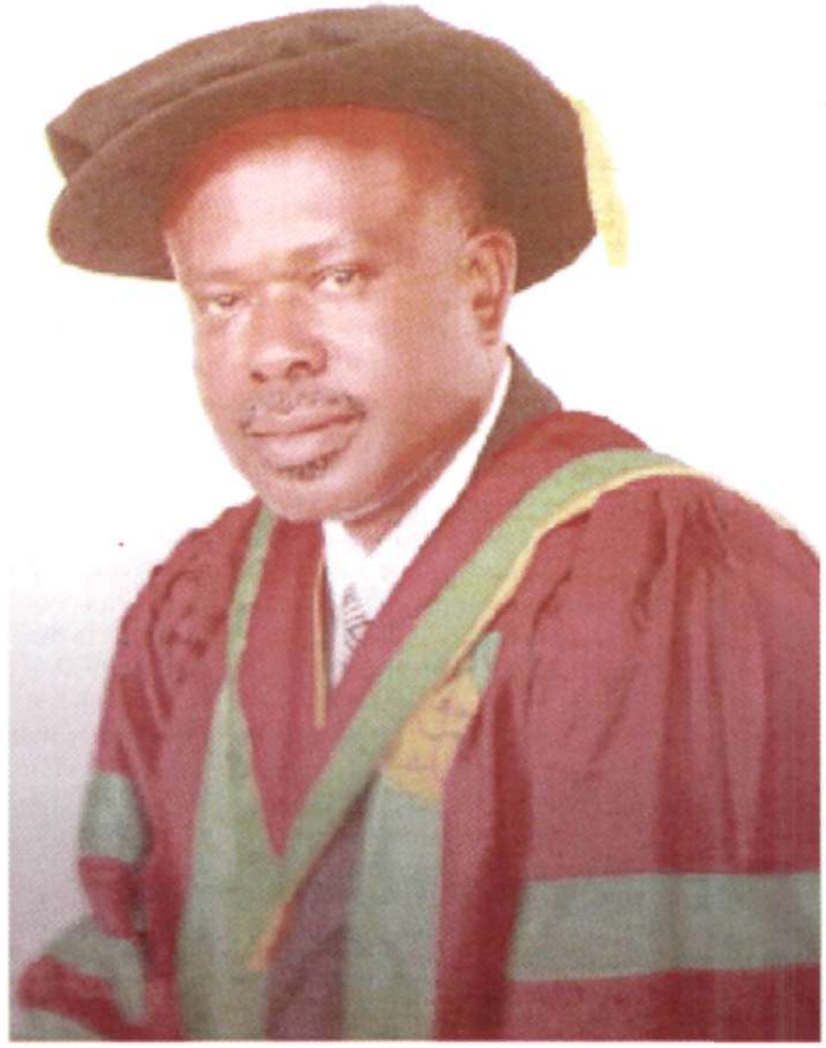
Chapter Three

The Search for Dairy Goat in Nigeria: The Northern Guinea Savannah Experience

The Search for Dairy Goat in Nigeria: The Northern Guinea Savannah Experience

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My profound gratitude goes to God Almighty my creator and my strong hold, His only begotten son Jesus Christ my redeemer and the Holy Spirit my comforter and sanctifier-to the three persons in one God be all the Honor, Adoration and praise forever and ever, Amen. All that I am, have and will become come from Him and for Him; to Him be the glory!

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Greatest ABUSITE, I can do nothing without you. You are the pride of good studentship in Nigeria, you deserve all the "gbosas". Thank you and keep shining. Without you the wonderful audience the essence of this presentation would not have been visibly appreciated.

Thank you for coming and for listening good.

Preamble

I am greatly honored by this opportunity to deliver this Inaugural Lecture. Today's lecture is the fourth from the Faculty of Agriculture and the first from the Department of Animal Science.

I am indeed grateful to the University for inviting me to give account of my academic stewardship after seven years of attaining my professorial chair in the Department of Animal Science, Ahmadu Bello University Zaria. The THRUST of my Animal Breeding and Genetics research efforts in the Department of Animal Science of this great University centered around the provision of quantity and quality milk, meat and egg to overcome hunger and ensure food security in Nigeria. This THRUST I am executing through studies in goat, cattle, sheep, rabbit, poultry and others. To date, I have a total of 203 reported studies to the Scientific community of the world, distributed as follows: Goat 56, Cattle 46, Sheep 33, Rabbit 21, Poultry 38 and Others 9. Today we are going to look at my contributions in this direction in the goat species. My lecture is therefore titled "The Search for Dairy Goat in Nigeria: The Northern Guinea Savanna Experience"

Nothing gives me greater pleasure than to speak about dairy goat in Nigeria, my life passion and dream. In my 26 years of surgeon in Ahmadu Bello University, I have been searching and looking for answers to the problem of food insecurity, hunger and malnutrition through the provision of quality and quantity animal protein. My approach to this, had been in the continuous attempts to develop and empower the small holder livestock farmers by improving their stock performance and production practices, particularly for small ruminants (sheep and goats). My focus on goats," the poor man's cow" in achieving this mission, no wonder has often nick named me the "Dairy Goat Man" among my peers in the Animal Science world. This lecture therefore will present all my research effort in the Nigerian indigenous goats with the main target at developing the truly Nigerian Dairy Goat.

The Search for Dairy Goat in Nigeria: The Northern Guinea Savanna Experience

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Introduction

In Sub-Saharan Africa, probably more than in any part of the world, the livestock sector is integral to the livelihood of the populations. It contributes significantly not only to food security and nutritional quality of the diet but also to national economies. In addition, the demand for livestock product is increasing very rapidly in this region owing to a combination of population growth, rising incomes and urbanization (Hoste, 1999). Therefore, the formulation and implementation of research and improvement strategies designed to meet these challenges is essential.

The World Health Organization (WHO) recommended protein requirement of an adult is 0.5-1.0g/kg/body weight/day (65g/day) and approximately 20g of this should come from animal protein source (Flchowsky, 1999). On the average, about 25g of animal protein is available per person per day and these ranges between 9g in Africa and 65g in north America (Flchowsky, 1999).Thus indicating that protein of animal origin for Africa is far below the recommended 20g per capita per day.

Animal milk is one good source that can be used to bridge this gap. Out of 537403x103 metric ton of total milk production from popular dairy animals (cow, buffalo, sheep and goats), goats contribute 10144 x 103 metric tons which is about 5% (FAO, 1997). In Africa, goats contribute 2078x103 metric ton which is about 9.2% of total milk production (22501x103 tone) from dairy animals in Africa (FAO, 1997).

The properties of a goat are not only determined by its genetic potential but also by the possibilities to manifest this potential. The extent to which it is possible to do so is determined mostly by the environmental factors (climate, feed, housing, health and general care) and animal factors (age , sex, and production capacity). A good dairy goat gives about3.4 liters of milk daily which is 900-1800kg milk in a 305 day lactation period (Haenlein,

1992). Compared to cows, goats will be nutritionally more economical because of their smaller size; requires less food and of a type much cheaper than a cow. This implies that the potential production of milk from goats could be further stimulated to increase the overall milk supply from dairy animals. Above all, goat milk fat and protein are readily digested; and the constituent amino acids (Jandal, 1996) absorbed more efficiently than those of cows.

There is dearth of information on dairy potentials of Nigeria goats. However, reviews of the performance of these goats show favorable reproductive characteristics (Akpa, 1999a; Iyiola-Tunji et al., 2008b) such as high fecundity and short generation interval. The red Sokoto goats are the most numerous (17.3 million) and widely distributed goat breed in Nigeria (Pagot, 1992). They are very prolific; twin births are common and three or four kid births are not unusual (Adu et al., 1979; Abubakar et al., 2013).

The Red Sokoto goat is the predominant breed of goats in Nigeria. It is commonly found among the agro-pastoralist mainly within the northern sub-humid and semi-arid zones of the country (Akpa et al., 2001a). Available information on the milking of indigenous African goats indicate that not much is known about their dairy characteristics (Akpa et al., 2001b). From existing records, lactation milk yield ranged between 24.0 and 120.3kg, with peak yield observed in the Red Sokoto goats of Nigeria (Egwu et al., 1995; Ruvuna et al., 1995; Akpa,1999b). Ehoche and Buvanendra (1983) reported that the average Red Sokoto goat produced 545g of milk per day. Also, in monitoring Red Sokoto goats on the field, Akpa and Duru (1999) showed that one day or average of two days record in a week was adequate in estimating total milk yield and therefore, could be used to monitor their yield characteristics.

The milk production of Red Sokoto goats at the agro-pastoral system for 120 days was reported to be 79kg with an average daily yield of 0.664kg (Akpa1999b). They are easily affordable to small scale farmers which make them or their crosses ideal dairy animals for rural farmers. Therefore, the overall objective of this lecture is to highlight my research experiences in goats aimed at promoting effective, efficient and sustainable dairy goat development in Nigeria. The presentation is grouped into goat production and management; goat herd structure and breeding practices; reproductive characteristics; body growth and measurements;

Morphological and their gene, and genotypic frequencies; matrix of genetic distance; blood biochemical polymorphism; adaptive and blood biochemical characteristics; milk yield, composition and estimations; lactation pattern and characteristics; mammary morphology and relationship with milk yield; incidence of supernumerary teats; genetic parameters and relationship estimations; and genomics studies.

Goat Production and Management

Africa has a population of 205 million sheep and 174 million goats, representing approximately 17% and 31% of the world total, respectively. About 75% of African livestock are associated with smallholders and agro-pastoral farming systems. Nigeria has over 38 million goats representing 4% of the world production (FAO, 2006), contributing about 20% of all the meat eaten in Nigeria. The potential of goat production in Nigeria is high as goats are found in all the ecological regions of the country. The high percentage of these animals are raised at small holder farmers level where they are managed extensively under the traditional system of production (Ikwuegbu et al.,1992) which had evolved different strategies and practices to tackle livestock production problems (Akpa, 2001; Akpa et al, 2002b; Akpa and Mohammed, 2004; Iyiola-Tunji et al, 2010). Despite this immense contribution to the world population of small ruminants, the African small ruminants produce only 14% of the worlds' milk and 15% of the worlds' skin (Ademosun, 1994).

Urbanization tends to require more processed foods, high value cereals, livestock products and vegetables. To meet this demand, agricultural production must increase and become more market oriented to supply urban areas. For livestock, this can be improved through better management. Production problems, possible interventions and animal performance need to be identified within the prevailing system. On-farm work can be complemented by on-station test for comparative performance evaluation and technology development. Therefore, for any production improvement to be successful, it must produce results relevant to the production system and increase economic returns to the producer. Studies were conducted on household goat herd size and factors affecting it in Zaria (Akpa et al.,1995b). The results revealed an average herd size of 19.8 goats which was significantly influenced

by source of foundation stock, labour and location. There was strong positive relationship (r = 0.64) between herd size and family size and length in production. Attempts to elucidate the impact of management strategies on reproductive traits of goats at a small holder level (Akpa et al.,1995a) revealed that grazing period, water and feed supply significantly ($P<0.05$) influenced age at 1st conception and maximum litter size obtainable. Goats that were grazed morning- evening and supplemented with feed and regular water supply performed better than others.

The value of fodder for goats has been emphasized and their utilization represents an important strategy in developing countries (Akpa et al., 2000b). The relative low productivity of animals in the semi-arid zone of Nigeria is mainly due to shortage of feeds and fodders, especially during the dry season period of the year (Hamidou et al., 2008). Types of feed and feeding system and their effects on household goats' production in Zaria were investigated (Akpa et al., 1995b). The feed types used by goat producers in various combinations either as conventional rainy or dry season feeds were offals, grasses,(hay or fresh), cotton seed cake (CSC), groundnut cake (GNC), groundnut haulms, beans pods, food scraps, leaves, potatoes, farm residues and silages. Most producers grazed (97.8%) their goats mainly in the morning and evening (46%) and all time (39.1%). When supplementary feeds are provided for goats, most producers (92.4%) do not measure the quantity given; and about 71.1% of the producers offer mineral- vitamin supplements to their goats.

To mitigate shortage of feed for goats in the semi-arid zone of Nigeria during the dry season, feeding combinations of supplement mixtures of maize bran, beans pod, Dichrostachys cinerea browse and gamba grass were assessed using 15 growing goats for 90 days (Akpa et al.,2000b). All the feeding combinations supported positive weight gain in the goats. Feeding of D. cinerea with or without supplement mixtures improved feed intake, weight gain and feed efficiency of goats during the dry season in the semi-arid zone of Nigeria. However, further studies are required to determine the optimum level of D. cenerea inclusion in feeds and possible anti-nutritional factors in it.

Studies conducted on milk production of Red Sokoto goats had variable results (Ehoche and Buvenadran, 1983; Akpa et al.,

2001b; Akpa et al., 2002a; Akpa et al., 2008). Much of these variations could be attributed to the management system under which the studies were conducted. A comparative study of milk production behavior of Red Sokoto goats under agro-pastoral and institutional system in the semi-arid climate of Nigeria (Table 1) revealed that milk production performance was better for agro-pastoral system (23.5- 69.7%) than institutional system, except for lactation peak (8.0%) and persistency (22.0%) (Akpa et al., 2008). The differences in the two systems could be attributed to differences in nutrition and management of the goats. The agro-pastoral system had a better potential in terms of feed and water supply for milk production but lacked the management ability for sustainability.

Table 1: Effect of management system on lactation characteristics of Red Sokoto goats

Characteristics	Institution	Agro-pastoral	Deviation (%)
Number of observations	20	20	20
Initial yield(kg)	0.447 ± 0.052^{b}	0.759 ± 0.066^{a}	-69.69
Average daily yield (kg/d)	0.439 ± 0.027^{b}	0.542 ± 0.036^{a}	-23.47
Total yield (kg)	52.679 ± 3.210^{b}	65.044 ± 4.313^{a}	-23.47
Peak yield (kg)	0.7454 ± 0.046^{b}	0.999 ± 0.105^{a}	-32.50
Peak week	5.250+0.624	4.800±0.531	+8.57
Persistency (%)	104.300 ± 6.587^{a}	80.599 ± 1.485^{b}	+ 22.72

a,b means on the same row with different superscripts differ significantly ($P<0.05$)

Management and improvement of any breed within a given environment will depend on identifying the major environmental constraints to performance and devising means to alleviate or control them, and on evaluating the breed for its adaptability to cope with constraints that cannot be readily controlled. Knowledge of these constraints will be useful in the modification or improvement strategies and / or adjustment of their performance.

Studies were conducted (Akpa et al., 2009; Abubakar et al., 2013) to examine the influence of age and month of mating on litter size (LS), kidding interval (KI), kidding weight (Kwt), mating weight (Mwt), and body size characteristics in 1000 Red Sokoto does of small holder farmers in Kano State. The results showed that the effect of age was significant ($P<0.01$) on all the measured parameters except post kidding weight gain (PKwtG), post kidding rate of gain (PKRG), and post kidding weight change (PKwt?). Litter size (LS), mating weight (Mwt), kidding weight (Kwt), 60 day

post kidding weight (60dPKwt) and the linear measurements (HW, BL, CG) increased with age and parity of the doe. The significant effect of age on the body size characteristics shows that age is a major determinant of growth and physiological development of the animals. It also revealed that the physiological and morphological growth of the animals go concurrently with age. However, the growth rates usually increase at a decreasing rate with advancement in the age of the animal. Akpa et al,(1998a) reported that the live weight of Maradi goats increased from birth to about 25-30 month of age and appeared constant thereafter. Litter size also increased with age indicating that younger and lighter does might produce less litter size than the older does (Alphonsus et al., 2010). The effect of month of kidding was significant (P<0.01- 0.05) on Mwt, Kwt, 60dPKwt, HW, and CG. This observation suggests the importance of designing breeding programme of the doe to coincide with the period of feed availability so as to ensure optimum live weight required for desirable conception rate and birth weight of kids. Mating weight and kidding weight are strongly related (Rafiq,1995) and were observed to increase with age, indicating that older does might give birth to heavier kids than the younger does.

In another study conducted (Akpa et al.,2011a), parity was one of the factors that exerted significant (P<0.05) influence on birth weight of the kids, with the concurrent increase in birth weight with parity up to the 5th parity and declined thereafter. This suggested that beyond the 5th parity the birth weight of the kids might depreciate. Also parity was observed to exert significant influence on the body weight of the kids at 1, 3, 6 and 9 month of age (Alphonsus et al., 2010), with the kids of parity 5 maintaining their superiority in weight, probably due to their initial advantage in higher birth weight.

