EVALUATION OF DAIRY CHARACTERISTICS AND LACTATION CURVE OF SMALL-HOLDER RED SOKOTO (MARADI) GOATS

By

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CERTIFICATION

This thesis entitled "EVALUATION OF DAIRY CHARACTERISTICS AND LACTATION CURVES OF SMALL-HOLDER RED SOKOTO (MARADI) GOATS" by GERALD NWACHI AKPA, meets the regulations governing the degree of DOCTOR OF PHILOSOPHY of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for higher degree. All quotations are indicated and the sources of information are specifically acknowledged by means of reference.



Nwachi Akpa

DEDICATION

This thesis is dedicated to my wife and children.

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ABSTRACT

The dairy characteristics of small holder Agropastoral Fulani Red Sokoto goats were evaluated using records obtained from a total of 92 does in 6 herds, collected over a two year period. The investigation include milk yield capacity, udder and teat characteristics, lactation persistency, and milk production curves. The effects of herd, season, parity, litter size and litter composition were also examined.

The results indicate that total milk yield was 79.827kg, daily yield 0.664kg, peak week yield 8.464kg and week at peak production 4th. Milk yield characteristics in Red Sokoto goats were highly variable with a range of 38.6 to 74.5%. The characteristics were significantly ($P<0.001 - 0.05$) influenced by herd, season, parity, litter size and litter composition of dam. Most of the correlations between the milk yield characteristics were positive and significant ($r = 0.29 - 0.99$; $P<0.001 - 0.05$). Highly positive and significant ($P<0.01$) correlations ($r = 0.42 - 0.99$) existed between total yield and average daily yield, peak yield, initial yield, day 120 yield, ascending phase total and average daily yields, respectively. The negative and significant ($P<0.01 - 0.05$) correlations ($r = -0.40$ to -0.30) were observed for peak week and initial yield; peak week and days in the ascending phase.

The udder and teat characteristics averaged, udder circumference (UC) 38.8; udder height (UH) 17.1; distance between teats (DT) 11.5; teat circumference (TC) 7.2 and teat length (TL) 5.2 cm in Red Sokoto goats. The traits were of low to high variability (13.7 - 42.9%). Season of kidding; parity, litter size and litter composition of dam significantly ($P<0.05$) affected udder and teat characteristics in Red Sokoto goats. The correlations observed for

udder and teat characteristics were positive and ranged from moderate to high (r = 0.38 - 0.91) and were highly significant (P<0.01), while their correlations with milk yield characteristics, though significant (P<0.01 - 0.05) were moderate to high (r = 0.25 - 0.52).

Lactation persistency in the Red Sokoto goats was 84% with a variability of 14.5%. Season of kidding significantly (P<0.05) influenced persistency of lactation in the goats. Parity, litter size and litter composition of dam did not affect (P > 0.05) lactation persistency in the goats.

The suitability of Exponential, Parabolic exponential, Inverse polynomial and Gamma-type models in assessing the pattern of lactation in Red Sokoto goats indicate that, with the exception of Exponential (R^2 = 69.3), all the models fitted well the lactation data (R^2 = 85.5 - 98.1%). The most efficient model was the Gamma-type in terms of best fit (R^2 = 98.1%) and describing the yield characteristics. Parameters obtained by fitting the Gamma-type model: $Y_t = at^be^{-ct}$ were subjected to statistical analysis, using herd, season, parity, litter size and litter composition of does. The results indicate that lactation curve of these goats is normal and characterized by increased milk production at early lactation, attaining a peak at approximately 2-5 weeks postpartum and thereafter decline slowly to the end of lactation. Parameters `a` and `c` were strongly and negatively correlated (r = -0.52; P<0.001). The curve parameters `a` and `c` differed by herd and season; and parity only affected (P < 0.001) parameter 'a'. None of the factors affected parameter 'b' significantly (P>0.05).

The non-homogeneity of milk yield characteristics in the Red Sokoto does suggest the possibility of development of dairy goats through within breed selection of high yielding does. Selection for higher initial milk yield may also improve other milk yield characteristics.

Mammary characteristics (excepting udder size) can be selected for without modifying milk yield in the goats.

Improvement on the lactation persistency in the Red Sokoto is possible through all year round feeding of high quality feeds and good management. The Gamma-type model was the most efficient in the lactation data of Red Sokoto goats. Also, the significant herd and seasonal effects may have practical implications in determining optimal feeding management and season of breeding to maximize total lactation yield.

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CHAPTER 1

INTRODUCTION

Agriculture in Nigeria is dominated by crop farming, characterized by the predominance of small economic units encompassing small holders with limited resources and low income. The traditional small holder pastoral and agropastoral farmers constitute the main milk producers. Although these farmers keep cattle, sheep and goats, they obtain milk mainly from cows. A large proportion of settled rural and semi-urban dwellers also keep goats primarily for meat production and cash income generation. Thus, goat milk is rarely used for human consumption, except by rural dwellers especially amongst the Shuwa-Arab, Kanuri and Pastoral Fulani who use it for infants and as a convalescing food (Fajeminsin, 1991).

Nigeria is endowed with large numbers of small ruminants which are yet to be fully investigated for milk production. Indeed, goats are the largest in number among the ruminant livestock in the country, totalling about 34.5 million, predominantly owned by the rural households and ownership is spread across all human age groups and sexes (FDLPCS, 1991).

The development of Nigerian dairy goats will require a critical evaluation of all the locally available breeds and their potentials for milk production. However, a number of studies have been carried out on milk yield and composition of the indigenous breeds of goats (Mba et al., 1975; Ehoche and Buvanendran, 1983; Fajeminsin, 1991). Generally, milk yield of the doe drops after few weeks in the indigenous breeds and by the 15th week, milk yield of the lactating doe becomes negligible (Ngere, 1985). The above reports on milk production of indigenous goats emanated from universities and research centres. There is information gap on investigation based on on-farm data for milk production.

The Red Sokoto (Maradi) goats have greater potentials for dairy than other breeds of goats in Nigeria. It has a milk yield of 75kg per lactation of 100 days with a peak yield per day

of 850g and 150kg for two lactations in one year (Devendra and Burns, 1983). In Niger Republic, it is commonly milked, giving daily yield of around 0.5kg in the dry season and up to 1.5kg in the wet season (Robinet, 1973).

Dairy production plays important roles as source of protein to improve the nutritional status of people, and as a means of generating and stabilizing incomes for the dairy farmer. The establishment of a suitable dairy industry will terminate the dependency on importation of milk products and lead to the attainment of self sufficiency in milk supply. Dairy goats are of economic and social importance due to the goat's ability to use vegetation in marginal areas, mountains and rangeland pastures, trees and shrubs (Rabasco et al., 1993).

