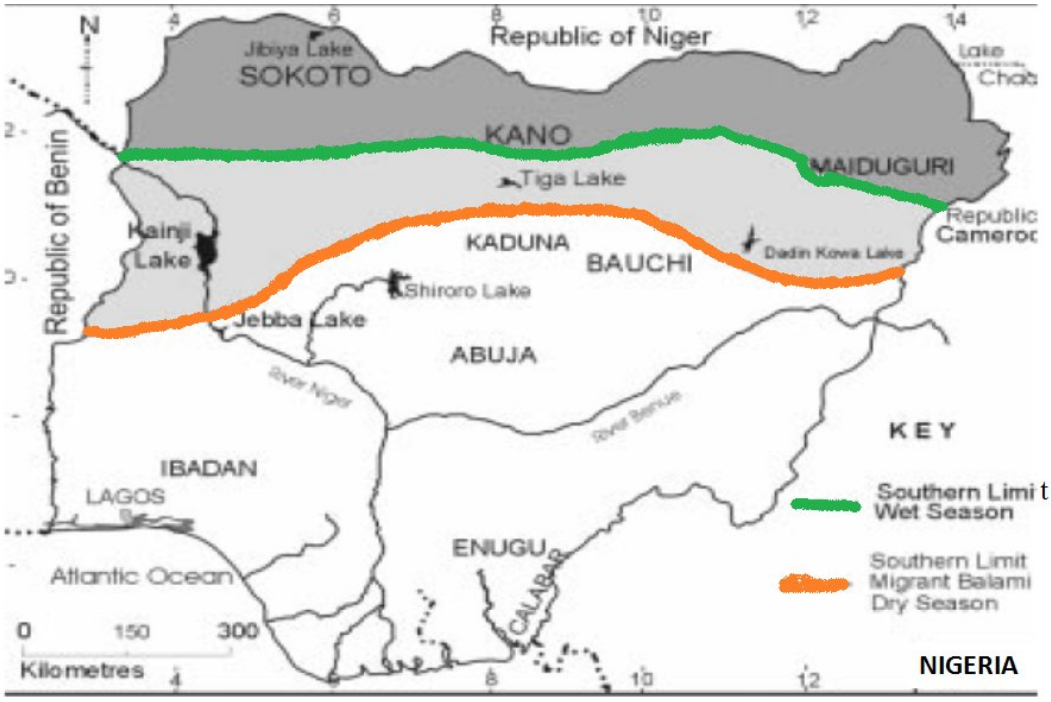


Figure 2. 1: Distribution of Balami sheep in Nigeria (Source: Blench, 1999)

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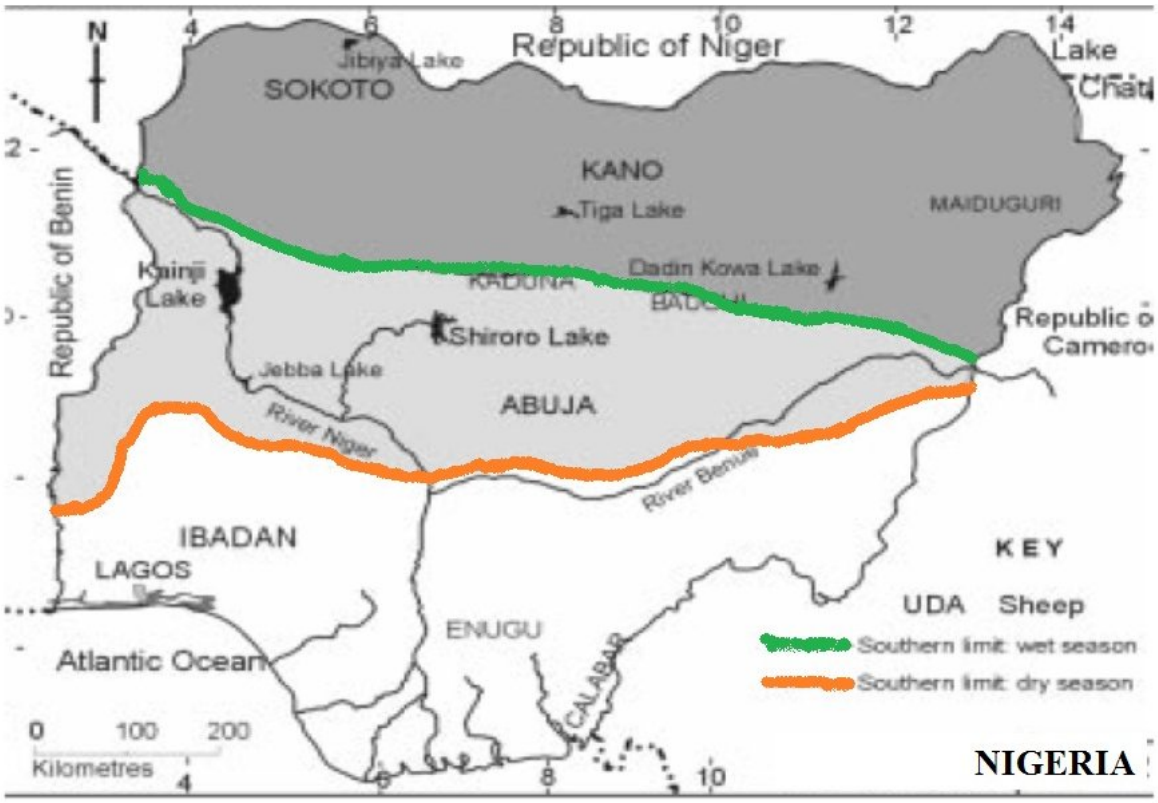


Figure 2. 2: Distribution of Uda sheep in Nigeria (Source: Blench, 1999)

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Figure 2. 3: Distribution of Yankasa sheep in Nigeria (Source: Blench, 1999)

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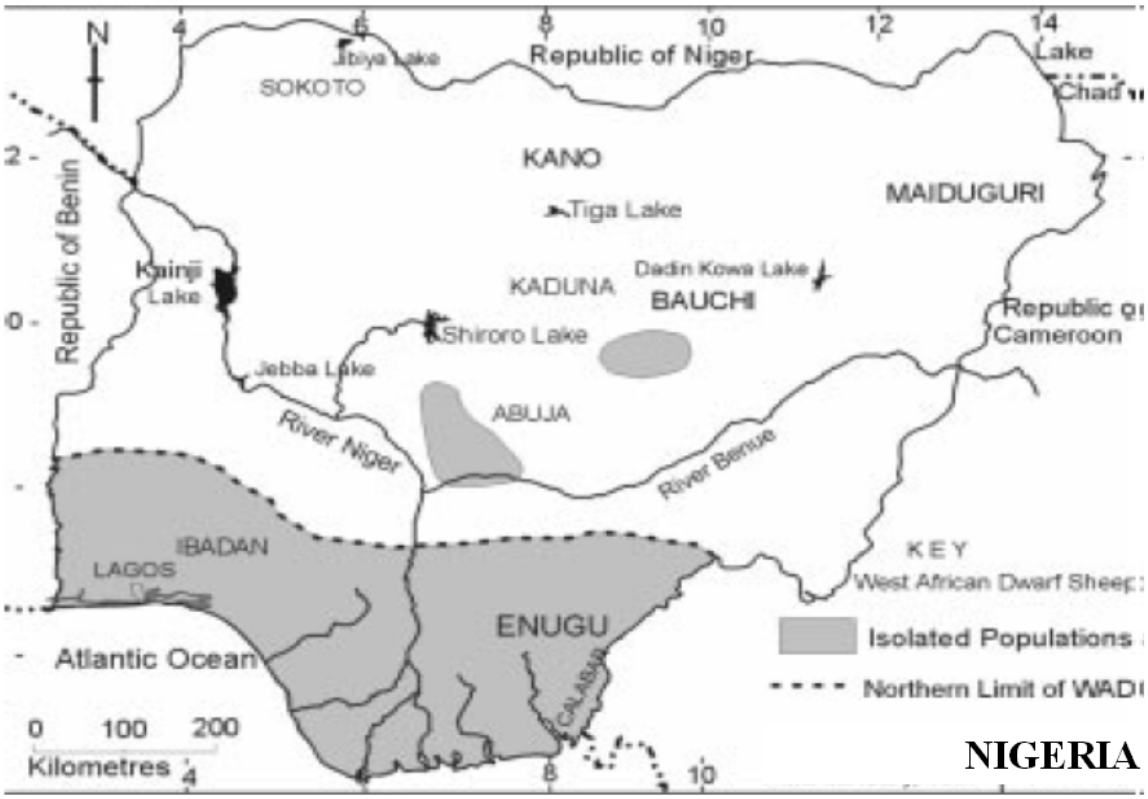


Figure 2. 4: Distribution of West African Dwarf sheep in Nigeria (Source: Blench, 1999)

Sheep are the second most numerous pastoral species in Nigeria after cattle, and small flocks usually accompany many cattle herds in the North and in the Middle Belt of the country (Bourn *et al*., 1994). The productivity of WAD sheep is substantially lower than that of other breeds. The skin of all Nigerian sheep can be used to process leather. The species are rarely milked in Nigeria (RIM, 1992). Sheep however have the potential to supply (yield) significant portion of the milk deficit in the country because sheep far exceed cattle in number in both rural and urban communities in Nigeria (RIM, 1992; Adewunmi, 2005).

The Balami is the fastest growing, attaining a weaning weight of 18kg in 12 weeks (Adu and Ngere, 1979; Oni, 2002). T

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its ability to survive under arid conditions is a characteristic that can be exploited in the utilization of non-arable land (Akinyemi, 2010). The Yankasa sheep has been reported to be superior to the WAD sheep interms of yearling weight, liveweight, productivity per animal and annual rate of return (Adu and Onwuka, 1991).

Sheep of Northern Nigeria are good producers of meat for human consumption (Ozung*et al*., 2011). According to Acharya (1998), liveweight constitutes an important economic trait in meat animals. Table 2.2 shows the comparison of mature body weight of Nigerian indigenous sheep.

Table 2. 2: Comparison of mature weights (kg) of Nigerian indigenous sheep

Breed	**Mature weight (kg)**	
	Male	**Female**
Balami	45-60	35-40
Uda	45-55	35-45
Yankasa	35-50	25-50
WAD*	25-30	20-25

*WAD = West African Dwarf
Sources: Adu and Ngere (1979); Aliyu(1990); Akinyemi (2010)

Data on reproductive performance of indigenous breeds of sheep in Nigeria show that these animals are far from expressing their biological potentials for reproductive rate and efficiency (LPP, 2006). One important trait of these sheep breeds is ability to cope with local diseases. The Udasheep is much less susceptible to foot rot than the other breeds in Nigeria (Geerlings *et al*., 2002).

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2.4 MANAGEMENT SYSTEMS IN SHEEP PRODUCTION

Sheep production systems in Africaare as numerous as the socio-economic and varied agricultural situations in the continent.The terms 'production' and 'management' systems are used interchangeably by many authors (Salako, 1988; Wilson, 1991; Markowitz, 1992; Akpa, 1999)to refer to means by which livestock are reared. Wilson (1991) grouped the production systems of sheep into two major types;these are traditional and modern. The twosystems differ essentially in the use of main factors of production (Akpa *et al*., 1994b), withtraditional systems based mainly on land and labour, while modern systems have large capital requirements and generally lesser requirement for oneof the other factors.Some major characteristics of each group of small ruminant production systems are provided in Table 2.3.

2.4.1 Housing

Proper housing and micro-climate control are the tools that provide the optimal conditions for the animal to thermo-regulate efficiently while maintaining sustainable production, especially in hot climates (Naas and Moura, 2004). The basic needs of sheep housing are simple. Naas and Moura (2004) recommended that sheep housing should be built with its longitudinal axis vertical to air movement during the critical diurnal heat loading hours. Slade and Stubbings (1994) stated that the organization and management of a sheep house should be determined by the breeding, type of production and feeding systems. It is also necessary to consider prevailing climatic conditions in building sheep houses.

Small ruminants are sheltered mainly for protection in most rural communities in Africa (Endeshaw, 2007; Tsedeke, 2007;

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shelterand housing type vary according to climate, geographical region, season, production system and personal preference of the farmer (Schoenian, 2006). Where sheep are grazed out during the day (semi-intensive system), only rudimentary night-time shelter that provides protection against the weather and predators needs to be provided (Iyiola-Tunji, 2007). An intensive system of production requires a higher shelter construction and management (Adu *et al*., 1986; Coffey, 2000; Nye and Moore, 2002; Hale, 2003).

Table 2. 3: Classification of small ruminant production types and systems in tropical Africa

Type	System	Macro-management	Main production factors	Nutrient source
Traditional	Pastoral	Nomadic/ semi-sedentary	Land	Range
	Agro-pastoral	Transhumant/ Sedentary	Land/labour	Range/crop by-products
	Agricultural	Sedentary	Labour/Land	Crop by-products/ Household waste /Forage
	Urban	Sedentary	Labour	Household waste/feed
Modern	Ranching	Sedentary	Land/capital	Feed/forage
	Feedlot	Sedentary	Capital/labour	Range/forage
	Dairy farm	Sedentary	Capital/ labour/land	Feed/forage
	Station	Sedentary	Land/labour/ capital	Range/forage/ feed

Source: Wilson(1991)

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2.4.2 Feeding

Herbage, the primary food for sheep, belongs to the group of feeds described as roughages. Roughages, in contrast to concentrates, are derived from leaves and stems of pasture and crop plants (Coleman and Henry, 2002). Herbage obtained by grazing provides the major source of nutrients for most of the world's sheep. However, the intake of herbage generally falls short of the amount needed to express genetic potential for production (Weston, 2002). Major constraints to adequate pasture consumption are related to:

(i) the amounts and spatial distribution of components of pasture biomass;

(ii) the chemical and physical properties of the herbage; and

(iii) environmental attributes associated with climate, disease and sheep behaviour.

Dove (2005) stated that nutritional management of sheep should involve the management of amount andquality of forage resource, as influenced by regional climate, seasonal weather conditions, and plant species present. Seasonal fluctuation in quality and quantity of pasture in Tropical and Mediterranean environments had been extensively reported (Boyazoglu and Flamant, 1990; Dove, 2002; Kamalzadeh*et al*., 2008). Supplementary feeding with pelleted feed (concentrates), grain, hay, orsilage is common in many sheep production systems. Frequently,when sheep consume a supplement, they reducepasture intake (Dove, 2002).

Some feeding-related problems in sheep production include overgrazing;insufficient rain;insufficient and inadequate balanced nutrients forearly growth; live-weight loss due to periodic restriction as a result of seasonal variation; efficiency of rumen microbial

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proteinsynthesis and negligible rumen by-pass protein due to lowqualityforages (Boyazoglu and Nardone, 2003; Kamalzadeh*et al*., 2008).

2.4.3 Breeding and Reproductive Management

Sheep, like many other livestock in Tropical Africa, are kept mostly in the traditional extensive system (Plate I). Breeding and reproductive management of sheep in this system is mostly through natural means.African small ruminants have the capacity to breed all the year round because of the almost equal number of hours of daylight throughout the year (photoperiodism). Wilson (1989) suggested that better management of breeding and reproductive processes could greatly improve output.

Rombaut and Vlaenderen (1976), Awotwi and Fynn (1992) reported 27%, and 45%, respectively, as twinning rate for WAD sheep reared in traditional system. Osuagwuh and Akpokodje (1981) also reported 27% twinning rate for the same breed reared in research stations. Adu and Ngere (1979) reported 128.5, 122.6, 111.4 and 121.8% as fecundity rates of Balami, Uda, Yankasa and WAD sheep, respectively, reared in a research station, while Haumesser and Gerbaldi (1980) reported 114% fecundity for Uda sheep reared under traditional system in Niger Republic.

Reproductive management techniques such as oestrus detection, oestrus synchronisation, flushing and artificial inseminationare not very common practices in traditional systems of sheep production (Gatenby, 2002; Iyiola-Tunji and Issa, 2010). These techniques are capable of improving the output of sheep both in traditional and modern systems of production.

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Plate I: Traditional extensive system of rearing of sheep
(Sheep roaming close to the major motor way in Samaru, Zaria)

2.5 TRAITS OF ECONOMIC IMPORTANCE IN SHEEP PRODUCTION

The objective of animal breeding is to improve the genetic worth of the animals in order for them to produce more efficiently under future production circumstances. Four key traits that are relevant for consideration in genetic improvement of sheep as reported by Luginbuhl (1998)are:

(i.) Adaptability to environmental and production conditions,

(ii.) Reproductive rate,

(iii.) Growth rate, and

(iv.) Carcass characteristics.

Animals that show better performance in the desired traits of economic importance can be selected by the farmer to become parents of the next generation.

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2.6 GROWTH RATE OFFARM ANIMALS

The simple concept of growth,meaning getting bigger, is perhaps ratherbetter than many of the complicatedattempts to formalize something of suchextraordinary complexity (Lawrence and Fowler, 2002). Growth (rate and pattern) is a major concern of livestock farmers. Malau-Aduli *et al*. (1996) reported that growth is a reflection of body size changes at different ages. Body size was also stated by Akpa *et al*. (2006) as one of the primary factors to consider in any improvement plan for sheep.A rapidly growing farm animal attains mature adult weight (market weight) and reproductive age much earlier than a slow growing animal and results in savings on maintenance cost (Orji and Steinbach, 1961).

Numerous authors (Hammond, 1932; Walton and Hammond, 1938; Brody, 1945;Palsson and Vergés, 1952; Everitt and Jury, 1966; Owens *et al*., 1993) had explained that two factors are in conflict as growth progresses. One is the accelerating force due to increase in number of replicating units, while the other counteracting (decelerating) force is the limitation of the greater complexity of the structures and the ability of the food supply to keep pace with the growth of the body. This was further explained by the authors to often result in an extended linear phase of growth where the two forces are more or less in balance (Figure 2.5).

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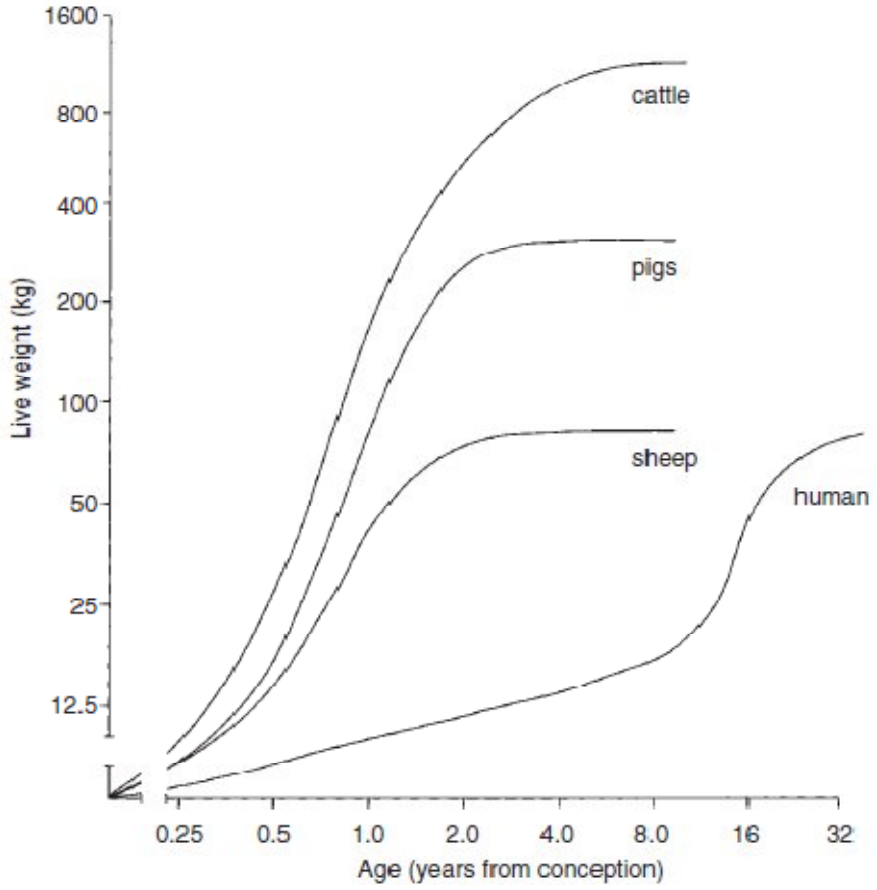


Figure 2. 5: Growth curves of major farm species and man
(Source: Lawrence and Fowler, 2002)

There are various techniques for measuring growth in live farm animals and other animalspecies (Table 2.4). Orji and Steinbach (1961) expressed the mature body weight of West African Dwarf sheep (WAD) using computer-generated quadratic growth curves. The curve showed that the mature body weight of ewe is about 33 kg attained between 30 and 36 months, while that of a ram is about 42 kg attained between 27 and 30 months of age.

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Table 2. 4: Techniques used in measuring growth in live farm animals and in other animals(O = objective technique; S = subjective technique)

Techniques	Objective/Subjective
Weight	O
Body measurements	O
Visual appraisal of live animal conformation	S
Dilution techniques	O
Neutron activation analysis	O
Probes	O
Balance studies	O
X-ray and computerized tomography	O
Nuclear magnetic resonance	O
Ultrasonic techniques	O
Bioelectrical impedance analysis	O
Video image analysis	O
Cell size in adipose tissue	O
Urinary creatinine excretion	O

Source: Lawrence and Fowler, 2002

2.6.1 Birth Weight of Sheep

Birth weight was expressed (Riggio *et al*., 2008;Thiruvenkadan *et al*., 2008; Vatankhah and Talebi, 2009; Petrovic *et al*., 2011) as the first observed trait in the life of an animal on which growth, production and reproduction traits are dependent. Birth weight of lambs had also been reported as an important factor in lamb survival (Hinch *et al*., 1985; Holst *et al*., 2002). Greenwood

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grow more muscles per kilogramme of weight gain. However, numerous factors had been shown to have effect on birth weight of lambs. These include breed of sire and ewe, management practices, parity,season of birth, sex of lamb and type of birth (Yapi-Gnaore *et al*., 1997; Casellas *et al*., 2007).

Jamison *et al*. (1961) and Taiwo *et al*. (1982) reported that breed of sire and ewe affected birth weight of sheep to various degrees. Karunanithi *et al*. (1994) and Mandal *et al*. (2003) stated that birth weight of lambs was lowest in the first parity and it increased as the parity advanced, with the maximum in the fifth parity.Thomson *et al*. (2004) recorded 0.32 kg more weight for ram than ewe lambs, which is in agreement with the observations of Dalton *et al.*(1980) and Hight and Jury (1970).The differences in birth weightsin favour of single than twin lambs as reported by Gardner *et al*. (2007) were attributable to the stress the twin suffered from diminished nutritional supply *in utero* (Ademosun, 1973; Adu, 1975; Ngere *et al*., 1979; Buvanendran*et al*., 1981; Taiwo *et al*; 1982 and Hassan, 1987).Robinson *et al*. (1977) reported that, for lambs *in utero*, as the number of foetuses increases, the number of caruncles attached to each foetus decreases, thus reducing the feed supply to the foetus and hence the birth weight of the lambs.Birth weights of sheep also vary with agro-ecological zones (Table 2.5).

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Table 2. 5: Birth weights of sheep breeds in different agro-ecological zones

S/N	Sheep breed	Agro-ecological zone	Location	Birth weight (kg)	Reference
1.	Merino		Australia	5.1	Holst *et al*. (2002)
2.	Assaf	Mediterranean	Israel	4.5	Gootwine *et al*. (1993)
3.	Sudan desert	Arid, semi-arid	Sudan, Eritrea and Chad	4.1±0.63	McLeroy (1961); Sulieman and Wilson (1989)
4.	Touabire	Arid	Southern Mauritania, Northern Mali, Northern Senegal,	3.7	Bradford and Berger(1987); Sow *et al*. (1987)
5.	Balami	Semi arid	Northen Nigeria	3.5	Adu and Ngere (1979); Ngere *et al*. (1979)
6.	Uda	Semi arid	Southern Niger, Northern Nigeria, Central Chad, Western Sudan and Western Cameroon	3.5	Ngere *et al*. (1979); Yenikoye *et al*. (1982); Yenikoye, (1984); Yenikoye *et al*. (1989)

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Table 2.5 (Continued): Birth weight of sheep breeds in different agro-ecological zones

S/N	Sheep breed	Agro-ecological zone	Location	Birth weight (kg)	Reference
7.	Yankasa	Semi arid and sub-humid, extending into the Northern Guinea savannah in the South	Northern and North-Central Nigeria	3.5	Ferguson (1964); Adu and Ngere (1979); Kwatu *et al*.(1983); Oyedipe *et al*. (1986); Otchere *et al*. (1987)
8.	Rambouillet		India	3.15	Jain *et al*. (1996)
9.	Peul-Peul	Semi-arid to sub-humid	Central Senegal	3.1	Tchakerian (1979); Bradford (1983)
10.	Black Maure	Arid, Saharao-Sahelian	Southern Mauritania, Northern Mali, Northern Senegal, Eastern Chad and North-Western Dafur	3.0	Wilson (1981); Dumas (1980)
11.	Toronke	Semi arid to arid	West-Central Mali, Southern Burkina Faso	2.9±0.88	Wilson and Light (1986); Bourzat and Wilson (1990)

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Table 2.5 (Continued): Birth weight of sheep breeds in different agro-ecological zones

S/N	Sheep breed	Agro-ecological zone	Location	Birth weight (kg)	Reference
12.	Macina	Humid area associated with the annual flood of the Niger river in the area of its distribution.	Mali and Niger	2.7±0.62	Dumas(1977); Wilson (1983)
13.	Ara Ara	Semi arid	South-Central and Central Niger	2.7	CECM (1985) and(1986)
14.	Blackbelly	Sub-humid tropics	Southern Mexico	2.59±0.01	Carrillo and Segura (1993)
15.	Pelibuey	Sub-humid tropics	Southern Mexico	2.51±0.02	Carrillo and Segura (1993)
16.	Fulbe		Cameroon	2.23±0.06	Ebangi *et al*. (2001)
17.	Djallonke (West African Dwarf)	Humid forest zone of West and Central Africa	Southern Senegal to Chad and Southern Cameroon, Gabon and DRC Congo	1.2 - 2.5	Adu and Ngere (1979); Francis (1988); Thys(1989)

2.6.2 Weaning Age and Weightof Sheep

Weaning is associated with a break in the dam-lamb contact. In sheep, under natural conditions, the rupture of the social bond is progressive (Orgeur *et al*., 1999). Abolude (2002) stated that weaning age and methods vary in the sheep industry. The permanent removal of lambs from ewe early in life had been reported to have substantial consequences on the lambs in the form of weaning shock (O'Brien, 1998). Mason and Rushen (2006)associated early wea

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corpus callosum size) and impairments in cognitive function. Abolude (2002) suggested that lambs should be weaned at 3 months of age.

Delayed weaning of lambs and breeding of lactating ewes had been documented (deNicolo, 2007) to possibly result in heavier lamb weight in the accelerated breeding system. Combellas (1981) however, obtained a similar weight (15.8 kg) at 20 weeks for WAD lambs that were weaned at both 56 days and 84 days.Selaive-Villarroel *et al*. (2008) concluded that weight at weaning is more important than age at weaning. They recommended an average weight of 10kg for white Morada Nova lambs raised in a tropical extensive system.

Several factors had been shown to affect weaning weights of lambs. Examples are age of lambs, lamb genotype, season of birth and weaning, sex and type of birth (Buvanendran*et al*., 1981; Akhtar *et al*., 2001; Babar *et al*., 2004; Iyiola-Tunji *et al*., 2011a).Afolayan (1996) and Akhtar *et al.* (2001) reported that male lambs were heavier than females at weaning. Lambs that were given birth to as singles were heavier than twins at weaning (Ceyhan *et al*., 2011).Bella and Haile (2009) stated that lambs born in the dry season were superior by 6.72%,as compared to lambs born in the wet season for weight at 120 days of age. They associated the effect of season with difference in the availability of feed and diseases. When lambing occurs during wet season, there is very high tendency for parasite infestation, which impairs growth performance. Carrillo and Segura (1993) reported that dam's weight at birth and weaning affected weaning weight of hair sheep in Mexico. They concluded that weaning weight is an indicator of the growth rate of the lamb and the maternal ability of the ewe.

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2.6.3 Yearling Weight ofSheep

Weight at one year (yearling weight) of ram and ewe lambs is an important trait in the selection of replacement breeding rams and ewes at the National Animal Production Research Institute, Shika, Zaria. Some of the factors that affect birth weight and weaning weight of sheep also affect sheep weight after weaning (Taiwo, 1979).

2.6.4 Pre-Weaning and Post-Weaning Average Daily Gain

Average daily gain (ADG) is a significant factor in assessing growth rates in most livestock species.Bela and Haile (2009) stated that fast growth performance is capable of allowing sheep to breed early and contribute more lambs in their lifetime. Lambs that grow fast will reach market weight early and will bring a quicker income to farmer.Gipson (1996) and Luginbuhl (1998) stated that growth of small ruminants can be effectively divided into growth before weaning (pre-weaning ADG) and growth after weaning (post-weaning ADG).There are substantial differences between the two divisions.Maternal environment and abilitywere reported (Ekiz, 2005; Maestripieri and Mateo, 2009)as some factors responsible for growth of mammals during the pre-weaning period,while genetic potentials of individual animal is responsible for growth after weaning. The major component of the maternal environment is milk yield (Bradford, 1972; Lewis and Beatson, 1999) but mothering includes a number of other factors, that are also significant for the physical environment of the young (Benyi *et al*., 2006).

Some of the factors that affect pre-weaning and post-weaning growth rate are parity, season of birth and weaning, sex, type of birth, etc. Parity did not have any significant

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effects on pre-weaning growth rate (Benyi *et al*., 2006; Gbangboche *et al*., 2006).The efficiency ofpre-weaning growth was, however, reported by Thiruvenkadan *et al*.(2011) to decrease with the advancement ofparity.According to Benyi *et al*. (2006) pre-weaning growth rate was significantly faster in lambs born in the dry season but the reverse was true for post-weaning growth rate (Benyi *et al*., 2006).Table 2.6 shows the average daily gain (ADG) for pre- and post-weaning in different sheep breeds.

Table 2. 6: Average daily gain (ADG) of pre- and post-weaningweight in different sheep breeds

S/N.	Sheep breed	Pre-weaning ADG (g)	Post-weaning ADG (g)	Reference
1.	Rahmani	162.0	180.58	Gaafar *et al*. (2011)
2.	Finn	94.25	149.16	Gaafar *et al*. (2011)
3.	Mecheri	63.84±0.75	29.52±0.43	Thiruvenkadan *et al*.(2011)

2.7 REPRODUCTIVE PERFORMANCE OF SHEEP

Shelton and Willingham (1992) stated that reproductive rate is the single most important factor contributing to the efficiency of production. Reproduction determines the rate of expansion of a flock; reproductive performance is therefore, a good measure of the productivity of sheep. In Sub-Saharan Africa, where small ruminant production is typically a low input venture, reproductive failure is the first sign of decreased productivity (Abassa, 1995).Reproductive performance of sheep is influenced by the productivity of each of the parents. The tendency of mating a ram to many ewes makes the effect of rams (in terms of its genetic contributions to a flock) to be enormous.In

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small ruminants, reproductive efficiency can be measured by fertility, prolificacy, fecundity and survival.The most important components of reproductive performance in sheep are age at first lambing, lambing interval, litter size, and length of ewe productive life (Taiwo, 1979; Abassa, 1995; Lafi*et al*., 2009).

2.7.1 Gestation Length in Sheep

Bellows and Ansotegui (2005) defined gestation length as the physiological period during which the foetus develops in the dam. Gestation length is affected by several factors including sire breed (Fogarty *et al*., 2005), dam age, litter size and lamb weight at birth (Cardy and Van Vleck, 1978 and Amoah *et al*., 1996). Longer gestation lengths had been recorded in older dams by Vatankhah *et al*. (2000) and Koyuncu *et al*. (2001). Ewes carrying single lambs also had longer gestation length as compared with those carrying multiples (Osinowo *et al*., 1994; Vatankhah *et al*., 2000; Koyuncu *et al*., 2001; Dwyer, 2003; Fogarty *et al*., 2005).

Lamb weight was also reported to have influenced gestation length (Knight *et al*., 1988; Osinowo *et al*., 1994; Vatankhah *et al*., 2000; Fogarty *et al*., 2005) and may be longer when the dam is carrying a male lamb (Koyuncu *et al*., 2001; Vatankhah *et al*., 2000; Fogarty *et al*., 2005). Endocrine function was explained by Klindt (2005) as sexually dimorphic with observable differences in male and females. He explained further that programming of sexual dimorphism begins with embryonic expression of the sex-determining gene (SRY) in males and secretion of Mullerian-inhibiting hormone (anti-Mu¨llerian hormone, MIH), which prevents development of internal reproductive tracts of females.

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Bradford *et al*. (1972) and Dwyer *et al*. (1996) concluded that genotype of lamb is more important than that of dam in determining gestation length. Selection for reduction in gestation length may indirectly increase prolificacy (Osinowo *et al*., 1994; Vatankhah *et al*., 2000). Gestation length in sheep has been reported to range from 145 to 155 days (Anderson *et al*., 1981) and Table 2.7.

Table 2. 7: Gestation length of different breeds of sheep

S/N	Sheep breed/type	Gestation length (days)	Reference
1.	Black faced	145.2	Thrift and Dutt (1972)
2.	Tabasco	149.3±3.1	Pena (1976)
3.	West African crossbred	151±1.9	Gonzalez *et al*. (1972)
4.	*IVM-IVF embryos cultured in cell-free medium	154.9±0.4	Holm *et al*. (1996)

* IVM = i*n vitro* matured; IVF = *in vitro* fertilized

2.7.2 Fecundity, fertility and prolificacy of sheep

Fecundity is defined as the number of offspring born per female of reproductive age per year.Prolificacy or litter size on the other hand is the measure of the number of lambs born per parturition. A general definition of fertility is the number of ewes lambing in

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relation to the number of ewes mated (Haumesser, 1975; Haumesser and Gerbaldi, 1980).High fecundity should reflect the performance of a female which exhibits relatively short parturition intervals and is prolific as well since fecundity is a product of fertility and prolificacy. Haumesser (1975) concluded that it is more useful to know the level of fecundity than that of fertility and prolificacy.