Goat Herd Structure and Breeding Practices

The knowledge of the smallholder herd structure and the system of management is essential for identifying opportunities to shape the future of small ruminant production in Nigeria. There is, therefore, need to study the herd structure of this smallholder goat Production and quantify the production, reproduction and socio-economic issues that affect goat production. This is expected to influence policy formulation that may lead to economically

sustainable production in smallholder livestock systems. Therefore, a survey was carried out in Kano State to evaluate the smallholder goat herd and breeding structure (Akpa et al., 2010a, Akpa et al., 2010b). The choice of Kano State for the study was based on the fact that in the traditional setting of Kano area which is in northern Nigeria, majority of families own goats. The goat herd distribution showed (Table 2) that the average herd size was 15.5, within the range of 4 to 30 goats. This is lower than the average herd size of 19.8 (Akpa et al., 1995a) and 19.2 in the range of 2 to 70 (FAO, 2009) reported in Zaria. Although the herd size ranged from 4 to 30 with the mean of 15.0 goats, majority of the farmers herd size was between 11 to 20 goats. The herd structure was made of 78 % females and 22 % males with average buck to doe ratio of 1:5.3, this was comparable to the smallholder goats herd structure in Zaria which comprised of 79.3 % females and 20.6 % males with average buck to doe ratio of 1:19.7. The goats showed higher incidence of multiple births (54 %) with twinning rate of 43 %.

Table 2: descriptive statistics of smallholder goat herds in Kano

Characteristics	N	Mean ±(se)	CV%	Min	Max
Herd size	58	15.5±0.38	43	4	30
Young goats	58	3.8±0.55	92.8	0	15
Young males	58	2.1±0.41	120.7	0	10
Young females	58	1.7±0.22	84.1	0	5
Adult goats	58	7.8±0.53	42.8	3	18
Breeding males	58	1.4±0.13	58.7	1	5
Breeding females	58	6.4±0.67	46.1	2	15
Maiden does	58	1.8±0.23	81.6	0	5
Nanny does	58	4.6±0.39	53.4	0	12
Buck to doe ratio	58	5.3±0.40	47.4	2	13
Litter size	58	1.7±0.04	42.9	1	4

N= number of smallholder herd studied

Goat keeping and production are profitable activities and it is known that increasing prolificacy is one of the factors that determine the profitability. The litter size in this study (Akpa et al., 2010b) ranged from 1 to 4 with the mean litter size of 1.7. This is similar to the Litter size range of 1 to 4 with a mean of 1.847 earlier reported by (Amoah et al., 1996) but higher than the maximum litter size of 3 reported by Amoah and Gelaye,(1990). Although litter size ranged from 1 to 4, majority (89%) of the goats had litter size of 1 and 2, with rare cases of quadruplets (0.3%). Litter size in this study

showed a tendency to increase from first parity to fifth parity and a reduction in the sixth parity (Table 3). These observations suggests that the parity level in which does prolific ability reaches its peak is between 4th and 5th parity, thus culling of does from the herd can be done beyond the 5th parity. It may be economically unwise to culled does at the early parities (except for ill-health) when the full genetic potential of their reproductive rate has not yet been fully expressed. This is supported by the earlier reports of many researchers (Das, 1993; Amoah et al., 1996; Akpa et al., 2001a; Sodiq et al., 2003) that the prolificacy of does tended to increase with advanced parity. Multiple births were common in this study; 44% single, 40.5% twins, 14.7% triplets and 0.8% quadruplets (n= 116). This is comparable with what was obtained at Shika, Zaria traditional management system; 32.6 % single, 58.8% twin, 7.2% triplet, 1.8 % quadruplet (n=123) and Niger traditional management system; 56.1% single, 40.9% twin, 2.8% triplet, 0.1% quadruplet (n=1668) reported by FAO (2009). The most frequent litter size was singles (44.0%), followed by twins (40.5%), which together accounting for 84.5% of births. This is comparable to the findings of Amoah et al.(1996) who reported that the most frequent litter size was twins (48.1%), with the next highest frequency being singles (34.6%), together accounting for 82.8% of births. Although incidence of quadruplets was rare (0.8) in this breed it was however observed that it occurred mostly on does of advanced parity. This increase in litter size with advance parity may be associated with the physiological maturity of the doe. It was observed that does giving birth to quadruplets remained in the herd for a long time, suggesting that the smallholder farmers in the study area are conscious of retaining does with high potential for multiple births in order to increase their herd size. Although the farmers started culling the does after the 2nd parity, majority of the does were culled after the 4th parity.

Table 3: The distribution of breeding does according to herd size

Attributes	10 Goats	11-20goats	21-30goats	Overall
Breeding head	48(30)	89(57)	21(13)	158
Breeding males	12(25)	21(24)	2(10)	35(22)
Breeding females	36(75)	68(76)	19(90)	123(78)
Buck to doe ratio	1:3	1:3	1:10	1:5
Litter size (LS)	83(28)	164(54)	54(18)	301
LS1	37(45)	71(43)	29(54)	137(46)
LS2	33(40)	72(44)	24(44)	129(43)
LS3	13(15)	20(12)	1(2)	34(10.7)
LS4	-	1(1)	-	1(0.3)

Figures in parenthesis are percentages

The significant effect of herd size on all the measured attributes in this study (Table 4) underscored the importance of herd size and herd management in the improvement of the herd performance, since performance of the herd is dependent on selecting the right animal for breeding purposes. Therefore, increase in herd size provides large gene pool for high selection intensity which will invariably increase the herd performance. Likewise, increase in herd size may increase the profitability of the farmer. Although buck to doe ratio increased with increase in herd size, it was however observed that the bucks were underutilized particularly in the traditional smallholder management system where bucks are allowed to run with the does indiscriminately. But in a controlled mating system, appropriate mating ratio is used. In this study the buck to doe ratio ranged from 2 to 13. This is far below the buck to doe ratio of 1:30 reported by Das and Sendalo (1990).

Table 4: Effect of herd size on the distribution of goats according to the observed attributes of the herds

Attributes	10 goats (21)	11-20goats (15)	21-30goats (15)	SEM	LOS
Young goats	2.0^{c}	4.4^{b}	10.8^{a}	0.38	**
Young males	1.1^{b}	2.4^{b}	6.8^{a}	0.31	**
Young females	1.0^{b}	2.0^{b}	4.0^{a}	0.17	**
Adult goats	5.7^{c}	9.1^{b}	14.0^{a}	0.33	**
Breeding males	1.2	1.5	1.8	0.13	ns
Breeding females	4.4^{c}	7.6^{b}	12.3^{a}	0.26	**
Maiden does	1.2^{b}	2.3^{a}	2.5^{a}	0.21	**
Nanny does	3.2^{c}	5.3^{b}	10.3^{a}	0.21	**
Buck to doe ratio	4.1^{c}	6.3^{b}	8.5^{a}	0.33	**

^{a,b,c} means within rows with different superscripts differ significantly ($P<0.05$)

In tropical Africa, there was no formal recording scheme on goats. Goats are kept in small numbers which are scattered far and wide in the area. In Nigeria, over 95% of the goats are raised under traditional systems of production. Each animal in a herd is kept for economic and social reasons. Sheep and goat flock structures as reported by Bayer (1989) and Otchere et al (1987) in Nigeria showed that females constituted over 70% of the flocks and a high proportion of males leave the flock before they developed their pair of permanent incisors. To ascertain these reports, a study was conducted (Akpa et al.,2010b) using Fifty-eight (58) randomly selected goat herds in Kano State. The study revealed that the herd structure of smallholder goats in Kano was made of more adult (67%) than young (33%) goats. For the young goats, the males (55%) were more than the females (45%). However, in the adult (breeding) goats, the females (82%) were more than the males (18%). Within the breeding females, the nanny does (72%) were more than the maiden does (28%). This shows that there was a high proliferation of males than females at the younger age which is an indication that the rate of male bearing was higher than the females in these herds. However as the animals grow to maturity the males are probably sold and only few are left for breeding purposes. This suggests that the farmers are conscious of keeping only those animals which are productive for the sake of increasing their herds. Also the decrease in the number of males at maturity could be attributed to differential mortality rate of male and female kids. This is supported by the earlier findings of Chikagwu-Malunga and Banda (2006) that mortality rate of suckling males were higher than the female.

So far, breeding improvements targeted at the smallholder herds have failed to give desired results due to the movement of breeding does in the herds before the projects were concluded (Akpa et al., 2001a). Therefore, any breeding strategy to be employed in order to bring about an improvement in the smallholder herds must understand their breeding structure. Consequently a study to ascertain the herd structure of breeding does of smallholder goat production system (Akpa et al., 2001a) was conducted in Kano using 15goat herds selected at random in 3 villages. A total of 250 breeding does were involved. The results indicate that parity of does in the observed herds ranged from 1 to 10. Twelve percent of the

does within the age range of 5-25 months were yet to kid for the first time. In the herds, does that did not kid at least once, after 25 months of age were culled. However, majority of the does were in their 2nd and 3rd parities and within the age range of 12-25 months. Twinning was common at 1st parity, irrespective of the age of does. Parity and litter size of does were the major determining factors on the observed herd structure for the breeding does. The observed structure indicates that < 12 months does constitute 20% of the herd; 12-25 months 48%, 26-39 months 11.2% and > 40 months 20.8%. Breeding does leave the herds starting from the 25th month of age and at parity 2,4,7 and 10, respectively. A study on breeding practices at the small holder goat herds (Akpa et al., 1998c) revealed that criteria used in meeting the selection of goats were based on health, udder development, bone structure, hair texture and tail structure.

Reproductive Characteristics of Goats

Increased production in goats cannot be possible without considering the reproductive abilities and characteristics of the goats. Also, an understanding of the reproductive characteristics of the goats as affected by various factors whether genetic or environmental is a fundamental component in enhancing their productive potentials (Akpa and Mohammed, 2004; Akpa et al., 2004a). There is dearth of information on the reproductive performance of Nigerian goats. To realize the full potentials of these animals, more work needed to be done in this direction. At the smallholder production system, Akpa et al (1995a) estimated the average age of goats at 1st conception, gestation length, and litter size at 1st kidding and maximum litter size to be 8.4 months, 6.4 months, 1.4 kids and 2.3kids, respectively. In another study, records of 625 kidding and 970 kids of West African dwarf and Red Sokoto goats collected over a four year period (1991-1995) were used to determine the effect of breed, parity, sex and season on gestation length, litter size, litter genotype and sex ratio of these goats (Akpa et al.,2004a). The gestation length, litter size and sex ratio were 147.5 days, 1.8kids and 50.6 %, respectively. Breed and season significantly ($P<0.01$) affected these traits, except sex ratio which was only influenced by season. Parity influenced litter size ($P<0.01$) and sex ratio ($P<0.01$).Litter size (LS), mating weight (Mwt),

kidding weight (Kwt), 60 day post kidding weight (60dPKwt) and the linear body measurements (HW, BL, CG) increased with age of the doe (Akpa et al.,2010a).

In a study conducted using 310 litter size records from 116 Red Sokoto does randomly selected from 22 smallholder goats herds in Kano state (Akpa et al.,2011b), it was found that the mean litter size per doe was 1.7 kids. Further studies on litter size in Red Sokoto goats from pedigree kidding records of 1,798 kids confirmed this finding; that the goats were prolific with an average litter size of 1.7 kids (Iyiola-Tunji et al., 2008b). Equally, sex ratio in these goats showed no deviation from hypothetical sex frequency in farm animals; a condition similar to what was obtained for WAD goats (Adebambo et al., 1994).

Another study conducted (Akpa et al., 2009) using 1000 Red Sokoto does under the small holder production system at Saunawa and Amarzakawa villages in Kano state, Nigeria showed the mean abortion rate(%), litter size(LS), kidding interval (KI), dams' mating weight (Mwt) and kidding weight (Kwt) to be 5.5%, 1.45 kids, 6.90months, 20.4kg and 24.7kg, respectively. The mean kidding interval of 6.9 month obtained by Akpa et al.(2009) was close to the value reported by Awemu, et al (1999) in Red Sokoto goats (215 days) raised under traditional system of management. It is as well very close 240 days reported by Adu et al.(1979) in Red Sokoto goats under intensive system of management. Therefore, it can be deduced from these studies that kidding intervals in Red Sokoto goat is near constant despite the differences in management systems. Usually there is a controlled breeding policy under intensive system of management to achieve the best breeding season, in contrast to the extensive or traditional system of management in which there is no control breeding, animals of all ages and sex are allowed to run together, hence the relative shorter kidding intervals.

Other studies on postpartum interval to conception in Red Sokoto goats (Akpa, 1999a) indicated an interval of 69.8 days. Parity and season significantly ($P<0.05$) influenced it. Does at their 3rd parity had the shortest interval while the longest was for the 1st parity does. Season of kidding was also an important factor that influenced kidding interval of the does. Animals that kidded in the early dry (24days) and early wet (28 days) had shorter intervals compared to late wet (44.5days) and late dry (38.7 days) seasons.

The results of the study suggest twice yearly kidding if does are first bred in the early dry season and rebred again after kidding at the early wet season.

Field assessments can be made of a buck's ability to mate, physical capability to mount, intromission achievement and ejaculation. Assessments can also be made of the quality of semen that the buck produces, which is in turn, related to physical characteristics of its genitalia. Yet whilst it is relatively easy to assess such traits in the field, their values as predictors of buck fertility unfortunately remain the subject of considerate debate. A study (Akpa et al., 2013c) was therefore carried out to determine the influence of age, hair type and body condition score on body and testicular measurements and semen characteristics in Red Sokoto goat. The average value was, body weight 15.02kg; heart girth 59.95cm; stature 54.95cm; chest width 8.37cm; withers height 53.4cm; body depth 32.86cm; body length 57.35cm; rump width 17.03cm; testicular length 12.00cm; testicular . circumference 17.38cm; testicular width 8.69cm; testicular weight 508.7g; semen volume 0.42ml; semen motility 79.52%; semen pH 8.58; sperm concentration 701.13 x 106; and live and dead ratio 0.82 x 106. Age and body condition score significantly ($P< 0.01$) influenced body weight, body conformation and testicular traits, but had a variable influence on semen characteristics. The body weight, body conformation and testicular traits increased with increase in age of the bucks. Hair type had no influence on body weight, body conformation traits and semen characteristics but had influence ($P< 0.01$) on some testicular traits. Bucks with BCS (4) were bigger in size (HG, ST, WH, BL, RW) and weighed more (BW) and had scrotum that are longer (TL), broader (TC), wider (TW), and heavier (TWT); hence produced more semen (SV) than those with BCS(3). The short smooth haired bucks gave better testicular dimensions than the long curly haired bucks. Therefore, the study showed that increase in age and body condition resulted in an increase in body and testicular size while hair type could be used as a predictor of testicular dimensions in Red Sokoto goat.

Another study (Ambali et al., 2013a) was carried out to study the influence of age, hair type and body condition on sperm morphology and cation concentrations in Red Sokoto goat. The observed average value for sperm morphology and semen cation

concentrations (millimol/litre) were detached mid piece 0.52, mid piece droplet 0.61, detached head 0.51, coiled and bent tail 1.01 and acrosome 0.61; Na 94.90, K 67.79, Ca 2.62 and PO4 5.42. Age and hair type significantly (P<0.05-0.01) influenced them. The study therefore revealed that older bucks with short-smooth hairs and higher body condition exhibited less occurrence of sperm abnormalities and appreciable concentration of Na+ than older, long curly haired and lower body conditioned bucks. The result of the study suggested that age 21-24 months, short-smooth hair type and higher body condition is a useful index in selecting bucks for semen quality and optimum performance in Red Sokoto goat.

Maintaining a high fertility by genetically superior bucks producing large numbers of high quality spermatozoa is important for the improvement of overall flock fertility. Any quantifiable physical traits that directly correlate with the fertilization capacity of semen could be potentially used as a measure of semen quality. Sperm production and quality can be affected by both animal size and physiological status. A study was therefore conducted to determine the relationships between body measurements, testicular and seminar characteristics (Akpa et al., 2013d). The result showed positive and significant correlations of body measurements with semen traits and testicular measurements with semen traits; therefore, bucks with larger body size would possess larger testicular size, produce higher semen volume with increased sperm concentration. This can be used to evaluate Red Sokoto goat for breeding soundness and genetic improvement for fertility.

Semen quality characteristics such as motility, sperm number and sperm morphology are of value in identifying breeding males of low fertility in small holder herds. An accurate morphology examination of spermatozoa thus enables the elimination of males with potentially low fertility prior to their use in breeding. The knowledge on correlations of male reproductive traits especially sperm morphological traits with other variables such as semen and testicular traits as well as body conformation traits may have important bearings to indicate the real producing ability of a male for sperm output and quality. A study was therefore conducted (Ambali et al., 2013b) to determine the relationships between sperm morphology, semen characteristics, testicular measurements and body conformation using 31 Red Sokoto buck. The study revealed

that bucks with good body size and higher semen volume and quality exhibited less sperm morphology defects. Therefore, semen traits such as semen volume, sperm concentration and live/dead ratio; and body measurement such as body weight, body condition score, heart girth and height at-withers could be used to estimate semen quality in bucks, thereby ensuring the elimination of unqualified bucks before being used for breeding purposes.