In small holder production systems, goats are important because they require low initial capital and maintenance costs; are able to use marginal land and crop residue, produce milk and meat in readily useable quantities, and are easily cared for by most family members (Ngategize, 1989). Goats produce more milk per unit of feed taken than most other ruminants (Devendra, 1975; Okello and Obwolo, 1985).

Park (1992) has recommended goat milk as a substitute for patients allergic to cow milk. Goat milk has been used to cure infants suffering from gastro-intestinal allergy and chronic enteropathy. Besides, goat milk differs from cow or human milk, due to its higher digestibility, distinct alkalinity, higher buffering capacity and certain therapeutic values in medicine and human nutrition (e.g. persons suffering from asthema, migraine, stomach ulcer)(Devendra and Burns, 1970; Park and Chukwu, 1989) . In Western Kenya, a comparative consumers acceptance of goat or cow milk products showed no significant difference in acceptability, taste and preference (Boor et al., 1987). On the other hand, goat milk samples were whiter, sweeter and creamier than cow milk.

Malnutrition in children and the health and inadequate productivity of adults in developing countries of the world is well known (IFRI, 1994). One of the causes of malnutrition is protein inadequacy which has been recognized as a major problem of developing countries, particularly in Africa (Olaloku, 1974; FAO, 1985 and 1986).

It is common knowledge that increased urbanization in Nigeria during the last three decades and the consequent changes in the life style of people to match improved cash income has led to increased demands for milk and milk products. Until recently, Nigeria depended largely on commercial imports for milk supply. With the introduction of the Structural Adjustment Programme (SAP), involving the devaluation of Naira, the prices of imported dairy products went beyond the reach of the average Nigerians.

In a recent review, Ademosun (1989) showed that a total of 55,187 tones of milk was imported into Nigeria in 1986 at a cost of 62 million Naira or 8.49 million US dollars. This is equivalent to 721.7 million Naira at today's costs. As a result of this exorbitant cost, the average Nigerian family can no longer afford milk in their diets thereby widening the protein calorie malnutrition gap already in existence.

It has been reported that the protein calorie malnutrition problem persisting in developing countries could become partly solved by using small ruminants for milk production. In Pakistan, sheep and goats together produce about 407,000 tones of milk annually (FAO, 1985; 1987). Therefore, taking advantage of the genetic diversity of the indigenous goats, it would be possible to select dairy goats from the locally available goat herds that would stand the test of time and bring about increased milk yield.

Furthermore, the relationships that exist between udder traits and milk yield and other associated traits are known for cattle (White and Vinso, 1974; Seykora and McDaniel, 1986; Rogers and Spencer, 1991). The influencing factors on udder traits (Norman et al., 1988),

method of evaluation (Vinso et al., 1982) and their heritabilities (Seykora and McDaniel, 1985) have also been investigated in cattle. The results of these studies have assisted in the improvement of mammary morphology and hence milking ability through selection programmes.

Of recent, interest is beginning to focus on morphological udder traits for small ruminants (Chavon, 1990; Malhar and Vrayla-Anesti, 1994; Rubert, et al., 1994). Such studies emphasize the relationships of the traits with milk yield, teat cup slips and milking management (Labussiere, 1988; Mavrogenis et al., 1988). Likewise, factors influencing mammary morphology are currently being studied (Mavrogenis et al., 1988; Fernandez et al., 1995) and there is dearth of information on repeatability and heritability of mammary traits. Identification of mammary traits for inclusion in selection programmes requires better understanding of morphological variations and the associated milk production.

In Nigeria, there is paucity of information on the dairy characteristics of the indigenous goats. If the ever widening shortfalls in dairy products supplies are to be met through indigenous production, there is therefore an urgent need to exploit the potential of alternative dairy animals such as goats in order to supplement milk from cows (Addo et al., 1980; Fasanya, 1986). It is hoped that with the establishment and expansion of goat breeding or multiplication centers, goat dairy industries, coupled with increased awareness of the importance of goat milk and the acceptance of goat milk by Nigerians, the heavy dependence on imported cow milk and its products can be reduced (Egwu et al., 1995). Therefore, efforts to improve goat milk production in the country will provide supplementary incomes to the weaker sections and combat the nutritional deficiencies prevalent among the poorer sections of the society.

The study reported in this work was therefore designed to evaluate the dairy characteristic and lactation curve in Red Sokoto goats. This study has been accomplished by estimating milk production capacity and persistency of lactation yield of small holder Red

Sokoto does; evaluating milk production curves for daily milk yield over 120 days lactation period and udder traits and their relationships with milk yield; and investigating the factors affecting lactation characteristics in the goats.

CHAPTER 2

LITERATURE REVIEW

2.1 THE INDIGENOUS GOATS OF NIGERIA

2.1.1 Breeds and distribution

Goats in Nigeria are of extremely diverse types. Three main breeds have been recognized and described (Adu et al., 1979; Devendra and McLeroy, 1982; Ngere, 1985; Osinowo and Abubakar, 1989). They include the West African long-legged (Sahel, Arab, Maure, Taureg), Red Sokoto (Maradi) and West African Dwarf (Cameroon dwarf, Nigerian dwarf, Fouta Djallon and Kirdi). Many other 'transitional types' probably crosses known as Borno White (Kyalla), Borno Red, Kano Brown and Maiduguri Brown, named according to their areas of origin are also encountered.

Their distribution is not even, ranging from isolated populations of black goats in the north east linked with the West African Dwarf (WAD) goats of the forest zone, the Red Sokoto (Maradi) goats widely distributed in the Sudan and northern guinea, and the Sahelian goats found in semi-arid zones of the country. In the southern guinea and forest zones, the WAD goats are predominant. Each of these types is well adapted to its natural environment or vegetation ecozone.

I. The Sahel or Desert goat.

They are medium to large sized, long-legged and are kept for meat, skin and milk. Their height at withers is about 51 - 65cm and mature live weight is about 35kg (19 - 37kg). These goats are found in the arid regions of North West Africa where rainfall and vegetation are sparse. The coat is short, hair covering is fine and the ears are variable and may be long or short.

II. **The West African Dwarf goat.**

They are found in West and Central Africa. They are indigenous to forest and derived savanna and are well adapted to the humid zones. Their height at withers is about 50cm and they weigh between 18 and 25kg. The WAD goat is hardy, of small body size with short legs and it is trypanotolerant. They are mostly used for meat.

III. **The Red Sokoto (Maradi) goat.**

They are the most numerous (17.3 million) (Adu et al., 1979). It is well defined, characterized by a uniform dark red coat colour, short and horizontal ears and it is horned in both sexes. They are found in the Sokoto province of Nigeria and Niger Republic. The breed is intermediate in size between the Sahel and WAD goats. Their height at withers is about 65cm. The mature live weight is about 25(23 - 38)kg.