Fecundity, fertility and prolificacy in ruminantsis affected by factors such as nutrition, age, diseases and season of mating (Wiltbank *et al*., 1962; Oyedipe *et al*., 1982; Lee *et al*., 1985; Akpa *et al*., 1994a; Akpa *et al*., 1994b).Supplementation during the mating period (shortly before the mating period and afterwards) could increase the number of ova shed and improve embryo survival. Smith and Somade (1994) stated that age of ewe is an important factor because fertility of ewe increases with age, and also starts to decline with old age.Mukasa-Mugerwa *et al.* (2002) recorded higher fertility from ewes that were mated during dry season. The same authors confirmed that lambing in the subsequent wet season further enhanced weaning rates and productivity due to better grazing during lactation. However, early dry season lambing in Yankasa sheep was reported to have resulted in moderate weaning weight when compared to lambing during late dry season (Akpa *et al*., 2001). Lambingrate is a good measure of ewe reproductive ability. Tables 2.8 and 2.9 show the estimates of fertility and prolificacy of ewes in Sub-Saharan Africa.

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Table 2. 8: Some estimates (%) of fertility of ewes in Sub-Saharan Africa

S/N	Sheep breed	Fertility (%)	Ecological zone	Country	Reference
1.	WAD	77.5	Humid	Nigeria	Dettmers *et al*. (1976)
2.	Nguni	79.1	Semi arid	Mozambique	Makinnon (1985)
3.	WAD	94.5	Humid	Cote d'Ivoire	Berger and Ginisty (1980)
4.	WAD	96	Humid	Cameroon	Branckaert (1977)
5.	Uda	103-109	Arid	Niger	Haumesser and Gerbaldi (1980)
6.	WAD	113.7	Humid	Congo	Betalou-Mbetaine (1992)
7.	Yankasa	120	Sub humid	Nigeria	Bayer (1986)
8.	Yankasa	121	Semi arid	Nigeria	Adu and Ngere (1979)
9.	Mossi	122	Semi arid	Burkina Faso	Nianogo (1992)
10.	Uda	122.6	Semi arid	Nigeria	Adu and Ngere (1979)
11.	Balami	128.46	Arid	Nigeria	Adu and Ngere (1979)

WAD = West African Dwarf

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Table 2. 9: Some estimates (%) of prolificacy of ewes in Sub-Saharan Africa

S/N	Sheep breed	Prolificacy (%)	Ecological zone	Country	Reference
1.	Mossi	102	Semi arid	Burkina Faso	Wilson *et al*. (1989)
2.	Massai	104	Sahel	Kenya	Wilson *et al*. (1989)
3.	Peul	105	Semi arid	Burkina Faso	Wilson *et al*. (1989)
4.	Adal	105	Semi arid	Ethiopia	Wilson (1982)
5.	Yankasa	106	Semi arid	Nigeria	Otchere *et al*. (1987)
6.	Uda	107	Arid	Chad	Dumas (1980)
7.	Uda	110	Semi arid	Niger	Gaillard (1979)
8.	WAD	111	Humid	Cote d'Ivoire	Berger and Ginisty (1980)
9.	WAD	117	Humid	Cameroon	Vallerand and Branckaert(1975)
10.	WAD	117	Humid	Senegal	Faugere *et al*. (1988)
11.	WAD	130.6	Humid	Ghana	Tuah and Baah (1985)
12.	WAD	133	Humid	Nigeria	Odubote(1992)
13.	*ALF	138	Highlands	Rwanda	Murayi *et al*. (1985)
14.	Vogan	140	Sub humid	Togo	Amegee (1978)
15.	Kirdi	138.5	Arid	Chad	Dumas (1977)
16.	WAD	172	Humid	Nigeria	Dettmers *et al*. (1976)

*ALF = African long-fat-tailed; WAD = West African Dwarf

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2.7.3 Sex Ratio of Lambs at Birth

The proportion of the two sexes is approximately equal in all vertebrates (Hagedoorn, 1946; Abdulwahid *et al*., 1988). Lush (1945) expressed sex ratios as the number of males per hundred females or as the percentage of male births among all births studied. Several authors (Lush, 1945; Karam, 1957; Skjervold, 1979; Kent, 1995; Lindstrom *et al*., 2002, Green *et al*., 2008) had reported slight andinconsistent deviations from equality in the sex ratio of lambs at birth. The explanations offered by Crew (1925) for the slight but real difference found between sex ratio were differential mortality of the embryos of the sexes and differences in the motility or longetivity of the two kinds of spermatozoa.

Skjervold (1979) reported that age of the dam, the nutritional level in the flock, litter size and lambing season had significant effect on the sex ratio. Kent (1995) and Macedo *et al*. (2007) also obtained a significant and positive correlation between flock age and the birth sex ratio. Kent (1995) stated that as the flock aged the birth sex ratio changed in favour of male, remained so for a number of years, before being in favour of female. Science Daily (2008) reported that maternal diet could influence the chance of a ewe to have either male or female offspring. Green *et al*. (2008) demonstrated that ewes fed a diet enriched with polyunsaturated fats for one month prior to conception have a significantly higher chance of giving birth to male offspring. Lindstrom *et al*. (2002) stated that environmental conditions have an inconsistent effect on offspring sex ratio in Soay sheep.

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Some of the values reported for sex ratio (% male births among all births)of lambs by various authors include 48.2% (Karam, 1957); 48.9% (Skjevold, 1979); 49.0% (Henning, 1939); 49.1% (Macedo *et al*., 2007); 49.5% (Chapman and Lush, 1932); 49.96% (Kent, 1995) and 55% (Akpa *et al*., 2002b).

2.8 MORTALITY RATES IN SHEEP PRODUCTION

Pre-weaning and post-weaning lamb mortality has been reported as one of major source of loss in sheep production (Otesile *et al*., 1983, Mousa-Balabel, 2010).It is well established that several factors could be responsible for pronounced mortality rate in sheep production. The magnitude of each factor on mortality rate differs among different husbandry and management practices (El-Hassan and Abu-Nikhaila, 2009). Mousa-Balabel (2010) related lamb mortality to ewes' body condition score, parity, lambing system (indoor or outdoor) and nutrition during pregnancy period. He stated that the most critical period for lamb survival is the first week of age.

Mousa-Balabel (2010) also observed that total lamb mortality tended to be higher in the first parity and declined until the fourth parity.The author further explained that significantly lower birth weight of lambs from first parity ewes could be responsible for this observation.Dwyer and Lawrence (1999) stated that effect of parity could also be seen on lamb mortality through the incidence of negative maternal behaviour, such as rejection (butting and abandonmentof lamb) and fear-like behaviour (withdrawing from the lamb, moving as the lamb attempts to suck). Ewes with low body conditions were reported to produce lambs with higher prenatal and neonatal mortality and lower lamb survival (Nordby *et al*. 1986; Khan, 1994; Mousa-Balabel, 2010).

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Micro-climatic adaptation of Nigerian sheep breed has been reported (Adu *et al*., 1986) as one of possible reasons for high mortality rate of breeds reared in agro-ecological zones to which such breed has not adapted. Rowland *et al*. (1992) associated housing of ewes at lambing time with a decreased risk of stillbirth; suggesting that this may be because of bettersupervision, or decreased losses due to starvation (which can be confused with stillbirths if lambing is not monitoredclosely).Rombaut and Van Vlaenderen (1975) found that parturition intervals of less than 7 months greatly increased lamb mortality. In Mali,Wilson and Durkin (1983) reportedthat parturition interval of 183days (about 6 months) or less resulted in a lamb mortality of more than 50%, whereas mortality declined to 25% when the interval was 245 days (about 8 months) or more.

Hygienic precautions in lambing pens are important because poor hygiene could allow lambs to have increased contact with pathogenic agents. Rowland *et al*. (1992) and Nash *et al*. (1996) observed that the risk of prenatal mortality increased when mothering pens were less bedded.Average mortality rate between 9 to 20% in most of sheep producing countries was reported by Binns *et al*. (2002). Matthewman (1980) found 15% adult annual mortality for sheep and goats in southern Nigeria. Wilson (1976) observed an overall mortality of approximately 30% for sheep in the semi-arid region of Sudan. Reduction of lamb mortality to an acceptable level of 4 to 5% should be the number one priority of any sheep producer.

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2.9 BREEDING SYSTEMS IN SHEEP PRODUCTION

There are various patterns or systems of breeding that may be employed by breeders and farmers for the improvement of sheep. These include out-crossing, crossbreeding, inbreeding and line breeding.

2.9.1 Out-Crossing and Crossbreeding

Out-crossing is the mating of unrelated individuals within a breed and crossbreeding is the mating of individuals of two or more breeds or varieties(Plate II) (Long, 2008). Crossbreeding results in hybrids.The Genetic effects of both out-crossing and crossbreeding are similar. The main objective is to overcome the deleterious effects of inbreeding and to introduce or combine desirable traits in the resulting crosses (Taiwo, 1979; Tibbo*et al*., 2006).



Plate II: Crossbreeding (mating between Uda ram and Yankasa ewe)

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2.9.2 Inbreeding

This refers to mating among closely related individuals (Plate III). The primary objective of inbreeding is to develop lines which can be commercially used (Vincent, 2005; Long, 2008). Inbred lines are developed usually from outstanding stocks and selection practice vigourously among the line. Inbreeding is usually associated with the appearance of genetic defects and a general decline in vigour and performance (Mandal *et al*., 2004; Ceyhan *et al*., 2011).

2.9.3 Line Breeding

This is a form of inbreeding in which an attempt is made to concentrate the inheritance of one ancestor or one line of ancestor in the linebred individuals (Vincent, 2005; Long, 2008). The ancestor is usually a male rather than a female, because the male generally produces many more descendants than the female and this allows the animal a greater opportunity to proof its merits by means of progeny testing (Norberg and Sorensen, 2007).

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Plate III: Inbreeding and pure line breeding (mating of Yankasa ram and Yankasa Ewe)

2.9.4 Genetic Basis of Heterosis

Heterosis is the advantage of crossbred individuals over the average of purebreeds used in the cross (Bourdon, 2000). Heterosis arises because dominance effects frequently create a situation in which the heterozygote is superior to the average of the two homozygotes (Buchanan, 2005). Schnell and Cockerham (1992) distinguished between two parts of heterosis: part I arising from dominance, and part II due to additive x additive (a x a)-epistasis. Di *et al*. (2011) reported that microsatellite markers had moderate potential to forecast heterosis of litter size in sheep. Table 2.10 shows average heterosis effects in crossbred lambs.

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Table 2. 10: Average heterosis effects in crossbred lambs

Trait	Level of heterosis (%)
Birth weight	3.2
Weaning weight	5.0
Pre-weaning daily gain	5.3
Post-weaning daily gain	6.6
Yearling weight	5.2
Survival: birth to weaning	9.8
Weight of lambs weaned per ewe exposed	17.8

Source: Notter, 1978

2.10 LINEAR BODY MEASUREMENTS IN SHEEP

Delgado *et al*. (2001) stated that knowledge of variation in the morphological traits is the first step in characterization of local genetic resources.Linear body measurements have been used in animals to estimate body weight (Topal and Macit, 2004; Yakubu *et al.,* 2005; Afolayan *et al*., 2006) and price of sheep in open markets (Iyiola-Tunji *et al*., 2011b). Some authors (Monsi, 1992; Okon *et al.,* 1997; Chineke, 1996; Akpa, 2000; Ozoje and Mgbere, 2002) had used linear body measurements to examine relationships among economic characteristics, reproductive performance and to study the interactions between heredity and the environment in several animals.This method of evaluating livestock is especially important in rural communities where weighing scales are not conveniently available (Sowande and Sobola, 2008; Yakubu, 2010).

Some of the body linear measurements studied by various authors (Salah*et al*., 1965; Tegbe and Olorunju, 1986; Otoikhia

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al., 2010; Yakubu, 2010) in livestock were neck length, back length, height at wither, loin girth, chest girth, leg length, *et cetera*. Ozoje and Mgbere (2002) reported on the use of skeletal dimensions such as shoulder width, heart girth and height at withers as good indicators of live weight and condition score. Heart girth that reflected the physiological status of animals had also been considered as the best indicator of live weight and condition score of pigs (Tegbe and Olorunju, 1986). Chineke (2005) is of the opinion that simple linear measurements that can reliably predict body weight without the use of weighing scales.

Linear measurements together with live body weight were influenced significantly by breed, age and sex of the animal (Semakula *et al*., 2010). Information on linear body measurements ofsheep breed found predominantly in Northern Nigeria and their crosses is scarce. However, some authors (Chineke, 1996; Yakubu *et al*., 2005; Afolayan *et al*., 2006; Sowande and Sobola, 2008; Akpa *et al*., 2010; Iyiola-Tunji *et al*., 2011b) had studied the relationship between linear body measurements and live weight of West African Dwarf and Yankasa sheep in Nigeria. Yakubu (2010) obtained positive relationships betweenbody linear measurements and body weight of Yankasa sheep and concluded that the association may be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (pleiotropy/linkage).

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2.11 GENETIC PARAMETER ESTIMATES FOR SHEEP

Genetic parameter estimates for weight at various ages and reproductive traits are essential for optimal breeding strategy that is capable of improving the efficiency of sheep production (Mohammadi *et al*., 2010; Selvaggi *et al*., 2011).Estimation of genetic parameters is necessary to determine the selection method to be used, estimate the maximum genetic gain that can be achieved and to obtain correct estimates of breeding values (Lobo *et al*., 2009). Genetic and phenotypic parameter estimates normally apply directly to the specific population and environment from which the data were collected. Thus, estimates may vary from one population to another depending on gene frequency, previous selection, environment and past history of the population (Becker, 1975; Mrode, 2005; Templeton, 2006; Iyiola-Tunji, 2007; Mohammadi *et al*., 2010; Selvaggi *et al*., 2011).The major genetic parameter estimates are heritability, repeatability, genetic and phenotypic correlations (Mrode, 2005; Rongling *et al*., 2007).

2.11.1 Heritability Estimates for Growth and Reproductive Traits

Heritability (h^2) is a measure of the strength of the relationship between performance (phenotypic values) and breeding values for a trait in a population (Bourdon, 2000). It is also definedby Hamilton (2009) as the proportion of the total phenotypic variance (V_P) that is caused by either all types of genotypic variance (V_G) or by only the additive genetic variance (V_A).High heritability indicates that a substantial proportion of the phenotypic variance is due to additive genetic variation, while non-additive genetic factors make a larger contribution to the phenotype when the heritability is low (Cameron, 1997). Heritability therefore is critically important to selection for polygenic traits (Templeton, 2006).

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Heritability values range from 0 to 1. As a rule, traits with heritabilities below 0.2 are considered lowly heritable, traits with heritabilities between 0.2 and 0.4 are considered moderately heritable, and traits with heritabilities above 0.4 are considered highly heritable (Bourdon, 2000). Traits related to fertility and survivability tend to be lowly heritable. Production traits like milk production and growth rate tend to be moderately heritable. The most highly heritable traits are typically carcass or "product traits" and traits that are related to skeletal dimensions (e.g., structural size and mature body weight). When a trait is highly heritable, relatives tend to "resemble" each other in the trait (i.e., they tend to have similar performance). Conversely, when a trait is lowly heritable, there is little resemblance among relatives(Bourdon, 2000; Mrode, 2005; Rongling *et al*., 2007).

Heritabilities of reproductive performance are low, but must not be ignored. Heritabilities of some reproductive traits such as age at pubertyare high which indicates a more rapidresponse to selection (Bellows and Ansotegui, 2005).Senneke *et al*. (2004) stated that parental misidentification is capable of reducing heritability estimates, and covariances interaction between fixed and random effects.Das *et al*. (1993) stated that post-weaning growth generally has higher heritability estimates than pre-weaning growth. They further stated that environmental factors, in relation to additive genetic factors, had more influence on growth of lamb early in life than its growth later in life. Harrington *et al*.(1962) and Thrift *et al*.(1973) attributed this observation to the high maternal influence associated with lamb growth performance early in life. High maternal influence has a tendency to increase the component of environmental variance and thereby lowers heritability estimates.Table 2.11 shows the heritability estimates for growth traits from different sheep po

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Table 2. 11: Heritability estimates for growth traits from different sheep population

S/N	Breed	Heritability of growth traits			Location	Reference
		BWT	WWT	P-ADG		
1.	D'man	0.34±0.08	0.52±0.10	-	Morocco	Boujenane and Kerfal (1990)
2.	Pelibuey	0.16±0.04	0.12±0.03	-	Mexico	Carrillo and Segura (1993)
3.	Barbados blackbelly	0.04±0.07	0.17±0.09	0.15±0.08	Mexico	Carrillo and Segura (1993)
4.	Djallonke (WAD)	0.39	0.54	0.21	Gambia	Bosso *et al*. (2007)
5.	Yankasa	0.05	-	-	Nigeria	Osinowo (2000)

BWT = birth weight; WWT = weaning weight; P-ADG = pre-weaning average daily gain; WAD = West African Dwarf

2.11.2 Repeatability Estimates for Growth and Reproductive Traits

Cameron (1997) described repeatability as a measure of similarity between observations within a group. Becker (1975) stated that repeatability could be considered as intra-class correlation, which is the expected correlation between observations within group, or class. Koger and Knox (1947), as well as, Taylor *et al*. (1960) had documented the tendency for repeatability estimates based on the likeness of adjacent records to be higher than those based on likeness of non-adjacent or randomly chosen records.

The repeatability model has been employed by Interbull (2000) for the analysis of data when multiple measurements on the same trait are recorded on an individual, such as litter size in successive pregnancies or milk yield in successive lactations. The repeatability model usually assumes a genetic correlation of unity between all pairs of records,equal variance for all record

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pairs of records. In practice, some of these assumptions may not hold (in the analysis of real data). A more appropriate way of handling repeated measurements over time is by fitting a random regression modelor a covariance function (Mrode, 2005).Just as heritability is necessary for predicting breeding values, repeatability is needed for predicting producing abilities.Knowledge of the repeatability of a trait can be useful in making culling decisions.When repeatability is high, poor producing individuals should be culled on the basis of their first record. When repeatability is low, decision in regards to culling should be made only after more records have been obtained.

Repeatability estimates like heritability also range from 0 to 1 and can be described as low, medium or high the same way as heritability (Bourdon, 2000).Repeatability estimates of less than 0.40 are considered low for efficientearly selection (Jawasreh and Khasawneh, 2007).Harrington and Whiteman (1967) reported repeatability estimates range between 0.12 and 0.24 for 70-day lamb weight of Rambouillet and Rambouillet X Panama-Rambouillet ewes which were sired by Dorset rams. Repeatability of ovulation rate averaged 0.18 for Sardi and 0.29 for D'Man, with corresponding values for litter size of 0.18 and 0.27 (Bradford *et al*., 1989). Boujenane *et al*. (1991) reported 0.24 as repeatability estimate of litter size for Sardi sheep. Said *et al*. (1999) used intra-class correlation method to estimate repeatability in Awassi sheep. They obtained 0.03, 0.46 and 0.26 as the estimates for litter size, ewe body weight and growth rate, respectively.

Hagger (2002) obtained 0.136, 0.119, 0.164 and 0.066 as the repeatability estimates of litter size in White Alpine, Brown-Headed Meat, Black-Brown Mountain and Valais Black-Nose sheep, respectively.Vatankhah and Talebi (2008) reported 0.11 as the estimates for litter size of Lori-Bakh

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0.04 as repeatability estimates for litter size in Improved Awassi, Local Awassi and Assaf sheep, respectively.

2.11.3 Genetic and Phenotypic Correlation for Growth and Reproductive Traits

Genetic correlation measures the strength of association between traits using additive genetic effects, while phenotypic correlation incorporates environmental effect with total genetic effect into the measure of association between traits (Scholtz and Roux, 1990). Some loci that influence one trait may have so-called pleiotropic effects and influence other traits.These effects may be complementary when an allele is favorable for both traits or it may be that the allele that is favourable for one trait is unfavourable for another. The effect of such genes creates a correlation between the genotypes for the traits. Geneticand phenotypic correlations may be positive or negative and will influence the performance of one trait when the other trait is subjected to selection pressure. The genes will also influence the rate at which the traits respond to simultaneous selection, such as within an index (Garrick, 2005). Phenotypic correlation coefficients are used to measure the strength of relationship or association between two quantitative traits.

Reliable genetic parameter estimatesare necessary for importanteconomic traits and to increase the accuracy of selection ofbreeding animals (Baneh *et al*., 2010). Thiruvenkadan*et al*. (2011) stated that an effective breeding plan can only bedevised after thorough knowledge has been obtained aboutthe inheritance of economically important traits. Estimatesof heritability, genetic and phenotypic correlations formthe basis of such information. This knowledge is required toformulate optimum breeding

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objectives and effectivegenetic improvement programme (Boujenane and Kerfal, 1990; Nasholm and Danell, 1996).

Genetic correlations between lamb weightsare generally high and positive (Maria *et al.,* 1993; Vaez Torshizi *et al.,* 1996; Notter, 1998; Snyman *et al.,* 1998; Mousa *et al.,*1999), and a high correlation between lamb weight and mature weight has also been recorded (Nasholm and Danell, 1996). Genetic correlations between liveweight and reproductive traits are positive,0·2 to 0·6, but not always significant (Waldron andThomas, 1992; Fogarty *et al.,*1994; Al Shorepy andNotter, 1996; Analla *et al.,*1997; Analla and Serradilla,1998; Rao and Notter, 2000; Bromley *et al.,*2001). Baker and Morris (1984) indicated zero or slightly negative genetic association between growth and fertility traits. Low and negative genetic correlations have been found betweengestation length and growthtraits (Bourdon and Brinks, 1986; MacNeil *et al.*,1984). Alade *et al*. (2006) reported low and negative genetic correlations (-0.122 to -0.22) between litter size and body weight. The authors also reported phenotypic correlations that ranged from -0.118 to 0.295 for the same traits.

2.12 HAEMATOLOGICAL PARAMETERS OF LIVESTOCK

The formation of blood cells (haemopoiesis) is determined by the interaction of multiple genes and involves cytokines and other protein factors (Munker*et al*., 2007). Nutrition, age, sex,genetics, stress and transportation are all known to affect haematological and biochemical parametersobserved in tropical and temperate animals (Ogunrinade *et al*., 1981; Bush, 1991 and Ogunsanmi *et al*., 1994). Interstitial, plasma and blood volumes have also been reported by MacFarlane(1975)to be influenced by age, sex, temperature, latitude, food quantity and quality

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disease.Fasae *et al*. (2011) demonstrated that environmental factors caused variation in haematological parameters of goats in different regions. Seasonal variations in air temperature are considered to be physiological stressors which affect the animal biological systems (El-Nouty *et al*., 1990). These stressors were suggested (Lee *et al*., 1976; Shaffer *et al*., 1981; El-Nouty *et al*., 1986) to exert significant influence on blood haematological characteristics of dairy animals. High environmental temperature has been identified as a factor which alters physiologicalparameters of birds (Donkoh, 1989; Belay and Teeter, 1993).

PackedCell Volume (PCV), Haemoglobin concentration (Hb), leucocyte counts (WBC) and Total Protein (TP) values are important haematological parameters, which are of importance in the assessment of health status of livestock (Hawkey *et al*., 1983), and are good indices of livestock adaptability to prevailing environmental conditions (Kaushish *et al*., 1976).Total protein contents were reportedly used as an indicator of the animals' nutritive status reflecting food intake and metabolism (Serdaru *et al*., 2011).

Tibbo *et al*. (2008) reported that goats within age group 12 and 24 months had significantly higher PCV than older age groups.Gartner *et al*. (1969) and Egbe-Nwiyi *et al*. (2000) explained thathigh red blood cells(RBC) values in the young ruminants may, among other things, be due to excitement orstress during handling. They explained that this could lead to the release of adrenaline and hence spleen contractionwhich could cause the release of stored RBC into circulation.Season affected almost all erythrocytic series in goats (Tibbo *et al*., 2008). They expressed that RBC and PCV were significantly lower during short rainy season than any other season, but the reverse was true for Mean Corpscular volume (M

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White blood cells and lymphocyteswere significantly higher in females than males, while the reverse was true in case of neutrophils. Lymphocytes significantly decreased as age increased while the reverse was the case for neutrophils.White blood cells was significantly higher during long rainy and immediately after rainy seasons.Rekwot *et al*. (1987) and Olayemi *et al*. (2009) associated ruminants managed extensively with high WBC counts. Fasae *et al*. (2011) attributed this phenomenon to high load of pathogenic microbes in ruminants reared extensively. Table 2.12 shows the erythrocyte and leucocyte value in human and some livestock.

Table 2. 12: Comparison of erythrocyte and leucocyte indices in human, cattleand goats

Parameters	Human	White Fulani	WAD sheep	Nigerian goats
RBC ($X10^6$ µl)	5.37±0.41	7.05±1.82	7.50±2.10	12.3±2.40
PCV (%)	46.50±4.36	34.08±4.12	27.40±4.50	26.10±4.10
Hb (g/dl)	15.06±1.27	9.80±1.37	8.42±1.50	8.59±1.31
MCV (fl)	87.70±5.7	46.85±5.25	38.30±10.50	21.80±4.40
MCH (pg)	27.69±2.16	NA	NA	NA
MCHC (g/dl)	32.39±0.76	NA	30.80±5.40	33.10±3.40
WBC ($x10^3$ µl)	6.22±1.43	9.98±2.66	15.25±4.69	16.10±4.55
Neutrophils ($X10^3$ µl)	3.15±0.87	NA	NA	NA
Lymphocytes ($X10^3$ µl)	2.35±0.85	19.90±9.30	38.5±13.6	46.80±10.80
Monocytes ($X10^3$µl)	0.13±0.16	0	1.50±1.60	0.90±0.90
Eosinophils ($X10^3$µ)	0.60±0.64	8.73±6.80	4.60±4.50	4.7±4.50
Basophils ($X10^3$µ)	0	0	NA	0

RBC = Red blood cells; PCV = Packed cell volume; WBC = White blood cells; Hb = Haemoglobin concentration; MCH = Mean corpuscular haemoglobin; MCHC = Mean corpuscular haemoglobin concentration; MCV = Mean corpuscular volume; NA = Not available.(Sources: Oduye and Fasanmi, 1971; Oduye, 1976 and Oduye and Adedovc

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2.13 BIOTECHNOLOGY IN ANIMALPRODUCTION

Urbanization, population and income growth are fuelling massive demands for food of animal origin in developing countries (Delgado *et al*., 1999). This process was termed by the authors as 'Livestock Revolution.' Table 2.13 shows the predicted increase in meat and milk consumption for the period 1993 to 2020. The increment is substantial and it also indicate large regional variability. The increasing demand for these products could be provided for through improved production using knowledge of biotechnology (Delgado *et al*., 1999).

Table 2. 13: Actual (1993) and projected (2020) per capita meat and milk consumption by region

	Meat (kg/year)		Milk (kg/year)	
Region	**1993**	**2020**	**1993**	**2020**
China	33	60	7	12
Other East Asia	44	67	16	20
India	4	6	58	125
Other South Asia	7	10	58	82
South East Asia	15	24	11	16
Latin America	46	59	100	117
West Asia/North Africa	20	24	62	80
Sub-Saharan Africa	9	11	23	30
Developing world	21	30	40	62
Developed world	76	83	192	189
World	34	39	75	85

Source: Delgado *et al*., 1999

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Biotechnology is any technological application that uses biological systems, living organisms, or its derivatives to make or modify products for specific use (Secretariat of the Convention on Biological Diversity, 1992). Agricultural biotechnology is one of the oldest areas of biotechnology and it involves the production or use of domesticated animals and crops for food production (Shmaefsky, 2005). Animal biotechnology is the application of scientific and engineering principles to the processing or production of materials by animals.Rege (1994) observed that animal production and health have probably benefited more from biotechnology than any other fields in agriculture and allied field.

The tools of biotechnology in animal production as stated by Renaville and Burny (2002) include genetic engineering, marker-assisted selection, gene sequencing, gene mapping and genetic distance studies. Montaldo (2006) stated that the use of genomic information (sequences or DNA and protein marker polymorphisms) for the genetic improvement and selection of animals requires the knowledge of the effect of physically mapped genes with effects on economically important traits or quantitative trait loci (QTL).Molecular markersare increasingly being used to identify and select the particular genes that are associated with desirable traits and it is now possible to select superior germplasms anddisseminate them using artificial insemination, embryo transfer and other assistedreproductive technologies (Madan, 2005; Van der Werf, 2007).

2.14 HAEMOGLOBIN POLYMORPHISM IN SHEEP

Several studies had linked adaptive and productive features of sheep to some variants of blood proteins (Gootwine, 1988; Salako *et al*., 2007; Akinyemi, 2010). One of the important erythrocyte proteins that h

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theselection process is the haemoglobin; an alpha and beta containing polypeptide chain (Salako *et al*., 2007).Polymorphism of the haemoglobins of sheep was first described in 1955 (Cabannes and Serain, 1955; Harris and Warren, 1955). Subsequent works of Tucker (1971) and Agar *et al*. (1972) confirmed the different variants of haemoglobin in sheep. Electrophoretic study of sheep haemoglobin types showed that there are three main genotypes, which are HbAA, HbBB and HbAB (Miresan, 2003; Tapio *et al*. 2003; Salako *et al*., 2007 and Akinyemi, 2010). These haemoglobin types are genetically determined in a simple Mendelian manner, none beingdominant (Evans *et al*., 1956).

These alleles vary among different breeds (Harris and Warren, 1955; Evans *et al*., 1958; Stormont *et al*., 1968). The Hb C appeared in anaemic sheep (Van Vliet and Huisman, 1964). A fourth allele, Hb D with electrophoretic mobility faster than Hb A, B and C was found to characterize some Yugoslavian sheep (Vaskov and Efremov, 1967). Specific foetal hemoglobins, designated as Hb F have also been identified in the domestic sheep and goats (Helm *et al*., 1958).

Akinyemi (2010) obtained very high frequency of Hb A in populations of Balami, Uda and Yankasa reared in the Northern Guinea Savannah zone of Nigeria, while Salako *et al*. (2007) reported a higher frequency of HbB in population of West African Dwarf sheep at low altitude in South-West Nigeria.Evans *et al*. (1958) had earlier suggested that Hb A has a selective advantage at higher altitudes because it constitutes the most common allele in highland breeds of English and Scotish sheep. Gootwine (1988) also demonstrated that ewes belonging to the HbAB genotype showed significant advantage over the other Hb genotypes in both lamb and milk production.

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CHAPTER THREE

MATERIALS AND METHODS

3.1 EXPERIMENTAL LOCATION

This study was conducted at the Sheep Project Unit of Small Ruminant Research Programme (SRRP) of National Animal Production Research Institute (NAPRI), AhmaduBelloUniversity, Shika-Zaria. The institute is located in Northern Guinea Savannah zone of Nigeria on latitude 11°12´16.78´´N and longitude 7°33´39.18´´E(Figure 3.1) with an elevation of 691 metres above sea level.



Figure 3 1: Satellite imagery of National Animal Production Research Institute, Shika, Zaria (Cordinates: Latitude 11°12´16.78´´N; Longitude 7°33´39.18´´E)

Being in the Northern Guinea SavannahZone, it receives a mean precipitation of 1,107mm per annum, stretching over 120-170 days from late April to early September (Oni *et al*., 1989; Otaru *et al*., 199

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2011). Seasonal distribution of rainfall is approximately 0.1%, late dry (January-March), 25.8%, early wet (April-June), 69.6%, late wet (July-September) and 4.5%, early dry (October-December) seasons. Average maximum temperature is 38.89^{o}C while the average minimum ambient temperature is 8.89^{o}C and the yearly average for the past 7 years is 25.55^{o}C(Issa *et al*., 2011). The mean relative humidity during dry and wet seasons are 21 and 72%, respectively. Good quality forage is more abundant in the late wet and early dry seasons while forages are generally scarce and very low in quality during late dry and early wet seasons (Oni *et al*., 1989; Otaru *et al*., 1993; Afolayan, 1996; Akpa *et al*., 2002a).

3.2 ANIMALS AND THEIR MANAGEMENT

The rams were kept separately at the Experimental Unit of NAPRI and reared under semi-intensive system. The Balami were sourced from Wudil Animal Market in Kano State. They were quarantined for two weeks. The other two breeds (Uda and Yankasa) were selected among the stock at NAPRI. The ewes that were selected for the studywere between two and three years old based on the recommendation of Taiwo *et al*. (1982).

3.2.1 Housing

The animals were housed in well constructed open-sided pens at night (Plate IV). The animals' shed was designed to provide good ventilation and drainage. It was opened away from the direction of prevailing wind so as to prevent draught. Feeding and drinking troughs were provided on either raised floor or on attachment to the wall of the shed. This helped in preventing contamination of feeds and water by faecal droppings, which could cause rejection and thereby reduction in productivity of the animals.

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Plate IV: Sheep house at NAPRI

3.2.2 Feeding

The sheep were fed concentrate supplements (3% of body weight) in the morning at 8:00 am. The concentrateswerecompounded using cotton seed cake, ground maize grain or maize offals, bone meal, vitamin and mineral premix and salt to make a diet of 18% crude protein (CP) for weaners and 15% CP for yearlings and other adult sheep. Gamba grass (*Andropogon gayanus*) hay was also provided after the concentrates. Nursing ewes and their lambs were kept intensively up to weaning at 90 days while the other sheep in the flock were daily released to graze on improved pastures of *Digitaria smutsii; Bracharia decumbens;* Gamba grass; *Cynodon dactylon and Hyperenia rufa*, between 8:00 amand4:00 pm.Drinking water wasprovided *ad libitum*. More feed were

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given to pregnant ewesduring the last two month of pregnancy corresponding to 3% of body weight.

3.2.3 Health

Routine medication consisted of anti-helminthic, drenching (deworming) which was carried out every month for the suckling lambs and every 45 to 60days for the weaned and adult sheep.Ectoparasite bath (dipping) was carried out every 2 weeks; as well as vaccination against endemic diseases.

3.3 SHEEP BREEDS AND BREEDING PLAN

Three breeds of sheep that are found predominantly in Northern Nigeria were used for this study. They were Balami, Uda and Yankasa.Detail descriptions of the three breeds of sheep were stated in Appendix 1.0.