Classical methods of semen evaluation generally measure sperm concentration, progressive mortality, the percentage of viable cells, and morphology. These assays may not be enough in predicting fertility outcome because only those samples with markedly poor quality semen can be identified. Among the most important aspect of the study on spermatozoa metabolism is the understanding of the chemical path ways involved in energy metabolism and maintenance of osmotic balance by ions present in semen which are important determinants of sperm viability.

Semen plasma is very important for sperm metabolism, function, survival, and transport in the female genital tract. Considerable attention is beginning to be paid to interrelationships of seminal cation to some measured traits that relate to semen quality in animals. Akpa et al.(2013e) therefore, studied the relationship between semen cation concentrations, semen characteristics, testicular measurements and body conformation traits in Red Sokoto goat. From the study bucks with adequate concentration of Ca exhibited better testicular dimensions; while bucks with good body structure showed high concentrations of K in seminal fluid, produced higher semen volume with increased sperm concentration and motility.

Body Growth and Measurements in Goat

Improvement of production performance in goats will require genetic improvement of their live body weight and linear body conformation. To achieve these goals, proper measurement of growth traits is required. Equally important is the need to understand the factors that influence them (Iyiola-Tunji et al., 2009). Also there is need to characterize the indigenous breeds of goats in Nigeria based on their body weight and linear body conformation. In a study conducted on smallholder Red Sokoto goat herds in five locations (Abuja, Jigawa, Katsina, Kano and Zaria) in the Northern Guinea

savanna zone of Nigeria, it was shown that the average body weight (BW), height at withers (HW), heart girth (HG) and body length (BL) were 23.56kg, 58.20cm, 66.38cm and 57.41cm, respectively (Table 5). The average BW of 23.56kg obtained in this study is within the range of 16-30 kg and 20-40 kg reported by Hassan and Ciroma (1990) and Osuhor et al., 2002, respectively in a composite herd population of both males and females of Red Sokoto goats. Also, the mean HW of 58.20cm is within the range of 56-67cm reported by Hassan and Ciroma (1990) and similar to the 58.2cm and 57.7cm reported by Ibrahim (2010). The mean HG of 66.38cm is within the range of 61-76cm reported by Hassan and Ciroma (1990) and comparable to the 65.0cm reported by Ibrahim (2010). However, the mean BL of 57.41cm obtained in this study was far below the range of 79-97cm reported by Hassan and Ciroma (1990). This variation could be as a result of differences in traits definition and measurements as well as population size.

Table 5: linear body conformation traits of Red Sokoto goats in different locations

Locations	N	Conformation traits			
		BW (kg)	HW (cm)	HG (cm)	BL (cm)
Abuja	94	21.60	57.70	62.40	-
Jigawa	1079	29.24	60.81	70.29	60.69
Katsina	1052	25.93	59.15	69.32	54.80
Zaria	821	20.65	58.95	64.10	55.10
Kano	1000	20.40	54.40	65.80	59.0
Overall	4046	23.56	58.20	66.38	57.41

BW=body weight, HW= height at withers, HG= heart girth, BL=body length

Attempts in evaluating the Red Sokoto goats, explored the influence of strain and sex on body weight (BW) and linear body measurements (body length, BL; height-at-withers WH; heart girth HG) and their relationships in six age categories (1-6, 7-12, 13-18, 19-24, 25-30 and 31-36 months) using 720 smallholder Red Sokoto goats of Nigeria (Akpa et al.,1998a). Sex significantly ($P<0.05$) influenced all body measurements at the given age categories with males weighing heavier and having wider HG than females; but females had longer and higher BL and HW. Kawu et al. (2006) equally observed sexual dimorphism in zoometrical traits of goats. Strain of Red Sokoto goat significantly ($P<0.01$) influenced the body measurements. Brown and light brown goats were

predominantly heavier in BW and had higher HW. Body weight was significantly ($P<0.01$) and positively correlated with BL, HW and HG and based on the magnitude of the correlations, HG and BL could be used to estimate BW of Red Sokoto goats across all ages. The constant ratios of BL: HG (10), BL: HG (0.9), and HW:HG (0.9) can be used to characterized the goats, irrespective of strain, sex or age, as belonging to the Red Sokoto goats of Nigeria.

The possible effects of parity, litter size and sex on kid body weight, growth rate and body linear measurements in Red Sokoto goats (Akpa, 2000) as a step towards employing them as correction factors in body weight estimation for selection purposes were evaluated using 240 kids born to 122 dams in Zaria. The average birth weight, heart girth, body length and height at withers was 1.2kg; 24.4cm and 26.3cm, respectively, and at 3 months of age was 5.5kg, 53.4cm, 53.7cm and 51.3cm, respectively. The 3 months average daily gain was 48g/d. Kids born singles weighed heavier than twins and triplets but with slower growth rate. Males weighed heavier than females. Litter size, sex and parity significantly ($P<0.05$) influenced 3 months body measurements but not at birth in Red Sokoto goat. Singles were superior to twins and triplets; but 1st parity kids were inferior to subsequent ones.

Furthermore, studies on the effect of parity on birth weight of Red Sokoto kids (Akpa et al., 2009; Akpa et al., 2011a), revealed that parity was one of the factors that exerted significant ($P<0.05$) influence on birth weight of the kids, with the concurrent increase in birth weight with parity up to the 5th parity and declined, indicating that beyond the 5th parity the birth weight of the kids might depreciate. This is contrary to the reports of Osinowo et al. (1994), and Awemu et al. (1999) in which, in their separate findings observed that body weight increased with parity, with the highest body weight occurring at the 6th parity. Such differences might be due to breeds and management differences. However, full reproductive capacity is not attained in any species at the first reproductive cycle, thus as parity increases kids are expected to mate and conceived readily. Therefore, available information on the parity level at which full reproductive efficiency is attained will help a lot in culling programme for dams of advanced parity level.

In another study, the effects of sex, month of kidding and dams' mating weight on birth weight, body weight and linear body

measurements at 1, 3, 6 and 9 month of age in small holder goats was evaluated (Akpa et al., 2010a). The effect of sex was significant (P<0.01) on the measured characteristics except on BL and CG at 9 month of age. The males were consistently heavier and bigger in size than the females from birth to 9 months of age, although the differences in BL and CG at nine months of age were not significant (P>0.05) (Table 6).

The mean values for male and female kid's body weight and linear body measurements increased in a similar manner from birth to 9 months of age, but with the highest rate of increase occurring within 3 months (12 weeks) of age. The rate of growth of kids from birth to 3 months of age was 2.01kg/ month, 2.03, 2.77 and 2.67cm/ month for BW, HW, BL and CG, respectively for males and 1.97kg/month, 2.03, 2.77 and 2.67cm/month.

Table 6: Effect of sex on birth weight, body weight and Body measurements at different ages in Red Sokoto kids.

Traits	N	Male	Female	LOS
Birth weight (kg)	1000	1.96±0.01^a	1.89±0.01^b	**
One month weight (kg)	1000	4.8±0.02^a	4.40±0.02^b	**
" " HW (cm)	1000	34.5±0.08^a	33.8±0.08^b	**
" " BL (cm)	1000	34.5± 0.14^a	33.00±0.14^b	**
" " CG (cm)	1000	37.7±0.09^a	35.8±0.09^b	**
Three month weight (kg)	1000	8.00±0.02^a	7.8±0.02^b	**
" " HW(cm)	1000	40.6±0.10^a	39.9±0.11^b	**
" " BL (cm)	1000	42.8±0.11^a	43.4±0.12^b	**
" " CG (cm)	1000	45.7±0.12^a	43.2±0.02^b	**
Six month weight (kg)	1000	10.7±0.02^a	10.3±0.20^b	**
" " HW(cm)	1000	45.6±0.20^a	45.5±0.09^b	**
" " BL (cm)	1000	46.8±0.09^a	48.0±0.09^b	**
" " CG (cm)	1000	50.1±0.09^a	48.0±0.09^b	**
Nine month weight (kg)	1000	13.3±0.02^a	12.8±0.02^b	**
" " HW(cm)	1000	50.8±0.10^a	48.5±0.10^b	**
" " BL (cm)	1000	54.8±2.08	51.2±2.08	ns
" " CG (cm)	1000	57.4±1.97	54.7±1.97	ns

a,b,c means within rows with different superscripts differ significantly (P<0.05)

* p<0.05, ** p<0.01, NS= not significant, HW=height-at withers, BL= body length, CG= chest girth

for BW, WH, BL and CG, respectively in females. Beyond this age (3 months) for the defined characteristics, growth was increasing at a decreasing rate up to the 9 months of age in which the average growth rate was 0.88kg/month, 1.70, 2.00 and 1.95cm/month for

BW, HW, BL and CG, respectively in males and 0.83kg/month,1.43, 1.30 and 1.92cm/month for BW, HW, BL and CG, respectively in females. Although such increase in the measurements with age is expected as the animal is developing but the developmental rate indicates that the highest development was at the pre-weaning which was almost twice that between weaning and 9 month of age. This suggests that the size of an animal at maturity will be dependent upon the developmental rate and the relationship between various body measurements at pre-weaning ages.

The observed high rate of increase in body weight and body dimension from birth to 3months of age, closely agreed with the result published by Taure and Meyer (1990), Bratte et al (1999) and Akpa et al. (2006a, b) in rams.

The superiority in body weight by males may be due to the fact that male fetuses grow faster during gestation and will have heavier weight advantage than the females (Gwaza et al., 2007). It may also be due to anabolic effect of androgen which is known to have growth and weight stimulating effect (Frandson, 1981).

Month of kidding had significant effect on birth weight ($P<0.01$) and body weight ($P<0.05$) at 1, 3, 6 and 9 months of age (Table 7). The variation due to month of kidding observed on birth weight and body weight of the kids to 9 months of age may be a reflection of the variations due to quality and quantity of pasture available for the does to feed on during the kidding period. It is logical to expect relationship between plane of nutrition of does and birth weight of kids. Thus, it may therefore, be necessary in small holder production system to design a breeding programme where by does kid toward the end of the dry season so as to benefit from the earlier rainy season nutritious pasture favorable for higher milk production, and optimum profitability as a result of rapid growth and heavier kids at birth and at weaning to later months.



Table 7: Effect of month of kidding on birth weight, body weight, and Body measurements at different ages in Red Sokoto kids

Traits	N	April	May	LOS
Birth weight (kg)	1000	1.9±0.01^{b}	2.09±0.01^{a}	**
One month weight (kg)	1000	4.5±0.02^{b}	4.60±0.02^{a}	**
" " HW(cm)	1000	33.6±0.09^{b}	34.3±0.09^{a}	**
" " BL (cm)	1000	33.5± 0.15^{b}	34.00±0.15^{a}	**
" " CG (cm)	1000	36.2±0.11^{b}	37.0±0.09^{a}	**
Three month weight (kg)	1000	7.60±0.02^{b}	7.9±0.03^{a}	**
" " HW(cm)	1000	40.1±0.11	40.2±0.11	ns
" " BL (cm)	1000	41.1±0.12	41.0±0.12	ns
" " CG (cm)	1000	44.9±0.13	44.7±0.12	ns
Six month weight (kg)	1000	10.5±0.02^{b}	10.7±0.20^{a}	**
" " HW(cm)	1000	44.9±0.13	44.1±0.09^{b}	ns
" " BL (cm)	1000	46.4±0.10	46.3±0.09	ns
" " CG (cm)	1000	48.1±0.11^{b}	49.70±0.09^{a}	**
Nine month weight (kg)	1000	12.6±0.02^{b}	13.5±0.03^{a}	**
" " HW(cm)	1000	49.9±0.12	49.8±0.10^{b}	ns
" " BL (cm)	1000	50.8±2.02	50.2±2.08	ns
" " CG (cm)	1000	54.7±1.97	55.2±1.90	ns

a,b,c means within rows with different superscripts differ significantly (P<0.05)

* p<0.05, ** p<0.01, NS= not significant, HW=height-at withers, BL= body length, CG= chest girth

The effect of dams' mating weight (DMwt) was significant (P<0.01-0.05) on all the measured characteristics except BL at one month of age, HW at 3 months of age, BL and CG at 9months of age. Birth weight increased with increase in dams' mating weight, this implies that dams with higher body give birth to heavier kids.

Despite the efforts of colonial authorities to preserve the purity of the Red Sokoto goats because of the commercial value of its skin, uncontrolled breeding among Nigerian goats is rampant, making breed classification increasing difficult. Therefore, a study was conducted to compare the zoometrical features of the Red Sokoto and West African Dwarf goats in three ecological locations with a view to determining the influence of breed and eco-zone on zoometrical differentiation of the major Nigerian breeds (Kawu et al., 2005). It was observed that with the exception of HW and shin circumference, the Red Sokoto goats in Zaria and Kano, WAD goats in Jos and Edo State maintained distinct head, limb and trunk zoometrical features. The similarity in HW and Shin circumference may be due to common ancestry and/ or uncontrolled crossbreeding.

Morphological Traits and Their Gene and Genotypic Frequencies in Red Sokoto Goat

Since characterization of a breed is the first approach to a sustainable use of animal genetic resource, studies on diversity and variability between indigenous goats on the basis of quantitative (morpho-structural) and qualitative (morphological) variables is very important. Thus, data from smallholder flocks of Red Sokoto goats (n = 888) randomly sampled in Katsina, in the Northern parts of Nigeria were used in 2010 to investigate the distribution frequencies of certain qualitative traits (Ijomanta, 2012). The animals were scored for the presence or absence of wattle, beard, horn, coat-colour and hair type (smooth or coarse).

The five qualitative traits (Wattle, Beard, Horn, Coat colour and Hair type) were used as classification variables. On the basis of incidence of wattles, animals were categorized into wattled (Waw) and non-wattled (Wa+) goats, presence (Brb) or absence (Br+) of beard, presence (Ho+) or absence (Hop) of horn and also for the presence (Stt) or absence (S+) of supernumerary teats. They were also scored for the head profile; sub-convex (Hpsv) or straight (Hpst) head profile. Goats were also assessed according to coat colour. The distribution of the various traits were expressed in percentages and categorized according to sex. The frequencies of the recessive alleles (Wa+, Br+, Ho+ S+ and Hpst) were estimated using Hardy-Weinberg equilibrium equation as shown below:

$$q = \sqrt{\frac{m}{M}}$$

Where, q = frequency of the recessive gene; m = observed number of animals exhibiting the particular recessive trait; M = total number of animals sampled. From q above, the frequencies of the dominant alleles (Waw, Brb, HoP , Sttand Hpsv) were calculated as follows: p = 1-q

Where, p = frequency of the particular dominant allele. The observed frequencies were tested against the expected Mendelian ratio of 3:1 corresponding to values of 0.75 for the dominant allele and 0.25 for the recessive allele using Pearson's chi-square test. The null hypothesis (Ho) was that the population is in Mendelian

proportions. Genetic distance between the goats at different locations was estimated at the wattle, beard, head profile and supernumerary teats loci using gene frequencies as follows:

$$d2 = (P1-P2)2$$

Where, d2 = genetic distance estimate between the two populations; P1 = gene frequency of population 1; P2 = gene frequency of population 2. The results showed that both sexes of Red Sokoto goats were wattled, beard and horned but at different frequencies (Table 8). The frequency of wattles (Waw) was very low (8%), however the wattle condition existed at a higher percentage for females (86%) than the males (14%). This was at variance to what was observed (Yakubu et al.,2010) in WAD goats, in which relatively higher proportion was observed in male (31.64%) than in female WAD goats (5.78).

As in the wattle, possession of beard was evident in both sexes. However, there was sexual dimorphism in its distribution, as more females (0.65%) exhibited the trait than males (0.35%). This is in contrast to the earlier findings of Yakubu et al., (2010) in which he reported higher preponderance of beard in males (33.33%) of Red Sokoto and (18.64%) of WAD goats than females (6.49 and 4.00% for Red Sokoto and WAD goats, respectively). The sexual difference observed is not unexpected since the occurrence of beard is due to a locus which is dominant in males and recessive in females. It is a secondary sexual characteristic under male hormonal action; thus, females displaying the trait are likely to have threshold levels of androgenic hormone (Yakubu et al.,2010). All the goats were horned (Ho+) regardless of sex (100% in each case).

WAD goats than females (6.49 and 4.00% for Red Sokoto and WAD goats, respectively). The sexual difference observed is not unexpected since the occurrence of beard is due to a locus which is dominant in males and recessive in females. It is a secondary sexual characteristic under male hormonal action; thus, females displaying the trait are likely to have threshold levels of androgenic hormone

(Yakubu et al.,2010). All the goats were horned (Ho+) regardless of sex (100% in each case).