2.2 Ownership Pattern, Flock Size and Structure of Goat Herds.

Pattern of ownership is varied and appears to be very complex. In the Southern guinea savanna, Bayer (1986) reported that Fulani agropastoralists did not own goats and if they did, they were entrusted to the care of crop producers. However, in the northern guinea savanna (Otchere et al., 1987) the Fulani agropastoralists traditionally keep sheep and goats. Francis (1988) reported that goats were more widely owned than sheep in South Eastern Nigeria (92% vs. 28% of households). In two villages of South Western Nigeria, approximately 60% of households owned either sheep or goats while 50% of these households owned goats (Mathewman, 1986). However, recent diagnostic survey reports from Sokoto, Bauchi and Plateau States indicate two major ownership patterns (Mijindadi and Lufadeju, 1995), mixed farmers and agropastoralists.

Goat flock size is larger in the drier north than in the humid south (Mathewman, 1986; Otchere et al., 1987; Francis, 1988; Akpa et al 1995a). In South Western Nigeria, average flock

size is in the range of 2 - 5 animals, while in the north it is 19.8 (2 - 93). In both South and North, flock sizes are larger for households who own mixed flocks. In some States like Sokoto, Bauchi and Plateau, flock size is 5 for mixed farmers and 20-50 for agropastoralists (Mijindadi and Lufadeju, 1995).

Each animal in a flock is kept for economic and or social reasons (Bayer, 1986; Otchere. et al., 1987) with over 70% of the flock being females. A high proportion of males leave the flock before they develop their first pair of permanent incisors. More than half of the females are breeding does. The early offtake of males from small ruminant flocks either for sale or home consumption is a normal practice worldwide. However, only where males or castrates have additional economic values as for wool, hair or the production of excessive fat are they retained. The Nigerian goats are kept predominantly for their meat and skin.

Akpa et al. (1997) studied the herd structure of breeding does of small holder goat production system in Kano. They observed that the herd structure of breeding does was guided by age, parity and litter size of does. Breeding does were observed to leave the herd from about the 25th month of age and at parities 2, 4, 7 and 10, respectively. They also observed herd structural form of young 20%, yearling 48%, adult 11.2% and aged 20.8%.

2.3 Small ruminant production systems.

Small ruminant production systems in the tropics may be grouped into subsistence, extensive, intensive and semi-intensive (Williamson and Payne, 1978; Devendra and McLeroy, 1982). The intensive system is becoming less common, perhaps due to the increasing pressure on land (Adenova, 1985). Although intensive and semi-intensive systems exist on some government and corporate farms in Nigeria (Nuru, 1985), these rely mostly on grazing reserves, sown pasture and the use of industrial by-products. Whereas the extensive traditional systems are predominantly practiced in Nigeria (Gefu and Adu, 1982; Ademosun, 1985a), the

management system has resulted in low productivity due to low level of nutrition and disease (Ademosun, 1985a) coupled with losses resulting from accidents, thefts or conflicts following crop destruction by animals (Egwu et al., 1995).

2.3.1 The subsistence system.

In this system, a few goats are kept to meet domestic needs for meat and milk. It is essentially a peasant enterprise. In this system, the goats may be allowed to range or may be tethered. This system is practiced nationwide especially in Southern Nigeria (Sumberg, 1985). The ranging goats (Upton, 1988) are characterized by scavenging and roaming around home and farmsteads, in search of feed. Animals are left to roam especially during the day. No forage crops are grown and manure is not returned to the cultivated crops, so links with crop production are slight. The entire village stock is a single interbreeding flock, and usually there are no attempts to control mating. Animals receive virtually no veterinary care, and mortality rate is relatively high, though variable - labour cost is negligible.

In the tethering system (Ndamukong et al., 1989), animals are housed at night and adults tethered during the day. Access to fresh grazing is provided by shifting the tethering site. This system is practiced in Nigeria, mainly during the cropping season to avoid damage to crops (Francis, 1988; Mijindadi and Lufadeju, 1995). A variety of green herbage is cut and offered to the animals daily. However, after crop harvest, animals are released to gleen residues and wastes from crop harvest (Mijindadi and Lufadeju, 1995).

Free roaming is predominant in Rivers, Edo, Delta and Benue States (Francis, 1988; Ayoade et al., 1993) while in Imo, Abia, Enugu and Anambra States, there is an on-going transition from free roaming to confinement due to increasing intensity of agricultural land use. A clear pattern of small ruminant production is emerging consisting of allocation of small supplements (cereal by-products and tuber peels) in the morning, before being sent to graze, and

in the evening after grazing (Akpa et al., 1995b; Mijindadi and Lufadeju, 1995).

2.3.2 The extensive system.

This is generally practiced in regions where the land is not immediately suitable for agricultural improvement and or is too difficult or costly to fence. In Nigeria, the system does not provide housing and the animals therefore, spend the night in streets, motor roads, or in porches of houses. It involves a minimum amount of labour and expense. The main determining features are favourable climatic condition, in particular a short wet season, the availability of grazing and browse, few predators and a low incidence of predial larceny (FAO, 1966). However, fully extensive system of production is not so common in the tropics (Devendra, 1982).

2.3.3 The semi-intensive system.

This system covers all degrees of compromise between extensive management and zero grazing, but usually involves controlled grazing of fenced pastures with some supplementary concentrate feeding. Animals are usually housed at night and fenced in paddocks of at least 2 ha during the day (Ndamakong et al., 1989). In Nigeria, natural grazing is still the back bone of this system and animals are restricted from indiscriminate movement.

According to Mack et al (1985), restriction of the movement of small stock in South Eastern Nigeria both during and after the cropping season is dictated by the production environment. Restriction of animal movement is encountered where open, derived savanna vegetation predominates but less common in heavily forested areas. In the northern parts of the country, crops such as cassava, which need to remain in the fields after the rainy season is often fenced to prevent damage by animals. Often, animals left on the loose break into fenced crop fields and these result in feuds and payment of compensation.

2.3.4 The intensive system.

This system involves continuous housing or "zero grazing". There is maximum protection from uncontrollable environmental factors, and it gives complete control over the destructive aspects of the goats feeding habits. Dairy goats in the tropics and small herds of goats in urban-fringe areas are often managed in this way. Confinement feeding for fattening of goats is a production system widely practiced in the north. Traditionally, it is practiced as a secondary occupation by urban farmers rather than by pastoralists. Rarely do the traditional stockmen engage in fattening. The source of fatteners can be weaners from the owners flock or they may be purchased from markets. Holdings per production unit range from one to ten animals.