3.3.1 Heat (estrus) Detection and Breeding Pattern

Heat detection was carried out twice daily; in the morning (7:00-8:00 am); and in the evening (5:00-6:00 pm) using apron fitted rams to pick ewes on heat because oestrus detection is difficult in the absence of rams for the sheep breed considered (Adu, 1972; Orji and Steinbach, 1975). Ewes on oestrus were separated from the flock into an isolated pen with a pre-determined ram. They were allowed to be together for three days under the assumption that mating would ensue. Pen mating method was used at the ratio of 1 ram to 10 ewes. After the third day, ewes were returned to their flock after the appropriate records were taken. Ewes that returned to heat after 21 days were rebred with another pre-determined ram to e

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Diallel breeding was used for the study. The breeding pattern was as shown in Table 3.1. A total of 65 Yankasa, 23 Uda and 16 Balami ewes were served by 4 Yankasa, 3 Uda and 3 Balami rams. Breeding of sheep was done twice a year;in the wet season (May 15-June 15) and dry season (November 15-December 15). Four breedings were conducted (2 in each of the years) and dated as follows: May 15thto June 15th, 2009; November 15thto December 15th, 2009; May 15thto June 15th, 2010 and November 15th to December 15th, 2010. Ewes gave birth in approximately 5 months after each breeding. All the lambs produced from the diallel breeding were ear-tagged soon after birth.

Table 3. 1: Diallel breeding pattern and the resulting lamb genotype

Sire breed	Dam breed	Lamb genotype
Yankasa	Yankasa	YK X YK
Uda	Uda	UD X UD
Balami	Balami	BL X BL
Yankasa	Uda	YK X UD
Yankasa	Balami	YK X BL
Uda	Yankasa	UD X YK
Uda	Balami	UD X BL
Balami	Yankasa	BL X YK
Balami	Uda	BL X UD

YK = Yankasa; UD = Uda; BL = Balami

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3.4 BLOOD COLLECTION AND ANALYSIS

Blood samples (5ml) were collected (Plate V) from 104 ewes and 10 rams that produced lambs between 2009 and 2011 through jugular venipuncture. The blood samples were placed in ethylenediamine tetra-acetic acid (EDTA) tubes to prevent coagulation and were transported in ice-pack (Plate VI) to the Genetic and Breeding Laboratory, Department of Animal Science, University of Ibadan, Nigeria.

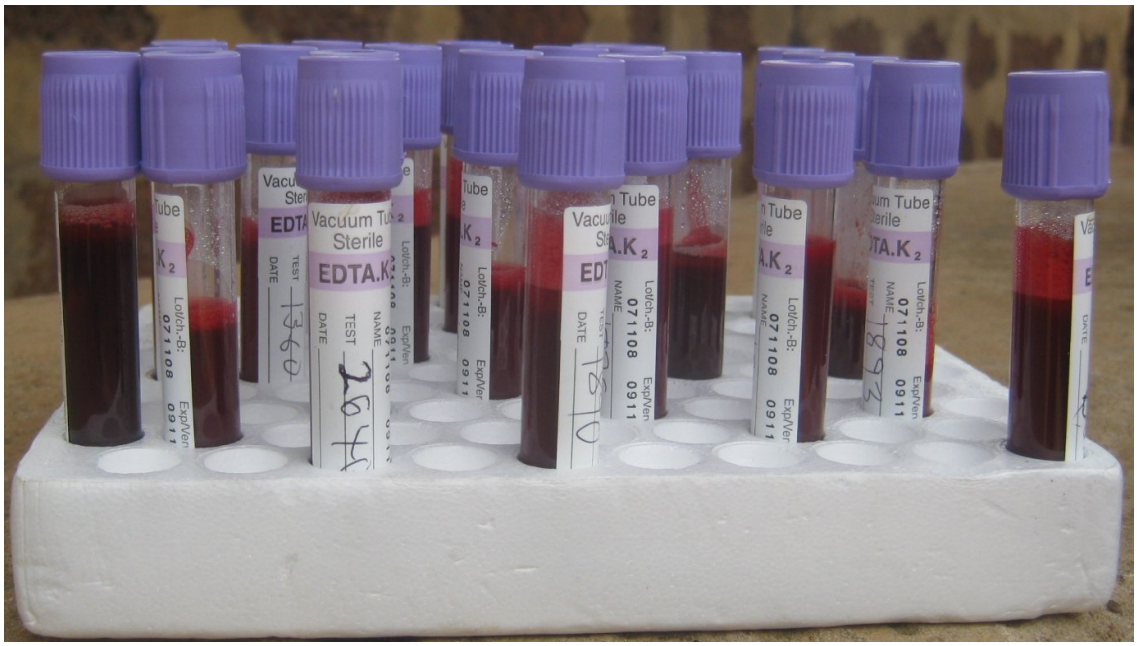


Plate V: Sheep blood collected into EDTA vacuum tubes

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Plate VI: Sheep blood sample transported in ice-pack

3.4.1 Electrophoretic Analysis of Blood Samples

Red blood cells (RBCs) were prepared from the erythrocyte fraction of blood by centrifuging at 3000 rpm for 10 minutes at 4^{o}C. The supernatant was decanted leaving the sediment (RBCs). The RBCswere washed in saline (0.155M NaCl) three times and centrifuged at 3000 rpm for 5 minutes at 4^{o}C. The RBC were lysed by using haemolysing reagent (0.3g EDTA; 2 ml potassium cyanate and 120 ml distilled water) to release haemoglobin.Subsequently, 0.5 ml of the haemolysing reagent was added toindividualanimal sample's sediment in a test tube to produce the haemolysates.Electrophoresis was carried out in a Shandon electrophoresis tank on cellulose acetate strips 34.5 x 150 m

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and cathode. The strips were ran for 40 minutes at a constant voltage of 350V according to the procedure described by RIKEN (2006) and Akinyemi(2010).

On separation, the strips were stained with Ponceau-S, later washed with 5% glacial acetic acid, and dried using filter paper. Interpretations were made based on the relative mobility of the haemoglobin bands towards the anode, with haemoglobin AA (single band) being the fastest while haemoglobin BB (single band) was the slowest and haemoglobin AB (double band) having slow and fast bands (Abdussamad *et al*., 2004; RIKEN, 2006; Akinyemi, 2010) as shown in Plate VII.

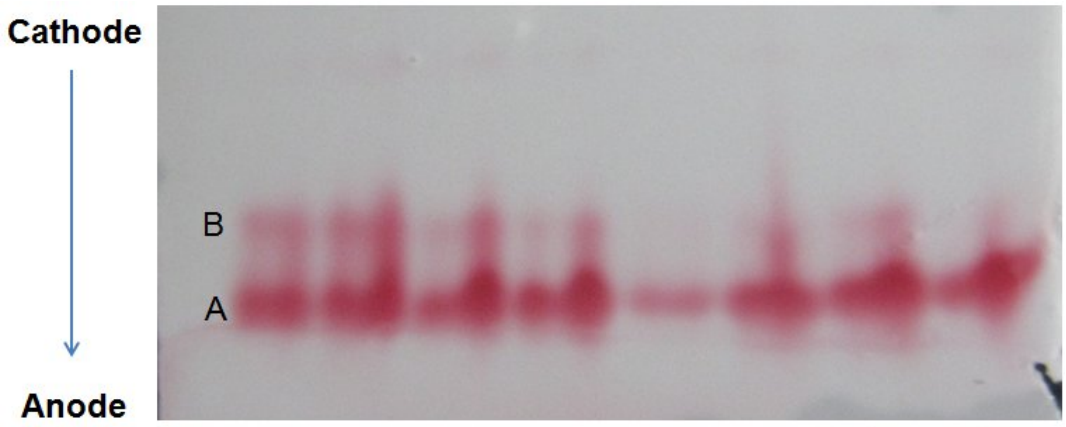


Plate VII: Electropherogram of haemoglobin variants

3.5 DATA COLLECTION AND MANAGEMENT

Records taken in this study included lamb's sire and dam, date of mating, date of birth, lamb's sex, type of birth, weight at birth, 90-Day weight (weaning weight), 180-Day and 360-Day weight (yearling weight). Parental haemoglobin type was determined andlinear body measurements were also taken at birth, 90, 180 and 360 days. The linear

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body measurements considered were neck length and back lengths, height at wither, loin girth, chest girth and leg length.

3.5.1 Measurementsof Body Weights

Body weights were recorded in kilogramme using Salter® scale as shown in Plate VIII. Data that were not collected at the desired date were adjusted using the following formula:

$$\text{Body weight at speci ic age} = \frac{X - X}{Y - Y} * Y - Y + X$$

Assumptions made were:

$j, k, L \neq 0$; $j, k, L > 1$; $k > j$; $L > j$ and $k \neq L$

Where:

X_{ik}= parameter measurement (growth trait or linear body measurements) after the desired date;

X_{ij} = value of parameter measured (growth trait or linear body measurements) before the desired date;

Y_k = Date of record;

Y_j = Date of previous record; and

Y_L= Age of animal on the day of record.

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Plate VIII: Body weight measurement using Salter® weighing scale

3.5.2 Linear Body Measurements

Body linear measurements were recorded in centimetre using a measuring tape. The description of each of the linear body measurements areshown in Plate IX:

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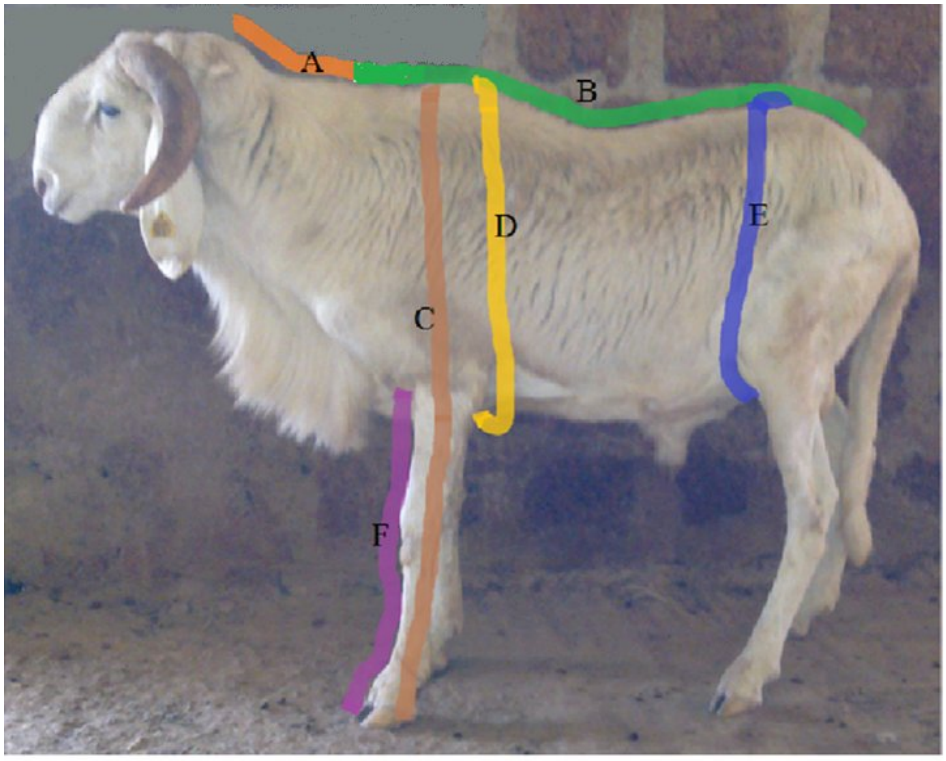


Plate IX: Linear body measurements

Neck length: The distance between the last atlas bone to the last cervical vertebra.

Back length:The distance from the last cervical vertebra anteriorly, the entire thoracic vertebra, sacral vertebra to sacro-coccygeal vertebra joints at the hip of the animal.

Height at wither:Measured from the tip of the scapula at the cervico-thoracic joint to the tip of the hoof.

Loin girth:Is the measure of the circumference at the loin, in a position anterior to the hind leg.

Chest girth:This was measured as the circumference posterior to the forelegs at right angles to the body axis.

Leg length:Leg length was measured from the hip of elbow joint to the tip of the hoof.

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3.5.3 Average Daily Gainsof Body Weightsand Linear Body Measurements

Average daily gains (ADG) of body weightswere calculated (in grams) using the respective formula:

$$90\ \text{Day ADG (ADG90)} = \frac{\text{Weight at 90 Day} - \text{Weight at birth}}{90} \times 1000$$

$$180\ \text{Day ADG (ADG180)} = \frac{\text{Weight at 180 Day} - \text{Weight at 90 days}}{90} \times 1000$$

$$360\ \text{Day ADG (ADG360)} = \frac{\text{Weight at 360 Day} - \text{Weight at 180 days}}{180} \times 1000$$

3.5.4 Relative Growth Rate

Relative growth rates (RGR) of body weights were calculated using the respective formula in accordance to Fitzhugh and Taylor (1971), Smith and Cundiff (1976), Stobart *et al*. (1986), Winder *et al*. (1990) and Schoeman and Jordan (1999):

$$90 - \text{Day RGR (RGR90)} = \frac{\text{LN (weight at 90 Day)} - \text{LN (weight at birth)}}{90} \times 100$$

$$180 - \text{Day RGR (RGR180} = \frac{\text{LN (weight at 180 Day)} - \text{LN (weight at 90 days)}}{90} \times 100$$

$$360\text{Day RGR (RGR360)} = \frac{\text{LN (weight at 360 Day)} - \text{LN (weight at 180 days)}}{180} \quad 100$$

Where LN is natural logarithm.

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3.5.5 Genotypic Frequency of Haemoglobin

Genotype frequency was calculated thus:

$$AA = \frac{\text{Number of AA}}{\text{Total number of samples}} \text{ x } 100$$

$$AB = \frac{\text{Number of AB}}{\text{Total number of samples}} \text{ x } 100$$

$$BB = \frac{\text{Number of BB}}{\text{Total number of samples}} \text{ x } 100$$

3.5.6 AllelicFrequency of Haemoglobin

Allelic frequency was calculated thus:

A = Total number of AA x 2 + ½ AB

B = Total number of BB x 2 + ½ AB

3.6 STATISTICAL ANALYSIS

The data for this study were analysed by the General Linear Model (GLM) procedures of SAS (SAS, 2003) using fixed effect model that incorporatedlamb genotype, dam's haemoglobin type, sex of lambs, type of birth,season of birth and weaning as fixed effects. Birth weight of lambs, weight at 90-Day (weaning weight), 180-Day and 360-Day, average daily gainfrom birth to 90-Day (ADG90); from 90-Day to 180-Day (ADG180) and from 180-Day to 360-Day(ADG360), relative growth rate from birth to 90-Day (RGR90); from 90-Day to 180-Day (RGR180) and from 180-Day to 360-Day (RGR360),and linear body measurements (neck length, back length, height at wither,

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loin girth, chest girth and leg length) at birth, 90, 180 and 360-Day were the dependent continuous variables. Pair-wise difference was used to separate the mean (SAS, 2003).The pre-test effects of season of birth and weaning on growth (birth weight, 90 and 360-Day) and some reproductive traits considered in this study were not significant (P>0.05). The linear model used was as summarized below:

$$Y_{ijklmq} = \mu + G_i + D_j + S_k + T_L + e_{ijklmq}$$

Where:

Y_{ijklm}= Observable characteristics.

μ = Overall Mean

G_i = i^{th} effect of lamb genotype (I = 1,2,3,4,5,6,7,8,9);

D_j = j^{th} effect of dam's haemoglobin type (J = 1,2,3);

S_K = K^{th} effect of lamb's sex (i = 1,2);

T_L = L^{th} effect of Litter type (birth type)(j = 1,2);

e_{ijkl} = Random error effect.

Chi square (SAS, 2003) was used to test the gene and genotypic frequencies of haemoglobin types in the parental population. Hardy-Weinberg's equilibrium used for testing the significance of gene and genotypic frequencies was based on the expansion of the binomial $(p + q)^2 = p^2 + 2pq + q^2$ in accordance to Salako *et al*. (2007).

The heritability, repeatability, genetic and phenotypic correlations for growth traitswere estimated using the sire models of Harvey (1990). The model for the estimation is as stated below:

$$Y_{ijk} = \mu + S_i + F_j + e_{ijk}$$

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Where:

Y_{ijkl}= measurement of a particular trait,

μ = population mean,

S_i= random effect of i^{th} sire with a mean of zero and constant variance σ_s^2,

D_j = random effect of j^{th} dam with a mean of zero and constant variance σ_d^2,

F_k= fixed effects observed to be significant, and

e_{ijkl} is random error with a mean of zero and constant variance σ_e^2.

Step-wise regression procedure of SAS (SAS, 2003) was used to generate prediction equations for the association between body weight at various ages and linear body measurements.

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CHAPTER FOUR

4.1 RESULTS

4.1.1 Diallel Breeding Pattern, Lamb Genotype and Dam's Haemoglobin Type

Table 4.1 shows the diallel breeding pattern and the resulting number of lambs. Most of the lambs at birth (110 out of 192) were from the pure Yankasa genotype (YK X YK). Proportion of lambs in relation to dam's haemoglobin type was as shown in Figure 4.1. About 70% of the lambs produced were from ewes with AB haemoglobin type (HbAB). The least frequency was for lambs from ewes with haemoglobin type BB (HbBB). Chi Square test revealed that allele A of dam's haemoglobin types was more numerous ($P<0.01$) than allele B (Figure 4.2). The values were 58.07, 57.88, 59.21 and 58.18% for the gene frequencies of allele A at birth, 90-Day, 180-Day and 360-Day, respectively.All the rams used in this study had HbAB.

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Table 4. 1: Diallel Breeding Pattern and the Resulting Number of Lambs

Sire Breed	Dam Breed	Lamb Genotype	Number of lambs			
			At birth	90-Day	180-Day	360-Day
Yankasa	**Yankasa**	**YK X YK**	110	93	65	25
Uda	**Uda**	**UD X UD**	18	16	11	6
Balami	**Balami**	**BL X BL**	3	3	3	1
Yankasa	**Uda**	**YK X UD**	18	18	14	9
Yankasa	**Balami**	**YK X BL**	3	3	1	1
Uda	**Yankasa**	**UD X YK**	20	16	13	8
Uda	**Balami**	**UD X BL**	4	4	2	1
Balami	**Yankasa**	**BL X YK**	9	7	2	2
Balami	**Uda**	**BL X UD**	7	5	3	2
		Overall	192	165	114	55

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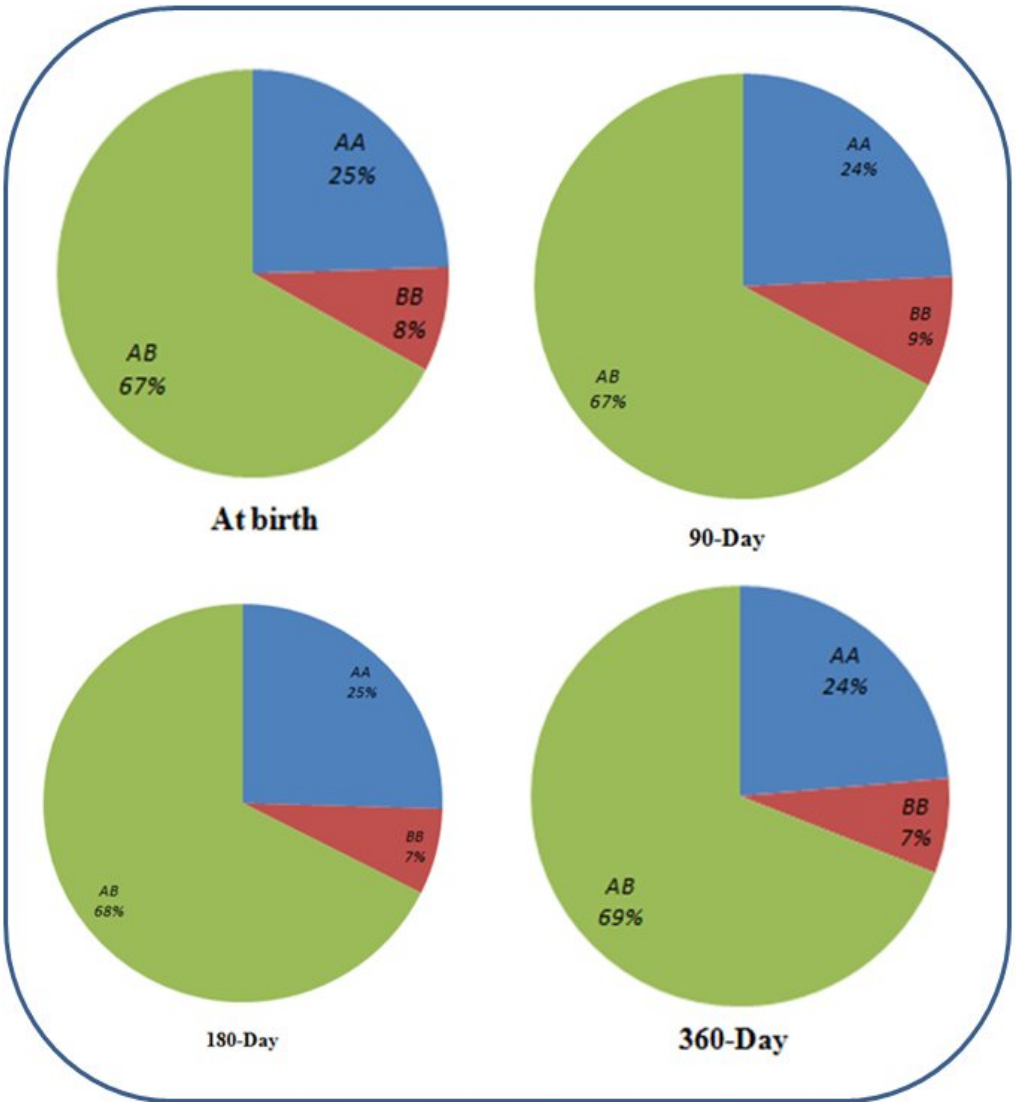


Figure 4. 1: Proportion of lambs in relation to dam's haemoglobin type

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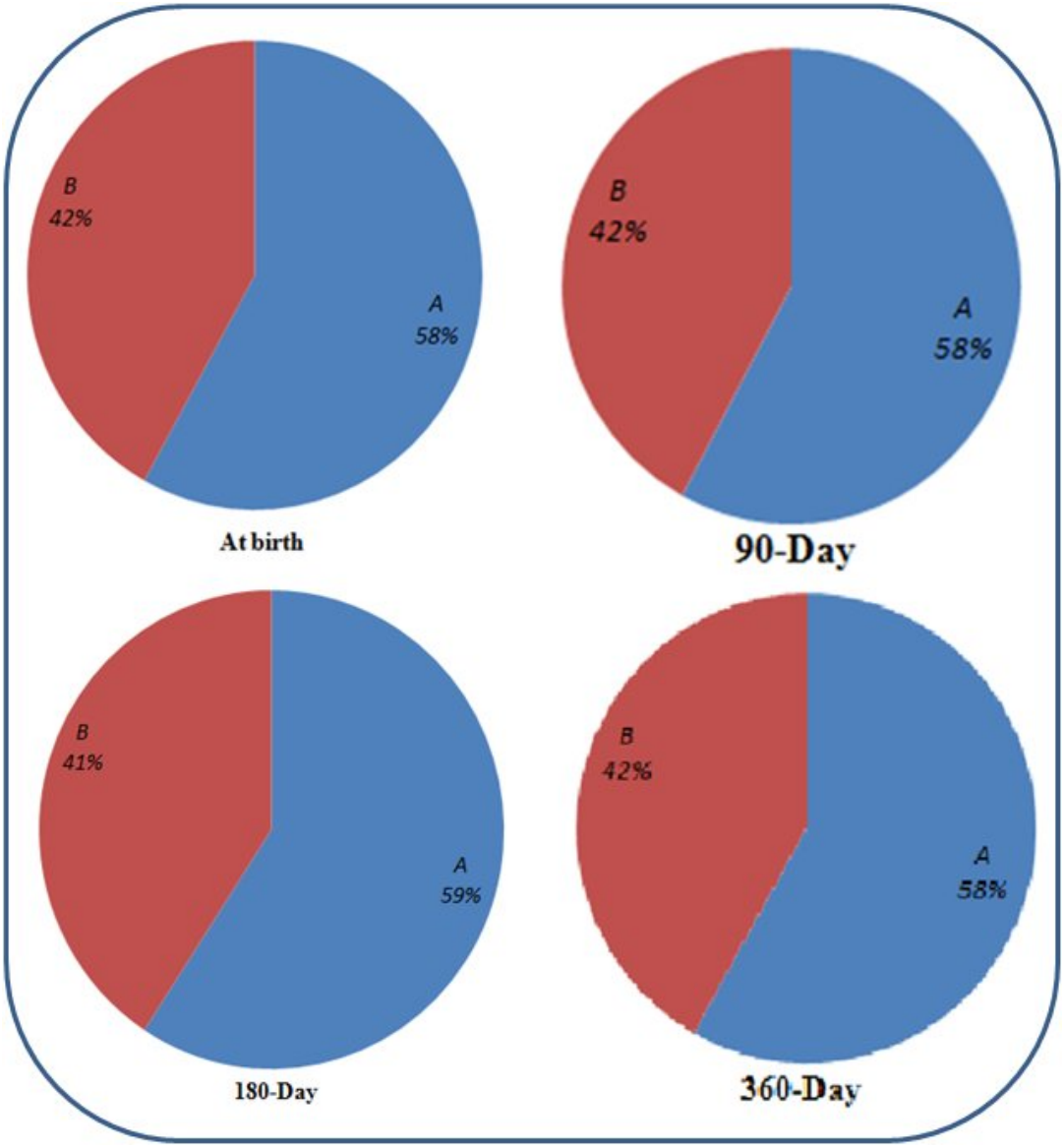


Figure 4. 2: Percent gene (allele) frequency

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4.1.2 Effect of Breed of Sire and Dam on Growth Traits

Tables 4.2 and 4.3 showed the effect of breed of sire and dam on growth traits of lambs from birth to 360-Day, respectively. At birth, lambs produced by Uda rams had the highest ($P<0.05$) birth weight (3.00±0.13 kg) as compared with lambs of Balami and Yankasa rams (Table 4.2). The birth weightsof lambs from Balami and Yankasa were 2.74±0.06 and 2.55±0.16 kg, respectively. Lambs from Balami rams were heavier ($P<0.05$) than lambs from Uda and Yankasa rams from 90-Day through to 360-Day. The lambs sired by Uda and Yankasa rams had similar ($P>0.05$) body weights from 90-Day to 360-Day. The weight of lambs from Balami rams was 22.70±2.60 kg as against 16.46±0.72 and 15.65±0.77 kg for lambs of Uda and Yankasa rams, respectively.

Breed of dam exerted no significant effect ($P>0.05$) on birth and 90-Day weights of lambs. However, body weight at 180 and 360-Day were affected ($P<0.05$)by breed of dam. Lambs from Balami ewes were heaviest with weight of 14.78±1.50 and 21.57±4.07 kg at 180 and 360 days, respectively. The least weightsat 180 and 360-Day were recorded for lambs from Yankasa ewes. The values were 11.45±0.36 and 15.47±0.76 kg for 180 and 360 days, respectively.

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Table 4. 2: Effect of breed of sire on growth traits of lambs

Breed of sire	N^1	Birth weight (kg)	N^2	90-Day weight (kg)	N^3	180-Day weight (kg)	N^4	360-Dayweight (kg)
Balami	15	2.55±0.16 [c]	12	9.44±0.42[a]	7	15.40±1.22[a]	5	22.70±2.60[a]
Uda	43	3.00±0.13[a]	37	8.51±0.35[b]	27	12.50±0.55[b]	17	16.46±0.72[b]
Yankasa	134	2.74±0.06 [b]	116	8.46±0.48[b]	80	11.11±0.40[c]	33	15.65±0.77[b]
Overall	192	2.79	165	8.54	114	11,70	55	16.54
SEM		0.05		0.35		0.33		0.61

[abc]Means along the column with different superscripts are significantly different (P<0.05)

N^1 = Number of lambs at birth
N^2 = Number of lambs at 90-Day
N^3 = Number of lambs at 180-Day
N^4 = Number of lambs at 360-Day

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Table 4. 3: Effect of breed of dam on growth traits of lambs

Breed of dam	N^1	Birth weight (kg)	N^2	90-Day weight (kg)	N^3	180-Day weight (kg)	N^4	360-Dayweight (kg)
Balami	14	2.81±0.20[a]	13	8.87±0.62[a]	7	14.78±1.50 [a]	3	21.57±4.07[a]
Uda	42	2.86±0.12[a]	38	8.34±0.35[a]	27	12.55±0.71[b]	15	18.18±0.64[b]
Yankasa	136	2.76±0.06[a]	114	8.57±0.48[a]	80	11.45±0.36[c]	37	15.47±0.76[c]
Overall	192	2.79	165	8.54	114	11.70	55	16.93
SEM		0.05		0.35		0.33		0.61

[abc]Means along the column with different superscripts are significantly different (P<0.05)

N^1 = Number of lambs at birth
N^2 = Number of lambs at 90-Day
N^3 = Number of lambs at 180-Day
N^4 = Number of lambs at 360-Day

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4.1.3 Effect of Lamb Genotype and Dam's Haemoglobin Type on Growth Traits

The effect of lamb genotype on growth traits of sheep of Northern Nigeria was as shown in Table 4.4. The heaviest birth weight (3.44±0.17 kg) was recorded in crossbred lambs from Yankasa rams and Uda ewes (YK X UD). The overall intermediate birth weight values were recorded in pure Balami (BL X BL), Uda (UD X UD) and Yankasa (YK X YK), lambs with values of 2.60±0.65, 2.99±0.20 and 2.73±0.07 kg, respectively Subsequently, pure Balami lambs (BL X BL) (11.08±1.05 and 18.17±0.83 kg) were superior ($P<0.05$) to all other lamb genotypes at 90 and 180-Day. The highest 360-Day (24.00±4.90 kg) was recorded by BL X YK while the lowest weight at 360-Day (14.79±0.89 kg) was recorded by YK X YK.

The effect of haemoglobin type of dams on growth traits was as shown in Table 4.5. Dam's haemoglobin type exerted no significant effect ($P>0.05$) on birth weight of lambs. However, HbAB and HbBB dams had lambs that were heavier ($P<0.01$) than lambs from HbAA dams at 90 and 180 days. The heaviest 360-Day weight (18.73±1.53 kg) was recorded for lambs from HbBB dams while the least weight (15.28±1.06 kg) was recorded by lambs from HbAA dams.

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Table 4. 4: Effect of lamb genotype on growth traits of lambs

Lamb genotype	Birth weight (kg)	90-Day weight (kg)	180-Day weight (kg)	360-Day weight (kg)
YK X YK	2.73±0.07^{d}	8.55±0.59^{de}	10.79±0.43^{d}	14.79±0.89^{d}
UD X UD	2.99±0.20^{c}	8.48±0.55^{e}	12.27±0.96^{c}	17.43±0.78^{bc}
BL X BL	2.60±0.65^{e}	11.08±1.05^{a}	18.17±0.83^{a}	-
YK X UD	3.44±0.17^{a}	8.61±0.45^{cd}	12.40±0.97^{c}	16.90±1.46^{c}
YK X BL	2.80±0.42^{d}	8.00±0.71^{e}	-	-
UD X YK	2.48±0.15^{f}	8.00±0.59^{e}	12.86±0.98^{c}	16.78±0.88^{c}
UD X BL	3.23±0.27^{b}	9.60±0.82^{b}	9.60±0.50^{e}	-
BL X YK	2.60±0.16^{e}	8.65±0.31^{c}	11.25±0.35^{d}	24.00±4.90^{a}
BL X UD	2.47±0.23^{f}	7.82±0.98^{e}	15.47±0.30^{b}	18.20±1.10^{b}
Overall	2.79	8.54	11.70	16.54
SEM	0.05	0.35	0.33	0.61

^{abcdef}Means along the column with different superscripts are significantly different (P<0.05)

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Table 4. 5: Effect of haemoglobin type of dams on growth traits of lambs

Dam's haemoglobin type	N[1]	Birth weight (kg)	N[2]	90-Day weight (kg)	N[3]	180-Day weight (kg)	N[4]	360-Dayweight (kg)
AA	47	2.72±0.10[a]	40	7.73±0.35[b]	29	11.04±0.64[b]	13	15.28±1.06[c]
BB	16	3.06±0.18[a]	14	8.74±0.62[a]	8	11.84±1.28[a]	4	18.73±1.53[a]
AB	129	2.78±0.07[a]	111	8.81±0.49[a]	77	11.93±0.41[a]	38	16.74±0.79[b]
Overall	192	2.78	165	8.54	114	11.70	55	16.54
SEM		0.19		0.35		0.33		0.61

[abc]Means along the column with different superscripts are significantly different (P<0.01)

N[1] = Number of lambs at birth
N[2] = Number of lambs at 90-Day
N[3] = Number of lambs at 180-Day
N[4] = Number of lambs at 360-Day

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4.1.4 Effect of Type of Birth and Sex of Lamb on Growth Traits

Table 4.6 shows the effect of type of birth and sex of lamb on growth traits. Single-born lambs (2.85±0.06 kg) were heavier (P<0.05) than twins (2.50±0.14 kg) from birth to 360-Day (17.00±0.69and 14.16±1.05 kg, respectively).Sex however had no significant effect (P>0.05) on birth and 360-Day weights of lambs (Table 4.6). However, sex affected (P<0.05) the weight of lambs at 90 and 180-Days. The values were 9.13±0.66 and 12.45±0.48 kg for males 7.98±0.22 and 11.00±0.44 kg for females at 90 and 180-Days, respectively.

Table 4.7 and 4.8 show effects of type of birth and sex of lambs within lamb genotypeon growth traits, respectively. The heaviest birth weight (3.56±1.06 kg) was recorded for single-born YK X UD lambs while the least birth weight (2.12±0.34 kg) was recorded for twin-born UD X YK lambs (Table 4.7). However, single-born BL X BL lambs had the heaviest body weight from 90 to 360-Day. A similar pattern was also observed in Table 4.8. Male YK X UD lambs had heaviest birth weight and subsequent body weights to 360-Day mostly favoured male BL X BL lambs.