Table 8 : Frequency (%) of the qualitative traits of Red Sokoto goats according to sex

Traits	Alleles	N	Frequency distribution		Polled
			Male	Female	
Wattle	Wa^{w}	71	0.14	0.86	8
	Wa^{+}	817	0.09	0.91	92
Beard	Br^{b}	170	0.35	0.65	19
	Br^{+}	718	0.03	0.97	81
Horn	Ho^{p}	0	0.00	0.00	0
	Ho^{+}	888	0.09	0.91	100
Head profile	Hp^{s}	24	0.72	0.28	3
	Hp^{sv}	864	0.07	0.93	97

Wa^{w} = wattled; Wa^{+} = non wattled; Br^{b}= presence of beard; Br^{+}= absence of beard; Ho^{p} = polled; Ho^{+} = horned; Hp^{st} = straight; Hp^{sv} = Sub-convex; St^{t} = presence of supernumerary teat; St^{+} = absence of supernumerary teat

The Red Sokoto goats have various colour patterns that are obvious; these colours are dark red, brown and light brown. In a survey conducted in four locations (Abuja, Jigawa, Katsina, Zaria) within the Northern Guinea Savanna zone in 2010 and 2011, where the breed is predominant (Fig 1-4, Table 9),it was revealed that in Zaria (n=821), the distribution of the Red Sokoto goats with dark brown colouration was higher (46.89%) than those with either red (32.89%)or light brown (14.62%) colouration. In Katsina, (n= 888) majority of the goats were brown (46.62%) followed by light brown (25.0%) and the least was dark red colouration (6.98%). Also in Abuja, (n=94), goats with brown colouration were in the majority (68.09%).

The apparent wide variation in coat colour is an indication that the goat populations have not been purified through impeccable selective breeding. Therefore, great opportunities exist for their improvement. One of the possibilities as postulated by Toth et al. (2006), is to design selection towards specific coat colour putting into cognizance the relationship between polygenetic effects of coat colour and other traits of interest (for example, physiology, morphology and productivity).

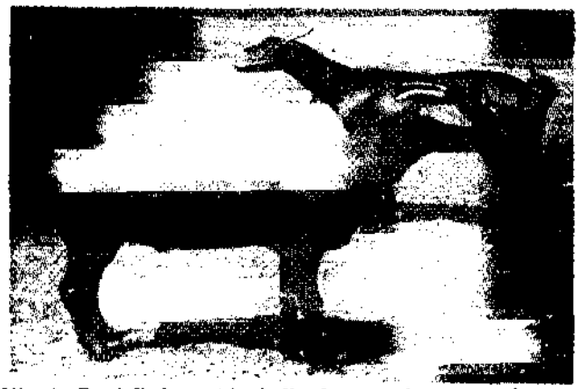


Fig 1: Red Sokoto/dark Red smooth coat colour

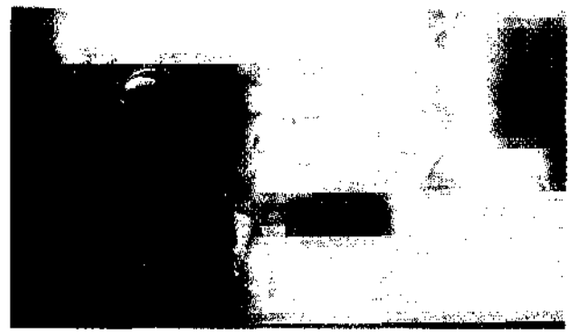


Fig. 2: Red Sokoto/brown coat colour



Fig 3: Red Sokoto goat /light brown coat colour

Structurally, majority of the Red Sokoto goats have short smooth hair (69.8%), followed by short rough hair (18.40%) and

long curly hair (11.8%), respectively. The preponderance of smooth hair structure could be an advantage as it provides a medium for convectional heat loss from the animal surface. This is supported by the assertion that hair structures have an important role to play in the adaptability of animals to different ecological zones (Banerji, 1984). Conclusively therefore, there are variations in the coat colour of the Red Sokoto goat with the predominant coat colour as brown; other common colours are light brown and dark red. The predominant hair type is short smooth hairs.

Table 9: Distribution of coat colour in smallholder goat herds in different locations

Location	N	Coat Colour			
		Dark Red	Brown	Light Brown	Others
Zaria	821	270 (32.89)	385(46.89)	120 (14.62)	46(5.60)
Katsina	888	62 (6.98)	414 (46.62)	222(25.00)	190(21.39)
Abuja	94	-	64(68.09)	21(22.34)	9(9.57)
Pooled	1803	323(18.41)	863(47.86)	363(20.13)	245(13.59)

Figures in parenthesis are percentages, i= goats with other colours other than the one listed



Plate 4: Light brown goat with rough hair type

The distribution of goats according to head profile in association with sex and coat colour is shown in Table 10. The head profile was strongly ($P<0.01$) associated with sex of the goats, but

independent of the coat colour. The sub-convex head profile was more peculiar to females than the males, while the sub-concave head profile was associated with the males than the females. Although there was no literature found that relates this observation, but this may probably be linked to the influence of secondary sex hormones on the development of both the males and females.

Table 10: Distribution of goats according to head profile in association with sex and coat colour

Attributes	Head profile	
	Sub- convex	Sub- concave
Sex		
Male	0	42
Female	75	3
X^2 value= 89.5; Table value at 1%= 6.63; df=1;**		
Coat colour		
Dark brown	**59**	17
Brown	17	12
Black	6	9
X^2 value = 5.96; Table value at 5% = 5.99; df =2; ns		



Plate 5: Brown with white spotted coat colour

A study was conducted in 2010 to morphologically characterize the Red Sokoto goat in Zaria and its environs. The study utilized records from 500 goats aged from 1 to 5 years and gave the following results: sub concave (94.4%) and sub convex (5.6%) head profile; small (61.8%) and medium (38.2%) ear size;

rigid ear consistency (100%); presence of horn (100%) in both sexes; vertically backward (88%); vertically backward and curved forward (11.4%) and arched (0.6%) horn types; raspil and calzon (61.6%); long (19.2%); and short (19.2%) hair types; and majorly non-wattled (96%). When wattled, it occurred bilaterally (85%) and unilaterally (15%) and non-paired. The observed coat colours in these goats were dark red (49.2%), brown (48.6%) and black (2.2%). The skin colour was predominantly brown (99.2%) with black in rare occurrence (0.8%). In another study on the incidence of wattle in 2011, 948 goats from 104 herds from northern and central plateau were used. Wattle incidence was (37.45%). Dams with wattle had (45.3%) chances of expressing it in their offsprings.

Gene Frequency of Qualitative Traits in Red Sokoto Goat.

The gene frequencies of observed qualitative traits in Red Sokoto goat are shown in Table 11. Frequencies of the dominant alleles for Red Sokoto goats was 0.04 (Waw), 0.11 (Brb),0.00 (Hop), 0.02 (Hpst) and 0.13 (STt). These values were quite lower than the expected Mendelian value of 0.75. However, higher frequencies were observed for the recessive alleles The P-value was highly significant ($p<0.01$).

Table 11: Gene frequencies of the observed qualitative traits in Red Sokoto Goats

Traits	*Alleles*	*Expected*	*Observed*	*Gene freq.*	*LOS*	χ^2*test*
Wattle	Wa^w	222	71	0.04	**	633.63
	Wa^+	666	817	0.96		
Beard	Br^b	222	170	0.11	**	343.67
	Br^+	666	718	0.89		
Horn	Ho^p	222	0	0.00	**	0.00
	Ho^+	666	888	1.00		
Head profile	Hp^s	222	24	0.02	**	808.79
	Hp^{sv}	666	864	0.98		
Supernumerary teats	St^t	202.8	195	0.13	**	221.00
	St^+	608.2	616	0.87		

Wa^w = wattled; Wa^+ = non wattled; Br^b= presence of beard; Br^+= absence of beard; Ho^p = polled; Ho^+ = horned; Hp^{st} = straight; Hp^{sv} = Sub-convex; St^t = presence of supernumerary teat; St^+ = absence of supernumerary teat

Table 12 shows the gene frequencies of the observed qualitative traits in Red Sokoto goats according to location and coat colour. Frequencies of the dominant allele ranged between 0.02 to

0.06 (Waw) for zones and 0.04 to 0.07 (Wa+) for coat colour. The gene frequencies observed generally for the dominant alleles at different zones and for coat colour ranged between 0.00 to 0.12, while higher frequencies (0.89 to 1.00) were recorded for the recessive alleles at the various zones and different coat colours for wattle, beard, horn and head profile. The observed frequencies of supernumerary teat (STt) on Red Sokoto goats was 0.08, 0.18 and 0.13 for Katsina, Daura and Malumfashi respectively while that of the coat colour was 0.31, 0.12, 0.21, and 0.12 for brown, light brown dark red and mixed colour, respectively.

Table 12 :Gene frequencies of the observed qualitative traits in Red Sokoto goats according to zone and coat colour

Traits	Alleles	N	Locations			Coat colour			
			Kat	Daura	Mal	BR	LB	DR	Mixed
Wattle	wa^w	71	0.04	0.02	0.06	0.04	0.04	0.07	0.04
	Wa^+	817	0.96	0.98	0.94	0.96	0.96	0.93	0.96
Beard	Br^b	170	0.10	0.09	0.11	0.09	0.11	0.08	0.12
	Br^+	718	0.90	0.91	0.89	0.91	0.89	0.92	0.88
Horn	Ho^p	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ho^+	888	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Head	Hp^{st}	24	0.02	0.01	0.01	0.01	0.01	0.01	0.03
profile	Hp^+	864	0.98	0.99	0.99	0.99	0.99	0.99	0.97
Sup.	ST^t	195	0.08	0.18	0.13	0.13	0.12	0.21	0.12
Teats	ST^+	616	0.92	0.82	0.87	0.87	0.82	0.79	0.88

Sup. teat= supernumerary teat; BR (brown); LB (light brown); DR (dark red); Wa^w = wattled; Wa^+ = non wattled; Br^b=presence of beard; Br^+= absence of beard; Ho^p = polled; Ho^+ = horned; Hp^{st} = straight; Hp^{sv} = Sub-convex; St^t = presence of supernumerary teat; St^+ = absence of supernumerary teat; Kat=Katsina; Malf=Malumfashi



Matrix of Genetic Distance of Red Sokoto Goat by Zone and Coat Colour

The estimated genetic distance of Red Sokoto goats between Katsina and Daura (Table 13) were 0.0004, 0.0001, 0.0001 and 0.0001 at the wattle, beard, head profile and supernumerary teat loci, respectively and 0.0004, 0.0001, 0.0004 and 0.0025 for Kastina and Malumfashi, while the genetic distance estimated for the qualitative traits in Daura and Malumfashi was 0.0002 (wattle), 0.0004 (beard) and 0.0025 (supernumerary teat). Genetic distances make it possible to evaluate the degree of genetic similarity between two populations by measuring the probability of one or more characters appearing in one of the populations but not in the other (Sournia, 1991). The minuscule values obtained at the Wa, Br, Hp and ST loci of goats are indications of phylogenetic relationship between the RSG at different location and is indicative of genetic similarity amongst the population of the RSG in these locations.

Table 13: **Matrix of genetic distance of Red Sotoko goats by locations**

Traits	Katsina vs Daura	Katsina vs Malumfashi	Daura vs Malumfashi
Wattle	0.0004	0.0004	0.0002
Beard	0.0001	0.0001	0.0004
Head profile	0.0001	0.0001	-
S/teats	0.001	0.0025	0.0025

S/teats= Supernumerary teats

Table14 shows the matrix of genetic distance of Red Sokoto goats by coat colour. The estimated genetic distance at the beard locus ranges between 0.0001 and 0.0016. At the wattle locus, the estimate observed was 0.0009 for BR and DR; LB and DR and DR and mixed colour patterns. The estimated genetic distance at the head profile locus for BR and mixed, LB and mixed, DR and mixed was 0.004 while that observed at the supernumerary teat locus ranged from 0.0004 to 0.0081.

Table 14:Matrix of genetic distance of Red Sokoto goats by colour

Traits	BR vs LB	BR vs DR	BR vs Mixed	LB vs DR	LB vs mixed	DR vs mixed
Wattle	-	0.0009	-	0.0009	-	0.0009
Beard	0.0004	0.0001	0.0009	0.0009	0.0001	0.0016
Head profile	-	-	0.0004	-	0.0004	0.0004
S/Teats	0.0004	0.0064	0.0004	0.0081	-	0.008

BR (brown); LB (light brown); DR (dark red); S/teats= Supernumerary teats

Blood Biochemical Polymorphism In Goats

Blood and blood components are undoubtedly essential biological characteristics and warrant consideration for the study of a breed. Studying the hematological picture is helpful for clinical diagnostics, but it is also essential to reflect the particular evolution of a breed or a population; actually, the fact that some blood factors are related to the suitability of the breeds under particular environmental conditions has been repeatedly suggested (Tibbo et al.,2005; Essein et al.,2011).

In the recent times, advances in the field of biotechnology has opened up a completely new area at molecular levels with the introduction of techniques such as routine electrophoresis employed for the detection of polymorphism at protein and enzyme loci as well as other serological and immunogenetic procedures for the measurement of variation(Salako et al., 2007). Hemoglobin (Hb) has been one of the most studied polymorphisms in vertebrate species since the infancy of both population and evolutionary genetics. However, owing to the close relationship between structure and function, this complex protein remains a fascinating subject from all points of view and especially in terms of its molecular, genetic and adaptive features.

The electrophoretic analysis of blood sample collected from goats at different locations in Abuja and Zaria and Katsina, Kano

and Jigawa States showed the presence of 3 haemoglobin genotypes; AA, AB and BB (Table 15, Plate 7). These 3 haemoglobin genotypes were produced by two co-dominant alleles HbA and HbB. However another allele HbC was detected (in association with the HbA allele to form HbAC genotype) at very low frequency, mostly in kids of between 1 to 12 months of age (Akpa et al., 2011c; Ibrahim et al., 2011; Alphonsus et al., 2012; Sam et al., 2012b). This HbC allele had earlier been reported by Salako et al.(2007) in the same breed (Red Sokoto goats) and Deza et al.(2000) in the goats of Colon and Ischlin, and this has been variously associated with incidence of anemia due to illness environmental stress in small ruminants. However, some studies identified HbC allele as foetal haemoglobin in very young kids and may not necessarily be an incidence of anemia or illness especially in the kids of less than 6 months of age. It can however indicate abnormality if it persist in high percentage beyond the neonatal age.

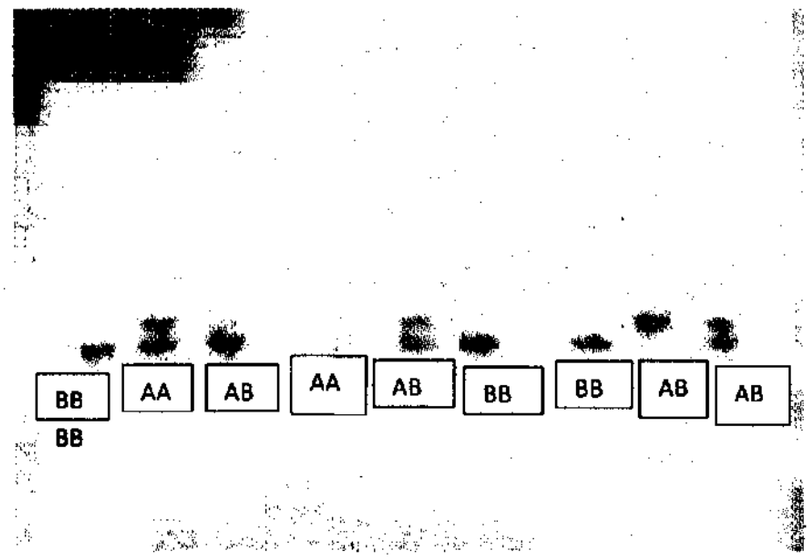


Plate 7: Haemoglobin electrophoregram in goats.

The frequency of the heterozygote haemoglobin type HbAB was higher than either of the homozygotes; HbAA and HbBB in all the four locations.

However, the preponderanceof HbA alleles was about twice that of the HbB allele; Abuja (0.66 vs 0.34), Jigawa (0.68 vs 0.32), Katsina (0.59 vs 0.41) and Zaria (0.60 vs 0.40).The similarity in the distribution pattern of the Hb-type in the four locations is probably due to similarity in topography and climatic condition, all the 4 locations of the study are situated on the high altitude of the Northern guinea savanna of Nigeria. However, this observation was at variance with the earlier report of Salako et al.(2007), who reported higher frequencies of HbB alleles than HbA allele in goats at their respective locations of studies. This variation is probably due to differences in the topographical locations; their studies were on goats at low altitudes of Bengal India (altitude 42fts above sea level) and Ibadan Nigeria (altitude 780fts above sea level), respectively, while the present study was conducted at the high altitude of Abuja(2552fts above sea level), Katsina (1525ft above sea level) and Zaria (2251ft above sea level) in Nigeria.