Almost all animals destined for fattening are castrated males, but occasionally females considered sterile are included in the scheme. The fattening period is usually 70 to 120 days. with a mean of 90 days. Animals are fed liberal rations of sorghum stover, cowpea, groundnut haulm and assorted husks (dussa). Micro-ingredients provided include roasted yellow sorghum, millet and dried pulp of locust bean fruit and/or finely ground leaves of baoba. Kanwa (Potash) is added to drinking water or mixed with 'dussa' as mineral supplement (Akpa et al., 1995b).

2.4. TROPICAL AFRICAN GOAT PERFORMANCE CHARACTERISTICS.

The performance characteristics of the indigenous African goats are summarized in Table 2.1. The number of breeds studied and the variety of research are remarkable. The number of animals and records involved in most studies, however, suggest large sampling variances of estimates. None-the-less, it appears that not enough systematic studies had been done on them. Large gaps still exist in our knowledge of their performance, even within breeds.

2.4.1 Puberty and Age at First Kidding.

Information on these, is still scanty for goats in Africa as a whole. Puberty, defined as the age at first oestrus in females and age at first ejaculation in males, is attained in all of them between the ages of 5 and 10 month (Osinowo and Abubakar, 1989; FMEST, 1984; Egwu et al., 1995). Body weight at puberty ranged between 7 - 13kg (Tables 2.1).

Figures quoted (Wilson, 1982) for age at first kidding gave a range between 9 and 15 months for goats. However, indigenous research efforts on goats (Table 2.1) showed that this is between 12 and 21 months in Africa.

These traits are influenced by both genetic and environmental factors. But these factors are yet to be fully exploited in both the indigenous and exotic goat breeds. However, it has been reported that breed, nutrition, flock size , rearing condition and season of birth of doe affect the traits (Wilson et al., 1984; Oureshi et al., 1991; Karua, 1991; Husain et al., 1992). It appears that these indigenous goats are early maturing as some become pregnant as early as 5 months (assuming a gestation period of about 5 months) and some males produce spermatozoa at this same age (Marire et al., 1987).

2.4.2 Fertility and Prolificacy

African goats are hardy, prolific and adapted to harsh conditions (Devendran and Burns, 1970; Adu et al., 1988). Under fairly good management, it is possible to have over 70% of does bred kidding in a herd. Twins have the highest frequency of being born and higher number at birth is possible (Ngere, 1985). Litter size in goats is between 1.18 to 1.79 in Africa (Table 2.1). The WAD goats of Nigeria with litter size of 1.58 - 1.79 and Zaraibi goats of Egypt with a litter size of 1.78 appear to be the most prolific.

Kidding intervals range from 234 to 281 days. However, postpartum intervals to first oestrus of 37.5 days in WAD goats (Kirkpatrick and Akindele, 1974) have been reported. This

reports confirm the potential for twice yearly kidding under good management. In spite of all odds, one kidding per year is common and three in 2 years is achievable.

2.4.3 Body Weight and Growth Rate.

Information on growth performance characteristics is summarized in Table 2.1. Average birth weight, preweaning growth rate, weaning weight and 6 month growth rate are much higher among the Red Sokoto goats than other breeds of goats excepting the Blended goats of Tanzania. Growth rate tend to fall below those of temperate breeds probably as a result of poorer husbandry and lack of genetic selection (Osinowo and Abubakar, 1989). The fastest growth in the new born is between 0-6 months. Animals are usually weaned at the age when they have attained weights between 300 - 400% of their birth weight, and about 30% of their mature weight (Ngere, 1985). In the indigenous goats, post weaning growth slows down immediately after weaning at 5 to 6 months and picks up in about 11 months of age (Ngere, 1985).

2.4.4 Milk Yield and Composition.

There are reports on the milking of indigenous African goats (Table 2.1). At present, not much is known about the dairy characteristics of the African goats. However, available report indicate that lactation milk yield range between 24 and 120.3kg. The highest peak yield has been observed in the Red Sokoto goats of Nigeria (850g); and the peak week range from 2 - 6 weeks.

There are variations in the reports on lactation length in African goats, even within breeds (Table 2.1). From the reports, lactation length range from 70 (Red Sokoto) to 266.0 $\pm$ 2.66 (Blended dairy goats of Tanzania) days. Apart from the Blended dairy goats of Tanzania, it appears there has been no systematic study of lactation length in African indigenous goats.

The lactation milk yield so far reported for African goats appears to be low when

compared with those of improved breeds such as the Saanen (331 - 1,010kg in 205 - 278 days); Toggenburg (532kg in 263 days) and Anglo-Nubian (143kg in 124 days) (Osinowo and Abubakar, 1989). Supplementary feeding might be necessary to ensure greater milk production of lactating does and better survival of their young.

2.4.5 Mortality and Disease.

Mortality in goats is 24% (Francis, 1991). In the African goats, mortality rates are usually high (10 - 40%) (Table 2.1); and young stock are particularly at risk in the first 3 months of life (Reynolds, 1986). Joshua and Olabode (1989) observed a preweaning mortality of 46.6% with kids found to be at greatest risk during the first week of birth, regardless of the management system used.

Disease prevalence, incidence and severity have been shown to vary with management system (Smith et al., 1988) and infectious conditions usually account for about 70% of all recorded cases. The more prevalent and serious diseases of goats have been reported by authors working with free-roaming (Adenowo et al., 1985) or confined (Akerejola, 1982; Otesile et al., 1983) goats. It has been reported that among the identified diseases, PPR is responsible for the majority of deaths (Braide, 1981; Omamegbe and Mecha, 1984; Majiyagbe, 1985; Francis, 1991). Other major diseases with the small ruminants appear to be helminthiasis and other internal and external parasites (Anesa, 1979; Buvanendran et al., 1981). From indirect evidence, our small ruminants appear to possess some measures of resistance against trypanosomiasis (Kramer, 1966; Trail et al., 1979). There is also some evidence of resistance to rinderpest in goats (Scott et al., 1970).

Table 2.1: Performance characteristics of indigenous goats of Africa.