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Table 4. 6: Effect of type of birth and sex on growth traits of lambs

Type of birth	N^1	Birth weight (kg)	N^2	90-Day weight (kg)	N^3	180-Day weight (kg)	N^4	360-Dayweight (kg)
Single	159	2.85±0.06[a]	136	8.85±0.41[a]	96	11.96±0.36[a]	46	17.00±0.69[a]
Twins	33	2.50±0.14[b]	29	7.10±0.38[b]	18	10.32±0.79[b]	9	14.16±1.05[b]
Overall	192	2.79	165	8.54	114	11.70	55	16.54
SEM		0.06		0.35		0.33		0.61
Sex								
Male	98	2.85±0.07[a]	81	9.13±0.66[a]	55	12.45±0.48[a]	27	17.14±1.03[a]
Female	94	2.73±0.08[a]	84	7.98±0.22[b]	59	11.00±0.44[b]	28	15.96±0.69[a]
Overall	192	2.79	165	8.54	114	11.70	55	16.54
SEM		0.19		0.35		0.33		0.61

[ab]Means along the column with different superscriptswithin type of birth or sex are significantly different (P<0.05)

N^1 = Number of lambs at birth
N^2 = Number of lambs at 90-Day
N^3 = Number of lambs at 180-Day
N^4 = Number of lambs at 360-Day

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Table 4. 7: Effect of type of birth within lamb genotype on growth traits

Lamb genotype	Type of birth	Birth weight (kg)	90-Day weight (kg)	180-Day weight (kg)	360-Day weight (kg)
YK X YK	**Single**	2.80±0.07^{e}	8.82±0.70^{cd}	10.94±0.46^{gh}	15.28±1.04^{f}
	Twins	2.39±0.16^{g}	7.28±0.55^{ef}	10.07±0.94^{ij}	12.83±1.43^{h}
UD X UD	**Single**	2.98±0.23^{d}	8.48±0.59^{d}	12.33±1.06^{e}	17.38±0.95^{de}
	Twins	3.10±0.30^{c}	8.40±0.00^{d}	11.60±0.00^{f}	17.70±0.00^{d}
BL X BL	**Single**	2.60±0.65^{f}	11.08±1.05^{a}	18.17±0.83^{a}	29.10±0.00^{a}
	Twins	-	-	-	-
YK X UD	**Single**	3.56±0.16^{a}	9.15±0.43^{bcd}	12.98±1.09^{d}	17.29±1.60^{de}
	Twins	3.00±0.50^{cd}	6.73±0.87^{f}	10.27±1.86^{hij}	13.80±0.00^{g}
YK X BL	**Single**	2.80±0.42^{e}	8.00±0.71^{de}	14.12±0.00^{c}	15.12±0.00^{f}
	Twins	-	-	-	-
UD X YK	**Single**	2.64±0.14^{f}	8.54±0.74^{cd}	13.48±0.84^{d}	17.08±1.00^{e}
	Twins	2.12±0.34^{i}	7.10±0.95^{f}	10.82±3.44^{gh}	15.90±2.40^{f}
UD X BL	**Single**	3.23±0.27^{b}	9.60±0.82^{b}	9.60±0.50^{j}	20.50±0.00^{c}
	Twins	-	-	-	-
BL X YK	**Single**	2.60±0.16^{f}	8.65±0.31^{cd}	11.25±0.35^{fg}	24.00±4.90^{b}
	Twins	-	-	-	-
BL X UD	**Single**	2.26±0.22^{h}	9.23±0.52^{bc}	15.47±0.30^{b}	18.20±1.10^{d}
	Twins	3.00±0.50^{cd}	5.71±1.14^{g}	-	-
	Overall	2.72	8.77	12.37	17.19
	SEM	0.05	0.36	0.31	0.48

$^{a-j}$Means along column with different superscripts differ significantly (P<0.01)

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Table 4. 8: Effect of sex within lamb genotype on growth traits

Lamb genotype	Sex	Birth weight (kg)	90-Day weight (kg)	180-Day weight (kg)	360-Day weight (kg)
YK X YK	**Male**	2.81±0.09^{d}	9.46±1.14^{c}	11.87±0.66^{g}	15.92±1.56^{gh}
	Female	2.64±0.11^{f}	7.66±0.30^{d}	9.75±0.43^{i}	13.74±0.90^{i}
UD X UD	**Male**	2.80±0.33^{d}	9.50±1.60^{c}	13.77±2.15^{d}	19.30±0.00^{d}
	Female	3.07±0.26^{c}	8.14±0.52^{d}	11.70±1.07^{g}	17.06±0.84^{f}
BL X BL	**Male**	3.25±0.05^{b}	12.10±0.40^{a}	19.00±0.10^{a}	29.10±0.00^{a}
	Female	1.30±0.00^{j}	9.04±0.00^{c}	16.52±0.00^{b}	-
YK X UD	**Male**	3.68±0.24^{a}	9.06±0.56^{c}	12.70±1.32^{ef}	15.90±1.90^{gh}
	Female	3.25±0.23^{b}	8.26±0.67^{d}	12.18±1.44^{fg}	18.15±2.42^{e}
YK X BL	**Male**	2.70±0.70^{ef}	8.25±1.15^{d}	14.12±0.00^{d}	15.12±0.00^{h}
	Female	3.00±0.00^{c}	7.50±0.00^{e}	-	-
UD X YK	**Male**	2.52±0.17^{g}	8.09±0.62^{d}	12.75±0.87^{ef}	16.14±1.06^{g}
	Female	2.38±0.31^{h}	7.81±1.47^{d}	13.12±2.83^{e}	17.85±1.62^{ef}
UD X BL	**Male**	3.00±0.00^{c}	7.70±0.00^{d}	9.10±0.00^{j}	-
	Female	3.30±0.36^{b}	10.23±0.73^{b}	10.10±0.00^{i}	20.50±0.00^{c}
BL X YK	**Male**	2.77±0.18^{de}	8.94±0.31^{c}	11.60±0.00^{g}	24.00±4.90^{b}
	Female	2.27±0.27^{i}	7.92±0.58^{d}	10.90±0.00^{h}	-
BL X UD	**Male**	3.00±0.50^{c}	5.71±1.14^{f}	-	-
	Female	2.26±0.22^{i}	9.23±0.52^{c}	15.47±0.30^{c}	18.20±1.10^{e}
	Overall	2.72	8.77	12.37	17.19
	SEM	0.05	0.36	0.31	0.48

$^{a-i}$Means along column with different superscripts differ significantly (P<0.01)

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4.1.5 Effect of Lamb Genotype on Linear Body Measurements of Lambs

Tables 4.9- 4.14 showed the effect of lamb genotype on linear body measurements (neck length, back length, height at wither, loin girth, chest girth and leg length) of sheep of Northern Nigeria and their crosses. Lamb genotype affected ($P<0.01$) all the body linear measurements. Lambs from Uda rams and Balami ewes (UD X BL) had the highest ($P<0.05$) neck length (16.75±2.53 cm), back length (25.00±2.27 cm), loin girth (43.00±4.38.53 cm) and Leg length (32.25±2.81 cm) at birth. However, BL X BL and crosses of Balami rams or ewes (YK X BL and BL X UD) had the highest neck length at 90-Day (Table 4.9) while BL X YK had the highest (30.00±1.80 cm) neck length at 360-Day.

Back length of BL X BL was the longest at 90 and 180-Day (Table 4.10). The BL X YK, however, had the longest back at 360-Day. Genotypes BL X BL and YK X BL recorded the highest height at wither at birth (Table 4.11). Thereafter, BL X BL had the highest value for height at wither from 90-Day (56.73±2.73 cm) to 180-Day (64.33±1.76 cm) (Table 4.11). The highest value for height at wither at 360-Day (73.20±2.90 cm) was recorded byBL X YK (Table 4.11). The growth of loin girth (Table 4.12) did not follow any specific pattern among the lamb genotypes. Lambs that had low loin girth at birth had the highest values for the trait at 360-Day. The BL X UD and BL X YK genotypes recorded 74.35±9.35 and 74.85±4.75 cm, respectively as the highest loin girth.

The YK X BL lambs had the highest (39.29±1.17 cm) chest girth at birth (Table 4.13). The least value for this parameter at

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UD X YK (33.53±0.86 cm) and BL X UD (33.37±0.84 cm). The YK X BL and BL X BL lambs had the highest chest girth at 90-Day with values of 50.97±2.24 and 50.60±1.73 cm, respectively. Genotype BL X BL also had the highest (57.77±2.87 cm) chest girth at 180-Day. However, BL X UD lambs which had one of the lowestchest girths at birth had the highest value (66.95±7.75 cm) at 360-Day. The least value at 360-Day (57.56±1.10 cm) was recorded by YK X YK lambs.

The UD X BL lambs had the longest (32.25±2.81 cm) legs at birth (Table 4.14) while YK X BL and BL X BL lambs had longest legs at 90-Day.The BL X BL lambs also had the longest (40.77±0.97 cm) legs at 180-Day. The highest value (43.85±1.55 cm) for leg length at 360-Day was recorded inBL X YK lamb while the least value (39.18±0.66 cm) was observed in YK X YK lambs.

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Table 4. 9: Effect of Lamb Genotype on Neck Lengths (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N[1]**	**Birth**	**N[2]**	**90-Day**	**N[3]**	**180-Day**	**N[4]**	**360-Day**
YK X YK	110	13.70±0.26^{cd}	93	19.68±0.30b^{c}	65	22.08±0.39^{d}	25	27.88±0.88^{b}
UD X UD	18	14.48±0.57^{b}	16	19.66±0.52^{c}	11	24.57±1.26^{b}	6	28.03±0.53^{b}
BL X BL	3	14.00±1.15^{c}	3	21.37±0.63^{a}	3	25.38±1.72^{a}	1	-
YK X UD	18	14.85±1.60^{b}	18	18.90±0.35^{d}	14	22.82±0.63^{c}	9	27.98±1.04^{b}
YK X BL	3	14.00±0.58^{c}	3	21.50±0.78^{a}	1	-	1	-
UD X YK	20	13.17±0.53^{e}	16	19.75±0.55^{bc}	13	22.17±0.65^{d}	8	27.36±0.92^{b}
UD X BL	4	16.75±2.53^{a}	4	19.94±0.73^{bc}	2	23.35±0.85^{c}	1	-
BL X YK	9	13.52±0.59^{de}	7	20.08±0.84^{b}	2	21.45±1.55^{e}	2	30.00±1.80^{a}
BL X UD	7	13.37±0.56^{de}	5	21.61±1.29^{a}	3	24.53±0.77^{b}	2	26.20±0.60^{c}
Overall	192	13.88	165	19.75	114	22.60	55	27.93
SEM		0.23		0.20		0.29		0.46

[abcde]Means along the column with different superscripts are significantly different (P<0.01)N[1] = Number of lambs at birth; N[2] = Number of lambs at 90-Day; N[3] = Number of lambs at 180-Day; N[4] = Number of lambs at 360-Day

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Table 4. 10: Effect of Lamb Genotype on Back Length (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N[1]**	**Birth**	**N[2]**	**90-Day**	**N[3]**	**180-Day**	**N[4]**	**360-Day**
YK X YK	110	21.75±0.31[d]	93	28.61±0.30[cd]	65	30.89±0.41[d]	25	34.80±0.65[d]
UD X UD	18	23.68±0.69[b]	16	29.56±0.88[b]	11	32.70±1.15[b]	6	36.12±1.41[c]
BL X BL	3	22.00±0.58[d]	3	30.73±0.82[a]	3	34.68±1.34[a]	1	-
YK X UD	18	22.98±0.87[c]	18	29.51±0.59[b]	14	32.41±0.80[b]	9	37.13±1.92[b]
YK X BL	3	23.00±1.53[c]	3	29.97±0.52[b]	1	-	1	-
UD X YK	20	21.06±0.82[e]	16	27.46±0.80[e]	13	30.17±0.79[e]	8	36.06±1.31[c]
UD X BL	4	25.00±2.27[a]	4	28.93±1.52[c]	2	31.70±2.70[c]	1	-
BL X YK	9	20.91±1.30[e]	7	28.40±2.30[d]	2	30.32±1.08[de]	2	43.75±2.95[a]
BL X UD	7	21.22±0.81[e]	5	28.85±1.60[cd]	3	32.90±0.12[b]	2	35.35±3.15[cd]
Overall	192	22.01	165	28.76	114	31.33	55	36.08
SEM		0.24		0.24		0.30		0.56

[abcde]Means along the column with different superscripts are significantly different (P<0.01). N^1 = Number of lambs at birth; N^2 = Number of lambs at 90-Day; N^3 = Number of lambs at 180-Day; N^4 = Number of lambs at 360-Day

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Table 4. 11: Effect of Lamb Genotype on Height at Wither (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N[1]**	**Birth**	**N[2]**	**90-Day**	**N[3]**	**180-Day**	**N[4]**	**360-Day**
YK X YK	110	39.83±0.49[e]	93	49.82±0.69[f]	65	54.07±0.58[f]	25	59.50±1.15[c]
UD X UD	18	44.27±1.36[b]	16	52.50±1.13[d]	11	57.79±1.57[c]	6	59.30±3.84[c]
BL X BL	3	45.33±2.60[a]	3	56.73±2.78[a]	3	64.33±1.76[a]	1	-
YK X UD	18	41.74±1.22[c]	18	51.34±0.87[e]	14	56.72±1.21[d]	9	59.62±0.00[c]
YK X BL	3	45.33±1.33[a]	3	54.80±1.07[b]	1	-	1	-
UD X YK	20	40.62±1.05[d]	16	48.43±2.12[g]	13	55.62±1.54[d]	8	55.44±8.03[d]
UD X BL	4	43.75±2.59[b]	4	51.73±2.45[de]	2	57.90±4.60[c]	1	-
BL X YK	9	39.81±0.93[e]	7	49.63±1.06[f]	2	55.50±1.50[e]	2	73.20±2.90[a]
BL X UD	7	43.65±1.20[b]	5	53.77±2.55[c]	3	61.17±0.78[b]	2	66.10±2.80[b]
Overall	192	40.90	165	50.49	114	55.54	55	60.23
SEM		0.37		0.49		0.48		1.43

[abcdefg]Means along the column with different superscripts are significantly different (P<0.01)N[1] = Number of lambs at birth; N[2] = Number of lambs at 90-Day; N[3] = Number of lambs at 180-Day; N[4] = Number of lambs at 360-Day

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Table 4. 12: Effect of Lamb Genotype on Loin Girth (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N[1]**	**Birth**	**N[2]**	**90-Day**	**N[3]**	**180-Day**	**N[4]**	**360-Day**
YK X YK	110	34.33±0.58^{de}	93	48.99±0.63^{e}	65	54.35±0.78^{e}	25	63.12±1.49^{c}
UD X UD	18	37.89±1.79^{b}	16	52.21±1.74^{b}	11	58.03±2.00^{d}	6	62.73±3.47^{c}
BL X BL	3	33.67±2.91^{ef}	3	55.40±3.60^{a}	3	65.07±3.12^{a}	1	-
YK X UD	18	37.06±1.75^{b}	18	52.10±0.98^{b}	14	57.59±1.18^{d}	9	64.72±2.43^{bc}
YK X BL	3	36.00±2.08^{c}	3	50.77±1.82^{cd}	1	-	1	-
UD X YK	20	35.01±1.71^{d}	16	50.51±2.10^{d}	13	58.56±2.18^{d}	8	66.12±2.36^{b}
UD X BL	4	43.00±4.38^{a}	4	51.60±3.57^{bc}	2	57.70±2.70^{d}	1	-
BL X YK	9	31.92±0.96^{g}	7	47.48±3.51^{f}	2	62.00±7.00^{b}	2	74.85±4.75^{a}
BL X UD	7	33.37±1.54^{f}	5	52.36±1.26^{b}	3	59.83±1.41^{c}	2	74.35±9.35^{a}
Overall	192	35.04	165	50.04	114	56.29	55	64.75
SEM		0.47		0.50		0.62		1.03

^{abcdefg}Means along the column with different superscripts are significantly different (P<0.01)N[1] = Number of lambs at birth; N[2] = Number of lambs at 90-Day; N[3] = Number of lambs at 180-Day; N[4] = Number of lambs at 360-Day

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Table 4. 13: Effect of Lamb Genotype on Chest Girth (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N^1**	**Birth**	**N^2**	**90-Day**	**N^3**	**180-Day**	**N^4**	**360-Day**
YK X YK	110	33.96±0.44^{e}	93	46.24±0.48^{cd}	65	50.97±0.57^{d}	25	57.56±1.10^{d}
UD X UD	18	36.28±1.21^{bc}	16	48.02±1.09^{b}	11	53.28±1.64^{c}	6	60.68±1.21^{c}
BL X BL	3	36.67±0.67^{b}	3	50.60±1.73^{a}	3	57.77±2.87^{a}	1	-
YK X UD	18	35.36±1.04^{d}	18	48.45±0.96^{b}	14	53.67±1.29^{c}	9	59.80±1.61^{c}
YK X BL	3	39.29±1.17^{a}	3	50.97±2.24^{a}	1	-	1	-
UD X YK	20	33.53±0.86^{e}	16	47.92±1.60^{b}	13	54.14±2.19^{bc}	8	61.04±2.18^{c}
UD X BL	4	33.75±2.57^{e}	4	46.45±1.27^{cd}	2	50.96±2.45^{c}	1	-
BL X YK	9	35.72±1.64^{cd}	7	45.79±2.53^{d}	2	54.30±7.70^{b}	2	63.95±1.45^{b}
BL X UD	7	33.37±0.84^{e}	5	46.92±1.63^{c}	3	55.03±3.57^{c}	2	66.95±7.75^{a}
Overall	192	34.44	165	46.99	114	52.33	55	59.72
SEM		0.33		0.37		0.51		0.76

^{abcde}Means along the column with different superscripts are significantly different (P<0.01)N^1 = Number of lambs at birth; N^2 = Number of lambs at 90-Day; N^3 = Number of lambs at 180-Day; N^4 = Number of lambs at 360-Day

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Table 4. 14: Effect of Lamb Genotype on Leg Length (Mean±SE) of Sheep of Northern Nigeria

	Back length (cm)							
Lamb genotype	**N[1]**	**Birth**	**N[2]**	**90-Day**	**N[3]**	**180-Day**	**N[4]**	**360-Day**
YK X YK	110	28.97±0.28^{e}	93	33.93±0.31^{e}	65	36.25±0.40^{d}	25	39.18±0.66^{e}
UD X UD	18	30.91±0.69^{b}	16	35.25±0.72^{bc}	11	37.67±1.01^{c}	6	42.03±1.35^{bc}
BL X BL	3	30.00±0.24^{c}	3	36.67±1.10^{a}	3	40.77±0.97^{a}	1	-
YK X UD	18	30.57±0.82^{b}	18	35.69±0.98^{b}	14	37.93±1.27^{bc}	9	42.96±2.39^{ab}
YK X BL	3	30.67±0.88^{b}	3	36.40±0.76^{a}	1	-	1	-
UD X YK	20	29.18±0.55^{de}	16	34.49±0.79^{d}	13	38.59±1.06^{b}	8	41.61±0.79^{cd}
UD X BL	4	32.25±2.81^{a}	4	34.26±0.86^{de}	2	37.60±1.60^{c}	1	-
BL X YK	9	29.52±1.02^{d}	7	35.25±1.45^{bc}	2	38.26±5.74^{bc}	2	43.85±1.55^{a}
BL X UD	7	29.33±0.84^{de}	5	35.07±1.64^{c}	3	36.87±1.49^{d}	2	40.60±0.20^{d}
Overall	192	29.48	165	34.50	114	37.10	55	40.89
SEM		0.22		0.25		0.34		0.56

^{abcde}Means along the column with different superscripts are significantly different (P<0.01)N[1] = Number of lambs at birth; N[2] = Number of lambs at 90-Day; N[3] = Number of lambs at 180-Day; N[4] = Number of lambs at 360-Day

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4.1.6 Body Average Daily Gains (ADG) of Body Weight of Sheep ofNorthern Nigeria and their Crosses

Figures 4.3 and 4.4 show the effect of sire and dam breeds on average daily gain (ADG) of sheep of Northern Nigeria. Breed of sire affected (P<0.05) ADG of lambs from birth to 360-Day. Balami-sired lambs had higher(P<0.05) body ADG from birth to 360-Day than lambs of Uda and Yankasa rams. Lambs from Uda and Yankasa rams had similar (P>0.05) body ADG from birth to 360-Day. The ADG observed in lambs sired by Balami rams were 75.07±3.93, 63.35±6.63 and 76.11±4.04 g for body weights between birth and 90-Day (ADG90), 90 and 180-Day (ADG180) and, 180 and 360-Day (ADG360), respectively. Lambs from Uda and Yankasa ram had reduced ADG as the animals aged (Figure 4.3).

Breed of dam did not affect (P>0.05) lamb ADG90 while it affected (P<0.05) ADG180 and ADG360 (Figure 4.4). Lambs from Balami ewes had higher (P<0.05) ADG180 and ADG360 than lambs from Uda and Yankasa ewes. Lambs from all the dam breeds had reduced ADG as the animals aged. Figure 4.5 shows the effect of lamb genotype on body ADG of sheep and their crosses. Lamb genotype affected (P<0.05) ADG90, ADG180 and ADG360. The BL X BL lambs had the heaviest ADG from birth to 180-Day with values of 94.22±5.02 g and 78.82±2.88 g for ADG90 andADG180, respectively.

The effect of dam's haemoglobin type on ADG of sheep of Northern Nigeria was as shown in Figure 4.6. Dam's haemoglobin type affected (P<0.05) ADG of lambs. Dams

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with HbAB and HbBBhad higher ADG90 and ADG360 values than lambs from HbAA dams ($P<0.05$). Figures 4.7 and 4.8 show the effects of type of birth and sex of lambs on body ADG of sheep. Type of birth affected ($P<0.05$) ADG90 and ADG180 (Figure 4.7). The ADG360 was not affected by type of birth of lambs. Single-born lambs had higher ($P<0.05$) ADG90 and ADG180 than twins. The ADG90 for singles was 65.84±4.50 g while twins had 51.28±4.21 g. The ADG180 for singles was 38.39±2.70 g while twins had 30.93±4.10 g. Sex of lambs affected ($P<0.05$) ADG90 while ADG180 and ADG360 were not affected ($P>0.05$) by sex of lambs (Figure 4.8). Male lambs had 68.70±7.28 g while females had 57.90±2.36g for ADG90.

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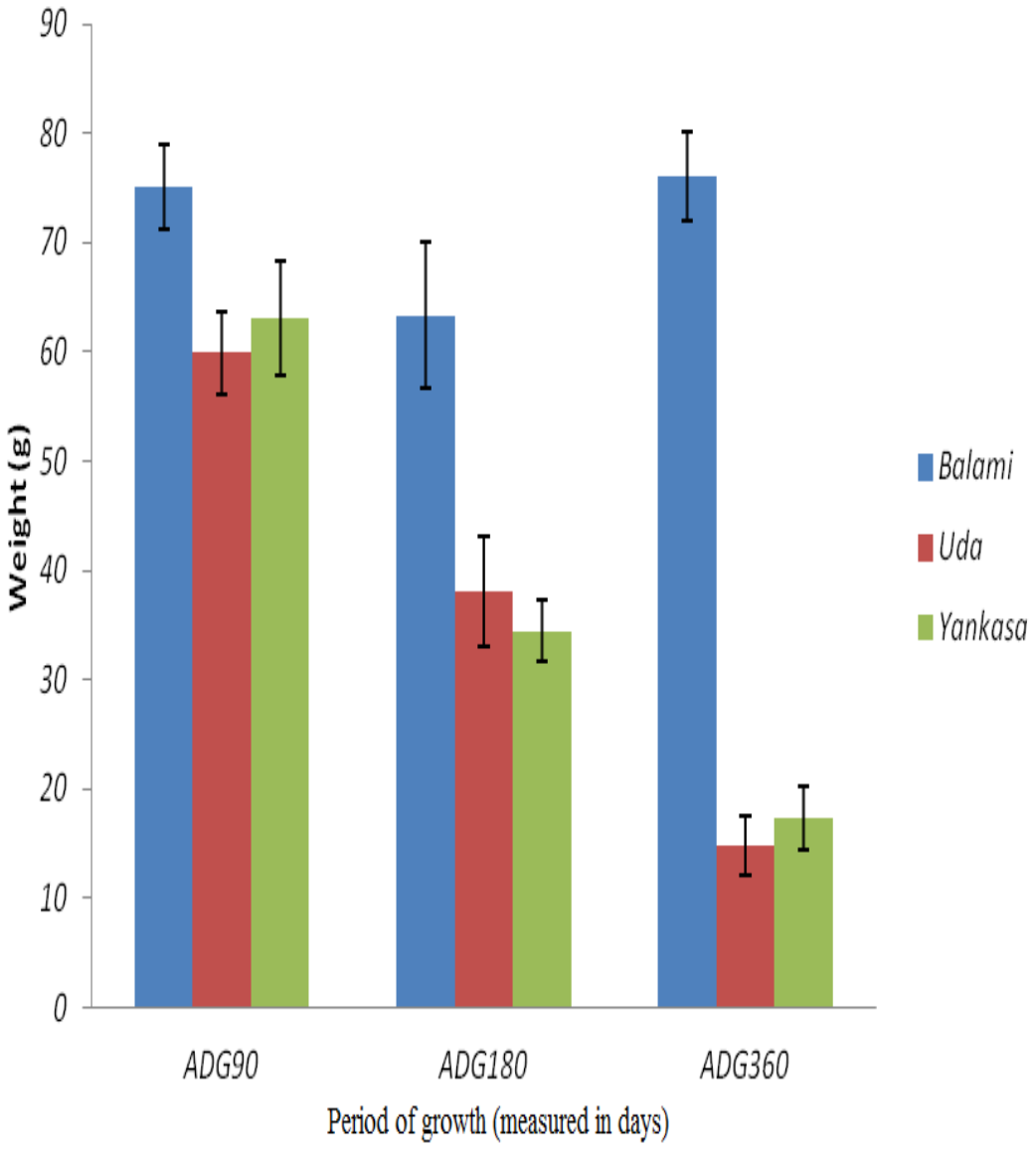


Figure 4. 3: Effect of Sire Breed on Body Average Daily Gain (ADG) (Mean±SE)of Sheep of Northern Nigeria

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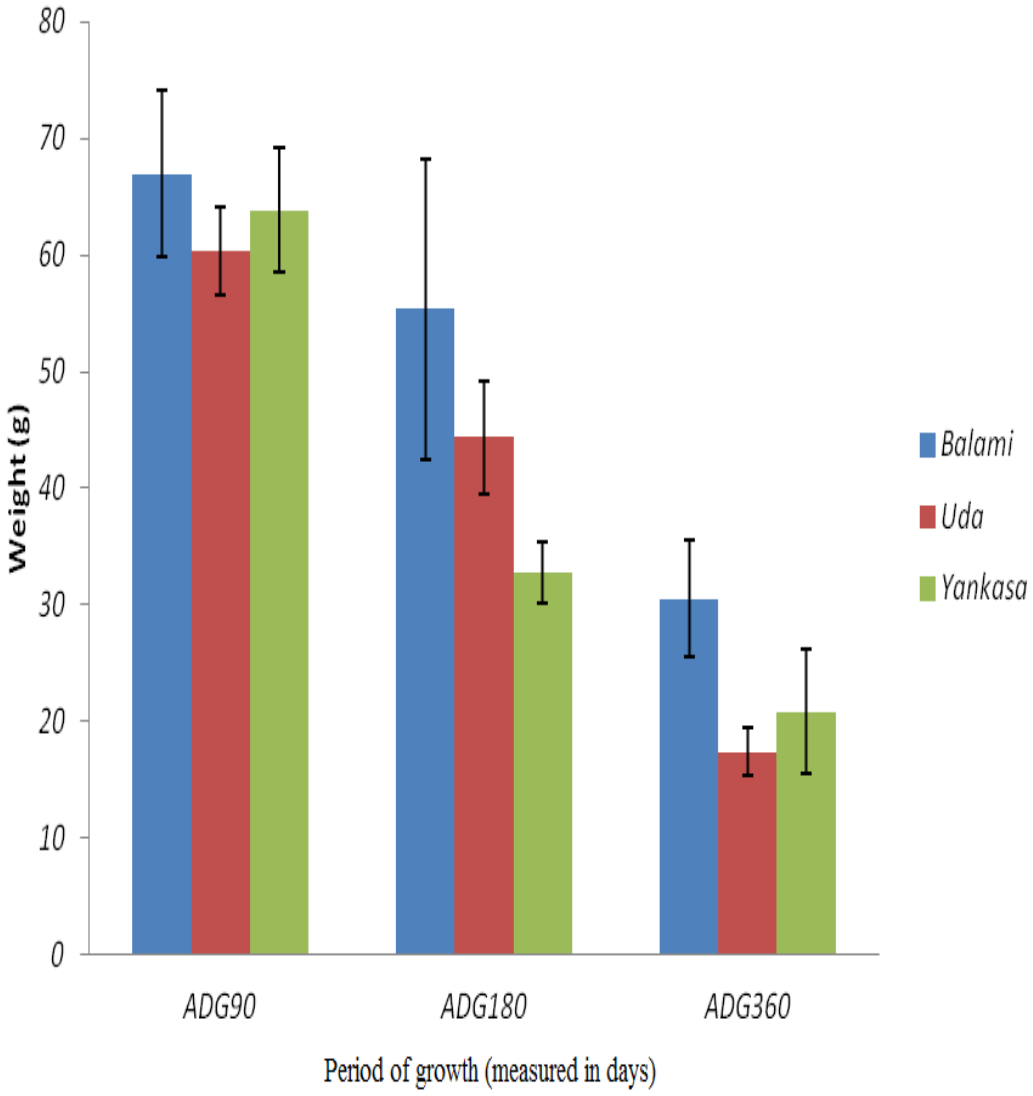


Figure 4. 4: Effect of Dam Breed on Body Average Daily Gain (ADG) (Mean±SE) of Sheep of Northern Nigeria

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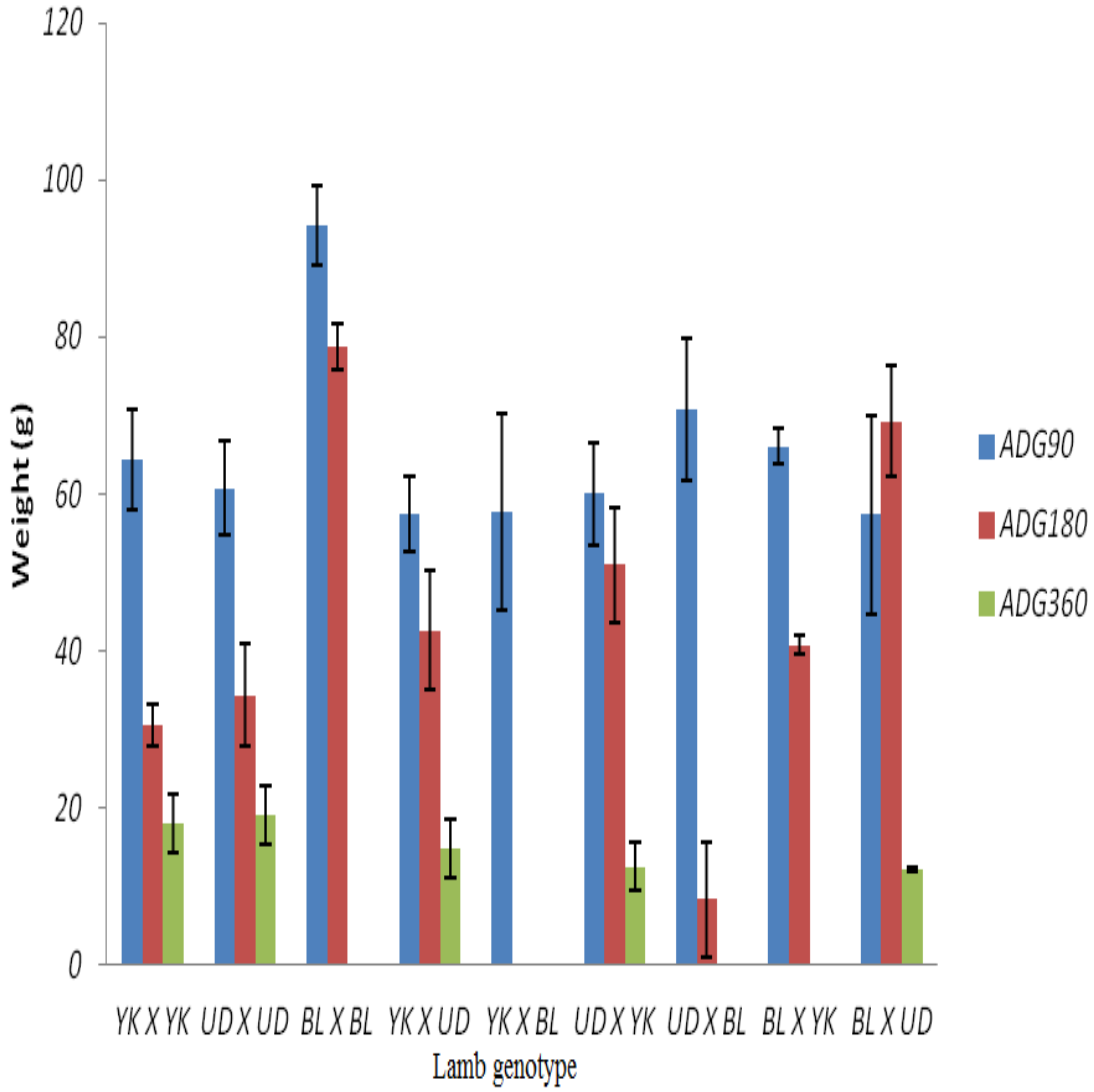


Figure 4. 5: Effect of Lamb Genotype on Body Average Daily Gain (ADG) (Mean±SE) of Sheep of Northern Nigeria and theirCrosses