The high preponderance of heterozygotes with intermediate heredity (AB) than either of the homozygote (AA or BB) usually indicates the proportion of heterozygotes in a random mating population. The similarity in the estimated heterozygotism in all the four locations studied therefore, suggests that proportions of heterozygotes in the samples were similar although the significance of the difference was not tested. It has a clear biological meaning as it can be regarded as the measure of genetic diversity at the hemoglobin locus in the investigated populations; hence showing that the studied populations have similar flock structure and mating pattern.

Table 15 : Gene and genotypic frequencies of haemoglobin (Hb) types in goats at different locations

Location	Sample size	Gene frequencies		Genotypic frequencies		
		HbA	HbB	HbAA	HbAB	HbBB
Abuja	94	0.66	0.34	0.36	0.48	0.16
Jigawa	150	0.68	0.32	0.43	0.50	0.07
Katsina	150	0.59	0.41	0.37	0.48	0.17
Zaria	211	0.60	0.40	0.36	0.48	0.16
Overall	605	0.63	0.37	0.38	0.48	0.14

The distribution of Hb-types in the study area was found to be independent of age, coat colour and head profile of the goats (Table 16). However, the foetal Hb AC was mainly observed in the young goats that were within one year of age (83%) and non beyond 2 years of age. This is in line with the report of Brandis (2000) that at birth about 80% of the neonate's haemoglobin is foetal

haemoglobin (Hb C) , this decreases rapidly so that by the age of 6 months less than 5% of the young's haemoglobin is HbC. Only very small amounts of Hb C are normally present in adults (<1% of total haemoglobin in adults).

Table 16: Distribution of goats according to haemoglobin types in association with age, coat colour and head profile

Age (months)	**AA**	**AB**	**BB**	**AC**
12	20	10	25	12
18	14	4	13	1
24	5	2	9	1
30	0	0	4	0
X^2value = 12.71; df= 9, Table value at 5% = 16.92; ns				
Coat colour				
Dark brown	26	11	30	9
Brown	10	4	13	2
Black	3	4	5	3
X^2 value= 6.17; df=6; table value at 5% =12.59; ns				
Head profile				
Sub concave	15	9	18	3
Sub convex	26	10	29	11
X^2 value=1.83; df=3; table value at 5%=7.81; ns				

Researchers had identified the existence of different types of potassium (K) in different species of animals, and that in sheep for instance, there are two types of K which is high potassium (HK) and low potassium (LK) with the LK type dominant over the high K type (Soysal et al.,2003). Also Gurcan et al (2010) reported a range of 4.23 to 11.69mmol/l for low K type in animals. In view of the forgoing, a study was conducted to investigate the type and concentration of potassium (K) in the blood of the Red Sokoto goats population in Katsina and Jigawa States. The study revealed the existence of two types of K in the goats, as high potassium (HK) and low potassium (LK) with the LK type dominant over the HK type (Table 17)

Table 17: Gene and Genotypic Frequencies of potassium types of Goats in Jigawa and Katsina States

Population	No of Animals	Gene Frequencies		Genotypic Frequencies	
		HK	LK	K^H	K^L
Overall	250	0.84	0.16	0.91	0.01
Katsina	100	0.83	0.17	0.91	0.01
Jigawa	150	0.85	0.14	0.92	0.01

The gene frequencies for the HK and LK were 0.844and 0.156, respectively, while the genotypic frequencies for the HK and LK types were 0.91 and 0.01, respectively (Table 17). This finding is in agreement with the reports of Cobanoglu et al. (2011) that the allele frequencies 0.80 and 0.20; 0.85 and 0.15; 0.87 and 0.13 for HK and LK respectively was observed in Saanen, Maltase and Turkish Hair goats, respectively in Turkey. Although LK type was dominant to its counterpart HK genetically but majority of the animals in the population studied were HK type. This observation was earlier reported by other authors (Al-Samarrae and Younis, 2011). A study was conducted in 2013 to define the genetic structure for haemoglobin, transferring and carbonic anhydrase using 300 goats each for Red Sokoto, Sahel and West African dwarf (WAD). The result showed that the three blood proteins were polymorphic across the breeds (Table 18). The polymorphic forms were haemoglobic (AA, AB, AC and BB), transferring (AA, AB, AC and BB) and carbonic anhydrase (FF and *SS*).

Table 18: Gene and Genotypic Frequencies of blood biochemical polymorphisms in Nigerian goat breeds.

Polymorphic Traits		Red Sokoto	Sahel	West African Dwarf
Haemoglobin (Hb)				
Gene Frequencies Hb A	Hb	0.41	0.55	0.43
Hb B		0.58	0.43	0.55
Hb C		0.01	0.02	0.02
Genotypic Frequencies Hb AA	Hb	0.23	0.39	0.23
Hb AB		0.31	0.38	0.30
Hb AC		0.01	0.02	0.02
Hb BB		0.45	0.21	0.45
Transferring (T_f)				
Gene Frequencies A	T_f	0.39	0.37	0.41
B	T_f	0.13	0.56	0.12

	T_f	0.48	0.07	0.47
C				
Genotypic Frequincies	T_f	0.13	0.22	0.13
AA				
	T_f	0.22	0.54	0.19
AB				
	T_f	0.53	0.11	0.55
AC				
	T_f	0.12	0.13	0.12
BB				
Carbonic anhydrase (C_A)				
Gene Frequencies		0.98	0.98	0.98
$C_A F$				
		0.02	0.02	0.02
$C_A S$				
Genotypic Frequencies		0.99	0.99	0.99
$C_A FF$				
		0.01	0.01	0.01
$C_A SS$				

Adaptive and Blood Biochemical Characteristics and Factors Affecting Them in Goats

Economic pressures of various kinds are forcing the production of livestock into climatic environments that are increasingly more remote from the considered ideal for optimal production and feed utilization. Thermal stress, which is one of the major factors that affect the productivity of many farm animals can be reflected in an easily observable changes in pulse rate, respiration rate, and rectal temperature. The most obvious index of thermal stress is body temperature response. Deviation from normal rectal temperature indicates that the animal is under stress, that its homeothermic mechanisms are compromised.

Adaptive characteristics of animals serve as a key to managing any livestock operation. Adaptive traits such as rectal temperature, heart rate, and flank movement have been documented to have some significant effect on genetic variations. Every normal animal has a range of individual adaptive traits in relation to a specific physiological pattern.

A work aimed at studying the effects of Haemoglobin type, sex and age on adaptive and blood biochemical characteristics of Red Sokoto goats was conducted (Akpa et al., 2013a, b) using 94 smallholder goats herd in Abuja, Nigeria showed that rectal

temperature (RT) is directly affected by the surrounding and ambient temperature, and high ambient temperature has a negative effect on productivity of the animal. The mean RT of the goats used for the study was 38.9oC with minimum and maximum body temperature of 38.1 and 39.4oC (Table 19). These values were within the reference range of goats in thermal neutral condition, thus indicating that the goats used for this research showed no clinical signs of stress during the research period. The body temperature of the goats exhibited minimal variations (CV=0.5%), thus implying that goats are homoeothermic animals, they can maintain near constant body temperature under wide range of environmental conditions.

The Heart Rate (HR) is the pulse that helps to know the beating rate of the heart which is measured in beats per minute (bpm) using stethoscope. The mean HR of the goats used in the study was 76.1 bpm, with the min and max HR of 70 and 80bpm. This is slightly higher than the range of 70 -75bpm reported by Derman and Noaks (1994) in goats. The minor difference observed in the values of the HR may be explained by differences in geographical conditions, season or climate and physiological conditions of the sample goats.

Rectal temperature and heart rate have shown to be good indicators of the thermal stress and may be used to assess thermal adversity of the environment (Al- Haidary, 2004).

Table 19: Summary Statistics of the measured characteristics in Red Sokoto Goats

Characteristics	N	Mean±SE	CV(%)	Min	Max
Rectal Temperature (°C)	94	38.9±0.02	0.5	38.1	39.4
Heart Rate (bpm)	94	76.1±0.39	3.8	70.0	81.0
Adaptive coefficient	94	4.3±0.02	5.0	4.1	4.6
Albumin concentration (g/l)	94	38.4±0.34	8.5	31.0	48.0
Hemoglobin concentration (g/dl)	94	8.9±0.16	17.1	4.0	12.7
Potassium concentration (Mmol/l)	94	4.0±0.06	14.7	3.0	5.8

Potassium is one of the intracellular elements that regulate the intracellular density of the cell. The amount of K-concentration is fairly high at intracellular membranes (Gurcan.,et al 2010). Relating the adaptive and blood biochemical characteristics of the

goats with their haemoglobin types, sex and age of the goats, it was observed that the variation of Hb type with adaptive and blood biochemical characteristics was significant (P<0.05) except Hb-concentration (Table 20). The relationship between Hb types and HR can be linked to the different levels of oxygen carrying capacity of the different Hb types. In this study, higher HR was observed in goats with Hb AA and AB, and Hb A is known to be the haemoglobin allele with highest affinity for oxygen. This is in line with the earlier report of Huisman et al.(1959) who related the preponderance of Hb A to it's greater affinity to oxygen. This could also explain the high adaptive coefficient observed on goats with Hb types AA and AB since adaptive coefficient is a function of HR and RT. The Adaptive Coefficient (AC) (which is the function of RT and HR) signifies the level of adaptability of the goats to the environments varied significantly (P<0.05) with Hb types , sex and age of the goats. The goats with Hb AA and AB had higher AC than those with BB and AC; likewise the bucks had higher AC than the does.

Table 20: Effect of hemoglobin type on adaptive and blood biochemical characteristics

Characteristics	Haemoglobin types				
	AA	BB	AB	SEM	LOS
Rectal Temperature (°C)	39.0^{a}	39.0^{a}	39.0^{a}	0.02	*
Heart Rate (bpm)	76.6^{a}	75.3^{b}	76.2^{a}	0.40	*
Adaptive coefficient	4.4^{a}	4.3^{b}	4.4^{a}	0.02	*
Albumin concentration (g/l)	37.6^{b}	39.2^{a}	38.6^{a}	0.34	*
Hemoglobin concentration (g/dl)	9.1	8.6	8.8	0.16	Ns
Potassium concentration (Mmol/l)	3.8^{b}	3.9^{a}	4.0^{a}	0.06	*
Number of observations	30	11	41	94	

The variation of HR, AC and Albumin concentration with sex was highly significant (P<0.01; Table 21). The RT of the buck and does were similar however, the HR was higher in bucks (78.5bpm) than the does (75.0bpm) This is probably due to the high sexual activity of the bucks. There was no significant (P>0.05) difference between the bucks and does in Hb and K concentration. Haemoglobin type had been reported to vary with breed and location (Abdussamad et al., 2004; Essien et al., 2011).

Table 21: Effect of Sex on adaptive and blood biochemical characteristics

Characteristics	Sex		SEM	LOS
	Buck	Doe		
Rectal Temperature (°C)	39.0	39.0	0.03	Ns
Heart Rate (bpm)	78.5[a]	75.0[b]	0.49	**
Adaptive coefficient	4.4[a]	4.3[b]	0.02	**
Albumin concentration (g/l)	39.8[a]	37.7[b]	0.49	**
Hemoglobin concentration (g/dl)	9.1	8.7	0.26	Ns
Potassium concentration (Mmol/l)	3.9	4.0	0.08	Ns
Number of observations	30	64	94	

[ab]: means within the same row with different superscripts differ significantly(P<0.01); :not significant;

Age significantly (P<0.05) influenced HR, AC and albumin concentration but had no significant influence on the RT, Hb and K concentration (Table 22). Although there was no trend in the variation of HR and AC with age, but it was observed that the HR and AC was higher in the older goats than the younger, however the albumin concentration significantly decreased with progressive increase in age of the goats.

Table 22: Effect of Age on adaptive and blood biochemical characteristics

Characteristics	Age of goat				SEM	LOS
	12mon	18mon	24mon	30mon		
Rectal Temperature (°C)	39.0	39.0	39.0	39.0	0.02	Ns
Heart Rate (bpm)	77.1[b]	74.4[c]	74.4[c]	78.5[a]	0.37	*
Adaptive coefficient	4.4[b]	4.3[c]	4.3[c]	4.5[a]	0.02	*
Albumin concentration (g/l)	39.2[a]	37.4[b]	36.7[c]	36.5[c]	0.32	*
Hemoglobin concentration (g/dl)	9.1	8.7	8.3	8.5	0.16	Ns
Potassium concentration (Mmol/l)	4.0	4.0	4.0	4.0	0.06	Ns
Number of observations	55	25	12	2	94	

[ab]: means within the same row with different superscripts differ significantly(P<0.05); ns: not significant;

The influenced of zone, breed, sex and age on adaptive characteristics of goat was studied using 929 goats in Jigawa State. The mean rectal temperature, heart rate and adaptive coefficient of goat were 38.6±0.02°C, 72.3±0.17bpm and 4.2±0.01, respectively. The characteristics were less variable (CV=1.45-7.12%). Zone, sex and age of the goat significantly (p<0.01) influenced the adaptive characteristics. However, breed of the goats (Sahel, Red Sokoto, West African dwarf and crosses) had no effect on them. The heart

rate and adaptive coefficient were higher for north east zone compared to north west and central zone of Jigawa state which were similar. On the other hand, rectal temperature decreased from north west (38.7°c) to north east (38.5°c) and central zone (38.4°c) of the state. Males had higher rectal temperatures, heart rates and adaptive coefficients than females; and these characteristics decreased with age in the studied goats.

Milk Yield, Composition and Estimations in Goats

Nigeria is endowed with large numbers of small ruminants, which are yet to be fully investigated for milk production. Goats are the largest group of ruminant livestock in the country, totaling over 38 million; predominantly owned by the rural households, with ownership spread across all age groups and sexes. The development of the Nigerian dairy goats will require a critical evaluation of all the locally available breeds and their potential for milk production. A number of studies have been carried out on the milk yield and composition of indigenous breeds of goats (Ehoche and Buvenandran, 1983; Akpa et al., 2005; Akpa et al., 2012) and products (Akpa et al., 2011d). Generally the milk yield of the does drops after a few weeks and becomes negligible by 15th week (Ngere, 1985). These reports emanated from universities and research centers; there is no information regarding on-farm milk production. Therefore, the milk yield characteristics of smallholder agro-pastoral Fulani Red Sokoto goats were evaluated using records obtained from a total of 92 does in 6 herds, collected over a 2 year period (Akpa et al., 2002a). The result indicated that the total yield was 79.8kg, daily yield 0.66kg, peak yield 1.21kg and day of peak production 28.7 day of lactation (Table 23)

Table 23: Least squares means for lactation milk yield characteristics of Red Sokoto goats

Characteristics	Mean	SD	CV (%)
Initial yield(kg)	0.946	0.432	45.7
Peek yield (kg/day)	1.209	0.661	54.7
Peak day	28.704	20.035	69.8
Total yield (kg)	79.827	30.813	38.9
Daily yield (kg/day)	0.664	0.258	38.6
Day 120 yield (kg/day)	0.432	0.192	44.4

The milk yield characteristics of Red Sokoto goats were highly variable with a coefficient of variability of 38.6 to 69.8%. The milk yield characteristics were significantly (P<0.01-0.05) influenced by herd, season, parity and litter size of the dam. Highly positive and significant (P<0.01) correlations(r= 0.66-0.99) existed between the total yield and the average daily yield, peak yield, initial yield and 120 yield. A negative and significant (P<0.05) correlation (r= -0.33) was observed between the peak day and initial yield. The non-homogeneity of the milk yield characteristics in Red Sokoto goats suggests the possibility of improving their daily production by selection of high yielding does. Selection for higher initial milk yield may improve other milk yield characteristics.

The goat is generally known to produce relatively more milk per unit of live weight compared to the cow. Also, as dairy animal, the doe is known to produce three times as much milk as the cow (Wilson, 1988), relative to body size. It has been reported that once daily milking could reduce fixed cost and may be used strategically as a quota management tool and could become the production system of choice in a programme intensification (Christopher and Richard, 1994). However, there is ample evidence to show that milking thrice or four times daily increased milk yield relative to once or twice daily milking, and once daily milking reduces milk yield in comparison to higher frequencies. (Carruthers and Copeman,1990). Therefore, the effect of milking frequency on milk yield characteristics (total yield, average daily yield, peak day, flow rate, dairy merit and persistency) of Red Sokoto goats was carried out (Akpa et al., 2004b). Thirty (30) lactating does were divided into three groups on milking frequency basis of once, twice and thrice a day milking of 10 animals each. All the does were at the 3rd lactation and were hand milked for a period of 120 days post-partum.

While milking frequency significantly (P<0.05) influenced total yield, average daily yield, peak yield and milk flow rate, did not affect peak day, dairy merit and persistency of these goats (Table 24). The milk yield characteristics increased with increase in milking frequency. Conversely, increase in milking frequency decreased milk flow rate.