CHARACTERISTICS	COUNTRY	BREED	N	MEAN	REFERENCE
REPRODUCTION					
Age at puberty (Mo.)	Nigeria	Red Sokoto	-	5 - 7	FMEST, 1984.
	„	WAD	-	5 - 6	„
	„	Sahel	-	5 - 7	Egwu et al., 1995
Body weight at puberty (kg)	„	Red Sokoto	-	11 - 13	FMEST, 1984
	„	WAD	-	7 - 8	„
Age at 1st kidding (Mo.)	„	Red Sokoto	-	12 - 15	Egwu et al., 1995
	„	Sahel	-	12 - 18	„
	„	WAD	-	10 - 21	„
	Malawi	Malawian	37	16.6±2.5*	Karua, 1989
	Swaziland	Swazi	-	301±55 days	Lebbi and Manzini, 1989
	Sudan	Local	-	15	Wilson, 1984
	Kenya	„	-	18.4	„
	Mali	„	-	15.5	„
Age at 1st conception (Mo.)	Malawi	Malawian	37	11.6±2.5*	Karua, 1989
	Sudan	Local	-	15	Wilson, 1984
	Kenya	„	-	18.4(555.8d)	„
	Mali	„	-	15.5(472.2d)	„
Kidding interval (d)	Nigeria	Sahel	-	276	Egwu et al., 1995
	„	Red Sokoto	-	260	„
	„	WAD	-	240	„
	„	„	-	275.68±6.08	Odubote, 1996
	Malawi	Malawian	197	40.1±9.1*(wk)	Karua, 1989
	Swaziland	Swazi	-	268±100	Lebbie and Manzini, 1989
	Sudan	Local	46	7.8(mon)	Wilson, 1984
	Kenya	„	332	10.6 „	„
	Mali	„	325	9.0 „	„
Kidding rate (%)	Nigeria	Red Sokoto	-	170-180	FMEST, 1984
	„	WAD	-	234	Adu et al., 1988
	Malawi	Malawian	328	141*	Karua, 1989
	Swaziland	Swazi	-	102*	Lebbi and Manzini, 1989
Annual kidding rate	Sudan	Local	-	2.4	Wilson, 1984
	Kenya	„	-	1.4	„
	Mali	„	-	1.6	„
Litter size	Nigeria	Sahel	-	1.57	Osinowo and Abubakar, 1989
	„	Red Sokoto	-	1.37(1.2-1.45)	„
	„	WAD	-	1.58(0.9-1.83)	„
	„	„	-	1.79±0.05	Odubote, 1996
	Tanzania	Blended goat	222	1.4*	Das, 1989
	Egypt	Zaraibi	-	1.78	Mourad, 1993
		Baladi	-	1.66	Sallam et al., 1988
	Sudan	Local	-	1.57	Wilson, 1984
	Kenya	„	-	1.25	„
	Mali	„	-	1.20	„
	Malawi	Malawian	574	1.4+0.5*	Karua, 1989
	Swaziland	Swazi	-	1.18±0.29	Lebbie and Manzini 1989
Postpartum interval to 1st oestrus (d)	Nigeria	WAD	-	37.5(3-63)	Kirkpatrick and Akindele, 1974

Table 2.1 (Contd.)

Postpartum wt. (Kg)	Malawi	Malawian	573	31.78±4.12*	Karua, 1989
	Ethiopia	Adal	122	33.0	Awgichew et al., 1991
	Tanzania	Blended goat	144	32.9	Das, 1989.
Fertility coeff.	Egypt	Zaraibi	-	0.95	Mourad, 1993
	„	Baladi	-	0.85	Sallam et al., 1988
Apparent Fertility (%)	Tanzania	Blended goat	222	63.7*	Das, 1989
Fecundity (%)	„	„	222	86.5*	„
Prolificacy (%)	„	„	222	136.2*	„
BODY WEIGHT AND GROWTH					
Birth weight (kg)	Nigeria	Sahel	-	1.5-2.0	Egwu et al., 1995
	„	Red Sokoto	-	1.5-2.0	„
	„	WAD	-	1.0-1.6	„
	Malawi	Malawian	783	1.8±0.45	Karua, 1989
	Swaziland	Swazi	-	1.9±0.14	Lebbie and Manzini, 1989
	Ethiopia	Adal	192	2.2	Awgichew et al., 1991
	Tanzania	Blended goat	222	2.5±0.05*	Das, 1989
	Sudan	Local	-	1.52	Wilson, 1984
	Mali	„	-	1.84	„
	Niger	Red Sokoto (Maradi)	130	2.05	Oumara, 1989
3 months wt. (Kg)	„	„	130	9.05	„
		Ethiopia Adal	192	8.9	Awgichew et al., 1991
	Nigeria	Red Sokoto	-	40-60	FMEST, 1984
	„	WAD	-	50-60	„
6 months growth	„	Red Sokoto	-	65-90	„
rate (g/d)	„	WAD	-	40-80	„
MILK PRODUCTION					
Total milk yield (kg)	„	Sahel	-	25-40	Egwu et al., 1995
	„	WAD	-	32-35	„
	„	Red Sokoto	-	60.4(45-75)	Osinowo and Abubakar, 1988
	Ethiopia	Adal	122	24.0	Awgichew et al., 1991
	Tanzania	Blended goat	83	120.3±8.72	Das, 1989
	Kenya (120d)	E/Afr. & Galla	10	26,555	Ruvuna et al., 1995
Daily yield (g)	Morocco	Black Moroccan	-	700±48	Hossaini-Hilali et al., 1993
Weekly yield (kg)	Nigeria	Red Sokoto	8	3.28±1.78	Akinsoyinu et al., 1981
Peak day yield (g)	„	„	-	850	Osinowo and Abubakar, 1988
	„	„	-	450-550	Egwu et al., 1995
	„	Sahel	-	500-600	„
	„	WAD	-	600-700	„
	Kenya	E/Afr. & Galla	10	347	Ruvuna et al., 1995
Peak week	Nigeria	Red Sokoto	8	5 - 6	Akinsoyinu et al., 1981
	„	WAD	-	5	Ngere, 1985
	Kenya	E/Afr. & Galla	10	2	Ruvuna et al., 1995
Lactation length (d)	Tanzania	Blended goat	83	266.0±2.66	Das, 1989
	Nigeria	Red Sokoto	-	92(84-100)	Osinowo and Abubakar, 1988
	„	„	-	70	Egwu et al., 1995
	„	WAD	-	126	Osinowo and Abubakar, 1988
	„	„	-	98	Egwu et al., 1995
	„	Sahel	-	80	„
Butter fat content (%)	Tanzania	Blended goat	83	2.7	Das, 1989

Table 2.1 (Contd.)

MORTALITY					
Preweaning mortality (%)	Nigeria	Red Sokoto	-	27-40	FMEST, 1984
	"	WAD	-	25-31	"
Adult mortality (%)	"	Red Sokoto	-	10-12	"
	"	WAD	-	10-4	"
Mortality (%)	Malawi	Malawian	89	15.6	Karua, 1989
	Swaziland	Swazi	-	30	Lebbie and Manzini, 1989
	Ethiopia	Adal	129	26	Awgichew et al., 1991
Abortion (% viable Birth)	Malawi	Malawian	41	7.6	Karua, 1989
Abortion coeff.	Egypt	Zaraibi	-	0.03	Mourad, 1993.