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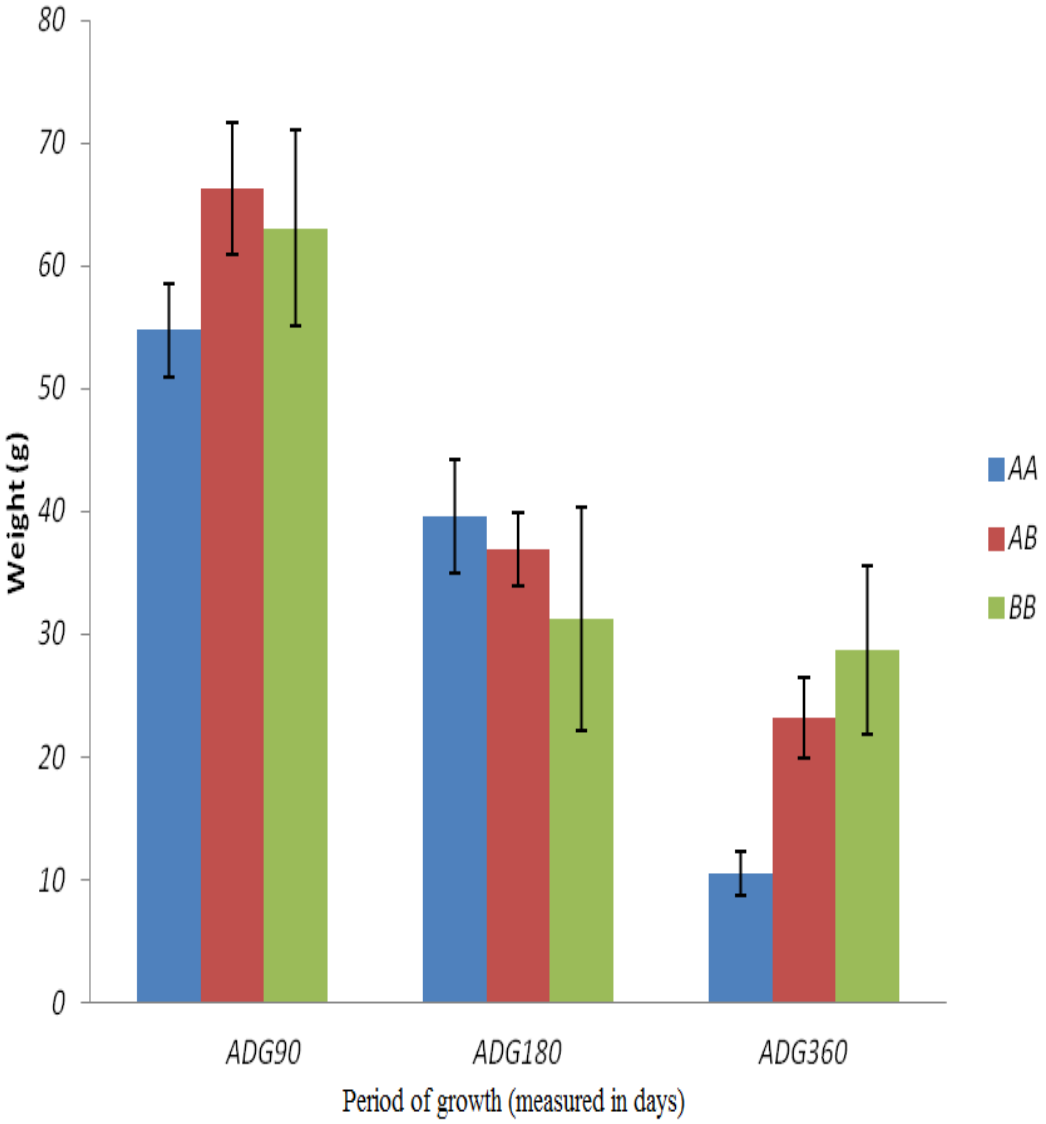


Figure 4. 6: Effect of Dam's Haemoglobin Type on Body Average Daily Gain (ADG) (Mean±SE) of Sheep of Northern Nigeria

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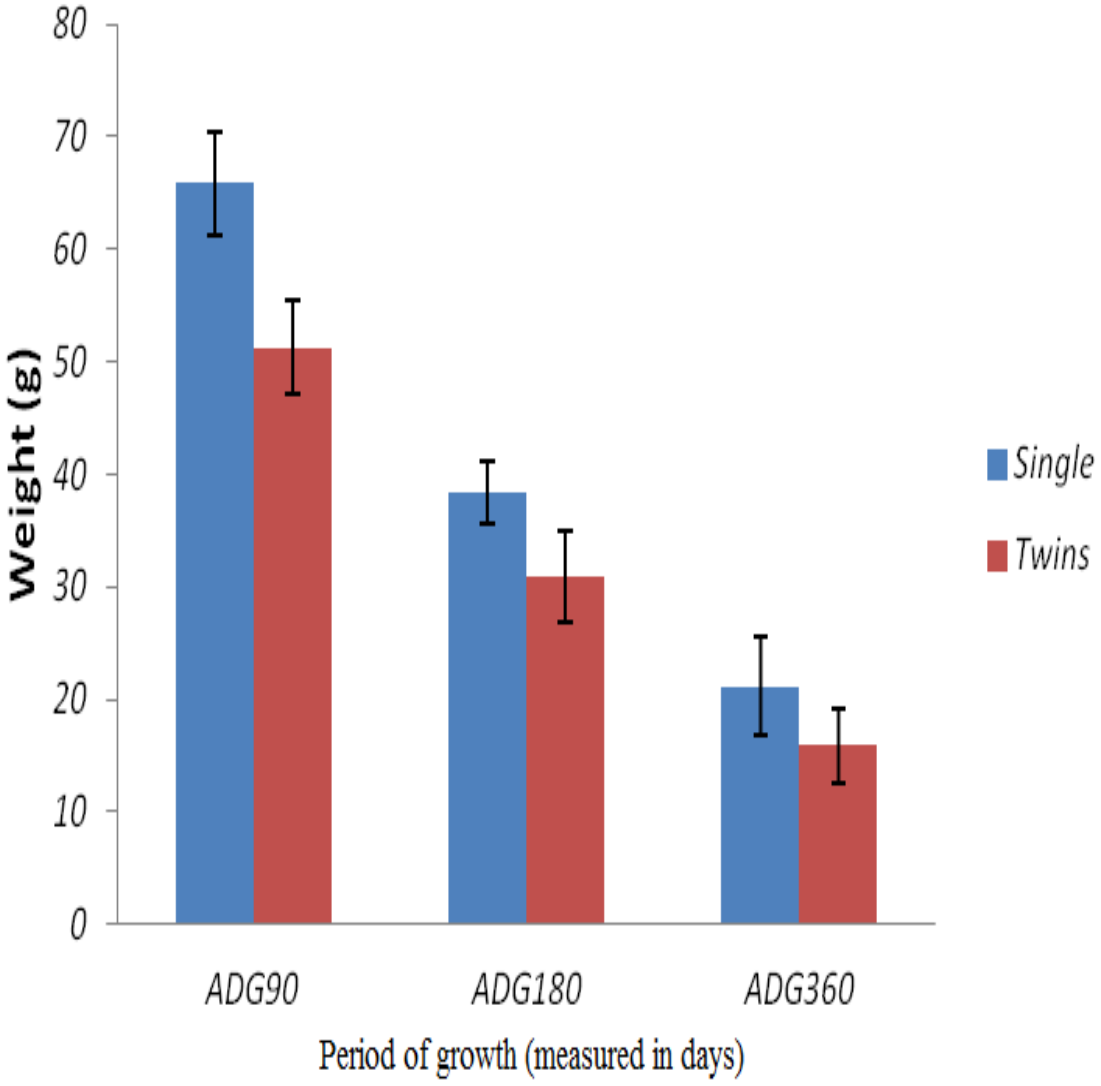


Figure 4. 7: Effect of Type of Birth of Lambs on Body Average Daily Gain (ADG) (Mean±SE) of Sheep of Northern Nigeria

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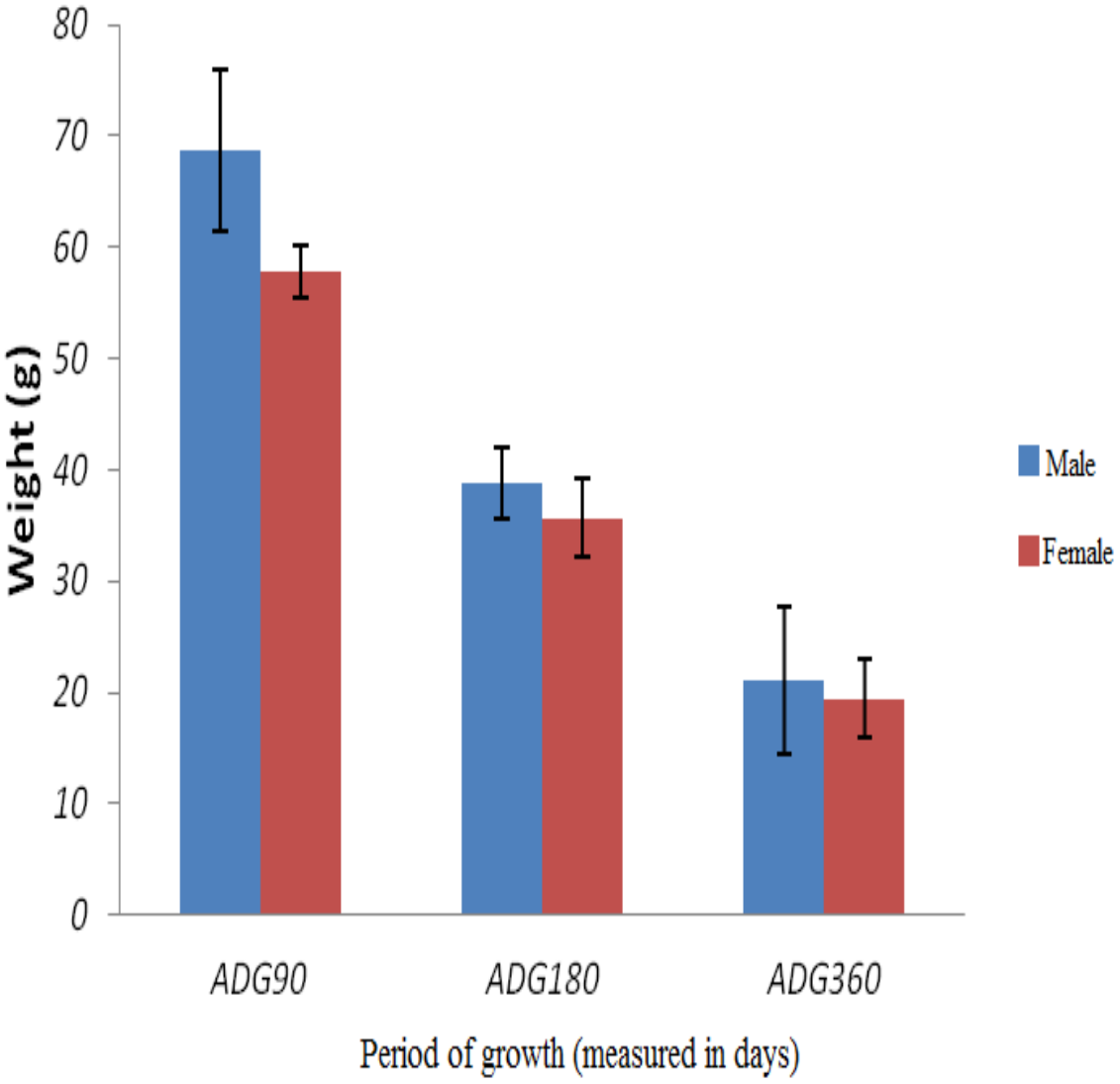


Figure 4. 8: Effect of sex of lambs on body average daily gain (ADG)(Mean±SEM) sheep of NorthernNigeria

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4.1.7 Body Relative Growth Rate (RGR) of Sheep ofNorthern Nigeria and their Crosses

Figures4.9 and 4.10 show the effect of breed of sire and dam, respectively, on RGR of lambs from birth to 90-Day (RGR90), 90 to 180-Day (RGR180) and 180 to 360-Day (RGR360). Breed of sire and dam both affected (P<0.05) RGR of lambs (Figure 4.9). Balami rams sired lambs that had the higher (P<0.05) RGR90 (1.44±0.08 %/day); RGR180 (0.51±0.03 %/day) and RGR360 (0.16±0.08 %/day) than Uda and Yankasa rams.

Lamb genotype affected (P<0.05) RGR (Figure 4.11). The BL X BL lambs had the highest RGR90 and RGR180 which were 1.69±0.23 %/day and 0.56±0.06 %/day, respectively. However, RGR360 favoured BL X YK lambs. The RGR90 and RGR180 of some of the crosses (YK X BL, UD X YK and BL X YK) were slightly higher than the RGR90 and RGR180 of purebred lambs of Yankasa and Uda.

Dam's haemoglobin type affected (P<0.05) RGR of lambs in the studied population (Figure 4.12). The RGR90 was higher in lambs from dams with haemoglobin type AB (1.22±0.04 %/day) than those of haemoglobin type AA (1.11±0.06 %/day). However, dams with haemoglobin type BB had lambs with the highest RGR360 (0.19±0.05 %/day). Sex and type of birth (Figures4.13 and 4.14, respectively) exerted no significant effect (P>0.05) on RGR90, RGR180 and RGR360 with the exception of RGR360 where female lambs had higher (P<0.05) value (0.12±0.02 %/day) than males (0.09±0.01 %/day).

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Table 4.15 shows the Pearson correlation coefficients between average daily gains(ADG) and relative growth rates (RGR) of lambs at various ages. RGR of lambs in this study had high, positive and significant ($P<0.01$) relationships with the corresponding ADG. The coefficients of relationships between RGR90 and ADG90, RGR180 and ADG180, RGR360 and ADG360 were 0.704, 0.730 and 0.977, respectively.

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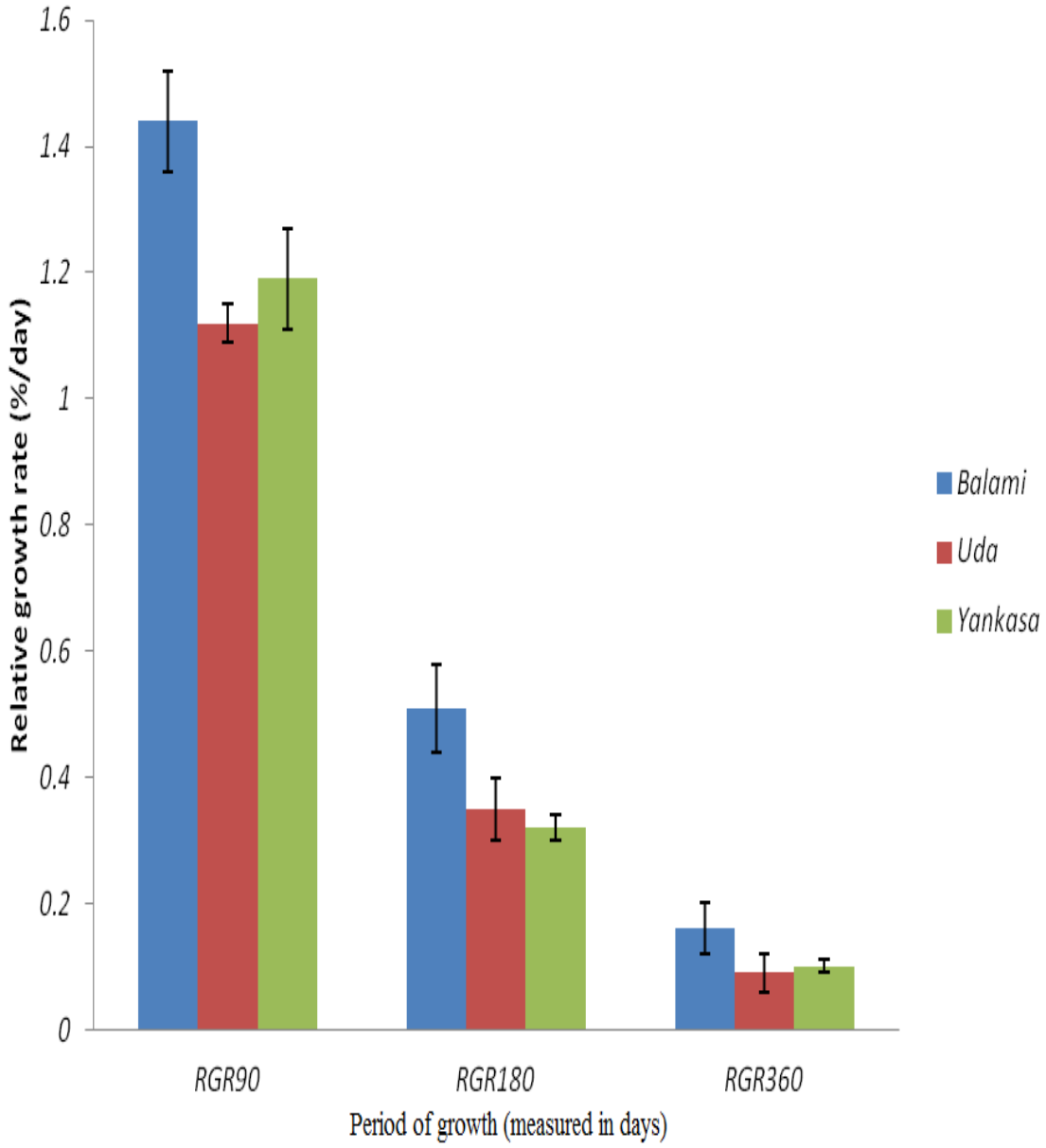


Figure 4. 9: Effect of Breed of Sire on Relative Growth Rate (RGR) (Mean±SE) of Sheep of Northern Nigeria

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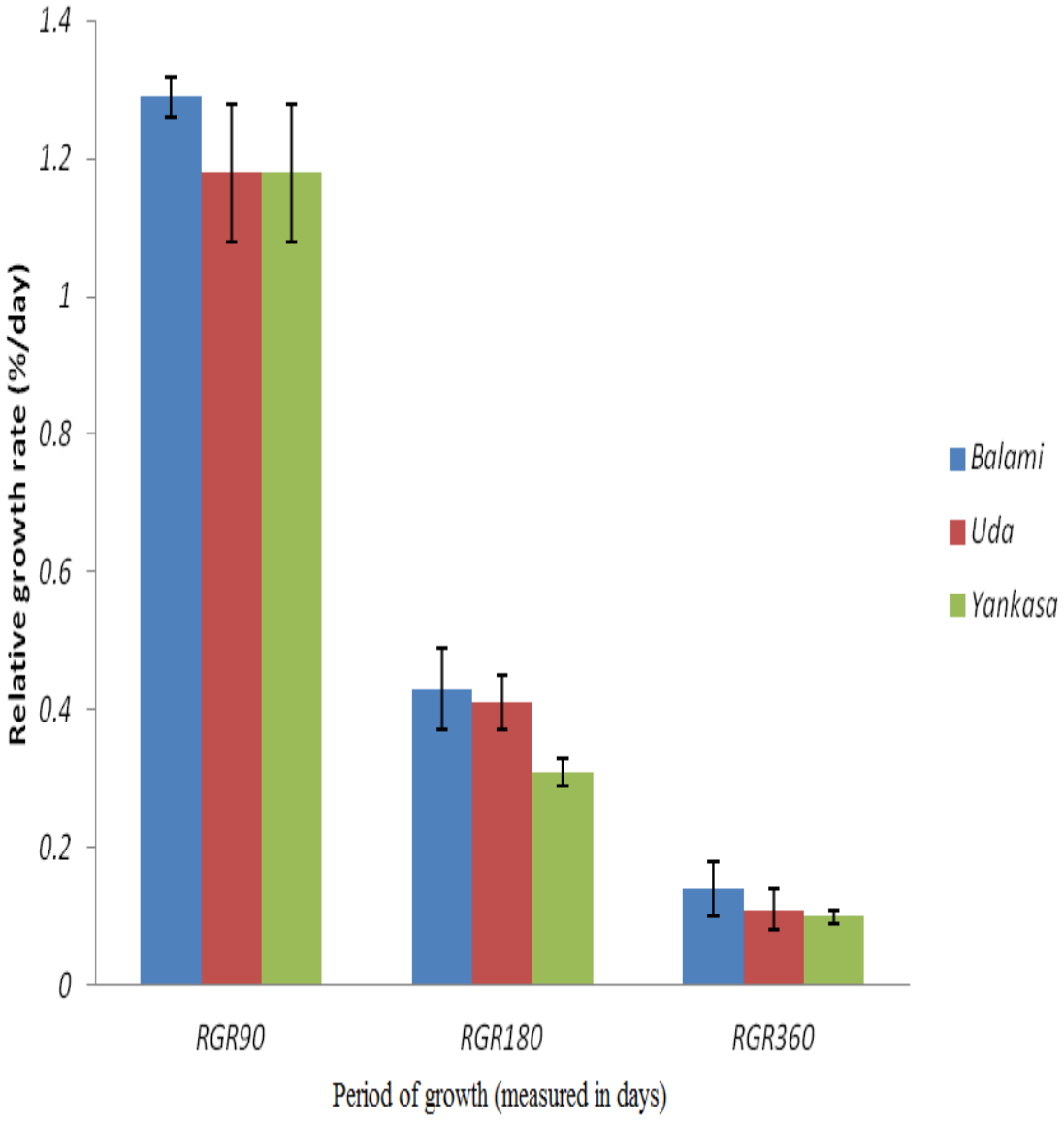


Figure 4. 10: Effect of Breed of Dam on Relative Growth Rate (RGR) (Mean±SE) of Sheep of Northern Nigeria

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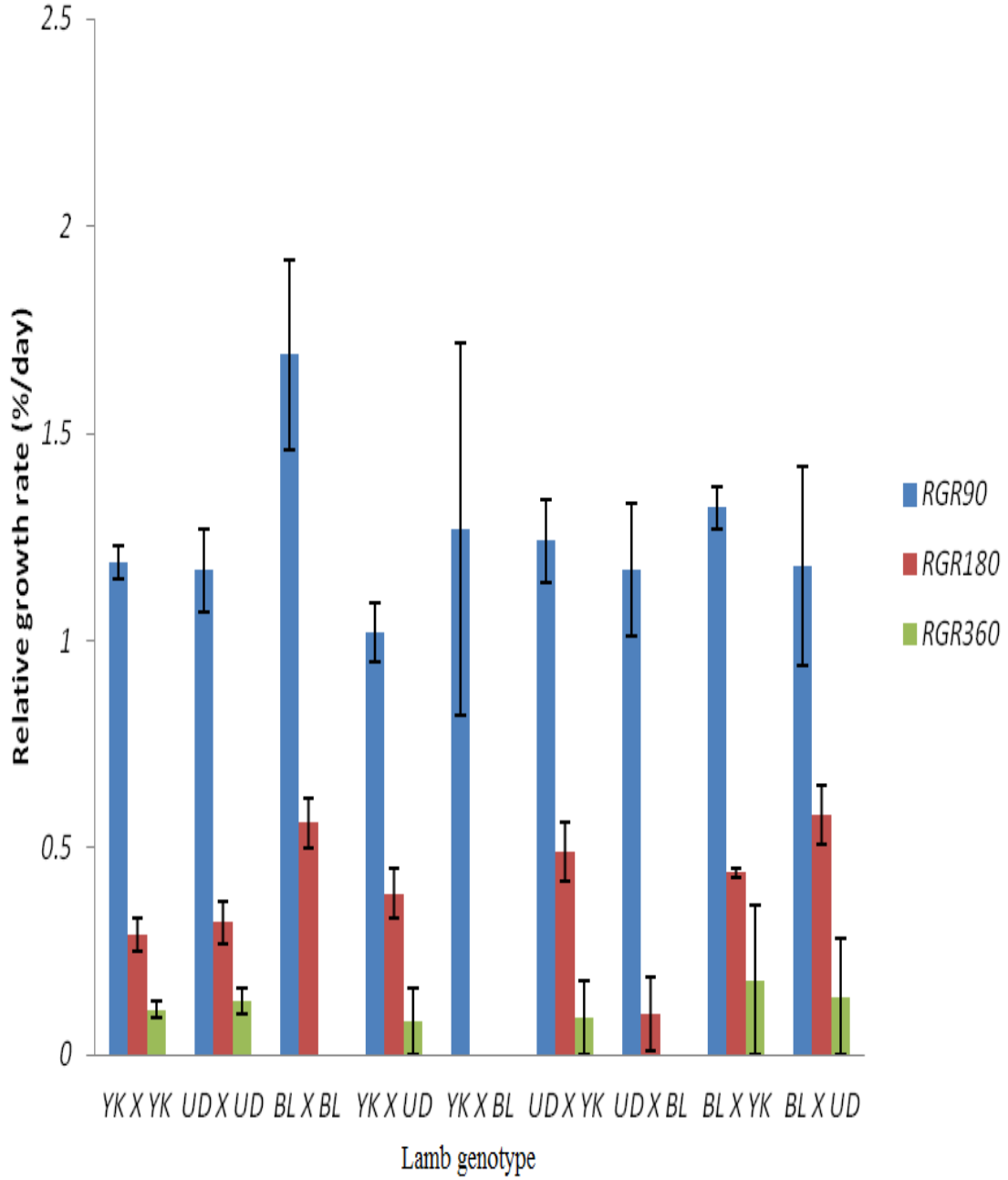


Figure 4. 11: Effect of Lamb Genotype on Relative Growth Rate (RGR) (Mean±SE) of Sheep of Northern Nigeria and their Crosses

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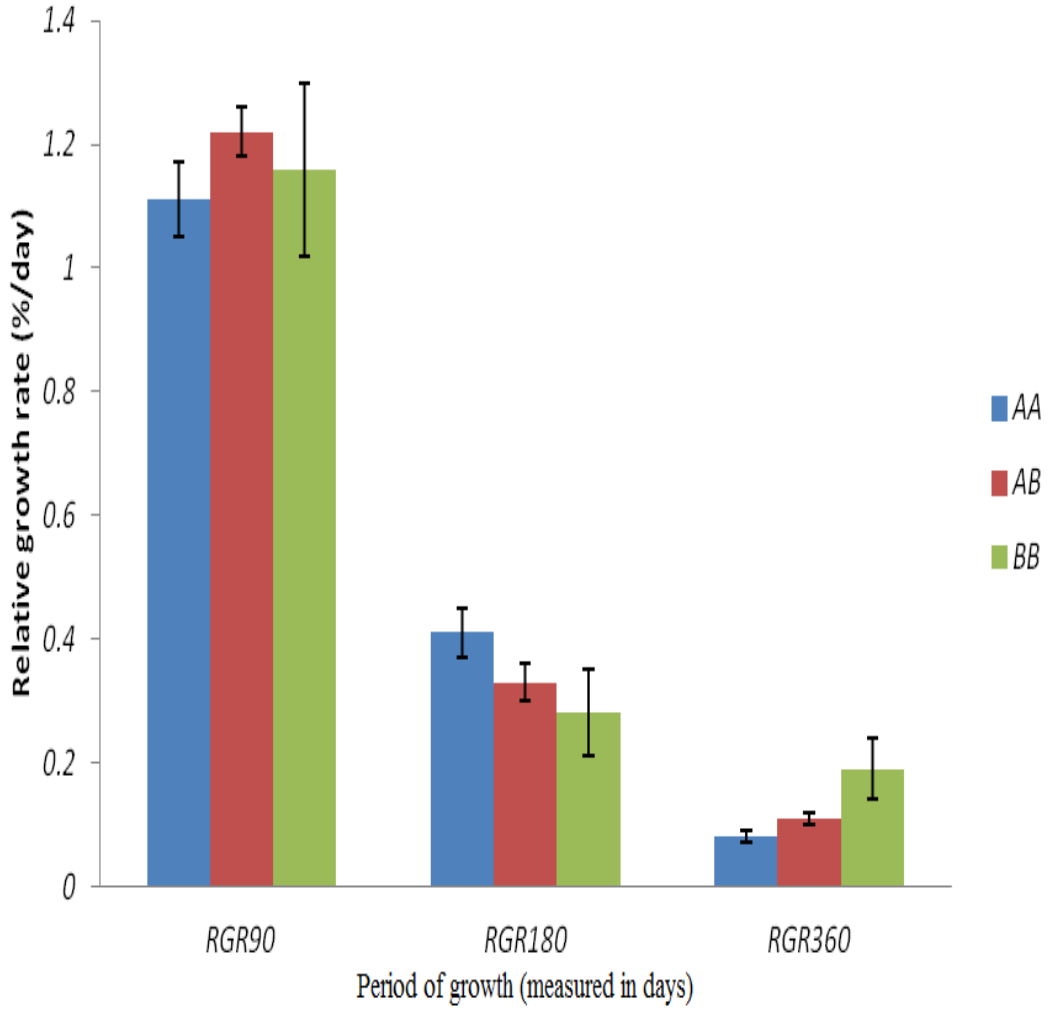


Figure 4. 12: Effect of Dam's Haemoglobin Type on Relative Growth Rate (RGR) (Mean±SE) of Sheep of Northern Nigeria

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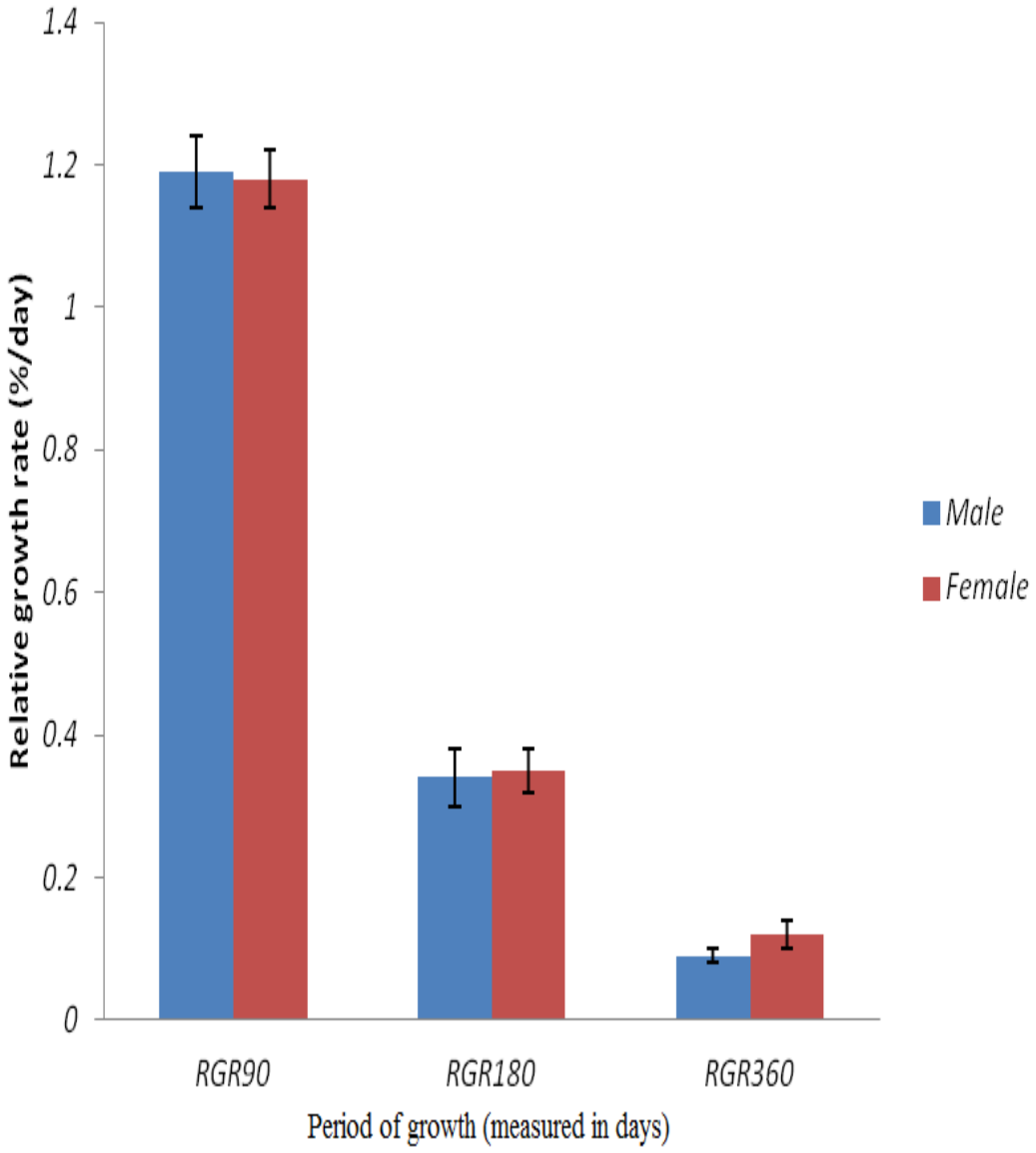


Figure 4. 13: Effect of sex of lambs on relative growth rate (RGR) (Mean±SE) of sheep of Northern Nigeria

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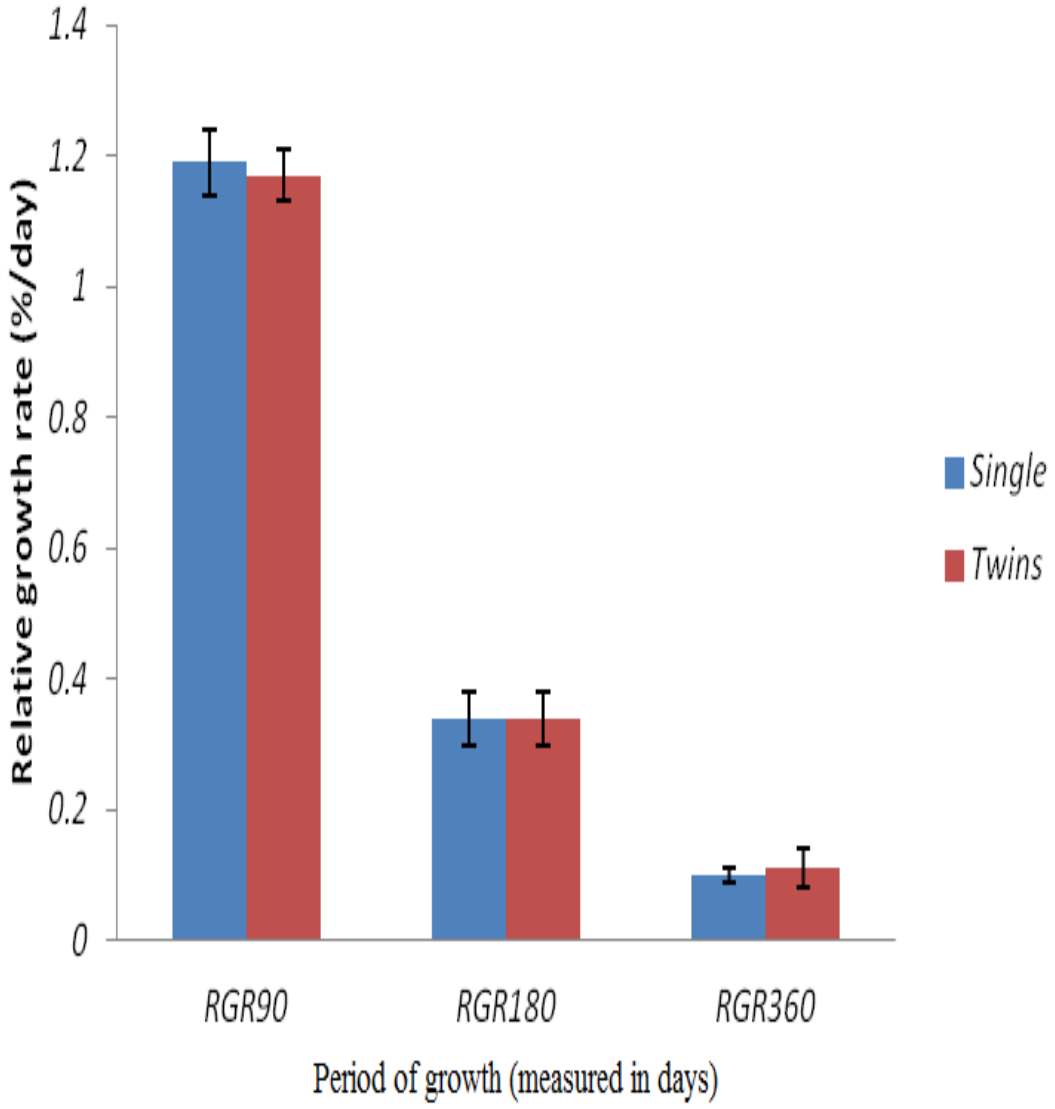


Figure 4. 14: Effect of Type of Birth on Relative Growth Rate (RGR) of Sheep of Northern Nigeria

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Table 4. 15: Pearson Correlation Coefficients of the Relationships between Average Daily Gain (ADG) and Relative Growth Rate (RGR) of Lambs at Various Ages

	Relative Growth Rate		
Average Daily Gain	**RGR90**	**RGR180**	**RGR360**
ADG90	0.704**	-0.142NS	0.131 NS
ADG180	-0.174*	0.730**	0.494**
ADG360	-0.120 NS	-0.068 NS	0.977**

**P<0.01; *P<0.05; NSNot significant

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4.1.8 Variability of Gestation Length and Litter Size among Sheep of Northern Nigeria

Table 4.16 shows the effects of sire and dam breeds on gestation length and litter size of sheep of Northern Nigeria. Sire and dam breeds affected ($P<0.05$) gestation length and litter size. Yankasa rams and ewes produced lambs with the shortest gestation length (151.84±0.23 and 151.85±0.20 days, respectively). The longest gestation length was recorded for lambs of either Balami rams or ewes. Balami rams only sired single lambs while Uda and Yankasa rams sired more lambs per dams served(Table 4.16). Uda ewes had higher ($P<0.05$) litter size (1.21±0.06) than Balami ewes which had litter size1.14±0.10. However, the litter sizes of Balami and Yankasa ewes were similar ($P>0.05$).