The observed corresponding incremental effects of milking frequency on milk yield characteristics have been reported by

several other workers (Erdman and Varner, 1995; Barpeled et al., 1995). As was observed by Barpeled et al. (1995), the main effect of milking frequency on milk yield was directly related to the actual milk removal from the udder, regulated by the presence of protein in the milk that inhibits milk secretion and the feedback inhibitor of lactation (FIL). As milk accumulates in the udder between milking, secretion rate gradually decreases because of the action of FIL.

More frequent removal of milk from the udder enables a longer maximal secretion rate than less frequent one, causing milk to accumulate in the udder between milking, leading to gradual decrease in milk secretion rate due to the FIL effect. Therefore, milking frequency is extrinsic in action; thus explaining why it had no influence on peak day, dairy merit and persistency which are intrinsic properties of the does that are less subjected to extrinsic influences.

Since labour for milking harvest accounts for as much as 80% of animal milking cost (Blake and McDaniel, 1978), and over 50% of the routine operational requirement of dairy farms (Albright, 1964), labour for milk harvest may be reduced by adopting a system of milking that allows high milk yield at a faster flow rate. For economics of milk production therefore, twice a day (TAD) milking appears to provide optimum milking frequency for Red Sokoto goats in this study. This is because there was a 40% (200 g) increase in milk yield with a marginal reduction in flow rate of 14% (0.6 g/s) compared to once a day (OAD) milking. Although thrice a day (THAD) milking had a significant increase in milk yield of 50% (300 g), there was a wide reduction in milk flow rate of 52% (1.5g/s) when compared with OAD milking. All the same, THAD milking provided an increase of 10% (56 g) over TAD), but this was not significant ($P>0.05$) and cannot compensate for the reduction in the milk flow rate of 31% or 0.9 g/s. This suggests a better profit and economic margins for TAD since milking speed determines the dairy labour profit.

Accurate prediction of yield responses to increasing milking frequency is required for sound decisions by dairy producers to optimize economic returns (Erdman and Varner, 1995). It has been reported that more frequent removal of milk enables a longer maximal secretion rate (Barpele et al., 1995). In Red Sokoto goats, both total milk yield and efficiency of milk

Table 24: Least squares means of dairy characteristics by milking frequency of Red Sokoto goats

Characteristics	N	Once	Twice	Thrice	Overall
Total yield (kg)	10	39.6±3.01[b]	60.1±3.59[a]	66.8±2.58[a]	55.5±2.95
Mean daily yield(kg/day)	10	0.3±0.03[b]	0.6±0.02[a]	0.6±0.02[a]	0.5±0.03
Peak yield (kg/d)	10	0.6±0.03[b]	0.9±0.06[a]	0.9±0.06[a]	0.8±0.04
Peak day(days)	10	27.5±1.41	36.8±6.71	36.8±6.71	33.8±4.01
Flow rate (g/s)	10	4.4±0.48	2.9±0.21[b]	2.9±0.21[b]	3.7±0.25
Dairy merit (%)	10	10.3±0.47	10.9±0.34	10.9±0.34	10.6±0.21
Persistency (%)	10	96.6±6.30	92.0±2.25	99.5±15.21	96.1±7.92

a,b means on the same row with different superscripts differ significantly (P<0.05)

production were influenced positively by increasing milking frequency (Akpa et al., 2001b). However, the effect of milking frequency on milk composition of the goats has not been ascertained. Therefore, the effect of three milking frequencies (once, twice and thrice daily) on milk yield and composition of Red Sokoto goats was ascertained using a total of 24 lactating does on lactation period of 120 days (Akpa et al., 2005). The total and daily milk yield, % fat, %protein, %total solids, %Ash and %non-solid fat were 56.028kg, 0.467kg, 5.35%, 5.71%, 15.53%, 0.83% and 10.17%, respectively. Milk yield and composition were significantly (P<0.01) influenced by milking frequency. Increasing milking frequency also increased milk yield and composition. Milk yield and composition were significantly (P<0.01) influenced by milking frequency (Table 25). Increasing milk frequency also increased milk yield and composition. Milk yield was significantly (P<0.05) and positively correlated with milk composition (r = 0.89-0.98) and; the relationship was significantly enhanced by milking frequency. The percentage increases in milk yield from once daily to twice and thrice, and from twice to thrice were 52.66, 69.50 and 11.03%, respectively. Twice daily milking may have a better economic feasibility for Red Sokoto goats.

Table 25: Effect of milking frequency on total milk yield and composition

Milk composition	Frequency		
	Once	Twice	Thrice
Number of observations	8	8	8
Milk yield (kg)	39.480±0.137[c]	60.270±0.221[b]	66.920±0.198[a]
Fat yield (kg)	1.986±0.007[c]	2.917±0.011[b]	4.118±0.012[a]
Protein yield (kg)	2.184±0.008[c]	3.458±0.013[b]	3.988±0.013[a]
Total solid	5.996±0.021[c]	8.555±0.031[b]	11.317±0.033[a]
Ash (g)	340.480±1.19[c] 0	468.720±1.750[b]	558.88±0.021[a]
NSF(kg)	3.999±0.014[c]	5.797±0.021[b]	7.189±0.021[a]

a,b,c means on the same row with different superscripts differ significantly (P<0.05); NSF: not-solid-fat

Milk flow rate in goats is highly heritable (Recodeu et al., 1989). Selection for this trait has been suggested as a means of reducing the need for milking labour, since labour for milk harvest may account for as much as 80% of annual milking cost and over 50% of routine operational requirement of dairy farms (Akpa et al., 2003d). For the dairy farmer, decision as to milking frequency can have large economic effects since increasing milk frequency results in higher variable cost, such as feeds, labour and utilities among others. Twenty-four Red Sokoto goats were hand milked for 120 days to determine milk flow rate (Akpa et al., 2003d). The does were grouped into three for once, twice and thrice a day milking to determine the effect of milking frequency on milk flow rate. The average daily milk yield and flow rate were 466.9g and 3.5g/sec, respectively (Table 26). Milking frequency significantly ($P<0.01$) influenced milk yield and milk flow rate (Table 26). The higher the milking frequency the higher the milk yield but with decreasing flow rate. Milk yield and flow rate were significantly ($P<0.01$) and positively correlated ($r=0.88$). Both milk yield and flow rate reached their peak at the 4th week lactation. The optimum milking frequency for Red Sokoto goats was twice daily milking, since there was 52.7% increase in milk yield from once a day with a marginal 7.9% reduction in milk flow rate.

Table 26: least squares means for average daily milk yield and milk flow rate over 120 days lactation period

Frequency	N	Milk yield (g)	Flow rate (g/s)
Once a day	8	331.8 ± 19.56^{c}	3.9 ± 0.19^{a}
Twice a day	8	506.5 ± 31.63^{b}	3.6 ± 0.23^{b}
Thrice a day	8	562.4 ± 28.33^{a}	2.9 ± 0.16^{c}
Overall	24	466.9±26.51(23.61)	3.5±0.19(22.90)

a,b,c means on the same row with different superscripts differ significantly ($P<0.05$)

A study was conducted in Jigawa and Katsina States to relate lactation characteristics of goats with haemoglobin and potassium polymorphisms (Sam et al., 2012b; Table27). Potassium type had no significant effect on the lactation characteristics while Hb type significantly ($P<0.05$) influenced only average daily milk yield and peak yield with the heterozygote Hb genotype AB being superior to genotypes AA and BB.

Efficiency of Milk Production

There is limited information on the measures of efficiency of milk production in goats. Therefore, the biological advantages of goats as milk animals have been grossly underestimated. The Red Sokoto goats are the most important breed of goats in Nigeria and contribute about 70% of the country goats' population (Osuhor et al., 2002). A knowledge of their milk production efficiency (dairy merit) and optimum milking frequency would be useful in achieving good management and selection programmes for an improved milk production (Akpa et al., 2001b).An attempt to investigate the influence of milking frequency on efficiency of milk production in Red Sokoto goats utilized 24 does, divided into three groups of 8 each and hand-milked once, twice and thrice a day for 120 days (Akpa et al.,2001b). The results showed that in 120 days lactation, the total milk yield and gross energetic efficiency of milk production (dairy merit) was 55.5kg and 8%, respectively (Table 28). The net energy efficiency value was 34.4%, indicating a recovery of 34.4% energy of the total digestible nutrient of feed in milk. Milking frequency significantly ($P<0.01$) influenced efficiency of milk production. The characteristics estimating efficiency of milk production in Red Sokoto goats were highly variable (CV= 21.4-42.7%). The 8% dairy merit of Red Sokoto goats was low but with the high estimates of coefficient of variability (42.74%), there may be chances for improvement through selection and better management. However, when compared with calculated 25.3% for Saanen goats (Gall, 1996), the Red Sokoto goat was 32% as efficient in milk production as Saanen goat.

Study to determine milk yield and efficiency of estimation of total milk yield using average records in non-suckling Red Sokoto goats was also carried out (Akpa and Duru.,1999). The result showed that 12 weeks milk yield characteristic of non-suckling Red Sokoto does was similar to already existing reports on the breed. Milking Red Sokoto does once a day could supply a family of 8 members a daily requirement of 65g of milk. Therefore, a household of 8 members can effectively use four breeding does cycled over the year to meet their dairy requirement. One day or average of two days weekly records was adequate in estimating total yield with minimum error, and therefore, could be used to monitor milk yield characteristics of these goats on the field.

Table 27: Lactation characteristics of goats in Jigawa and Katsina States Based on Haemoglobin and potassium Types (mean ±se)

Factor	ADY(g)	TY(kg)	IY(g)	PD(days)	PY (g)	LL(days)	LDY(g)
Hb-type							
HbAA	253.70±2.92[a]	30.19±0.59	241.00±4.93	34.60±0.69	359.72±5.66[a]	119.00±1.57	107.13±0.61
HbAB	257.00±2.78[a]	30.32±0.58	244.42±0.58	32.68±0.67	385±36.15[a]	118.73±1.54	106.17±0.60
HbBB	240.55±5.55[b]	27.32±1.13	247.43±9.20	32.79±1.27	350.170[b]	113.60±2.99	105.96±1.16
K-type							
HK	248.41±2.01	29.65±0.59	244.36±3.39	33.09±0.47	360.41±4.05	118.32±1.12	106.94±0.43
LK	247.19±4.69	29.25±0.99	239.33±7.90	32.80±1.11	349.64±9.43	117.87±2.62	106.64±1.01

ADY = Average Daily Yield, TY = Total Yield, IY = Initial Yield, PD = Peak Day, PY =Peak Yield, LL = Lactation Length, LDY = Last Day Yield, Hb-type = hemoglobin type, K-type = potassium types

Lactation Pattern and Characteristics

Dairy development in Africa is still at its primary stage. What the farmers and researchers require now are simple parametric models that would describe the lactation pattern of the animals, which is necessary for their nutritional and reproductive management estimation of total lactation yield, expected time of peak production, peak yield and management decisions on the level of culling(Akpa et al.,2003c). Model to be used must be able to determine some differences such as low and high milk production. The suitability of exponential, parabolic exponential, inverse polynomial and gamma-type models in describing the lactation pattern of agro- pastoral Red Sokoto goats was assessed using 1122milk yield records (Akpa et al., 2003c). A total of 66 does from 6 herds were milked over a two year period (Table 30). Milk yield characteristics vary from 25 to 70% with the maximum variability observed for the week at peak production. The most efficient model was the gamma-type in terms of best fit (R2 = 98.1%; RSD= 0.0213; Random distribution of residuals, ($P<0.05$) and in describing the yield characteristics (Table 29).

Table 28: Least squares means for character estimating efficiency of milk production

Characters	N	Mean	Minimum	Maximum	CV(%)
Body weight (kg)	24	25.0±0.54	20.3	32.0	10.47
Total milk yield(kg)	24	55.5±3.95	29.8	78.0	26.09
Total fat yield (kg)	24	3.0±0.20	1.5	4.8	33.11
FCM(kg)	24	67.6±4.19	34.4	103.3	30.36
FCM(kg/w)	24	2.72±0.18	1.58	3.83	31.63
FCM (kg MW)	24	6.05±0.38	3.50	8.73	31.79
FCM (day/kgW)	24	0.02±0.001	0.01	0.07	30.25
FCM (day/kgMW)	24	0.05±0.03	0.03	0.07	31.10
NEE(%)	24	34.4±1.50	23.87	43.78	21.41
DM(%)	24	8.0±0.70	3.44	12.95	42.74

In goats, determination of lactation peak and other characteristics of the curve (rapidity in achieving the peak and persistence) are very important for genetic and feeding purposes. The level of peak yield and persistency determine to a large extent, the shape of the lactation curve(Akpa et al.,2002a).Milk yield of 66 nursing does recorded in Zaria, Nigeria were used to characterized the lactation curve and study the influencing factors in Red Sokoto goat (Akpa et al.,2002a). Lactation curve parameters obtained by fitting the model, Yt = atbe-ct were subjected to statistical analysis, using herd, season, parity, litter size and litter composition of dams. The result indicated that the lactation curve of these goats was characterized by milk production increasing in early lactation, attaining a peak at approximately 2 to 5 weeks post-partum and thereafter declining slowly to the end of lactation (Fig. 8, 9 and 10). The observed total yield, peak yield, peak day and the estimated persistency defined as C-(b+1) were 79.3kg, 1.2kg, 20.5 and 143.3, respectively (Table 30). Parameters 'a' and 'c' were strongly but negatively correlated (r= -0.53; P<0.05) and parity only affected (P<0.01) parameter 'a'. None of the factors significantly influenced parameter 'b'. The significant herd and season effects may have practical implications in determining optimal feeding management and season of breeding to maximize total lactation yield. Shapes of the lactation curve provided by the gamma-type model strongly suggest that animals with higher initial level of production are likely to attain the peak faster and thereafter decline at a slower rate than those with lower initial level of production. Non- genetic factors influencing the shape of lactation curve in Red Sokoto goats were herd, season and parity.

Table 29:Estimates for curve parameters and yield characteristics by models (Mean±SE)

Parameter/character	N	Gamma	Parabolic	Inverse	Exponential
b_0	66	0.452±0.03	0.968±0.036	0.006±0.0016	1.358±0.036
b_1	66	0.444±0.053	0.0045±0.002	0.0001±0.000	-
b_2	66	0.020±0.001	-0.00011±0.000	0.000018±0.00	0.011±0.005
R^2	66	98.1±0.07	94.2±0.22	85.5±0.05	69.3±0.53
Residual SD	6	0.0213	0.0213	0.0423	0.0709
Peak yield (kg/d)	66	1.148±0.090	-	1.290±0.024	-
Peak week	6	3.2±0.54	-	2.8±1.96	-
Total yield (kg)	6	93.0±0.31	91.5±0.22	97.4±0.29	86.7±0.16

Table 30:Actual and gamma-type means and standard errors for lactation characteristics

Characteristics	Actual			Gamma	
	N	Mean	SE	Mean	SE
Total yield (kg)	66	79.3	2.36	83.9	0.031
Peak day	66	20.5	2.52	13.7	3.78
Peak yield(kg)	66	1.2	0.05	0.978	0.121
Persistency	66	-	-	143.2	0.02

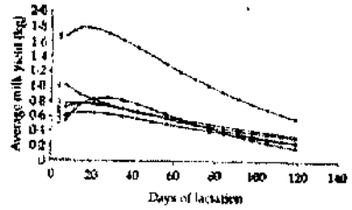


Figure 1 Effect of herd on goat lactation curves (herd number given on graph).

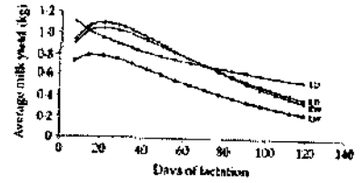


Figure 2 Effect of season of kidding on goat lactation curves: ED early dry; LD late dry; EW early wet; LW late wet.

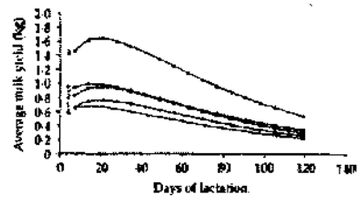


Figure 3 Effect of parity of doe on goat lactation curves (parity number given on graph).