* Calculated from average values.

N = Number of animals used in the estimation.

2.4.6 Tropical dairy goat breeds

Mason (1951) described some 60 recognized breeds. Most of these breeds are multipurpose animals. The only groups really bred for dairy production originated primarily in Europe. Some exceptions may be the Jamunapari, Beetal and Barbari of India, the Sudanese Nubian of East Africa and the Damascus of Medeterranean region.

The JAMUNAPARI of the Punjab and utter Pradesh of Northern India is a dual purpose goat that has undergone some selection for milk production. Its coat colour is white with patches of talk or black often on the head. It has a large convex face and large pendulous ears. The average milk yield is 160-200kg over 210 to 240 days. The maximum yield reported is 544kg in 250 days (NDRI, 1976).

The BEETAL is a large spotted black goat of the Punjab in India. It has large pendulous ears, a Roman nose and wattles are usually present on both sides of the lower neck. Milk yield averages 140-230kg in 150 to 225 days. The maximum yield reported for beetal goats was 592kg in 100 days to 700kg in 200 to 250 days (Mason, 1951).

The DAMASCUS is a red goat of the eastern Mediterranean region. The does are polled or horned and they have wattles hanging from the lower neck. Milk production is usually highest during the sixth lactation. Average milk yield ranges from 400-550kg over a lactation length of 238-263 days (Mason, 1951).

The SUDANESE NUBIAN originated in East Africa. It has the typical Nubian convex face with large ears. Colour markings vary enormously. Average milk yield is low, about 1.0-1.25kg per day; but usually only 60kg per lactation (Mason, 1951).

The SAANEN breed is generally regarded as the highest milk yielder. It has a creamy white coat and originated in Switzerland. They are either polled or horned and do not generally carry wattles. Average lactation yield in temperate region is 880-900kg in 275 to 300 days. The

world lactation record for goats is held by a Saanen doe in Australia of 3,084kg milk with 3.3% butterfat in 305 days (Mason, 1951). The Saanen and Saanen crosses are the most popular in dairy in Europe.

The TOGGENBERG originated in Switzerland. Their coat colour varies from deep chocolate brown to light fawn with white on the face, ears, legs and rump. They are usually polled with wattles on each side of the lower neck. Toggenbergs averaged 600 - 900kg milk, 3.3% butterfat in 275 to 305 days (Mason, 1951). The record production for the breed is 2,614kg in 305 days.

The ANGLO-NUBIAN resulted from crossing the African Nubian with English and Swiss goats in Great Britain. It has become a popular breed in the United States. The Nubian is characterized by a Roman nose with long pendulous ears. It is a consistent milker with average yields between 700-900kg in 275 to 300 days. Often it is referred to as the Jersey of goat breeds. The Anglo-Nubian has a high fat percent, often above 4.5 (Mason, 1951).

The EUROPEAN ALPINE comes in many colours and markings, ranging from various combination of white and black through shades of cream and fawn to reddish brown. The does are good milkers and averages 60 - 900kg over a lactation length of 250 to 305 days (Mason, 1951).

2.4.7 Dairy Goat Milk Yield, Composition and Lactation Length.

Table 2.2 shows the dairy goat production traits. The number of breeds studied and the variety of research though remarkable, were mainly from India. The number of animals and records involved in most studies, however, suggest large sampling variances of estimates

Table 2:2 Dairy goat production trait.

TRAIT	COUNTRY	BREED	N	MEAN VALUE	REFERENCE
daily yield (g)	India	-	-	341.2±75.8	Tewatia et al., 1995
	"	Barbari	84	804(8 wks)	Mittal et al., 1977
	"	Jamnapari	22	1041(8 wks)	"
Peak yield (g)	"	Black Bengal	112	377.91±19.718*	Das et al., 1982
	"	Malabari	58	800 ± 70	Mukundan et al., 1983
	"	Saanen x Malabari	23	1000 ± 150	"
Milk yield (kg)	"	Jamunapuri	139	62.6 ± 5.74	Yadav et al., 1983
	"	Beetal	136	87.18 ± 5.89	"
	"	Barbari	174	62.78 ± 5.85	"
	"	"	34	82.68	Barhat et al., 1978
	"	Black Bengal	150	32.41 ± 5.31	Yadav et al., 1983
	"	"	77	20.44 ± 1.04*	Das et al., 1982
	"	Malabari	58	49.4 ± 10.24	Mukundan et al., 1983
	"	Saanen x Malabari	23	117.3 ± 20.51	"
	"	Jakharana	12	121.80	Barhat et al., 1978
	"	Marwari	21	91.37	"
	"	Sirohi	20	115.94	"
	Turkey	Kil	-	80 - 130	Guney et al., 1992
	Czechoslvakia	White polled	204	1215	Macha, 1982
	"	Fawn polled	59	1044	"
	Mexico	Local	30	299 ± 34	Montaldo et al., 1995
	"	Alpine	91	459 ± 20	"
	"	Granadina	52	353 ± 26	"
	"	Nubian	105	370 ± 19	"
	"	Saanen	71	428 ± 23	"
	"	Toggenburg	54	422 ± 26	"
Lactation length (d)	Mexico	Local	30	288 ± 11	"
	"	Alpine	91	251 ± 7	"
	"	Granadina	52	237 ± 9	"
	"	Nubian	105	230 ± 7	"
	"	Saanen	71	244 ± 8	"
	"	Toggenburg	54	259 ± 9	"
	India	Black Bengal	77	133.31 ± 3.95*	Das et al., 1982
	"	Beetal	-	205.6 ± 13.0	Melha and Mishra, 1980
	"	Alpine x Beetal	-	228.4 ± 6.9	"
	"	Saanen x Beetal	-	243.2 ± 22.0	"
	"	Malabari	58	139.5 ± 20.25	Mukunda et al., 1983
	"	Saanen x Malabari	23	215.0 ± 40.53	"
	"	Barbari	34	127.39	Barhat et al., 1978
	"	Jakharana	12	114.66	"
	"	Marwari	21	105.80	"
	"	Sirohi	20	133.70	"
Milk fat (%)	"	-	-	5.72 ± 0.74	Tewatia et al., 1995
	Czechoslavakia	White polled	204	3.59	Macha, 1982
	"	Fawn polled	59	3.08	"
Milk fat prod. (kg)	"	White polled	204	43.6	"
	"	Fawn polled	59	39.4	"
Milk protein (%)	India	-	-	5.13 ± 0.41	Tewatia et al., 1995
	Czechoslavakia	White polled	204	2.89	Macha, 1982
	"	Fawn polled	59	39.4	"

Table 2.2 (Contd.)