Effect of lamb genotype on gestation length and litter size of sheep of Northern Nigeria was as shown in Table 4.17. The shortest and longest gestation lengths($P<0.01$) were recorded for YK X UD and YK X BL lambs with values of 151.60±0.71 and 154.33±0.88 days, respectively. Dam's haemoglobin type (Table 4.18) and sex of lambs (Table 4.19) exerted no significant ($P>0.05$) effect on gestation length of sheep. Type of birth (Table 4.19) affected gestation length ($P<0.05$). Twins had shorter gestation length than singles with values of 150.55±0.61 and 152.29±0.81 days, respectively.

The highest litter sizes were found for Uda breed used as either sire (UD X YK) or dam (BL X UD) with values of 1.30±0.11 and 1.29±0.18, respectively. All lamb that had Balami as either sire or dam, except BL X UD, were single-born (litter size 1.00±0.00).

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Table 4. 16: Effect of Sire and Dam Breeds on Gestation Lengths and Litter Sizes of Sheep of Northern Nigeria

Sire breed	N	Gestation length (days)	Litter size
Balami	15	152.73±0.36[a]	1.00±0.00[b]
Uda	43	152.21±0.32[b]	1.16±0.06[a]
Yankasa	134	151.84±0.23[c]	1.19±0.03[a]
Overall	192	151.99	1.17
SEM		0.19	0.02
Dam breed			
Balami	14	152.79±0.49[a]	1.14±0.10[b]
Uda	42	152.17±0.55[b]	1.21±0.06[a]
Yankasa	136	151.85±0.20[c]	1.16±0.03[ab]
Overall	192	151.99	1.17
SEM		0.19	0.03

N is the number of lambs

[abc]Values within subset with different superscripts differ significantly (P<0.05)

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Table 4. 17: Effect of Lamb Genotype on Gestation Lengths and Litter Sizes of Sheep of Northern Nigeria

Lamb genotype	N	Gestation length (days)	Litter size
YK X YK	110	151.88±0.22^{ef}	1.17±0.04^{bc}
UD X UD	18	152.89±0.67^{b}	1.11±0.08^{c}
BL X BL	3	152.67±0.33^{bc}	1.00±0.00^{d}
YK X UD	18	151.06±0.85^{g}	1.22±0.10^{b}
YK X BL	3	154.33±0.88^{a}	1.00±0.00^{d}
UD X YK	20	151.60±0.71^{f}	1.30±0.11^{a}
UD X BL	4	152.50±1.04^{cd}	1.00±0.00^{d}
BL X YK	9	152.22±0.64^{de}	1.00±0.00^{d}
BL X UD	7	153.00±0.95^{b}	1.29±0.18^{a}
Overall	192	151.99	1.17
SEM		0.19	0.03

$^{a-g}$Means along the column with different superscript are significantly different (P<0.01)

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Table 4. 18: Effect of Dam's Haemoglobin Type on Gestation Lengths and Litter Sizes of Sheep of Northern Nigeria

Dams' haemoglobin type	N	Gestation length (days)	Litter size
A	47	152.04±0.44[a]	1.17±0.06[a]
B	16	152.00±0.56[a]	1.13±0.08[a]
AB	129	151.97±0.22[a]	1.18±0.03[a]
Overall	192	151.98	1.17
SEM		0.19	0.03

[a]Means with the same superscript are not significantly different (P>0.05)

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Table 4. 19: Effect of Type of Birth and Sex of Lambs on Gestation Lengths of Sheep of Northern Nigeria

Type of birth	N	Gestation length (days)
Single	159	152.29±0.18[a]
Twins	33	150.55±0.61[b]
Overall	192	151.99
SEM		0.19
Sex		
Male	98	151.97±0.29[a]
Female	94	152.01±0.24[a]
Overall	192	151.99
SEM		0.19

[ab]Means along the column with different superscripts are significantly different (P<0.05)

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4.1.9 Mortality Rates of Sheep of Northern Nigeria and their Crosses

Figures 4.15, 4.16 and 4.17 show the mortality rates of sheep of Northern Nigeria in relation to lamb genotype while Figures 4.18, 4.19 and 4.20 show the mortality rates in relation to dam's haemoglobin type from birth to 90, 90 to 180-Day and 180 to 360-Day, respectively. Figures 4.21 and 4.22 show the mortality rates in relation to type of birth and sex of lambs, respectively. The overall mortality rates of lambs in the studied population from birth to 90-Day, 90 to 180-Day and 180 to 360-Day were 14.06%, 30.91% and 51.75%, respectively.

4.19.1 Mortality rates in relation to lamb genotype

The highest percent mortality from birth to 90-Day (28.57%) was recorded in BL X UD lambs. The BL X BL, YK X UD, YK X BL and UD X BL had no mortality from birth to 90-Day (Figure 4.15). The mortality rates increased tremendously as the lambs grew to 180-Day (Figure 4.16). The BL X YK lambs had the highest percent mortality (77.78%) from birth to 180-Day. However, BL X BL had no mortality from birth to 180-Day. All the lamb genotypes had very high mortality from 180 to 360-Day (Figure 4.17) with the exception of YK X BL and BL X YK that had no mortality from 180 to 360-Day.

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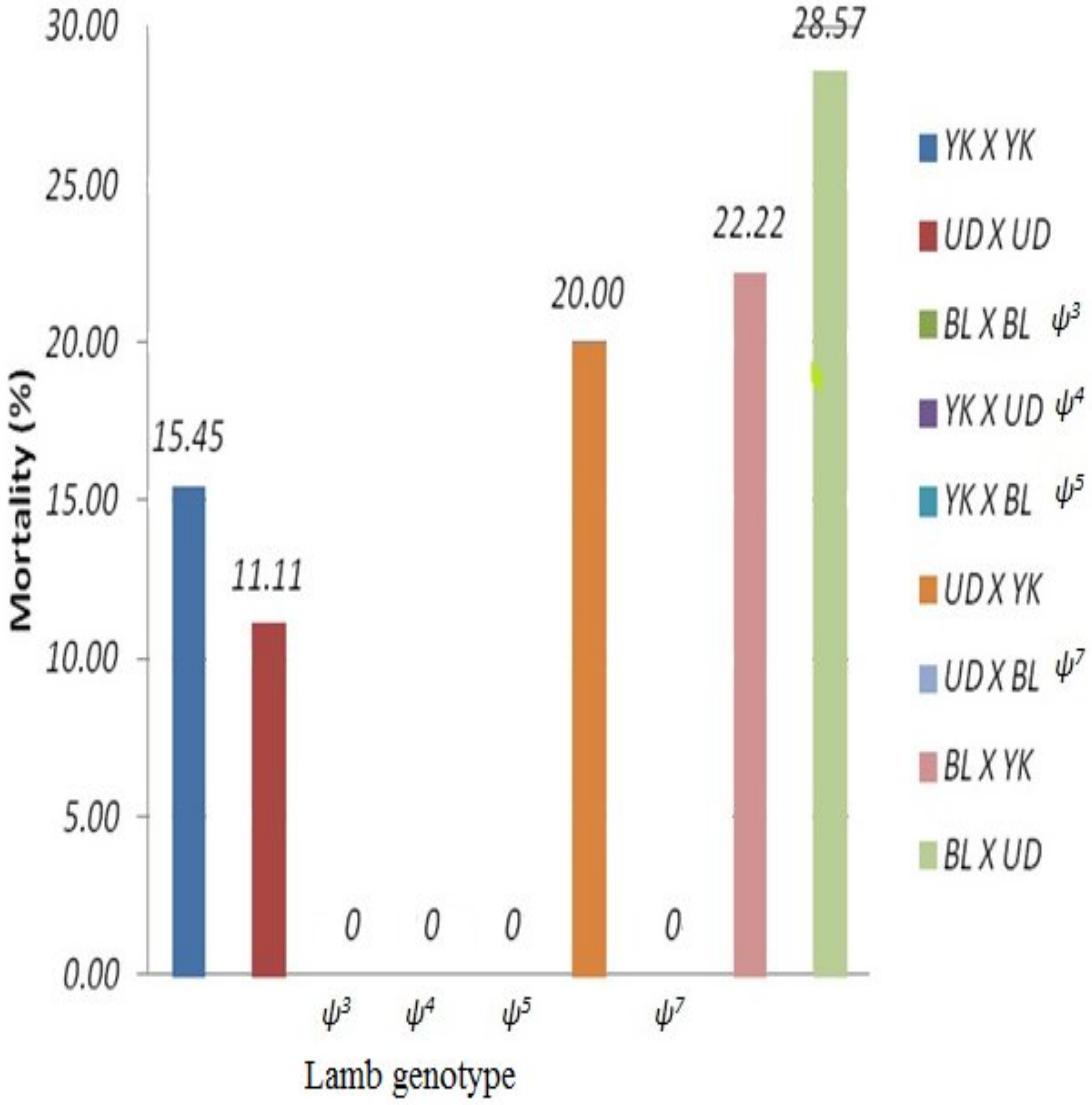


Figure 4. 15: Mortality Rates of Sheep of Northern Nigeria in Relation to Lamb Genotype from Birth to 90-Days

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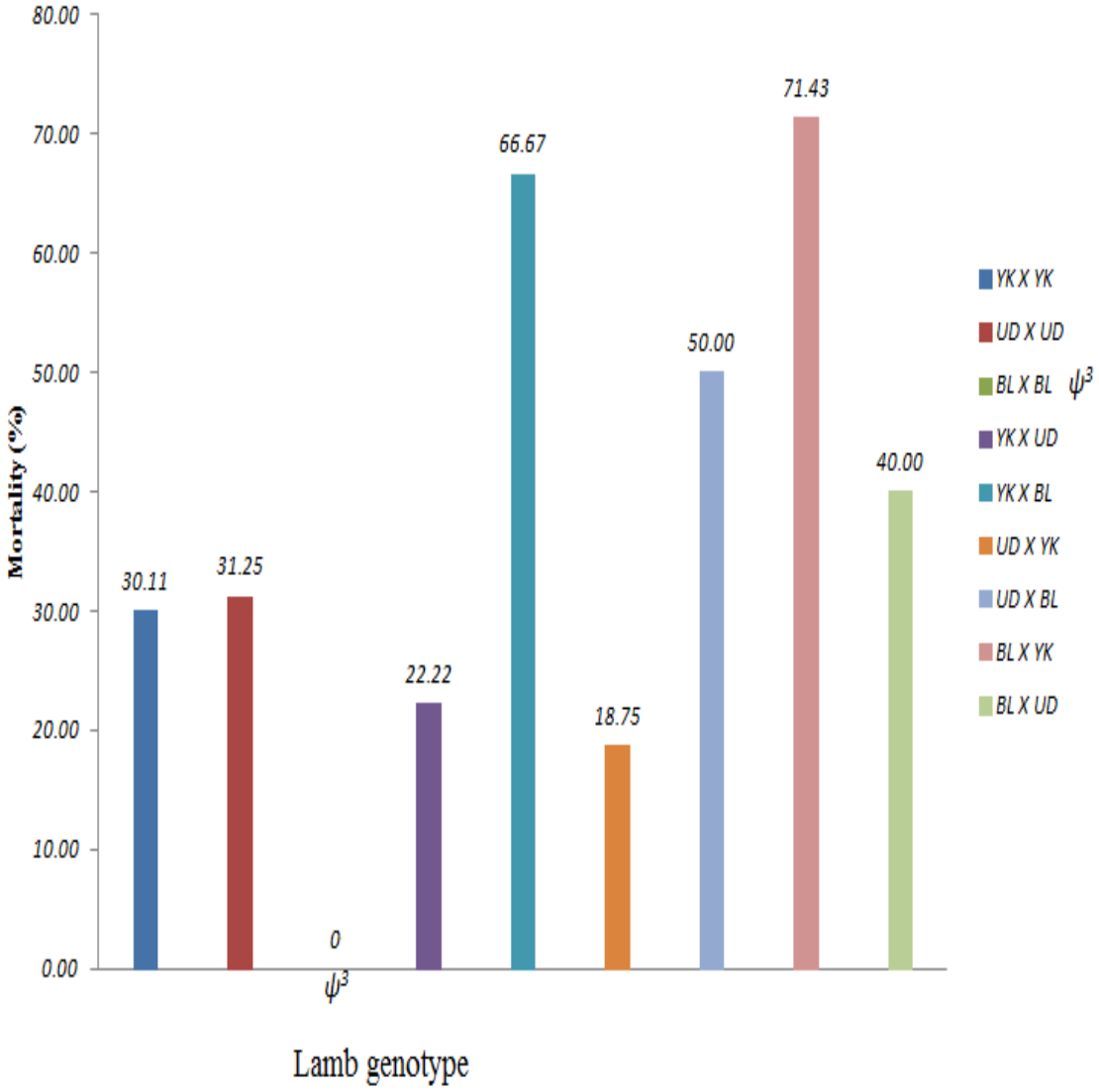


Figure 4. 16: Mortality Ratesof Sheep of Northern Nigeria in Relation to Lamb Genotype from 90 to 180-Days

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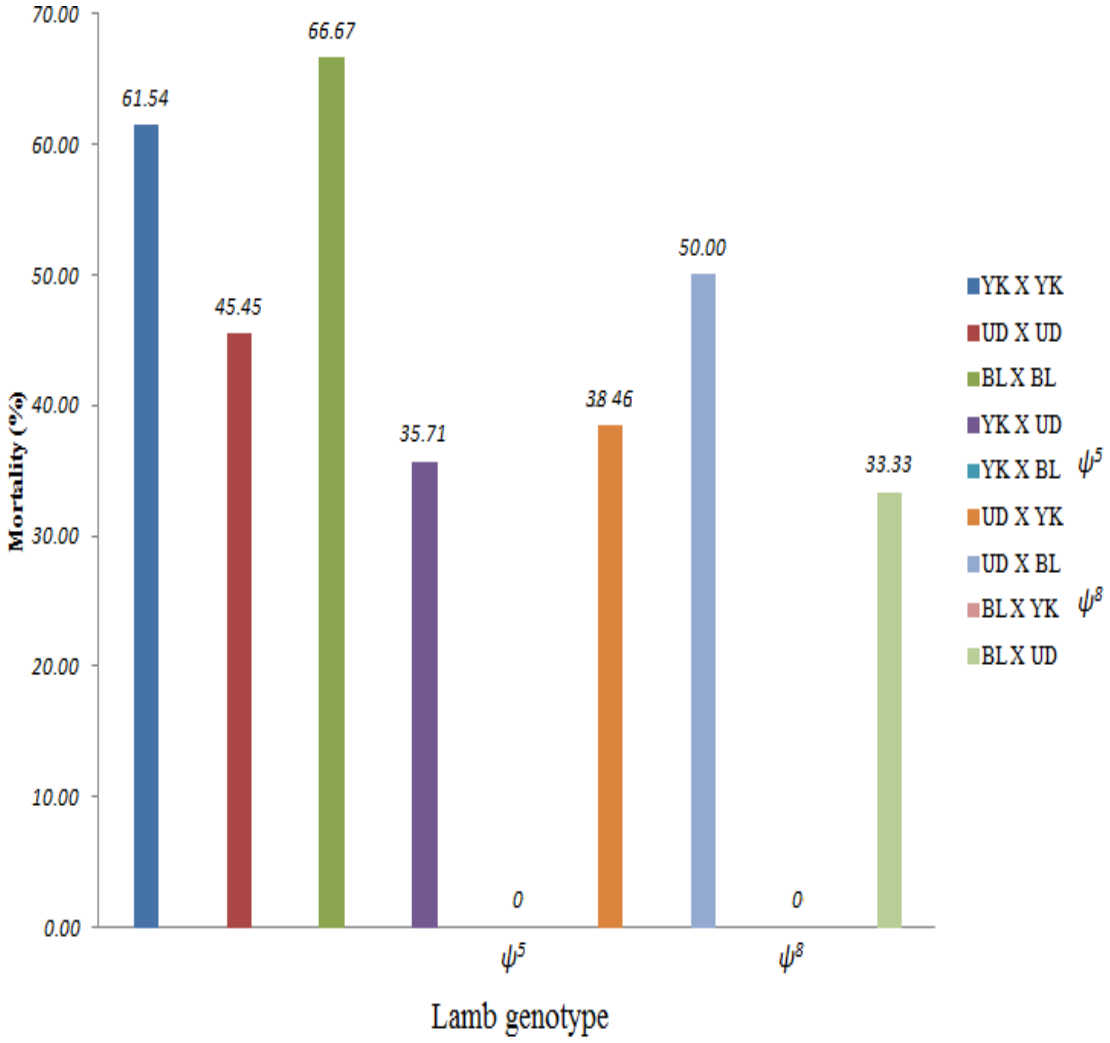


Figure 4. 17: Mortality Rates of Sheep of Northern Nigeria in Relation to Lamb Genotype from 180 to 360-Days

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4.1.9.2 Mortality rates in relation to dam's haemoglobin type

The highest percent mortality from birth to 90-Day (14.89%) was observed in lambs produced by dams with haemoglobin type A (HbAA) as shown in Figure 4.18. Percent mortality rates of lambs produced by dams with haemoglobin type BB and AB (HbBB and HbAB) from birth to 90-Daywere slightly lower than that of HbAA (14.89%). The values for HbBB and HbAB were 12.5% and 13.95%, respectively (Figure 4.18). HbBB had the highest percent mortality from birth to 180 days (50%) as shown in Figure 4.19. The highest percent mortality (34.04%) from 180 to 360-Day was recorded for lambs produced by dams with HbAA (Figure 4.20).

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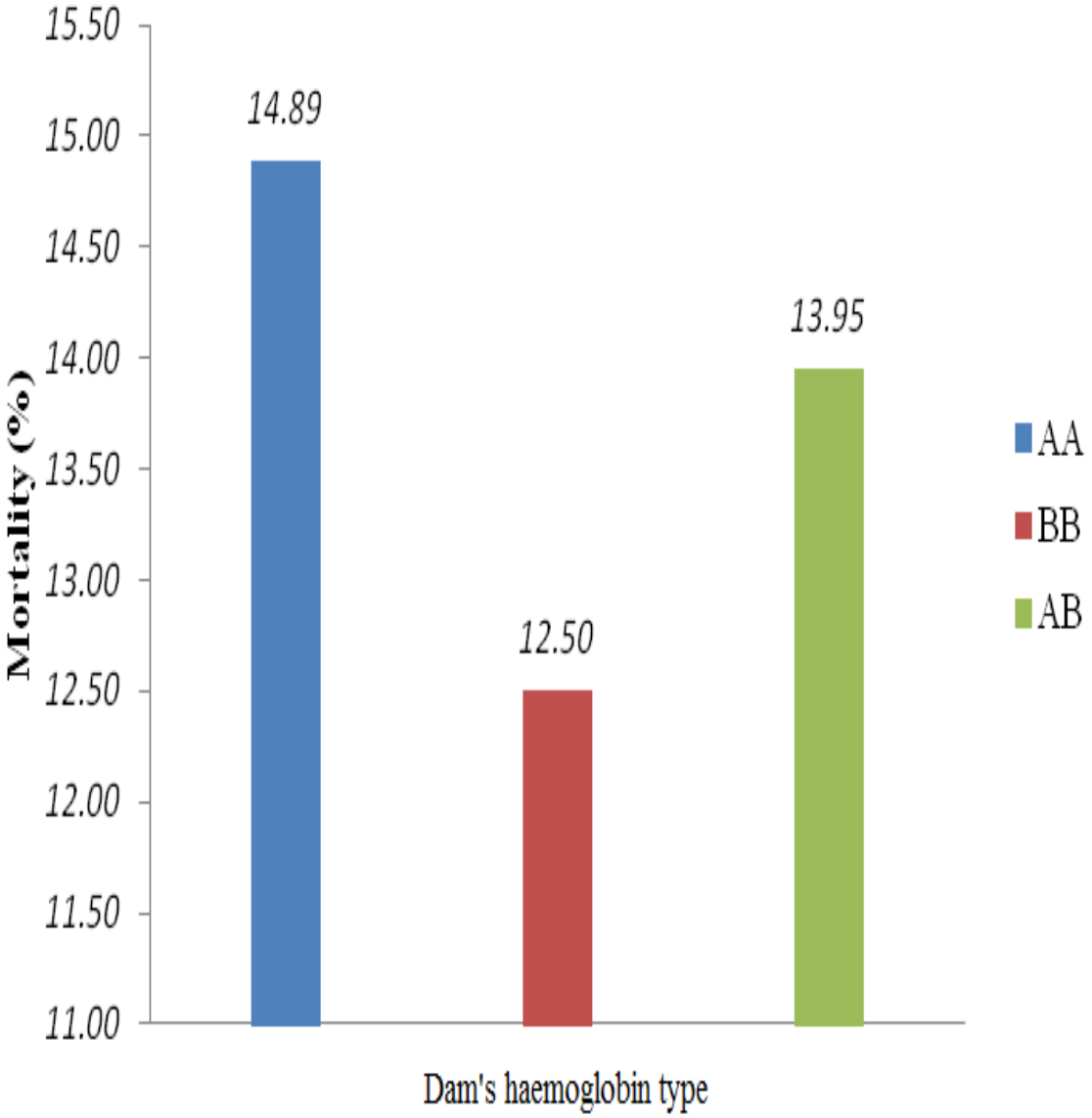


Figure 4. 18: Mortality Rates of Sheep of Northern Nigeria in Relation to Dam's Haemoglobin Type from Birth to 90-Day

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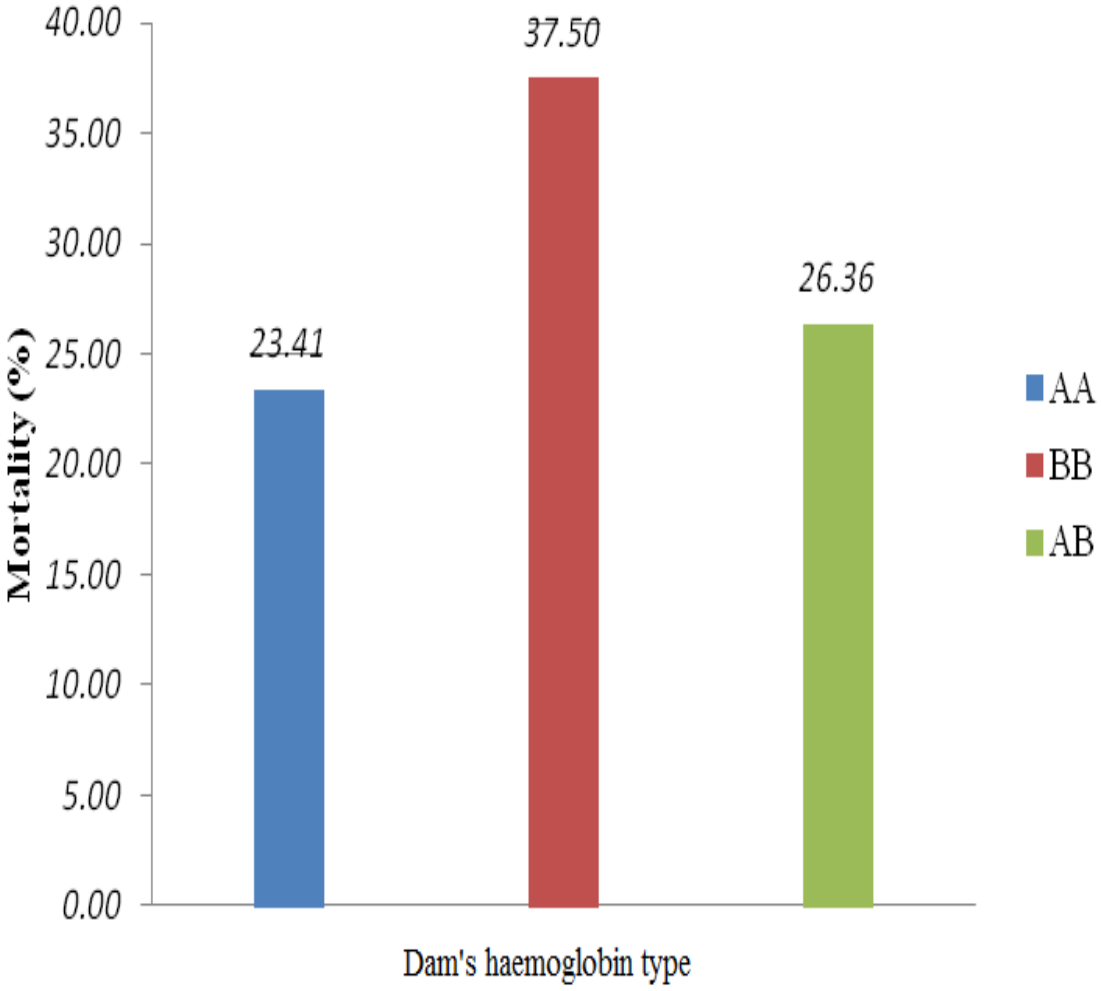


Figure 4. 19: Mortality Rates of Sheep of Northern Nigeria in Relation to Dam's Haemoglobin Type from 90 to 180-Day

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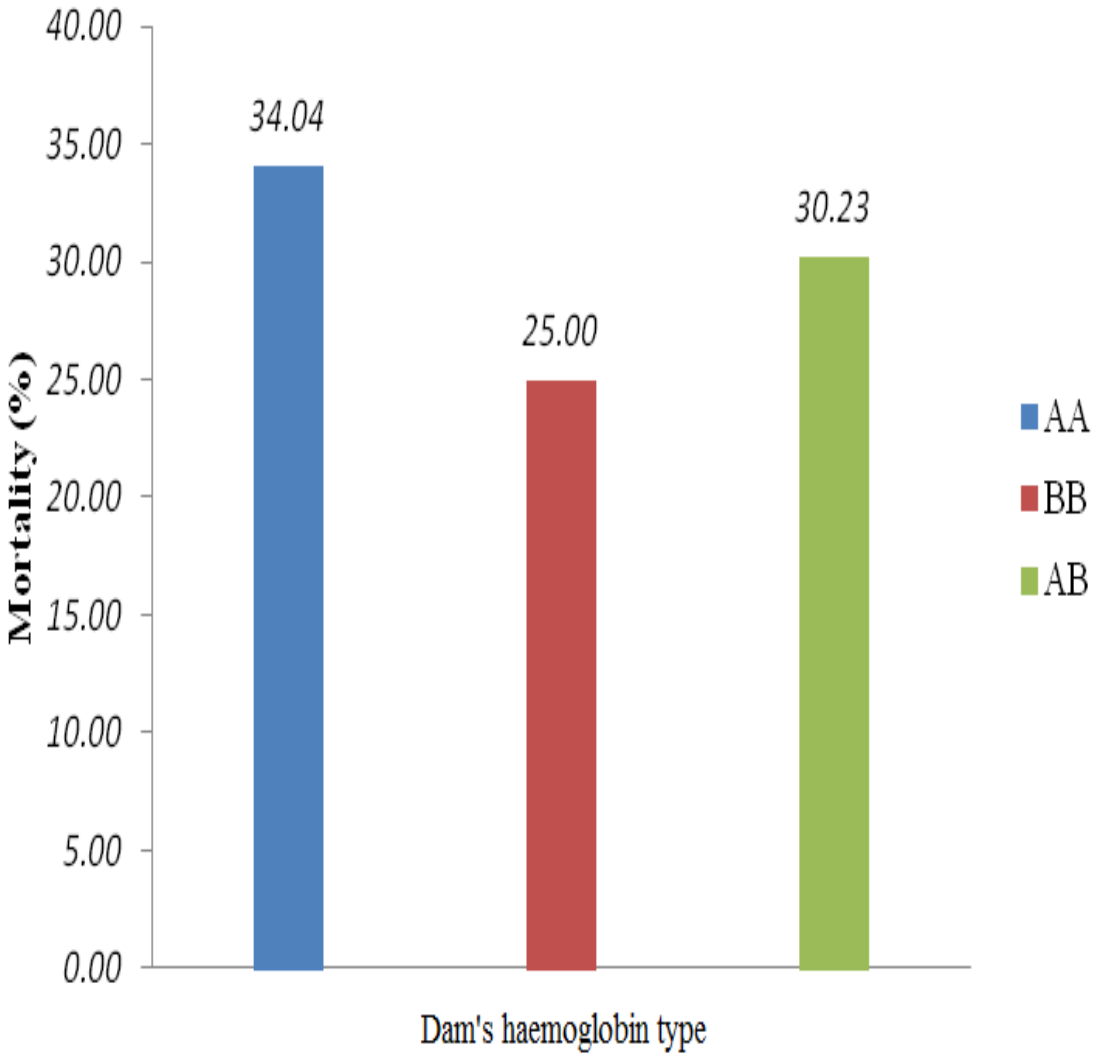


Figure 4. 20: Mortality Ratesof Sheep of Northern Nigeria in Relation to Dam's Haemoglobin Type from 180 to 360-Day

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4.1.9.3 Mortality rates in relation to type of birth and sex of lambs

Higher percentage of lamb loss from birth to 90-Day (Figure 4.21) was observed among single-born lambs (14.47%) than twins (12.12%). However, twins had more lamb loss than singles from birth to 180 and 180 to 360-Days. The percent mortality was generally higher for male lambs than females at all the stages of measurements (Figure 4.22).