If the ever widening shortfalls in dairy production supplies are to be met through indigenous production, there is an urgent need to exploit the potentials of goats as dairy animals to supplement milk from cows. Understanding the ascending phase lactation events would assist in breeding and management of Red Sokoto goats as dairy goats. Therefore, the ascending phase milk yield characteristics of Red Sokoto goats were evaluated using 120 days milk yield records obtained from 92 lactating does in 6 herds, collected over a two year period (Akpa et al., 2000a). The ascending phase milk yield characteristics (number of days, daily yield and total yield) were highly variable (47.6-74.5%) and were significantly ($P<0.01$) influenced by herd, season and parity, but not by litter size and litter composition (Table 31). Highly positive and significant ($P<0.01$) correlation ($r = 0.62$) exist between total yield and ascending phase total and average daily yield, respectively. Negative and significant ($P<0.05$) correlation($r = -0.30$) was observed for peak week and days in the ascending phase. The significant herd and season effects may have practical implications in determining practical feeding management and season of breeding to maximize total lactation yield. The effect of parity points to the fact that, it is not necessary to cull lactating does before parity 5. The lactation

persistency of agro-pastoral Red Sokoto goats was evaluated using records obtained from 92 does in 6 herds collected over a two years period (Akpa et al., 2003a). The result indicated a lactation persistency of 84% with variability of 14.5%. Season of kidding significantly (P<0.05) influenced lactation persistency in Red Sokoto goats.

Table 31: Least squares means for ascending phase milk yield characteristics by herd, season, parity, litter size and litter composition

Factors	N	No of days	Daily yield (kg)	Total yield (kg)
Herd				
1	12	33.8±5.59	0.897±0.084	20.6±1.66 [b]
2	20	30.0±2.65	1.009±0.077	36.5±2.67 [b]
3	10	21.6±4.47	0.869±0.038	28.4±2.29 [b]
4	10	14.9±5.25	1.096±0.068	17.9±2.81 [b]
5	18	20.7±4.17	1.198±0.117	23.7±1.62 [b]
6	22	24.9±44.12	1.129±0.067	25.8±2.16 [b]
Season				
Early dry	14	24.7±7.34 [a b]	0.951±0.082	24.5±3.61
Late dry	22	37.6±16.33 [a]	1.121±0.056	30.1±2.66
Early wet	35	16.4±2.22 [b]	0.995±0.041	22.6±1.01
Late wet	21	17.0±2.64 [b]	1.081±0.071	22.0±2.42
Parity				
1	30	28.7±4.48	0.788±0.043 [b]	22.3±1.31
2	24	17.0±3.31	1.243±0.08 [a]	23.1±2.53
3	16	24.2±5.06	1.241±0.072 [a]	27.9±2.33
4	13	22.2±5.83	0.924±0.049 [a b]	25.4±4.01
5	9	26.0±5.86	0.965±0.061 [a b]	24.8±3.89
Litter size				
1	41	22.8±3.06	1.047±0.050	19.8±1.20
2	34	23.6±4.31	0.971±0.039	22.8±3.33
3	17	27.8±3.35	1.09±0.530	30.6±2.31
Litter composition				
Male (single)	23	28.4±5.59	1.076±0.063	23.9±1.25
Female (single)	18	16.5±3.17	1.020±0.042	21.7±2.07
All males	13	16.3±4.30	0.959±0.061	18.2±1.18
All females	17	22.8±11.21	1.024±0.034	24.6±2.78
Male and female	21	37.7 ±13.30	1.081±0.010	34.6±6.62

a,b,c means on the same row with different superscripts differ significantly (P<0.05)

Mammary Morphology And Relationship With Milk Yield

The udder is the main body part of a dairy animal commonly understood to be related to its milk production capacity. In goats, udder characteristics, milk production, and milking time and rate are traits with adequate genetic variation to allow selection response

(Mavrogenis et al., 1989). The knowledge of the relationships between these traits can be utilized in the design of breeding programmes to improve milk quantity and quality, and to identify certain morphological and physiological factors related to changes in these traits. Sources of variation in morphological udder traits of Red Sokoto goats were investigated (Akpa et al., 1998b). Results of the investigation indicated that udder and teats size characteristics in Red Sokoto goats were similar to those found in dairy goats. These traits increased with increase in age and parity of doe; thus indicating the possibility of the morphological aptitude of the goat udder to mechanical milking improving as parity and age of doe increased. Effect of coat type on these traits showed that does with smooth and shiny coat had higher udder circumference and udder length than those with rough and doll coat; implying that coat type can be used for udder characterization in Red Sokoto goats. The udder size characteristics were positively correlated; implying that improvement in one would lead to improvement on the others. Wattle had no significant effect on the morphological udder characteristics in Red Sokoto goats.

There is rising interest on small ruminants morphological udder traits (Mather and Vrayla-Anesti.,1994) with emphasis on the relationship of the traits with milk yield, teat cup slips and milking management (Labussiere,1988) and factors that affect them (Fernandez et al.,1995). In the Red Sokoto goats, studies were conducted to elucidate the udder morphological traits, factors affecting them and relationship with milk yield (Akpa et al., 2003b; Sam et al., 2012a). The results showed that in lactating Red Sokoto goats, the average udder and teat size characteristics were udder circumference 38.8cm; udder height 17.1cm; distance between teats 11.5cm; teat circumference 7.2cm; and teat length 5.2cm (Table 32). Udder circumference and udder height were low in variability (13.7-16.1%) while the teat size traits were moderately to highly variable (28.6-42.9%). Thus, there is adequate variation in these traits to allow for selection response.

Table 32: least squares means for milk yield and udder size characteristics in Red Sokoto goats

Characteristics	Mean±se	CV%
Initial yield (kg)	0.946±0.034	45.7
Daily yield (kg/d)	0.664±0.021	38.9
Peak yield (kg)	1.205±0.051	52.2
Total yield (kg)	79.827±2.390	38.6
Udder circumference (cm)	38.800±0.910	13.7
Udder height (cm)	17.100±0.450	16.1
Distance between teats (cm)	11.500±0.550	28.6
Teat circumference (cm)	7.200±0.570	42.9
Teat length (cm)	5.100±0.300	34.7

Increasing parity increased udder and teat size up to 3rd parity when it leveled at the 4th and 5th parities. Udder circumference, udder height, distance between teats and milk yield increased with increase in litter size. Udder size characteristics were positively correlated with milk yield. Low correlation of teat size with milk yield suggest that they can be selected for, without modifying milk yield because their genetic correlations with milk yield are nil or at best low(Mavrogenis et al.,1989)

Prediction of milk yield from external measurements of udder in Red Sokoto goats can be based on udder height, udder circumference, distance between teats and teat length. The positive correlation between udder and teat size traits would suggest that as udder height increased, UC, TL and TC would increase correspondingly; thus, making wider udder desirable since cistern height and teat position and angle may increase (Fernandez et al.,1995). The season of kidding affected udder traits, and therefore would be considered in designing breeding programmes to improve milk production in Red Sokoto goat. Does kidding in the wet season had larger UC and longer UH than does kidding in the dry season. Multiparous does producing all male kids had the largest UC; while UH was longest for multiple bearing does irrespective of sex composition.

Incidence of Supernumerary Teats in Smallholder Goats

One of the major udder abnormalities that affect milking efficiency of dairy animals is the presence of supernumerary teat. The trait is hereditary and not uncommon in goats to have a kid born with extra teat or teats (supernumerary) with multiple ends. These

small teats are commonly imperforated and are not harmful but occasionally they leak during milking and they can also become infected from time-to-time. Therefore, female kids should be examined for this abnormality. The variations that occur in the expression of supernumerary teats in matured females are the normal two teat condition, occurrence of one extra teat and occurrence of two extra teats (Plate 8). In a survey of 58 smallholder Red Sokoto goats herds (comprised of 332 females and 119 males) in Kano state, it was observed (Akpa et al., 2010b) that the incidence of supernumerary teats was not common (11%) in the population of the goats in the studied area and was observed to decrease with increase in herd size (Table 33). Also, in another study conducted in Katsina state, it was observed that, out of the 811 female goats studied, only 24% of them expressed supernumerary teat of varying degrees; (1, 2 or 3). This suggests that the incidence of supernumerary teats in Red Sokoto goats is minimal and when present it is mostly bilateral.

Table 33 : Incidence of supernumerary teats in does of smallholder goats in Kano state

Attributes	≤ 10 goats	11-20 goats	21-30 goats	Overall
Number of herds observed	46	9	3	58
Number of goats observed	242	125	84	451
Number of females observed	191(58)	89(26)	52(16)	332(74)
Females with normal teats	167(57)	81(28)	46(16)	294(89)
Females with supernumerary teats	24 (63)	8(21)	6(16)	38(11)
Female with unilateral supernumerary teats	13(50)	8(31)	5(19)	26(68)
Female with bilateral supernumerary teats	11(92)	0(0)	1(8)	12(32)

Figures in parenthesis are percentages

A study conducted in 2011 on the incidence of supernumerary teats in Nigerian goats using 948 goats from 104 herds in the northern and central plateau revealed an incidence of (37.67%). Positioning of supernumerary teat was unilaterally on the left teat (46.67%) or the right teat (24.85%) or bilaterally (28.48%). Dams with supernumerary teats had (43.45%) chances of expressing it in their offspring's.



Plate 8: Supernumerary teats in Red Sokoto goat

Genetic Parameters and Relationship Estimations

Genetic improvement programme in low input system could be greatly enhanced if they were designated to primarily target farmers (Ahuya et al., 2005). Where flock sizes are small, farmers know their animals very well and in many cases can recall the pedigree of their animals. It is preferable to start with a few of the most important traits in a breeding objective rather than a combination of all the important traits (Philipson et al.,2006). If measurements such as animal weights are linked to prices in organized marketing system, farmers quickly realized how useful records are and adopt them (Kosgey and Okeyo, 2007). Adaptability of genotypes to the existing and future environments, as well as the need and aspirations of the farmers, is paramount for genetic improvement of small ruminants at small holder level. Estimation of genetic parameters is very important for any genetic improvement programme. The genetic make-up of the individual includes additive genetic combinations. These combinations interact with the environmental conditions such as climate, nutrition and management and intrinsic factors such as sex, age, physiological status as well as other extrinsic factors (maternal effect and random environmental factors) to determine the ultimate expression of animal performance

(Wattiaux, 2002). The goal of livestock production is to produce quantity and quality product with maximum efficiency. Unbiased heritability and repeatability estimates as well as accurate correlations (genetic and phenotypic) among performance traits in the breeding objective and the selection criteria are required to design selection programme for livestock.

A study was carried out (Iyiola-Tunji et al., 2008a; Akpa et al.,2009) to estimate the heritability and repeatability of body weight and body measurements at different stages of growth of kids and the relationships that exist between the body weight and body measurements of Red Sokoto kids up to 9 months of age at the smallholder production system. The estimates of heritability ranged from 0.59 to 0.93, while the corresponding repeatability estimates ranged from 0.70 to 0.97 which were considerably high at all ages for the measures of growth of Red Sokoto kids (Table 34). In another study (Iyiola-Tunji et al., 2008a), heritability, repeatability and phenotypic correlations of growth traits of Red Sokoto goats were estimated; heritability estimates were 0.99, 0.97, 0.76 and 0.70 for adjusted weaning weight, weaning weight, yearling weight and post weaning daily gain. The repeatability of birth weight, adjusted weaning weight (ADWT) and yearling weight (WT12) was 0.39, 0.28, and 0.17, respectively. Findings from these studies suggest that better appraisal of Red Sokoto goats for body weight will be possible by considering the relationship between post weaning daily gain and WT12. This relationship between post weaning daily gain and WT12 may help breeders in early selection of replacement stock through performance testing.

Table 34: Estimates of heritability (h^2) and repeatability(r) for body weight and body measurements in Red Sokoto kids at different growth stages.

Trait	h(+se)	r(+se)
Birth weight	0.59± 0.02	-
One month weight	0.93± 0.02	0.97 ± 0.001
One month height-at-withers	0.78± 0.02	0.81 ±0.001
One month body length	0.70± 0.02	0.79 ±0.001
One month chest girth	0.74± 0.02	0.79 ±0.001
Three month weight	0.78 ±0.03	0.95 ±0.001
Three month height-at-withers	0.80 ±0.02	0.81 ±0.001
Three month body length	0.70 ±0.03	0.85 ±0.001
Three month chest girth	0.83 ±0.02	0.91 ± 0.002
Six month weight	0.70 ±0.03	0.96 ± 0.001
Six month height-at-withers	0.75 ±0.03	0.83 ±0.001
Six month body length	0.72 ±0.03	0.74 ±0.002
Six month chest girth	0.68 ±0.03	0.70 ± 0.002
Nine month weight	0.63 ±0.03	0.91 ±0.003

Nine month height-at-withers	0.71 ±0.02	0.83 ± 0.002
Nine month body length	0.70 ±0.02	0.81 ± 0.001
Nine month chest girth	0.80± 0.03	0.89 ± 0.004

The high heritability and repeatability estimates for the growth traits and their positive relationships are indications that selection for improved body weight and size early in life of these goats is possible. Estimation of genetic parameters for some reproductive traits in Red Sokoto goats have been conducted (Akpa et al., 2004a), From this study heritability of gestation length, litter size, litter genotype and sex ratio were 0.37, 0.589, 0.285 and 0.205, respectively. The genetic correlation of gestation length with litter size, litter genotype and sex ratio were -1.031, - 1.518 and 0.411, respectively. The genetic correlation of litter size with litter genotype and sex ratio were 0.867 and 0.269, respectively. The observed moderate to high heritability of these traits in the study might indicate the possibility of improving them through selection. Other relationship study of reproductive traits in Red Sokoto goats (Akpa, 1999a) revealed that the dams' body weight at kidding was negatively correlated with post-partum interval to conception ($r = -0.62$, $P<0.01$). Thus, indicating that the heavier the body weight, the shorter the interval. The repeatability estimate for postpartum interval to conception was low (0.03).

Heritability and relationship estimates for morphological udder traits have been conducted in Red Sokoto goats (Akpa et al., 1998b). The heritability of udder morphological traits was high for udder circumference (0.64), udder length (0.42) and teat circumference (0.49) but low for teat length (0.16). The correlated relationship between the udder morphological traits was significant and positive ($P<0.05$; $r = 0.24$-0.57). The positive relationships between the morphological udder traits and the high heritability estimates of UC, UL, and TC may implicate them as possible selection markers to improve the Red Sokoto goats milking ability.

The measured growth characteristics which are birth weight, 1, 3, 6 and 9 months of age BW, HW, BL and CG, respectively, were positively correlated amongst themselves. However, the correlated relationships of BL and CG at 6 months of age with other measures of growth were not significant ($P>0.05$) and ranged between 0.017 and 0.098; except the relationship between BL and

HW at 6 months of age (P<0.05; r = 0.439). At the other age categories, the relationships were strong and significant (P<0.01-0.05). Birth weight had the strongest relationship with BW at 1 month (0.983), followed by its relationship with BW at 9 months of age (0.749). The relationship between HW and BW was strongest for HW, and WT6; while that of BL was for BL3 and WT6 (0.585).

Animal live weight is an important feature but can seldom be measured in rural areas due to lack of reasonably accurate scale. Hence, relationship between body weight and linear body measurement such as HG, BL, and HW that can easily be measured could be used in BW estimation. Therefore, a study was conducted (Akpa et al., 2009) to estimate body weight using combination of linear body measurements in Red Sokoto goats (Table 35). The results revealed that linear body measurements significantly (P<0.01) estimated BW of Red Sokoto kids at various age categories with good efficiency (R2 = 49.2 82.4%). At one month of age, BW was best estimated by a combination of HW, and BL (R2 = 82.35%).

Estimation of BW at 6 months of age showed that it would best be estimated by combing HW, BL and CG(R2 = 62.80%). At 9 month of age, combination of HW and CG would give the best estimate (R2 = 68.05%). This implies that combination of linear body measurements can be used with high degree of reliability to estimate body weight in Red Sokoto goats.

Table 35: Prediction of weight traits using combination of linear body measurements at 1, 3, 6 and 9 months of age in Red Sokoto kids

Traits	Prediction equations	LOS	R^2 (%)
One month weight	$Y_1 = -6795 + 0.03292X_1 + 0.02755X_3$	**	82.35
Three month weight	$Y_2 = 1.86789 + 0.002081X_1 + 0.04518X_2$	**	49.20
Six month weight	$Y_3 = 6.02011 + 0.02044X_1 + 0.0095814X_2$	**	62.80
Nine month weight	$Y_4 = 3.33120 + 0.12452X_1 + 1.68024X_3$	**	68.05

** P< 0.01, * P< 0.05, LOS : level of significant, R2: coefficient of determination; X1:height at withers; X2: body length; X3: chest girth

In a similar study (Akpa et al., 2010a) the prediction equations relating body weight characteristics with the combination of linear body measurement adequately estimated mating weight,

kidding weight and 60day post kidding weight in Red Sokoto goats (R2 = 54.7 72.0%). However, the equation for the prediction of 60 day post- kidding weight using the combination of linear body measurements (HW, BL, CG) was the best, explaining about 72% (R2 = 72.0%) of the variation in the 60d PKwt of the does followed by kidding weight (R2 = 55.4%) and mating weight (R2 = 54.76%), respectively (Table.36). It is therefore possible to estimate 60 day post kidding weight (60dPKwt) of the Red Sokoto does using linear body measurements.

Table 36: Effect of sex on birth weight, body weight and Body measurements at different ages in Red Sokoto kids.