Milk Protein prod. (kg)	„	White polled	204	35.1	„
	„	Fawn polled	59	32.2	„
Total solid (%)	India	-	-	17.3 ± 1.55	Tewatia et al., 1995
Dry period (d)	„	Malabari	58	162.8 ± 55.12	Mukundan et al., 1983
	„	Saanen x Malabari	23	190.8 ± 76.86	„

* Estimated from more than one value.
N = Number of animals used in the estimation.

The various studies carried out on goats indicate that milk yield and composition depends on body condition, nutrient intake, number of offsprings being suckled, lactation number, stage of lactation, parity, season and year of lactation, as well as on breed and genetic potential of the animals (Reynolds, 1986; Kala and Prakash, 1990; Julio, 1991; Mavrogenis and Papachristoforou, 1991). Also, shortage of water has been reported to inhibit milk production (Little et al., 1976). Increasing fat and protein contents of milk appear to decrease average daily milk yield with advancing stage of lactation (Kala and Prakash, 1990). On the other hand, increasing lactose content increases milk yield.

Sala et al., (1991) showed that while season of kidding had no effect on milk yield or lactation length, parity influenced both traits, thus, indicating that parity of doe might be a more important factor in the determination of the two traits in goats. Breed differences in milk yield in goat (Kala and Prakash, 1990; Boylan and Sakul, 1991) have shown that peak yields were attained according to the individual characteristics of the breed. Breeds with shorter lactation lengths attained their peaks earlier than those with longer lactation lengths. Crossbred animals tend to give more milk than purebreds (Mukandan et al., 1983; Awgichew et al., 1991). Consequently, sire groups have influence on milk yield and composition in goats but probably not on the udder conformation (Skjevdal, 1991). It seems that favourable environment enhances the sire group effects on milk yield and composition.

The effect of litter size on lactation milk yield was shown to be higher for females producing twins than for those producing singles or triplets with milk yield being lowest for first lactation and highest for 3rd to 5th lactations (Julio, 1991). This is in line with the fact that age of doe affects her milk yield and lactation length in goats (SZK, 1991). The yield and lactation length increased with increasing age of doe. However, it appears there is a limit to which increase in age can lead to an increase in lactation milk yield and length. For instance, in a total of 7 lactations (Mavrogenis and Papachrostoforou, 1991), lactation milk yield was greatest in the 2nd and 3rd lactations.

2.5. THE INDIGENOUS GOATS PRODUCTION CONSTRAINTS.

The primary constraints to goat production is disease with 40 to 50% of the animals failing to survive to 12 months (Reynolds et al., 1988). In West Africa, periodic outbreaks of PPR (Kata) can decimate village livestock populations. It is therefore, risky for farmers to build large herds of sheep or goats in the absence of veterinary care or medications.

Another constraint is nutrition, particularly for confined animals. The growth rates of confined village animals are only half those of free-roaming animals (Reynolds et al., 1988). Free roaming animals can select the most nutritional parts of grass and browse, but confined animals are limited in choice to what the farmer provides from the bush and from fallow land. Purchased feed is rarely offered to small ruminants.

The necessity for the daily management of the stock is yet another constraint (Ndamukong et al., 1989). Labour problems arise when children leave home and many owners had off farm work which restricted their involvement with routine management of the animals (Ndamkong et. al., 1989). The fear of animals being stolen necessitate tethering close to the home, and good pastures might not always be available in the immediate vicinity.

Land availability for grazing is continually being reduced by encroachment of

cultivation (Reynolds et al., 1988; Ndamukong et al., 1989). In some areas, there is now insufficient land because of increasing population density and hence fallow periods are being shortened. The regeneration of soil fertility is therefore, limited and crop yields decline. Frequent confrontations between livestock owners and crop farmers induces most owners to limit stock numbers to those they can conveniently manage and watch.

Poor quality of genetic resources in the indigenous breeds is a big constraint to increased productivity. With very little knowledge on the genetic potentials of the animals, little progress can be achieved through breeding for higher productivity.

2.5.1 PROSPECTS FOR IMPROVEMENT OF INDIGENOUS GOATS

These will depend much on whether their values as small domestic animals is adequately recognised. Small size is significant on account of their economic, managerial and biological advantages. Attendant to these features is their high fertility and short generation interval, which means that milk production begins 5 months after initial mating and that the first carcass may be on sale in less than a year.

The aspects that merit special mention and may be worthy of exploitation are the higher efficiency for cellulose digestion and feed utilization for milk production of goats. Both are important, as they raise questions as to the role of goats in increasing meat and milk production. Evidence from Pakistan (Wahid, 1965) and from Greece and Cyprus (French, 1970) suggests that goats are relatively more efficient and economic than some other ruminants in this role. The prospects for increased productivity, based on exploiting these special features inherent in the goat, should have the objectives of increasing the number and size of kids and frequency of kidding and lengthing the productive life-span.

Any management intervention must take cognizance of the small size of household flocks , the fact that the farmers are primarily crop farmers and even some times delegate the

care of livestock to women and children as well as the need for improvement in health and nutrition which must be simple, adaptable and dependent on locally available resources. Ademosun (1988) proposed an appropriate management system for the West African Dwarf goats as one that will have the following basic characteristics: complete confinement of animals, improved nutrition through the use of browse leucaena and gliricidia supplemented with salt lick; provision of shelter, vaccination against PPR and ecthyma and dipping against mange and lice; and control of occasional health problems such as diarrhoea, caseous lymphadenitis and pneumonia. A package such as this must develop a model that would be adaptable under the village system while at the same time, incorporating the above characteristics.

Other management techniques for reducing peri- and post-natal kid losses have been proposed (Horst, 1989). These include the introduction of boxes for overcoming low temperature losses of newborn, artificial rearing by whole milk replacer and early weaning procedures, mineral supplementation and prophylaxis against coccidiosis and endoparasites.

On the breeding scheme to be adapted (Horst, 1989), this should be such that will consist of the creation of a new breed with improved productive adaptability which is to be used by several private farms and national organisations for further multiplication and selection. For a wide testing programme, the value of the systematic introduction of genes for improving growth and milk production has to be proved. Also, significant additive genetic effects, important maternal direct and indirect (heterosis) effects has to be explored, to lead to the consolidation of a synthetic line of a purpose type. Basic techniques have to be adopted to build up a deep frozen semen bank which will not only use imported resources but also valuable local ones. Oestrus behaviour, hormonal profile studies and modified synchronisation techniques will have to be introduced to improve gene transfer into the nucleus as well as into the field stock.

Means of early pregnancy diagnosis (e.g. ultrasonic screening) has to be applied to goats in order to facilitate reproductive selection.