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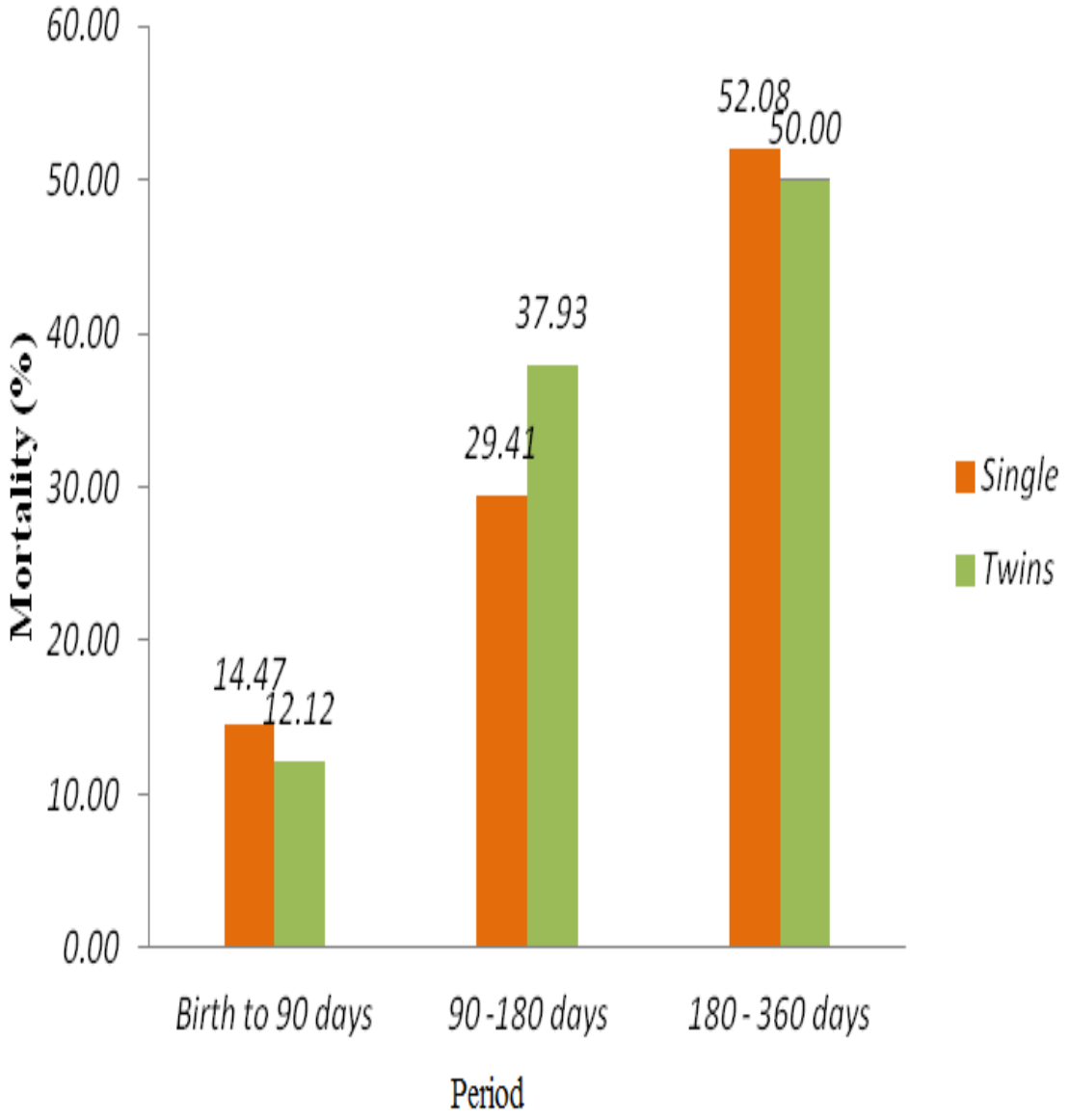


Figure 4. 21: Mortality Rates of Sheep of Northern Nigeria in Relation to Type of Birth of Lambs

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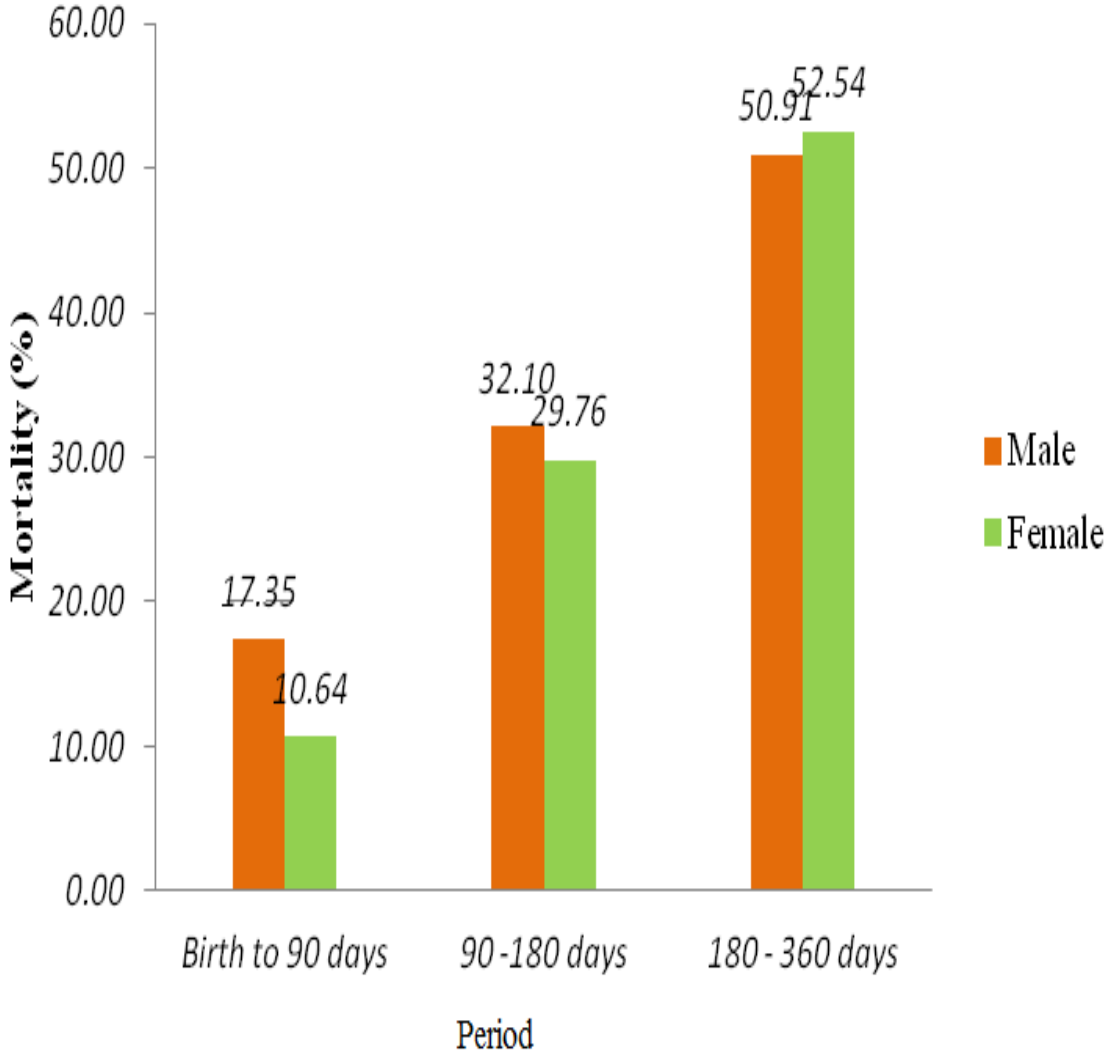


Figure 4. 22: Mortality Rates of Sheep of Northern Nigeria in Relation to Sex of Lambs

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4.1.9.4 Distribution of dam's haemoglobin type within lamb genotype

Figures 4.23 - 4.26 show the distribution of dam's haemoglobin types within lamb genotype at birth, 90, 180 and 360-Days, respectively. Each of the 9 lamb genotypes had very high proportion of HbAB. The dam's haemoglobin type BB (HbBB) were only found in YK X YK, UD X UD, YK X UD, BL X YK and BL X UD lambs at birth and 90-Day (Figures 4.23 and 4.24). At 180 and 360-Day (Figures 4.25 and 4.26), HbBB were completely lost to mortality except for a very small proportion that were found only in YK X YK (8.0%) and UD X UD (16.67%) at 360-Day.

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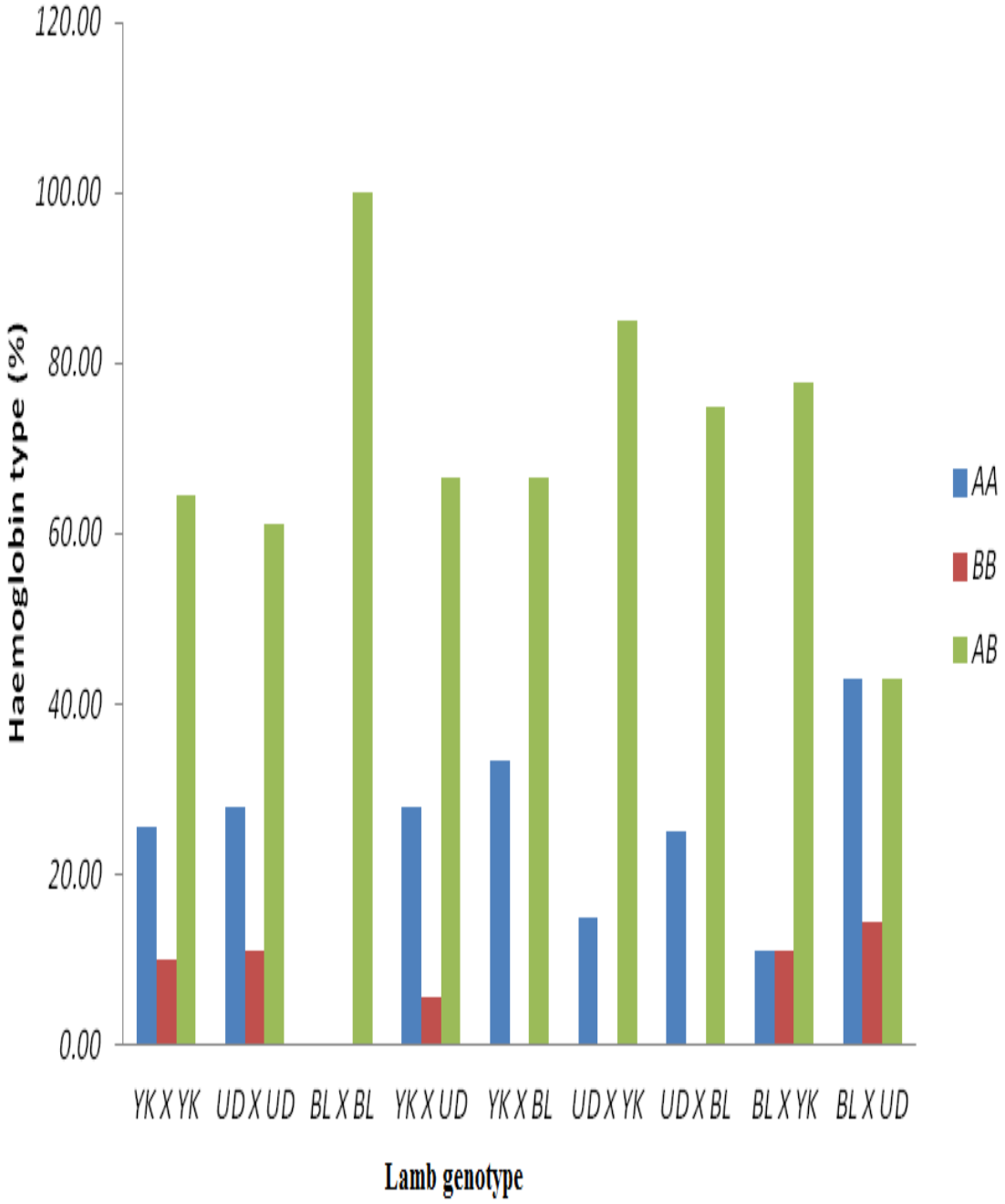


Figure 4. 23: Distribution of Dam's Haemoglobin Types within Lamb Genotype at birth

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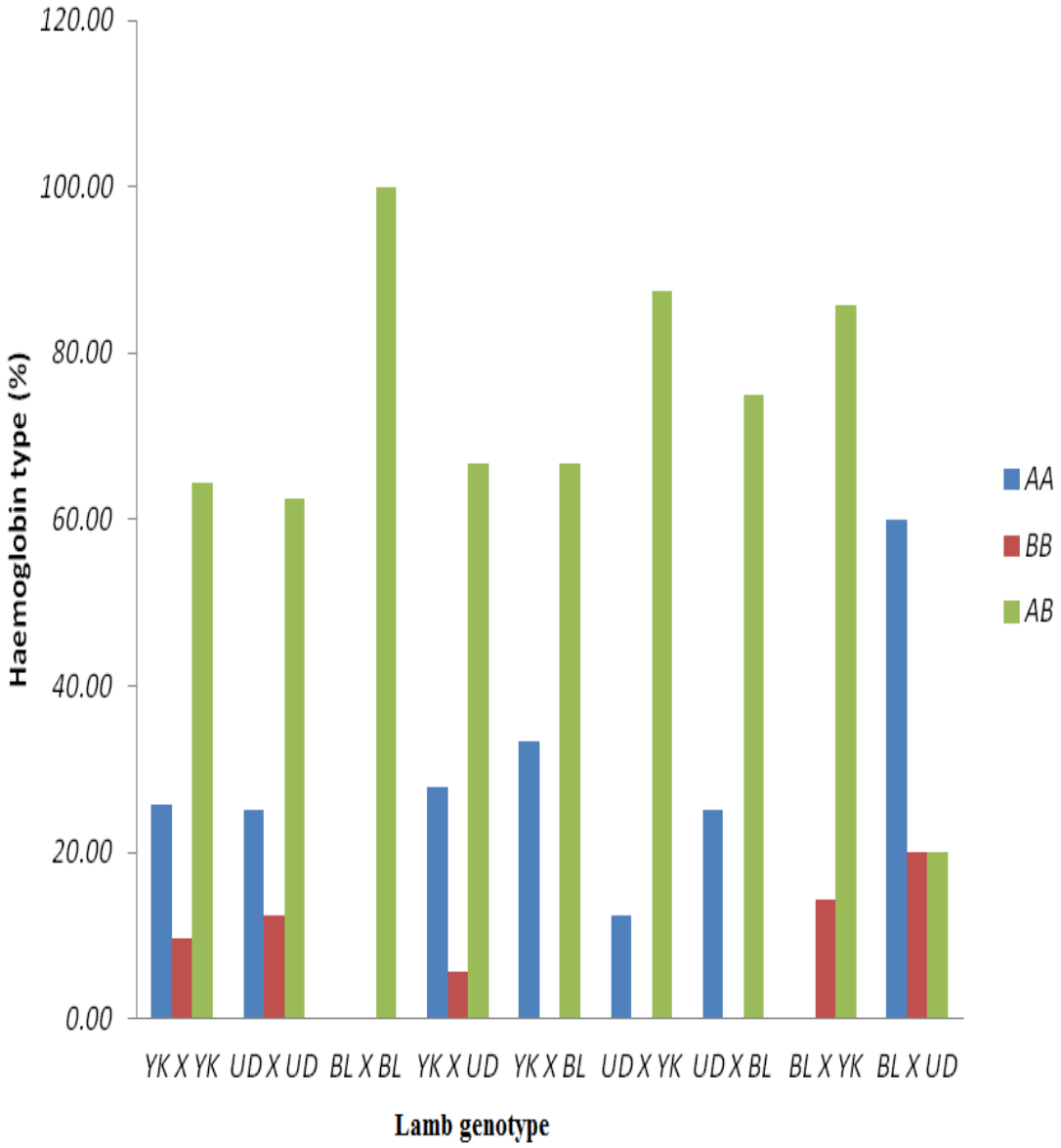


Figure 4. 24: Distribution of Haemoglobin Types within Lamb Genotype at 90-Days

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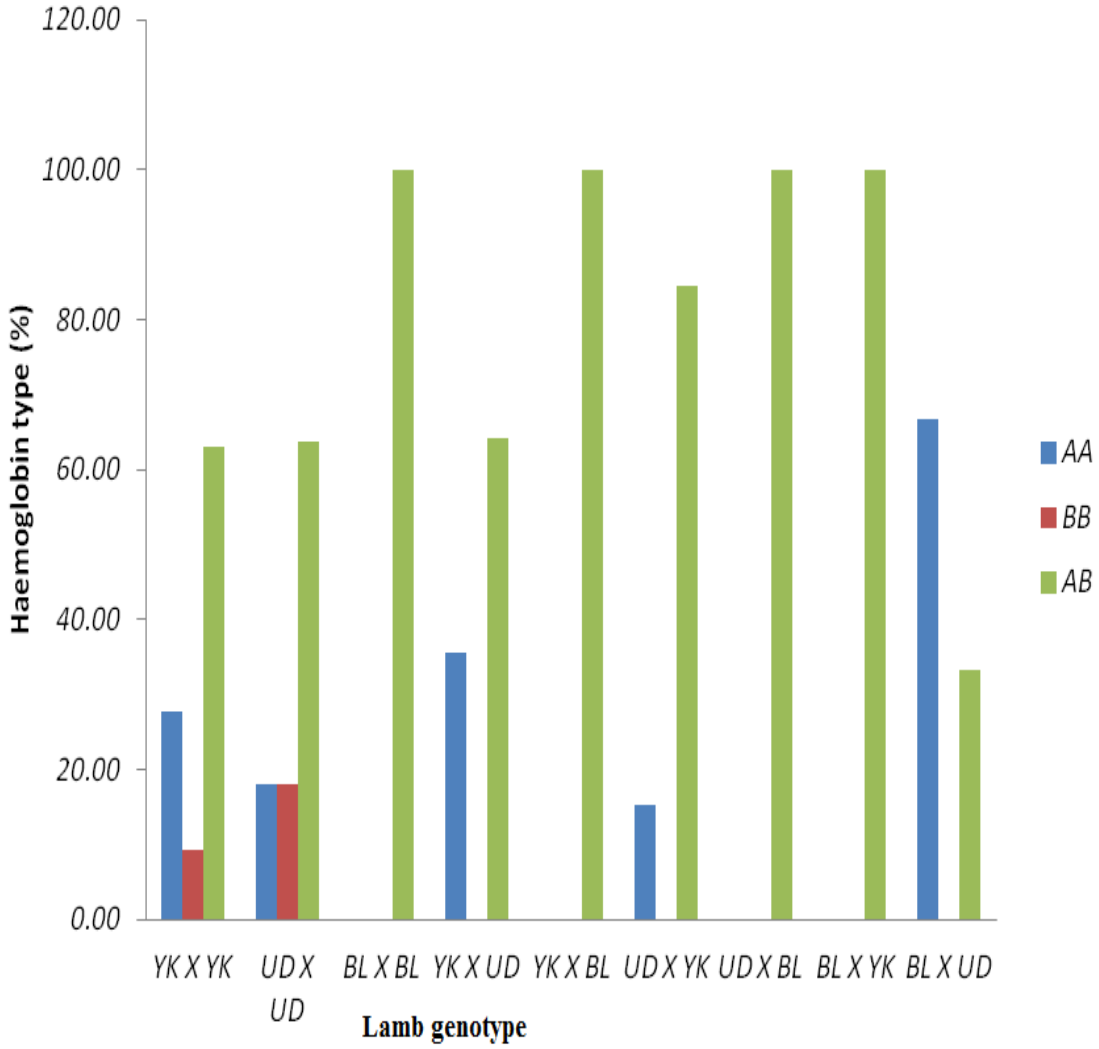


Figure 4. 25: Distribution of Haemoglobin Types within Lamb Genotypes at 180-Days

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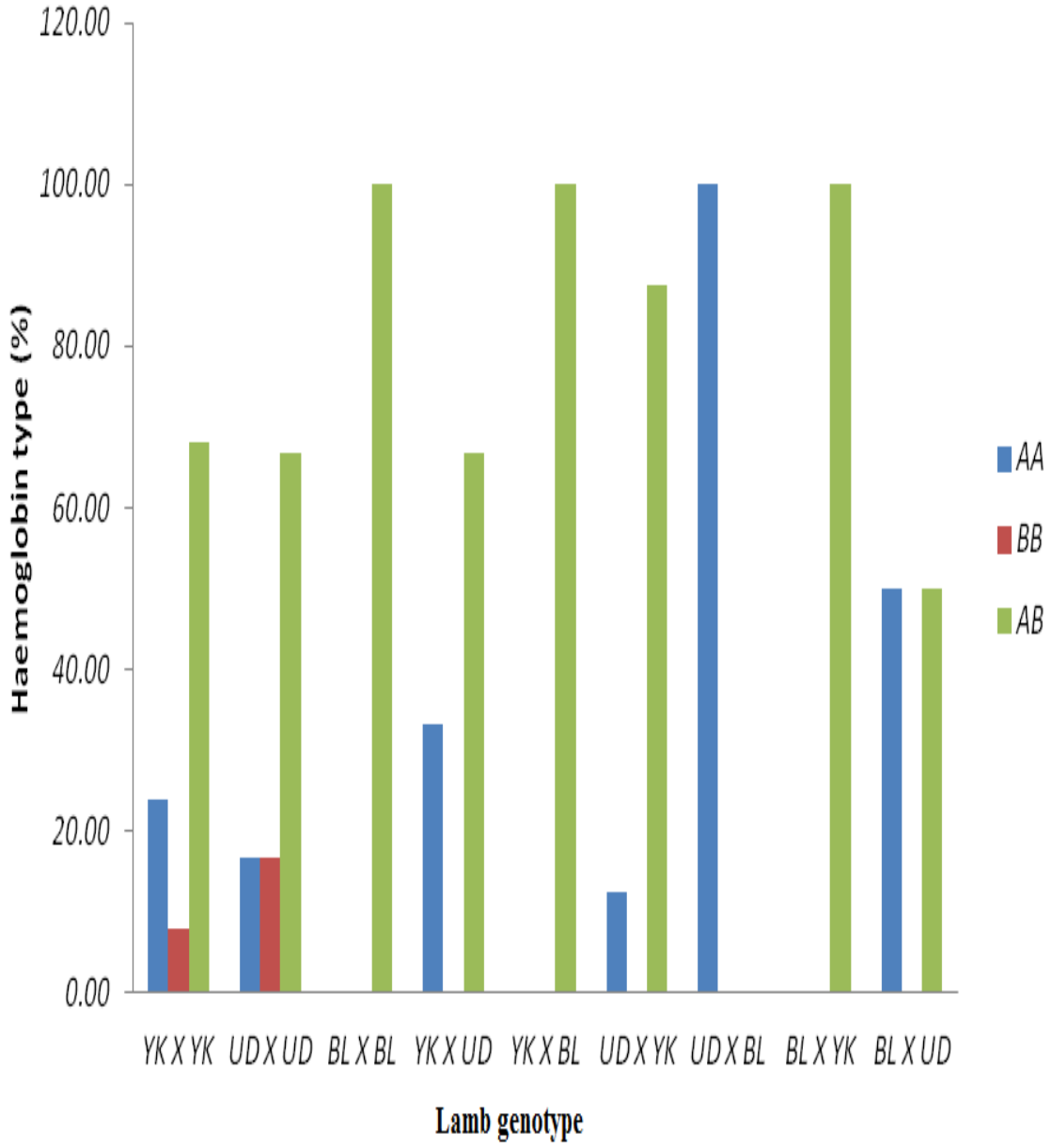


Figure 4. 26: Distribution of Haemoglobin Types within Lamb Genotypes at 360-Days

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4.1.9 Genetic parameter estimates of growth traits and linear body measurements for Yankasa lambs

Tables 4.20 to 4.23 show the genetic parameter estimates (heritability, repeatability, genetic, phenotypic and environmental correlations) of Yankasa lambs at birth, 90-Day, 180-Day and 360-Day.

4.1.9.1 Genetic parameter estimates for body weight and linear body measurements of Yankasa lambs atbirth

Table 4.20 showsthe genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at birth. The phenotypic correlation (r_p) of birth weight with neck length (0.155) and height at wither (0.157) were low and not significant ($P>0.05$). However, the relationship (r_p) of birth weight with back length (0.222; $P<0.05$), loin girth (0.247; $P<0.01$), chest girth (0.242; $P<0.01$) and leg length (0.205; $P<0.05$) were moderate (medium). Genetic correlation (r_g) between the traits however were not available. The heritability (h^2) estimates for birth weight (0.078±0.236), back length (0.024±0.220) and leg length (0.018±0.218) were also low.

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Table 4. 20: Phenotypic correlations (below diagonal) and heritability estimates along the diagonal of body weight and bodylinear measurements for Yankasa lambs at birth

	Birth weight	Neck length	Back length	Height at wither	Loin girth	Chest girth	Leg length
Birth weight	0.078±0.236	-	-	-	-	-	-
Neck length	0.155^{NS}	-	-	-	-	-	-
Back length	0.222*	0.705**	0.024±0.220	-	-	-	-
Height at wither	0.157^{NS}	0.744**	0.615**	-	-	-	-
Loin girth	0.247**	0.619**	0.633**	0.645**	-	-	-
Chest girth	0.242**	0.515**	0.410**	0.577**	0.369**	-	-
Leg length	0.205*	0.631**	0.682**	0.678**	0.593**	0.580**	0.018±0.218

^{NS}Not significant; *P<0.05; **P<0.01

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4.1.9.2 Genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at 90-Day

Table 4.21shows the genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at 90-Day. The r_p between 90-Day weight and all the linear body measurements were moderate and positive while r_p among linear body measurements were all high and positive. The $r_g$and h^2 estimates were not available except the h^2 estimate for neck length which was low (0.155±0.290).

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Table 4. 21: Phenotypic correlation (below diagonal) and heritability estimates along the diagonal ofbody weight and body linear measurements for Yankasa lamb at 90-Day

	90-Day weight	Neck length	Back length	Height at wither	Loin girth	Chest girth	Leg length
90-Day weight	-	-	-	-	-	-	-
Neck length	0.310**	0.155±0.290	-	-	-	-	-
Back length	0.322**	0.649**	-	-	-	-	-
Height at wither	0.324**	0.575**	0.557**	-	-	-	-
Loin girth	0.307**	0.535**	0.637**	0.459**	-	-	-
Chest girth	0.278**	0.491**	0.608**	0.569**	0.578**	-	-
Leg length	0.295**	0.622**	0.591**	0.534**	0.516**	0.618**	-

**P<0.01

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4.1.9.3 Genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at180-Day

Table 4.22shows the genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at 180-Day. The r_p between 180-Day weight and all the linear body measurements were high and positive. Furthermore the interrelationships (r_p) between linear body measurements weremedium to high and positive ($P<0.05$).The r_g between loin girth and chest girth (0.921±0.152) as well as chest girth and leg length (0.941±0.348) were very high and positive. The h^2 estimate of 180-Day weight for Yankasa lambs was high (0.765±0.514). Similarly, height at wither (0.492±0.465), loin girth (0.734±0.509) and chest girth (0.513±0.469) had high h^2 estimates. However, the h^2 estimate of leg length (0.394±0.444) was medium and positive.

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Table 4. 22: Genetic correlation (above diagonal), phenotypic correlation (below diagonal) and heritability estimates (coloured diagonal) of body weight and body linear measurements for Yankasa lamb at 180-Day

	180-DayWeight	Neck length	Back length	Height at wither	Loin girth	Chest girth	Leg length
180-DayWeight	0.765±0.514	-	-	-	-	-	-
Neck length	0.530**	-	-	-	-	-	-
Back length	0.545**	0.668**	0.197±0.396	-	-	-	-
Height at wither	0.807**	0.549**	0.639**	0.492±0.465	-	-	-
Loin girth	0.772**	0.457**	0.541**	0.745**	0.734±0.509	0.921±0.152	-
Chest girth	0.733**	0.373**	0.480**	0.705**	0.810**	0.513±0.469	0.941±0.348
Leg length	0.656**	0.359**	0.464**	0.634**	0.689**	0.576**	0.394±0.444

**P<0.01

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4.1.9.4 Genetic parameter estimates for body weight and linear body measurements of Yankasa lambsat360-Day

Table 4.23shows the genetic parameter estimates for body weight and linear body measurements of Yankasa lambs at 360-Day. The r_p between 360-Day weight and all the linear body measurements were high and positive. Similarly, the interrelationships (r_p) between linear body measurements weremedium to high and positive ($P<0.05$).The r_g among body weight at 360-Day and linear body measurements were not available except for high r_g obtained for the relationships between 360-Day weight and chest girth (0.747±0.380) and 360-Day weight and leg length (0.847±0.300). The h^2 estimate of weight at 360-Day was high and positive (0.805±0.961). The h^2 estimates for back length (0.670±0.961) and chest girth (0.869±0.960) were also high.

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Table 4. 23: Genetic correlation (above diagonal), phenotypic correlation (below diagonal) and heritability (coloured diagonal) of body weight and body linear measurements for Yankasa lambs at 360-Day

	360-Day weight	Neck length	Back length	Height at wither	Loin girth	Chest girth	Leg length
360-Day weight	0.805±0.961	-	-	-	-	0.747±0.380	0.847±0.300
Neck length	0.781**	-	-	-	-	-	-
Back length	0.727**	0.541**	0.670±0.961	-	-	-	-
Height at wither	0.844**	0.644**	0.685**	-	-	-	-
Loin girth	0.724**	0.481**	0.594**	0.628**	-	-	-
Chest girth	0.814**	0.584**	0.664**	0.734**	0.789**	0.869±0.960	-
Leg length	0.754**	0.563**	0.743**	0.743**	0.682**	0.855**	-

**P<0.01

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4.1.10 Prediction of Body Weight using Linear Body Measurements

Tables 4.24 – 4.27 showed the prediction equations of body weights of sheep of Northern Nigeria and their crosses using linear body measurements.

4.1.10.1 Prediction equations for birth weight

Loin girth (R^2 = 0.129) and chest girth (R^2 = 0.015) were the only linear body measurements that contributed to the prediction equation for birth weight (Table 4.24) of the overall population. Loin girth accounted for about 56% variability of birth weight of UD X UD female lambs. Neck length (35.67%) and loin girth (13.01%) were the most important linear body measurements for the variability of birth weight of UD X UD lambs of either sex. Table 4.24also shows that the coefficient of determination (R^2) of the prediction equations for birth weight of most of the classes of lambs considered were low at birth, except in BL X BL where the variability of birth weight was mostly accounted for by chest girth (99.8%).

4.1.10.2 Prediction equations for 90-Day weight

Table 4.25 shows prediction equations for 90-Day body weight of sheep of Northern Nigeria and their crosses using linear body measurements. Loin girth contributed about 100% of the variability of 90-Day weight of BL X BL (both male and female) and UD X UD males. Height at wither accounted for 67.52% and 50.16% of 90-Day weight of UD X UD (both male and female) and UD X UD females, respectively. Loin girth (35.23%) and chest girth (53.8%) were the major contributors to the variability of 90-Day weight of the combined population of the crosses. The prediction equations for BL

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X BL, male UD X UD, female YK X YK, UD X UD and female crosses had high R^2;corresponding to 0.997, 0.993, 0.737, 0.675 and 0.630, respectively.

4.1.10.3 Prediction equations for 180-Day weight

Table 4.26 shows prediction equations for 180-Day body weight of sheep of Northern Nigeria and their crosses using linear body measurements. Height at wither featured prominently in the equations for the overall population, YK X YK, crosses (both sexes), male YK X YK, female UD X UD and male crosses. However, leg length accounted for 76.14% of the variability of 180-Day weight of UD X UD (in both sexes). The R^2 of all the equations generated for prediction of 180-Day weight in this study were high.

4.1.10.4 Prediction equations for 360-Day weight

Table 4.27 shows prediction equations for 360-Day weight of sheep of Northern Nigeria and their crosses using linear body measurements. Back length accounted for most of the variability of 360-Day weight of male crosses (69.01%), crosses (63.61%), female UD X UD (62.28%), female crosses (60.97%) and overall population (55.39%). Height at wither accounted for most of the variability of 360-Day weight of male YK X YK (78.22%) and the entire YK X YK (71.50%). Chest girth was mostly responsible for the variability of 360-Day weight of female YK X YK (78.07%).All the prediction equations for 360-Day (yearling) weight of sheep of Northern Nigeria and their crosses had high R^2 values (0.690-0.954).

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Table 4. 24: Prediction equations for birth weight using linear body measurements of sheep of Northern Nigerianand their crosses

Class of lambs	Prediction equation	Predictor$^{\varphi}$	R^2
Overall	$Y = 0.754 + 0.037X_1 + 0.02X_2$	X_1 = Loin girth (0.129); X_2 = Chest girth (0.0152)	0.144
YK X YK	$Y = 1.025 + 0.021\ X_1 + 0.029\ X_2$	X_1 = Loin girth (0.0641); X_2 = Chest girth (0.0271)	0.091
UD X UD	$Y = 2.081 - 0.131\ X_1 + 0.074\ X_2$	X_1 = Neck length (0.357); X_2 = Loin girth (0.130)	0.487
BL X BL	$Y = 38.350 - 0.975\ X$	X = Chest girth (0.998)	0.998
Crosses	Y = 1.069 - 00808 X	X = Back length (0.1547)	0.155
YK X YK (males)	$Y = 2.076 - 0.073\ X_1 + 0.065\ X_2 + 0.042\ X_3$	X_1 = height at wither (0.0642); X_2 = Loin girth (0.0406); X_3 = Chest girth (0.0676)	0.172
YK X YK (females)	$Y = 0.820 + 0.055\ X$	X = Chest girth (0.0775)	0.078
UD X UD (female)	$Y = 0.022 + 0.081\ X$	X = Loin girth (0.5631)	0.563
Crosses (male)	$Y = -0.661 + 0.085\ X$	X = Height at wither (0.2391)	0.239
Crosses (female)	$Y = -1.125 + 0.046\ X_1 + 0.068\ X_2$	X_1 = Loin girth (0.2718); X_2 = Chest girth (0.701)	0.342

Y = birth weight; $^{\varphi}$Values in parenthesis are the partial coefficient of determination (partial-R^2) contribution of the preceding predictors.

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Table 4. 25: Prediction equations for 90-Day body weight of sheep of Northern Nigerian and their crosses using linear body measurements

Class of lambs	Prediction equation	Predictor$^{\varphi}$	R^2
Overall	$Y = -9.373 + 0.291X_1 + 0.140X_2 + 0.102X_3$	X_1 = Neck length (0.1276); X_2 = Height at wither (0.0356); X_3 = Loin girth (0.0141)	0.177
YK X YK	$Y = -13.345 + 0.447X_1 + 0.183X_2$	X_1 = Back length (0.1207); X_2 = Height at wither (0.308)	0.152
UD X UD	$Y = -12.450 + 0.399X$	X = Height at wither (0.6752)	0.675
BL X BL	$Y = -4.985 + 0.290X$	X = Loin girth (0.9971)	0.997
Crosses	$Y = -3.846 + 0.80X_1 + 0.171X_2$	X_1 = Loin girth (0.3523); X_2 = Chest girth (0.538)	0.406
YK X YK (males)	$Y = -9.275 + 0.379X$	X= Loin girth (0.0953)	0.095
YK X YK (females)	$Y = -15.774 + 0.240X_1 - 0.138X_2 + 0.129X_3 + 0.525X_4$	X_1 = Back length (0.6346); X_2 = Height at wither (0.683); X_3 = Chest girth (0.153); X_4 = Leg length (0.192)	0.737
UD X UD (male)	$Y = -21.461 + 0.589X$	X = Loin girth (0.9928)	0.993
UD X UD (female)	$Y = -8.105 + 0.313X$	X = Height at wither (0.5016)	0.502
Crosses (male)	$Y = -0.707 + 0.186X$	X = Chest girth (0.2671)	0.267
Crosses (female)	$Y = -8.685 + 0.463X_1 + 0.064X_2 + 0.096X_3$	X_1 = Chest girth (0.5032); X_2 = neck length (0.782); X_3 = Loin girth (0.483)	0.630

Y = 90-Day body weight; $^{\varphi}$Values in parenthesis are the partial coefficient of determination (partial-R^2) contribution of the preceding predictors.

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Table 4. 26: Prediction equations for 180-Day body weight using linear body measurements of sheep of Northern Nigerian and their crosses

Class of lambs	Prediction equation	Predictor$^{\varphi}$	R^2
Overall	$Y = -22.159 + 0.326X_1 + 0.151X_2 + 0.152X_3 + 0.078X_4$	X_1 = Height at wither (0.6815); X_2 = Chest girth (0.441); X_3 = Neck length (0.0145); X_4 = Loin girth (0.061)	0.746
YK X YK	$Y = -20.209 + 0.368X_1 + 0.204X_2$	X_1 = Height at wither (0.6402); X_2 = Loin girth (0.0675)	0.708
UD X UD	$Y = -18.965 + 0.829X$	X = Leg length (0.7614)	0.761
Crosses	$Y = -19.829 + 0.239X_1 + 0.250X_2 + 0.397X_3 - 0.187X_4$	X_1 = Height at wither (0.6022); X_2 = Chest girth (0.0894); X_3 = Back length (0.0591); X_4 = Leg length (0.0308)	0.782
YK X YK (males)	$Y = -27.279 + 0.433X_1 + 0.300X_2 + 0.158X_3$	X_1 = Height at wither (0.7543); X_2 = Back length (0.0321); X_3 = Leg length (0.0156)	0.802
YK X YK (females)	$Y = -16.429 + 0.145X_1 + 0.154X_2 + 0.294X_3$	X_1 = Chest girth (0.6116); X_2 = Loin girth (0.0433); X_3 = Neck length (0.0367)	0.692
UD X UD (female)	$Y = -19.150 + 0.544X$	X = Height at wither (0.8013)	0.801
Crosses (male)	$Y = -25.654 + 0.268X_1 + 0.542X_2 + 0.118X_3$	X_1 = Height at wither (0.6889); X_2 = Back length (0.0637); X_3 = Chest girth (0.0542)	0.807
Crosses (female)	$Y = -18.332 + 0.468X_1 + 0.375X_2$	X_1 = Neck length (0.7002); X_2 = Chest girth (0.0560)	0.756

Y = 180-Day body weight; $^{\varphi}$Values in parenthesis are the partial coefficient of determination (partial-R^2) contribution of the preceding predictors.