Traits	Prediction equations	LOS	R^2(%)
Mating weight (Y1)	Y1= - 20.639-0.047X1+0.190X2 + 0.0494X3	**	54.7
Pre-kidding weight gain (Y2)	Y2= 3.73 + 0.037 X1+0.107X2-0.019X3	NS	9.9
Pre-kidding rate of gain (Y3)	Y3= 0.017 – 0.005X1 + 0.010X2 – 0.003X3	NS	4.5
Kidding weight (Y4)	Y4= 15.070 +0003X1 + 0.277X2 + 0.355X3	**	55.4
60 days post kidding weight (Y5)	Y5= 26.741 + 0.118X1 +0.143X2 + 0.529X3	**	72.0
Post kidding weight change (Y6)	Y6= 11.337 – 0.115X1 + 0.120X2 – 0.156X3	**	11.3

X1=height-at-withers. X2=body length, X3= chest girt; ** P<0.01; NS=not significant; LOS: level of significant

Genomics Studies in Nigerian Goats

One of the primary goals in the management of animal population is to maintain their genetic diversity at a high level and their inbreeding at a low level. To estimate the future breeding potential of a livestock breed, it is necessary to characterize the genetic structure and estimate the level of genetic diversity within the breed. For this purpose, pedigree information and genetic materials are used. From genetic materials, microsatellite markers and mitochondrial DNA displacement loop (D-loop) are commonly used to describe the genetic polymorphism, genetic distance and geographical origin of domestic animals. A study was conducted in 2012 and 2013 (Ojo, 2013) using data from 200 goats to evaluate Nigerian breeds of goat in terms of body size; allelic frequencies of different gene loci; degree of polymorphism in markers; genetic relationships between the Nigerian goats; and genetic diversity within and between the Nigerian goats. The goats were sampled from Jigawa, Kaduna and Oyo states of Nigeria with 60 goats each sampled from Red Sokoto, Sahel and West African dwarf, and 20 from Kano brown.

The body size descriptors of the Nigerian breeds of goat are presented in Table 37. The Sahel breed had the highest body size which was highly variable, followed by Red Sokoto which was similar to Kano brown. The least means for body size descriptors were observed for WAD. The principal component analysis of body size determinants in the studied breeds revealed that for Sahel and WAD, height at withers (0.76 and 0.72 respectively) had the greatest contribution to body size; while for Red Sokoto and Kano brown, the largest contribution came from heart girth (0.82). The principal component analysis (PCA) of the allele frequency data of the Nigerian goat breeds using 25 microsatellite markers is presented in Figure 4. The variation accounted for by PC1 and PC2 were 31.04% and 19.06%, respectively; which adds up to 50.1%. This result shows that the Nigerian breeds of goat are admixed and that there are no distinct clusters on the basis of geographical regions where the breeds were sampled.

Table 37: Descriptive statistics of the phenotypic traits of the Nigerian Indigenous goat breeds.

Trait	Sahel			Red Sokoto			West African Dwarf			Kano Brown			LOS
	Mean ± SE	σ^2	CV(%)	Mean ± SE	σ^2	CV(%)	Mean ± SE	σ^2	CV(%)	Mean ± SE	σ^2	CV(%)	
Body length (cm)	65.4±0.90^{a}	48.72	10.67	61.6±0.60^{b}	21.64	7.55	53.8±0.84^{c}	42.71	12.339	59.9±0.56^{b}	6.26	4.16	**
Height at wither (cm)	63.2±0.70^{a}	29.16	8.55	61.3±0.61^{a}	22.43	7.73	55.9±0.86^{c}	41.87	11.579	59.2±0.75^{b}	11.12	5.63	**
Chest girth (cm)	65.4±0.75^{a}	33.91	8.90	63.3±0.98^{a}	57.62	12.00	55.9±0.94^{c}	52.49	12.97	62.7±0.66^{b}	8.66	4.70	**

CV=coefficient of variation; LOS= level of significance; **= P<0.01; σ^2 = variance

^{a,b,c} Means in the same row with different superscripts are significantly different at P<0.05

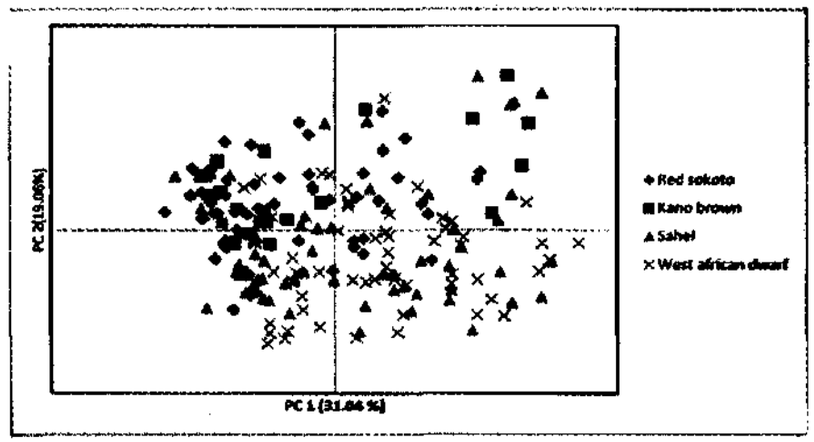


Figure 4: Two-dimensional graph representing the relationship between PC1 and PC2 using allele frequency data from 25 micro-satellite loci typed in 4 Nigerian goat populations.

The allelic frequencies of different gene loci in the Nigerian breeds of goat as observed in the different measures of genetic variations (i.e. Number of alleles, Number of effective alleles and Shannon index) showed that all the studied loci were highly polymorphic, having more than four alleles in all loci across the breeds; effective alleles for Sahel 1.12-7.90, Red Sokoto 1.34-9.29, Kano brown 1.13-8.99, and WAD 1.12-8.57; and Shannon index in most cases was above 1.0 across breeds. The application of F-statistics to determine the extent of inbreeding and outcross in the Nigerian breeds revealed inbreeding status (0.143) for Sahel. Although the inbreeding status was low, 20 out of the 25 loci studied had inbreeding status while only 5 showed outcross, indicating the presence of more heterozygotes at those loci. Red Sokoto showed inbreeding/ homozygous status for 18 loci while exhibiting outcross status for 7 loci. The outcross and inbreeding/ homozygous status was exhibited in 10 and 15 loci, respectively in Kano brown. In the WAD the population had a low inbred status (0.167) with 6 showing outcross while 19 loci exhibited inbreeding/ homozygous status.

The dendogram or un-weighted pair group method analysis (UPGMA) tree of the Nigerian goats mitochondria DNA (mtDNA) sequences is shown in Figure 5. The phylogenetic tree shows that all the breeds originated from a common source. However, WAD diverged first and is more genetically distinct. This was followed by Sahel and lastly, Red Sokoto and Kano brown, though separated are more genetically and closely related.

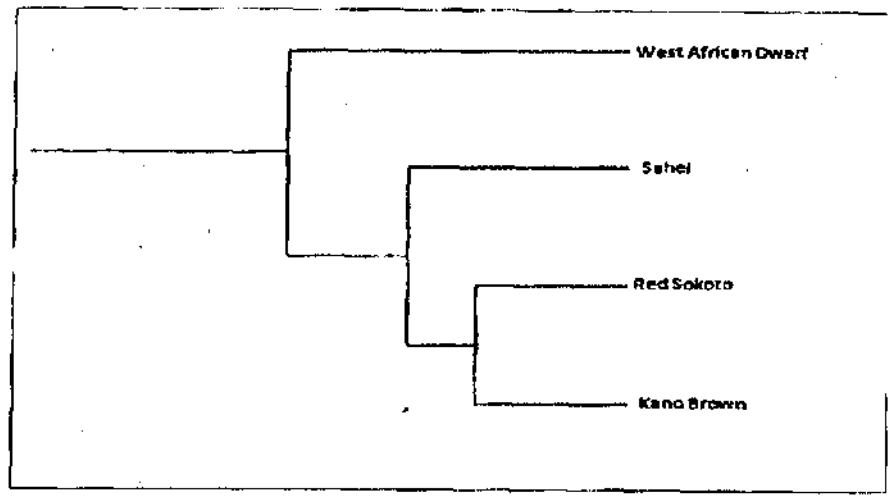


Figure 5: Dendogram representing the genetic relationship between the four Nigerian populations

An evano-graph in Figure 14 was plotted to detect the genetic structure of the Nigerian goat breeds, as well as to determine the true number of clusters (K) for them. The value with the highest mode (delta K) is usually an indication of the true number of clusters. From the Figure, the variability among the breeds was from K=2 to K=5. The highest likelihood was observed at K=2, indicating two major locations (North and South) for the Nigerian breeds of goat.

The estimated population structure among breeds is presented in Figure 15. To examine relatedness between the breeds, allelic frequencies were analyzed using structure 2.0. Each individual was represented by a vertical line, often partitioned into coloured segments with the length of each segment representing the proportion of the individual's genome from K=2 to K=6. The first level of clustering (K=2) reflects the primary locations of the Nigerian breeds of goat, namely northern and southern Nigeria. There was a distinct cluster at this level which is consistent with the known locations of the goat breeds in Nigeria. Subsequent levels (K=3 to K=6) clearly showed signatures of admixture of the the goats, indicating that the Nigerian goat breeds were not genetically differentiated but had admixtures that might have resulted from

indiscriminate mating between breeds as well as migration between breeds.

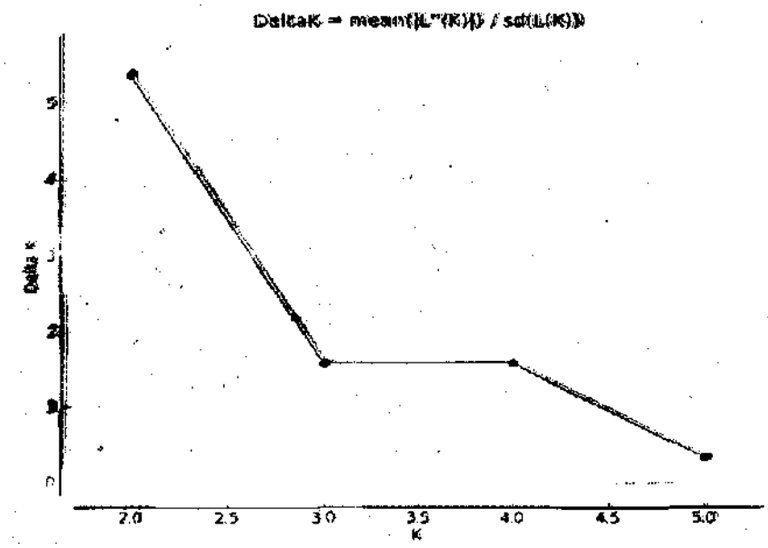


Figure 14: Evano graph of Nigerian goat population

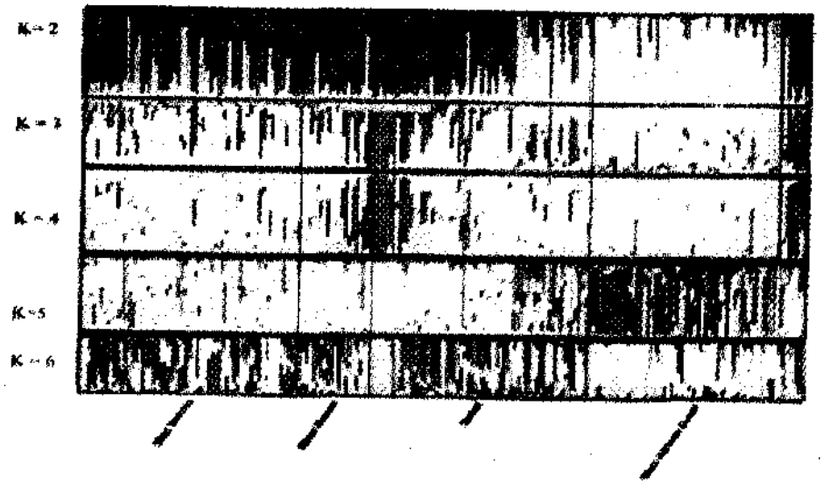


Figure 15: Estimated population structure of the Nigerian goat population

Summary and Conclusion

Summary

Studies, spanning over a period of 21 years (1992-2013) were used to evaluate the dairy potentials of red Sokoto goat (RSG). The studies encompassed production and management, heard structure and breeding practices, reproduction, body growth, morphological structures, genetic distance, blood biochemical polymorphism, adaptation, blood biochemistry, milk yield and composition, lactation pattern, mammary morphology, incidence of supernumerary teats, genetic parameters and relationship estimations, and genomics. The investigations revealed that the average herd size of goats in Zaria was 19.8 goats; which was influenced by source of foundation stock, labour and location. Goats grazed morning and evening and supplemented with feed and regular water supply performed better than others. Milk production behavior of RSG was better for agro-pastoral (23.5-69.7) than institutional system except for lactation peak week (8%) and persistency (22%). Goats herd structure and breeding practices showed that 48% of the does were in their 2nd and 3rd parity and aged between 12 and 25 months. Criteria used in meeting the selection goals were based on health, udder development, bone structure, hair texture and tail structure. Breeding of does at early dry season and rebreeding after kidding at early wet, offers an opportunity for twice yearly kidding in RSG. Brown and light brown goats were superior in body weight and height at withers; and HG and BL could be used to estimate BW of RSG across ages. On milk yield and composition, 120 days milk yield traits were TY 55.5kg, ADY 0.466kg, PY 0.791kg, PD33.8day, flow rate 3.7g/s, dairy merit 10.6% and persistency 96.1%. Milk composition was fat 5,35%, protein 5.7% TS 15.53%, Ash 0.83% and SNF 10.17%. The optimum milking frequency for RSG was twice daily milking. The lactation pattern was characterized by increasing milk production at the early lactation, attaining a peak at approximately 2-5 weeks and thereafter declining slowly to the end of lactation. However, in lactating RSG, the average udder and teat size traits was UC38.8cm, UH 17.1cm, DbT 11.5cm, TC 7.2cm and TL 5.2cm. Udder size traits were positively correlated with milk yield. The heritability of

udder morphological traits was high, UC 0.64, UH 0.42, and TC 0.49. The genomics studies in the Nigerian breeds of goats showed that 96% of the total genetic variation was due to genetic differences within breeds while 4% was due to differences between breeds. There was low genetic differentiation (Fst 0.030) between breeds and high level of admixture across the breeds. The inbreeding coefficient (Fis) in the breeds was low (0.105) with high gene flow (14.868). The Nigerian breeds of goat originated from a common source with the WAD diverging first; followed by the Sahel and last, the Red Sokoto and Kano brown which although separated are more genetically and closely related. Therefore, the RSG is numerous with good growth and reproductive potentials that would support its development as dairy goat. Its dairy traits in terms of milk yield and composition, flow rate, dairy merit, persistency and production pattern are comparable with those of typical dairy goats. However, in its dairy development path-way, the following factors should be considered: herd, age, parity, litter size, postpartum intervals to conception, nutrition, management, coat colour and texture, body and udder structures, milking frequency, adaptability and compatibility with other indigenous breeds. The morphological udder traits of RSG have high heritability that would support improvement of their milking ability with much progress.

Future Research Direction

To develop a Nigerian breed of goat with the following descriptors:

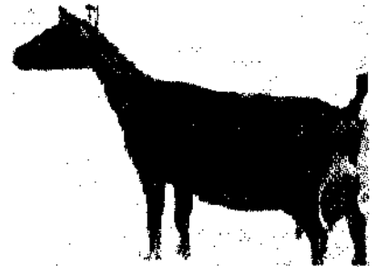
* Brown, short, smooth and shiny haired goat
* > 30kg body weight at maturity
* Twice yearly kidding
* >2 kids per kidding
* > 2.5 kg milk/day in 120 days lactation period
* Highly feed efficient
* Well adapted to the Tropical Savannah Environment

Conclusion

The Red Sokoto goat is highly prolific with favourable growth and reproductive characteristics. A successful breed improvement at the smallholder level should consider health, udder development, bone structure, coat colour and hair texture, age, parity and litter size of does.

Milk yield traits in RSG were non-homogenous and therefore, suggest the possibility of improving daily production by selecting high yielding does. The observed high lactation persistency suggests the ability of RSG to maintain milk production throughout lactation. From the existing lactation pattern, does with higher initial yield would attain the peak faster and thereafter decline at a slower rate than those with lower initial level of production.

Coat colour can be used for udder characteristics in RSG; and prediction of milk yield from external udder traits can be based on UH, UC, DBT and TL. However, the high heritability estimates of UC, UH and TC may implicate them as possible selection markers to improving RSG milking ability. However, in designing improvement programmes for the milking ability of RSG, the following factors are to be considered; herd, season, parity, litter size, coat texture and colour, management, milking frequency, and closeness and compatibility with kano brown goat.






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