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Table 4. 27: Prediction equations for 360-Day body weight using linear body measurements of sheep of NorthernNigerian and crosses

Class of lambs	Prediction equation	Predictor$^{\varphi}$	R^2
Overall	$Y = -27.571 + 0.362X_1 + 0.198X_2 + 0.348X_3 + 0.154X_4$	X_1 = Back length (0.5539); X_2 = Height at wither (0.1350); X_3 = Neck length (0.058); X_4 = Chest girth (0.0186)	0.766
YK X YK	$Y = -27.282 + 0.275X_1 + 0.380X_2 + 0.263X_3$	X_1 = Height at wither (0.7150); X_2= Neck length (0.1111); X_3 = Chest girth (0.0472)	0.873
Crosses	$Y = -15.437 + 0.495X_1 + 0.233X_2$	X_1 = Back length (0.6361); X_2 = Height at wither (0.0651)	0.701
YK X YK (males)	$Y = -25.969 + 0.437X_1 + 0.536X_2$	X_1 = Height at wither (0.7822); X_2 = Neck length (0.1718)	0.954
YK X YK (females)	$Y = -26.305 + 0.505X_1 + 0.197X_2$	X_1 = Chest girth(0.7807); X_2= Height at wither (0.00446)	0.825
UD X UD (female)	$Y = 27.301 + 1.219X_1 - 1.955X_2$	X_1 = Back length (0.6228); X_2 = Neck length (0.3093)	0.932
Crosses (male)	$Y = -12.560 - 0.822X$	X = Back length (0.6901)	0.690
Crosses (female)	$Y = -12.022 + 0.401X_1 + 0.232X_2$	X_1 = Back length (0.6097); X_2 = Height at wither (0.1152)	0.725

Y = 360-Day body weight; $^{\varphi}$Values in paren thesis are the partial coefficient of determination (partial-R^2) contribution of the preceding predictors

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CHAPTER FIVE

5.0 DISCUSSION

5.1.1 Population of the Experimental Animal

Yankasa was the most numerous stock in NAPRI because it forms the base population of sheep in the institute. Several studies (Adu and Ngere, 1979; Taiwo *et al*., 1982; Kwatu *et al*., 1983; Oyedipe *et al*., 1986; Hassan, 1987; Osinowo *et al*., 1994; Afolayan, 1996; Afolayan *et al*., 2006; Akinyemi, 2010) had been conducted on Yankasa sheep, which encouraged multiplication of the breed in the study area. The other breeds of sheep (Balami and Uda) were fewer in number because they were only recently introduced for research purpose through the 2008 to 2011 development plan of the Institute.

5.1.2 Frequency of Dam's Haemoglobin Type

The high frequency of allele A and haemoglobin type AB (HbAB) of the dam's haemoglobin type in this study is similar to the results of Abdussamad *et al*. (2004) who also obtained very high frequency of allele A and HbAB in population of Nigerian Zebu cattle and their crosses in Zaria, Nigeria. The abundance of allele A of dam haemoglobin and HbAB (67%) in the population of this study suggests a better adaptation of the haemoglobin type to the region. It also suggest that genotype HbAB is favoured through natural selection in ruminants of Northern Guinea savannah Zone of Nigeria.

Salako *et al*. (2007) however reported higher frequency of allele B in population of West African Dwarf sheep at low al

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Nigeria (Forest Zone). Evans *et al*. (1958) had earlier suggested that allele A of haemoglobin type has a selective advantage at high altitudes because it constituted the most common allele in highland breeds of English and Scotish sheep. It has been estblished that the affinity of allele A for oxygen is 30 to 50% greater than allele B (Dawson and Evans, 1965; Chamley and Holland, 1969). Dodgson and Holland (1993) suggested that the faster rate of release of oxygen from HbBB may be because it has lysine at position HCl in the β-chain whereas the other haemoglobins have arginine. Oxygen level reduces as the altitude increases above sea level (Ian, 1998).

5.1.3 Effect of Breed of Sire and Dam on Growth Traits

The results of this study confirmed the earlier reports by several authors (Jamison *et al*.,1961; Taiwo *et al*., 1982; Yapi-Gnaore *et al*., 1997 and Casellas *et al*., 2007) that breed of sire and damexert great effect on birth weight and subsequent growth traits of sheep to varying degree. The report of Bourfia and Touchberry (1993) on the effect of breed of sire and damson growth traits of three Moroccan sheep breed is similar to the result from this study. Balami sire and dam produced the fastest growing lambs,thus supporting earlier reports byAdu and Ngere (1979) and Oni (2002).

5.1.4 Effect of Lamb Genotype on Growth Traits

The heaviest birth weight (3.44±0.17 kg) of crossbred lambs of Yankasa rams and Uda ewes (YK X UD) in this study is within the range of birth weight reported by Adu and Ngere (1979), Kwatu *et al*. (1983), Oyedipe *et al*. (1986) and Otchere *et al*. (1987) for sheep of Northern Nigeria(Balami, Uda and Yankasa). However, the birth weight of pure Balami lambs (BL X BL) of 2.6

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for the same breed by Adu and Ngere (1979). Birth weight in this study varied according to the report of Holst *et al*. (2002) which showed that lamb genotype affected birth weight (Merino and crossbred lambs). Crossbred lambs involving Balami as dam (UD X BL and YK X BL) expressed heterotic effect over the purebred lambs at birth. Bourfia and Touchberry (1993) also observed similar heterotic effect in three Moroccan breeds of sheep.

Subsequent growth rate favoured BL X BL lambs (though not higher in birth weight) more than other lamb genotypes. This is contrary to the report of Greenwood *et al*. (2000) which stated that high birth weight lambs grew more muscle per kilogramme of weight gain. The better growth rate of BL X BL lambs than the other lamb genotypes in this study could be as a result of inherent superior genetic potential of the breed for growth (Adu and Ngere, 1979). The birth weight (1.91±0.02 kg) of West African Dwarf (WAD) sheep as reported by Zahraddeen *et al*. (2007) is lower than values for all lamb genotypes of in this study. This observation supports the earlier report (Adu and Ngere, 1979) that WAD is the smallest breed of sheep in Nigeria.

5.1.5 Effect of Dam's Haemoglobin Type on Growth Traits

Lambs of dams with HbAB and HbBB were heavier than those of HbAA at 90 and 180-Day while HbBB dams had the heaviest lambs at 360-Day. This result is in agreement with the earlier report of Gootwine (1988) that ewes of HbAB genotype showed significant advantage over other haemoglobin genotypes in lamb weight changes. Haemoglobin type BB showed possible advantage in growth of lambs at later ages which indicates that the earlier su

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haemoglobin type (HbAB) over the homozygous (HbAA) could be as a result of epistatic effect of allele B of the dams haemoglobin for faster growth rate in the heterozygous form. Barowicz and Pacek (1984) had earlier observed that Polish Long-Wool ewes of the haemoglobin type BB had higher lamb birth weight than ewes of HbAA and HbAB.

5.1.6 Effect of Type of Birth and Sex of Lambs on Growth Traits

The observed effect of type of birth on growth rate in this study is in agreement with Buvanendran *et al*. (1981); Afolayan (1996); Akhtar *et al*. (2001) and Babar *et al*. (2004). The difference in birth weight in favour of singles than twin lambsispossibly attributable to the stress the twin lambs suffered from diminished nutritional supply *in utero* (Ademosun, 1973; Adu, 1975; Ngere *et al*., 1979; Buvanendra *et al*., 1981; Taiwo *et al*; 1982 and Hassan, 1987; Gardner *et al*., 2007).Robinson *et al*. (1977) reported that, for lambs *in utero*, as the number of fetuses increases, the number of caruncles attached to each foetus decreases, thus reducing the feed supply to foetuses and hence birth weights of the lambs.Knight *et al*. (1988); Osinowo *et al*. (1994); Vatankhah *et al*. (2000) and Fogarty *et al*. (2005) had separately stated that birth weight of lambs decreased as litter number increased.Single born lambs were heavier than twins at all stages of growth considered, this is in agreement with the reports of Carrillo and Segura (1993) on Pelibuey and Barbados sheep of Mexico; Salako (2002) on WAD and Yankasa sheep and Ceyhan *et al*. (2011) on Sakiz sheep.

Contrary to expectations, sex of lambs had no effect on overall birth weight and 360-Day (yearling) weight. Several authors had reported that sex of lambs exerted great

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influence on birth weight and subsequent growth rate because of sexual dimorphism. Klindt (2005) had explained that endocrine functions are often sexually dimorphic, different in males and females. He explained further that programming of sexual dimorphism begins with embryonic expression of the sex-determining gene (SRY) in males and secretion of Mullerian-inhibiting hormone (anti-Mu¨llerian hormone, MIH), which prevents development of internal reproductive tracts of females. The expression of sexual dimorphism in terms of overall body weight gain (considering the entire population) was possibly masked by genetic potentials for fast growth expressed by females of some crossbreeds and BL X BL. However, it was noted that male YK X UD lambs had heaviest birth weight, and subsequent body weight to 360-Day favoured male BL X BL lambs in agreement to the already stated reasons.

5.1.7 Average Daily Gains (ADG) and Relative Growth Rate (RGR)

Balami rams sired lambs that had the highest average daily gains from birth to 360-Day. This result was in agreement with Adu and Ngere (1979) who stated that Balami is the fastest growing sheep breed among indigenous sheep breeds in Nigeria. The overall ADG90 (63.27±3.80 g); ADG180 (37.17±2.37 g) and ADG360 (37.17±2.37 g) are lower than 79.3 g/day reported by Akpa *et al*. (1994a) for Yankasa lambs and 162.0 g/day reported by Gaafar *et al*. (2011) for Rahamani and Finn sheep.The linear decrease in ADG as the lambs aged in this study is in agreement with the report of Oni *et al*. (1989) and Iyiola-Tunji (2007). They reported that body weight of Bunaji calves and Red Sokoto kids with higher birth weight grew slower, because of increasing body surface area.

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Average daily weight gain for body weight were affected by breed of sire and dam; lamb genotypes and type of birth. However, sex of lambs did not affect ADG180 and ADG360 contrary to the results from other investigations (Mandal *et al*., 2003; Mokhtari *et al*., 2008; Mohammadi *et al*., 2010; Thiruvenkadan *et al*., 2011). The report of Swenson and Reece (1993) had also attributed the difference in body weight gains of male and female lambs with advancement of age to the increasing differences in endocrine system.

The relative growth rate (RGR) in this study generally decreased as the lambs aged as reported by Adu and Ngere (1979); Lewis *et al*. (2002) and Ulutas *et al*. (2010). Balami rams and ewes had lambs with higher RGR from birth to 360-Day. Adu and Ngere (1979) had stated that Balami is the fastest growing sheep in Nigeria. The RGR90 and RGR180 of some of the crosses (YK X BL, UD X YK and BL X YK) were slightly higher than those of purebred lambs of Yankasa and Uda. This may be due to the expression of heterotic effect. The coefficients of relationships between RGR90 and ADG90, RGR180 and ADG180, RGR360 and ADG360 were 0.704, 0.730 and 0.977, respectively. The high coefficients of relationship between these two proportionate measures of growth rate revealed some level of similarities in their mode of estimation. Any of the two (ADG and RGR) can be used when considering proportionate growth of sheep.

4.1.8 Variability of Gestation Length and Litter Size

The overall gestation length (151.99±0.19 days) observed in this study is similar to 151±1.9 days reported by Gonzalez *et al*. (1972) for West African crossbred lambs. The

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gestation length of 145.2 days reported by Thrift and Dutt (1972) is lower than the average gestation length reported in this study. The variability of gestation length observed in this study corroborates the reports that several factors contributed to variations in gestation length of sheep. The factors included sire and dam breed (Fogarty *et al*., 2005), dam age, litter size and lamb weight at birth (Cardy and van Vleck, 1978 and Amoah *et al*., 1996). Longer gestation lengths had been recorded in older dams (Vatankhah *et al*.,2000; Koyuncu *et al*. 2001). Ewes carrying single lambs also had shorter gestation lengthsas compared with those carrying multiples (Osinowo *et al*., 1994; Vatankhah *et al*., 2000; Koyuncu *et al*., 2001; Dwyer, 2003; Fogarty *et al*., 2005).

Lamb weight was also reported to have influenced gestation length (Knight *et al*., 1988; Osinowo *et al*., 1994; Vatankhah *et al*., 2000; Fogarty *et al*., 2005) and was longer when the dam was carrying a male lamb (Koyuncu *et al*., 2001; Vatankhah *et al*., 2000; Fogarty *et al*., 2005). Bradford *et al*. (1972) and Dwyer *et al*. (1996) concluded that genotype of lamb is more important than that of dam in determining gestation length. Selection for reduction in gestation length may indirectly increase prolificacy (Osinowo *et al*., 1994; Vatankhah *et al*., 2000).

In this study, Uda sire and dam showed clear advantage over Balami and Yankasa in terms of litter size in this study. The highest litter size (1.30±0.11 and 1.29±0.18) recorded for UD X YK and BL X UD are similar to the values (1.31) obtained by Tuah and Baah (1985) for WAD sheep in Ghana; 1.33 for WAD sheep in humid Nigeria (Odubote, 1992). Uda sheep reared in Niger (Gaillard, 1979) and Chad (Dumas, 1980) however recorded lower litter sizes (1.10 and 1.11 respectively) than the ones in this

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study.The difference in litter size in this study could be as a result of inherent genetic potential for multiple births in Uda sheep than in the other breeds considered.

5.1.9 Mortality Rates of Sheep

The overall mortality of lambs in the studied population from birth to 90-Day (14.06%) is in agreement with the average mortality rate of 9 to 20% reported by Binns *et al*. (2002) in most of sheep producing countries. Subsequent mortality rates during post-weaning period (90 to 180-Day and 180 to 360-Day) in this study negates the earlier understanding that majority of lamb losses due to death (mortality) were supposed to be during the pre-weaning (birth to 90-Day) period (Otesile *et al*., 1983; Mousa-Balabel, 2010). The average post-weaning mortality rates (30.91% and 51.75% for 90 to 180-Day and 180 to 360-Day, respectively) in this study are exceptionally higher than values reported by Wilson (1976) and Matthewman (1980) and are not acceptable for commercial interest in sheep production.

The pure Balami lambs and some crosses of Balami as ewe had no lamb mortality from birth to 90-Day in contrast to the claim by Adu *et al*. (1986) that micro-climatic adaptation of Nigerian sheep breed was one of possible reasons for high mortality rate of breeds reared in agro-ecological zones to which such breed has not adapted.Pure Balami lambs also recorded no mortality from birth to 180-Day.

Contrary to expectation, higher percentage of lamb loss from birth to 90-Day (Pre-weaning period) was recorded for single-born lambs (14.47%) than for twins (12.12%) and from 180 to 360-Day (52.08%

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mortalitieswere generally higher for male lambs than females at all stages of growth. Van Niekerk and Pimentel (2004) observed that mortality rate increased proportionally among twins as the number of twin birth increased. Twin lambswere reported (Hunter, 1957) to have obtained 68% of milk obtained by a single lamb, hence the differences observed in the pre-weaning mortality of single-born and twin-born lambs. Higher litter size had been shown to reduce birth weight and hence the survival of lambs (Turkson and Sualisu, 2005).

It is known that several factors could be responsible for pronounced mortality rate in sheep production. The magnitude of each factor however, differs among different husbandry and management practices (El-Hassan and Abu-Nikhaila, 2009). Some authors (Wiener *et al.*, 1983; Upton, 1984; Wilson *et al*, 1985) had described the effects of the number of lambs born, parity, management, nutrition and other environmental variables on mortality rate, but only a few (Dennis, 1974; Otesile *et al*, 1982; Eales *et al.*, 1983) gave information on the actual causes of death.Dennis (1974) attributed lambs deaths in Western Australia to acquired neonatal infections. Otesile *et al*. (1982) listed pneumonia, haemonchosis, *peste de petitis ruminants* and enterotoxemia as the common causes of mortality of sheep in the humid zone of Nigeria. Haughey (1983) stated that about 65% of perinatal lamb losses in Australia were caused by the starvation-mismothering-exposure (SME) complex, a syndrome comprising birth injuries, cold-induced starvation, abnormal behaviour of newborn lambs, inadequate milk supply, udder and teat abnormalities.

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5.1.10 Heritability Estimates for Growth Traits and Linear Body Measurements of Yankasa Lambs

The low h^2 estimates at birth in this study indicateshigh influence of environment on the traits at that stage. Carrillo and Segura (1993) had also obtained similar low h^2 for birth weight of Barbados and Pelibuey sheep in tropical environment of Mexico. However, Boujenane and Kerfal (1990) as well as Bosso *et al*. (2007) obtained moderate h^2 for birth weight and high estimates for weaning weight in D'man and Djallonke (WAD) sheep in Morocco and Gambia, respectively. The high h^2 estimates for body weight and some of the linear body measurements at 180 and 360-Day in this study are in agreement with Das *et al*. (1993) who stated that post-weaning growth generally has higher heritability estimates than pre-weaning growth. They stated that environmental factors, in relation to non-additive genetic factors, had more influence on early lamb gain than on gains later in the lamb's life. Harrington *et al*. (1962) and Thrift *et al*. (1973) attributed this observation to the high maternal influence associated with lamb growth performance early in life. High maternal influence has a tendency to increase the component of environmentalvariance to the lamb thereby lowering heritability estimates.

5.1.11 Phenotypic and Genetic Correlation for Growth Traits and Linear Measurements of Yankasa Lambs

Phenotypic (r_p)and genetic(r_g) correlations may be positive or negative and will influence the performance of one trait when the other trait is subjected to selection. They will also influence the rate at which the traits respond to simultaneous selection, such as within an index (Garrick, 2005). The r_p between body weight and linear body

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measurements were mostly medium at birth (except neck length which had low r_p with birth weight) and 90-Day. Subsequently, the relation was high and positive at 180 and 360-Day. The r_p among linear body measurements were mostly high and positive from birth through to 360-Day. The positive and high r_p between body weight and most of the linear body measurements indicate that the general growth of the lambs is directly proportional to the growth of the other body components (leg, loin, chest, neck and back) as well as increase in height. Therefore, any of the components can be used as selection index for the improvement of Yankasa sheep.

Most of the r_g for genetic association among body weight and linear body measurements were not available. The r_g(where available) were generally high and positive for the association between body weight and linear body measurements. This is an indication that selection for one trait will simultaneously improve the other. Lynch (1999) had reported that genetic correlations are particularly difficult to assess because they require accurate estimates of three parameters: the genetic variances of the two traits, and the genetic covariance between them. Because all three estimatesare generally obtained from the phenotypic covarianceof relatives, they can take on any value. Thus,contrary to the situation with the well-known product-moment correlation, estimates of the genetic correlationcan fall outside of the parametric limits (±1)or can be undefined when one of the geneticvariance estimates is negative (Hill and Thompson, 1978). Samplesizes of a few thousand pairs of relatives are oftennecessary to achieve estimates that can confidently beinterpreted at the level of even single significant digits(Van Vleck and Henderson, 1961; Brown, 1969; Klein,1974; Visscher, 1998), although a simple

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knowledgeof the sign of the genetic correlation can be achievedwith less, but still substantial, effort.

5.1.12 Prediction of Body Weights using Linear Body Measurements

The accuracy of functions used to predict live weight or growth characteristics from live animal using linear body measurements is of immense financial contribution to livestock production enterprises (Afolayan *et al*., 2006). The prediction equations generated in this study incorporating different predictors agree with Yakubu (2010) who stated that morphometric characters of sheep are genetically controlled and unique to each breed of sheep. Baffour-Awuah *et al*. (2000) had suggested that predictors that consider volume of an animal in terms of circumference and body length tend to give better accuracy of prediction of live weight of animals. Semakula *et al*. (2010) affirmed that linear body measurements together with live body weights were influenced significantly by breed, age and sex of the animal. The prediction equations for sheep of Northern Nigeria were generated with intense consideration of the foregoing facts (Baffour-Awuah *et al*., 2000; Afolayan *et al*., 2006; Semakula *et al*., 2010; and Akpa *et al*., 2010).

Loin girth (0.352%) and chest girth (5.38%) were the major contributors to the variability of 90-Day weight of the combined population of the crossbred lambs. This result is in agreement with the report of Akpa *et al*. (2010) who had indicated some measure of similarity in height at wither, body length and heart girth of Balami, Uda and Yankasa sheep of Northern Nigeria. The medium phenotypic correlation coefficients between 90-Day weight and linear body measurements might have contributed to the relatively high c

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prediction equations generated for 90-Day weight of all classes of lambs that involved Yankasa sheep.

Height at wither featured prominently in the equations for the overall population, YK X YK, crosses (both sexes), male YK X YK, female UD X UD and male crosses. This is in agreement with Khan *et al*. (2006) who had reported a very high phenotypic correlation (0.746) between body weights of goats found in Peshawar, Pakistan and height at wither at age 4 to 12 months.

All the prediction equations for 180-Day and 360-Day (yearling) weight of sheep of Northern Nigeria and their crosses had high R^2(0.69 to 0.954) which are similar to those reported earlier for Yankasa sheep (Afolayan *et al*., 2006 and Yakubu, 2010).These high coefficients of determination (R^2) are indication of high level of reliability of prediction equations for body weight using linear body measurements in this study.

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CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

This study was designed to genetically evaluate the potential for improved growth rate and some reproductive traits of Balami, Uda and Yankasa sheep in the Northern Guinea Savannah Zone of Nigeria. The study was conducted at the Sheep Project Unit of Small Ruminant Research Programme of National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika, Zaria. The experimental animal were reared using semi intensive method while nursing ewes and their lambs were kept intensively from birth to weaning at 90 days.

Diallel breeding was used for the study. A total of 65 Yankasa, 23 Uda and 16 Balami ewes were served by 4 Yankasa, 3 Uda and 3 Balami rams to produce 192 lambs used in the study. Blood samples were collected from the rams and ewes. The samples were analysed for haemoglobin polymorphism within the parental population using cellulose acetate electrophoresis. Body weight in kilogramme and linear bofy measurements (neck length, back length, height at wither, loin girth, chest girthand leg length)in centimetres of lambs were recorded at birth, 90, 180 and 360-Day.

The data for the study were analysed by the General Linear Model Procedures of SAS using fixed effect model that incorporated lamb genotype, dam's haemoglobin type, sex of lambs and type of birth as fixed effects. Pair-wise difference was used to separate the mean. Chi square was used to

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haemoglobintypes in the population. The heritability, genetic and phenotypic correlations for growth traits were estimated using the sire model of Harvey. Step-wise regression of SAS was used to generate prediction equations for the association between body weight at various age and linear body measurements.

The haemoglobin type HbAB was the most predominant in the studied population. Allele A of the haemoglobin type was the most numerous. Lambs of Uda crosses were heaviest at birth. However, pure Balami lambs (BL X BL) were superior in body weights at 90 and 180-Day to all other lamb genotypes. The heaviest 360-Day weight (18.73±1.53 kg) was recorded in lambs from dams with haemoglobin type BB.

Sex had no significant effect ($P>0.05$) on birth and 360-Day weights of lambs, but affected ($P<0.05$) weights of lambs at 90 and 180-Daysshowing better performance of male. The average daily gain (ADG) and relative growth rate (RGR) were affected ($P<0.05$) by dam's haemoglobin type, lamb genotype, type of birth and sex of lambs. The HbAB and HbBB types both recorded higher ADG90 and ADG360. The coefficients of relationships between RGR90 and ADG90, RGR180 and ADG180, RGR360 and ADG360 were very high.

Yankasa rams and ewes produced lambs with the shortest gestation lengths (151.84±0.23 and 151.85±0.20 days, respectively) while the longest gestation length was recorded for lambs of Balami rams or ewes. The highest litter size was recorded in crosses of Uda sire (UD X YK) or dam (BL X UD).

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The overall mortality of lambs in the studied population from birth to 90-Day, 90 to 180-Day and 180 to 360-Day were 14.06, 30.91 and 51.75%, respectively. However, BL X BL recorded no mortality from birth to 90-Day and 90 to 180-Day. Most lamb genotypes recorded very high mortality from 180 to 360-Day with the exception of YK X BL and BL X YK which had no mortality from 180 to 360-Day.

Some of the linear body measurements had medium to high and positive phenotypic and genetic correlations with body weight at all stages of growth of lambs. Heritability estimates for Yankasa lambs were very low at birth, but high and positive at 180-Day (0.765±0.514) and 360-Day (0.805±0.961). The prediction equations for body weight featured prominently the linear body measurements at different proportions as the lambs grew. The coefficients of determination (R^2) of the prediction equations were mostly low at birth but were substantially high at later ages of growth.

6.2 CONCLUSIONS

1. Selective advantage possibly favoured HbAB and allele A of the haemoglobin genotype in the studied population while lambs of HbBB dams had the faster growth rate.

2. Balami sheep (used as either sire or dam) expressedtheir superior genetic potential in terms of faster growth rate than Uda and Yankasa.

3. Values obtained for relative growth rate (RGR) and average daily gain (ADG) were similar in the studied population.

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4. Heritability estimates of body weight and some linear body measurements for Yankasa lambs were high at 180 and 360-Days indicating lesser effect of the environment on the traits in the studied population.

5. Linear body measurements that consider volume of animal in terms of circumference (chest girth and loin girth) and body length (back length, neck length and height at wither) tend to predict live weight of lambs more accurately.

6.3 RECOMMENDATIONS

1. Genetic improvement of growth traits of Nigerian sheep using indigenous stock should focus on the exploitation of genetic potentials in terms of faster growth rate of Balami sheep.

2. Efforts to improve survivability of lambs produced by dams with HbBB should be considered because they have great potential for faster growth rate.

3. Uda sheep breed should be used for breeding programmes on improvement of litter size.

4. Either ADG or RGR should be used as daily growth growth indicator when considering selection of lambs as parents of the next generation.

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5. Selection for improved growth rate in the population of Yankasa sheep should be based on individual weight records of lambs at 180-Day.

6. Weighing charts and bands should be produced on the basis of prediction equations.

7. Studies should be conducted on how to increase productivity of sheep and prevent post-weaning mortality.

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APPENDICES

Appendix 1: DETAIL DESCRIPTION OF SHEEP OF NORTHERN NIGERIA

Highlights of the key features of Northern Nigeria sheep breeds are given below.

Appendix 1. 1: BALAMI

Balamisheep has also been called Bornu at various times because people of the Bornu tribe own the breed in large numbers. It is the pre-dominant breed in the North-Eastern part of the country around the Bornu State. This breed is characterized by white hairy coat, convex head, long tail, large and droopy ears, and presence of large spiral horn in the male (Plate X) but not in the female. Males also have a well developed dewlap (chest region) which occurs like a fold of skin with a mane (hair). The Balami is a large breed with average adult weight of 45-60kg for male and 35-40kg for females. Average height at wither is about 79-89.5cm for male and 76.5 to 89.4cm for females.

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Plate X: Balami ram

Appendix 1. 2: UDA

This breed is pied coloured (Plate XI and XII). They are also called 'Fulani' or 'Bali-Bali' since the Fulani pastoralists owned large number of this breed. The breed is found in the Sahelo-Sudan vegetation zone of Nigeria with large flocks being found near Kotangoraarea (Niger State) in the dry season. The animal's characteristics include convex face, pied coat colour (could be entirely black or brown in the frontal half of the animal, while the rear half is completely white), long, large and pendulous ears with males bearing white large spiral horn. The Uda is a large breed with a mature weight of 45-55kg for males and 35-45kg for females. Average height at wither is 74.89.3 for males and 71.5-83.0cm for females.

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Plate XI: Three week old Uda lamb



Plate XI

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Appendix 1. 3: YANKASA

The breed is also called Hausa. This is apparently the most dominant breed of sheep in Nigeria being most numerous and most widely distributed among Nigerian breeds of sheep. It is normally found mostly in the Northern states of Nigeria occurring within the Sahelo-Sudan and Guinea Savannah area. These animals are of medium size compared to the Balami and Uda which are larger ones and the dwarf breed of the Southern Nigeria.

Average adult weight is 35-40 kg for male and 25-40 kg for females. The colour patterns are predominantly white with black patches around the eyes, ears, muzzle and occasionally feet (Plate XIII). The females have a cartilaginous outgrowth below the chin often called tassles. The males have hairy dewlap. Unlike the Balami and Uda which are adapted only to the arid environment of the North or the South-based dwarf breed adapted to humid conditions. The Yankasa is found throughout the semi-arid and sub-humid zones of Nigeria. The breed constitutes about 60% of the estimated 22 million sheep in Nigeria (Aliyu, 1990). At NAPRI, males have been obtained that weighed 45 kg and females 39 kg.

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Plate XII: Yankasa ram

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Appendix-Table 1: Analysis of Variance for Birth Weight

Source of variation	df	Mean square	P value	LOS
Dam breed	2	0.178	0.0569	NS
Sire breed	2	1.417	0.0396	*
Haemoglobin type	2	0.754	0.2204	NS
Lamb genotype	6	1.797	0.002	**
Type of birth	1	2.737	0.0198	*
Sex	1	1.052	0.1465	NS
Season of birth	1	0.2401	0.5138	NS

df = Degree of freedom; P value = Probability level; LOS = Level of Significance; NS = Not significant

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Appendix-Table 2: **Analysis of Variance for 90-Day Weight**

Source of variation	df	Mean square	P value	LOS
Dam breed	2	1.5003	0.929	NS
Sire breed	2	4.7489	0.045	*
Haemoglobin type	2	16.2161	0.029	*
Lamb genotype	6	6.7462	0.0105	*
Type of birth	1	54.2197	0.0117	*
Sex	1	50.5755	0.95	NS
Season of birth	1	0.0807	0.164	NS

df = Degree of freedom; P value = Probability level; LOS = Level of Significance; NS = Not significant

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Appendix-Table 3: Analysis of Variance for 180-Day Weight

Source of variation	df	Mean square	P value	LOS
Dam breed	2	55.2437	0.0060	**
Sire breed	2	31.765	0.0493	*
Haemoglobin type	2	6.0409	0.0256	*
Lamb genotype	6	16.2821	0.0158	*
Type of birth	1	28.2764	0.0397	*
Sex	1	54.8641	0.0227	*
Season of birth	1	61.613	0.0253	*

df = Degree of freedom; P value = Probability level; LOS = Level of Significance

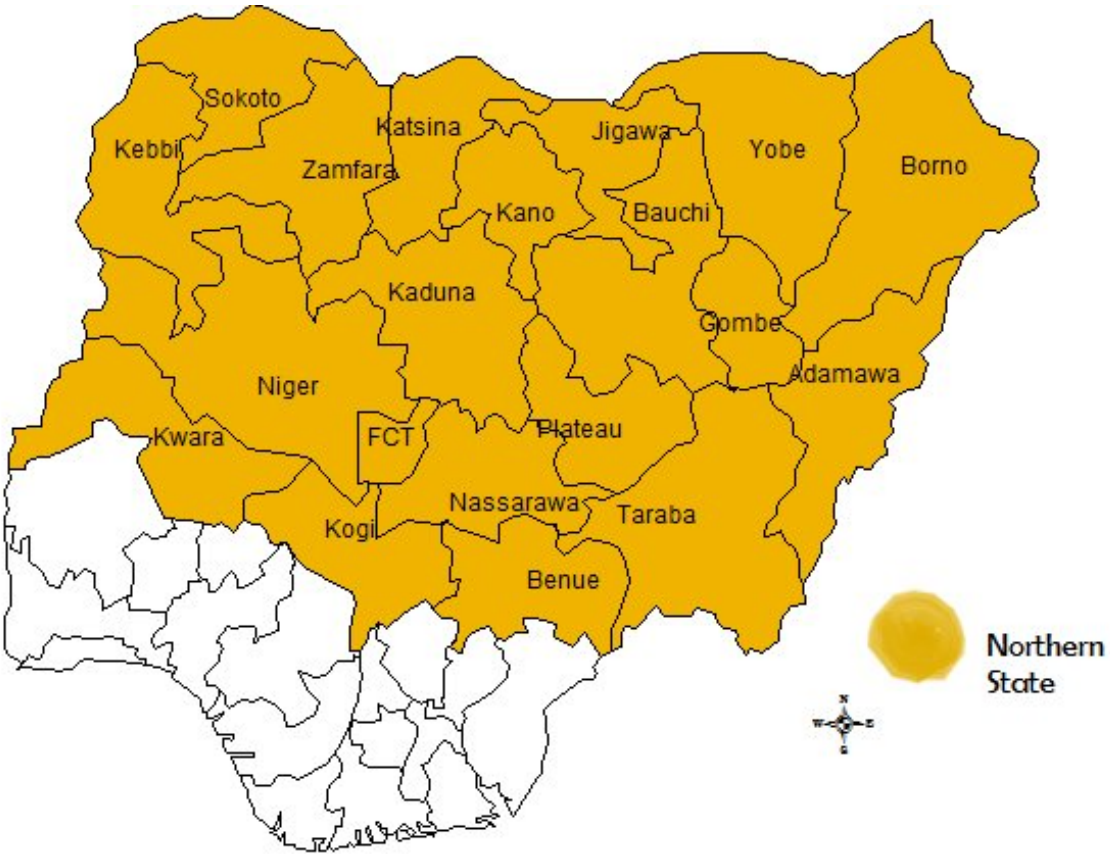
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Appendix-Table 4: Analysis of Variance for 360-Day Weight

Source of variation	df	Mean square	P value	LOS
Dam breed	2	79.4293	0.0104	*
Sire breed	2	71.4162	0.0158	*
Haemoglobin type	2	16.0299	0.0365	*
Lamb genotype	6	21.1546	0.0258	*
Type of birth	1	24.4091	0.0217	*
Sex	1	16.768	0.3048	NS

df = Degree of freedom; P value = Probability level; LOS = Level of Significance; NS = Not significant

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Appendix-Figure 1: Map of Nigeria showing the 19 Northern States

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