The next phase will be directed to higher productivity (Horst, 1989) including breeding aspects (semen, embroyo storage and transfer, genome analysis), to product processing and development (improvement of milk quality, new milk products and processing of skins), and to intensify biotechnology. In this respect, a local strain for a particular purpose (e.g. meat, milk, skin) will be created by further up-grading of the synthetics with improved breeds, of a particular type, as long as upgrading generations prove superior to the preceding ones.

2.6 COMPOSITION AND USEFULNESS OF GOAT MILK.

There is a shortage of information on the significance of goat milk in human nutrition, allergy, dietetics, pediatrics and medicine (Park, 1994). However, on a worldwide basis, more people drink goat milk than that of other species (Haenlein and Caccese, 1984; Park and Chukwu, 1989). In Nigeria, many people still refuse to take goat milk. This refusal is usually attributed to the smell, which potential consumers find objectionable (Addo et al., 1980; Ehoche, 1983). The most important constraints are lack of awareness of its nutritional advantage and adequate education on the health related importance of goat milk in Nigeria (Egwu et al., 1995).

A comparison of the composition of goat milk and its nutritive value with those of the cow, buffalo and human milk is presented in Table 2.3. Goat milk differs from cow or human milk in having a higher digestibilitgy, distinct alkalinity, higher buffering capacity, and certain therapeutic values (Devendra and Burns, 1970; Haenlein and Caccese, 1984; Park and Chukwu, 1989; Park, 1991). Between 40 - 100% of patients allergic to cow milk protein tolerate goat milk (Park, 1994). Goat milk has been recommended as a substitute for those who suffer from allergies to cow milk or other food sources (Van der Horst, 1976; Taitze and Armitage, 1984). The use of goat milk as a hypo-allergenic infant food or cow milk substitute in human diets has

been reported in persons suffering from eczema, asthma, chronic catarrh, migraine, colitis, hay fever, stomach ulcer, epigastric distress and abdominal pain due to allergenicity of cow milk protein (Walker, 1965; Taitze and Armitage, 1984).

Table 2:3 Composition of goat milk in comparison to cow, buffalo and human milk.

	Value per 100g milk			
Component	Goat	Cow	Buffalo	Human
Moisture (%)	86.8	87.5	81.0	88.0
Protein (%)	3.3	3.2	4.3	1.1
Fat (%)	4.5	4.1	8.8	3.4
Carbohydrate (%)	5.6	4.4	5.6	7.4
Minerals (%)	0.8	0.8	0.8	0.1
Energy (kcal)	72.0	67.0	117.0	65.0
Calcium (mg)	170.0	120.0	210.0	28.0
Phosphorus (mg)	120.0	90.0	130.0	11.0
Iron (mg)	0.3	0.2	0.2	-
Sodium (mg)	11.0	16.0	19.0	-
Potassium (mg)	110.0	140.0	90.0	-
Vit. A (IU)	182.0	174.0	160.0	137.0
Vit. C (mg	1.0	2.0	1.0	-
Thiamine (ug)	50.0	50.0	40.0	20.0
Riboflavin (ug)	40.0	190.0	100.0	20.0
Niacin (ug)	300.0	100.0	100.0	-
Free folic acid (ug)	0.7	5.6	3.3	1.3
Total folic acid (ug)	1.3	8.5	5.6	-
Vit. B_{12} (ug)	0.05	0.14	0.14	0.02

Source: Anjaneyulu et al., (1985).

Goat milk fat contains significantly greater cotents of short and medium chain length fatty acids (C4:0 -C12:0) than cow milk fat (Chandran et al., 1992; Haenlein, 1992). This difference may contribute to more rapid digestion of goat milk fat, since lipase attacks ester linkages of such fatty acids more readily than those of longer chains (the smaller fat globle size of goat milk would have better digestibility compared to cow milk (Haenlein and Caccese, 1984; Stark, 1988; Chandan et al., 1992). Caproic (C6:0),caprylic (C8:0), capric (C10:0) and medium chain length fatty acids have been utilized for treatment in a variety of malabsorption patients suffering from chyluria, steatorrhea, hyperlipoproteinemia and in cases of intestinal reaction, coronary bypass, premature infant feeding, childhood epilepsy,cystic fibrosis and gallstones. These fatty acids are metabolically unique in providing energy in growing children through inhibition of cholesterol deposition and dissolution of cholesterol in gallstones (Kalser, 1971; Tantibhedhyanangkul and Hashim, 1975; Haenlein , 1992).

Average size of goat milk fat globules is smaller than that of cow and other species' milk. Comparative average diameters of fat globules for goat, cow, buffalo and sheep milk were reported as 3.49, 4.55, 5.92 and 3.30 um, respectively (Juarez and Ramos, 1986). Goat milk is considered to form a softer, more friable curd when acidified, which may be related to low contents of α_{s1} - casein in the milk (Haenlein and Caccese, 1984; Chandan et al., 1992).

Goat milk also has a greater iron bioavailability in anaemic rats than cow milk (Park et al., 1986). Anaemic rats fed on goat milk grow significantly better, had higher liver weights and haemoglibin regeneration efficiency than those on cow milk (Park et. al., 1986). Mack (1953) also observed that children on goat milk surpassed those on cow milk in weight gain, stature, skeletal mineralization, bone density, blood plasma, vitamin A, calcium, thiamine, riboflavin,

niacin and haemoglobin concentrations. However, goat milk has been blamed for development of goat milk anaemia due to deficiencies of folic acid and vitamin B_{12} in the milk (Nicol and Davis, 1967; Davidson and Townley, 1977; Park et al., 1986). However, goat milk has better buffering capacity, which is good for the treatment of ulcer (Devendra and Burns, 1970; Haenlein and Caccese, 1984; Park, 1991; Park, 1992). Goat milk contain significantly higher non-protein N than cow milk, and higher levels of nitrogen moieties and phosphate in goat milk were positively correlated with higher buffering capacity (Park, 1991).

Table 2.4 gives the chemical composition of goat milk. Widely varying values for milk consituents in goats have been attributed to age (Mittal, 1979), breed, season, stage of lactation (Agrawal and Bhattacharyya, 1978; Akinsoyinu et al., 1981; Pilla et al., 1982; Kala and Prakash, 1990), plane of nutrition (Singhal and Mudgal, 1985), herd, lactation number, month of kidding and number of kids (Rabasco et al., 1993). Akinsoyinu et al., (1981) indicated that total solids and energy in milk declined in Red Sokoto goats as lactation progressed.

Table 2.4 Gross chemical composition of goat milk (%).

	Breed				
Component	Jamunapari	Beetal	Barbari	Black Bengal	Parbatsar
Water	85.31	86.38	86.07	81.93	85.43
Total solids	14.69	13.62	14.93	18.07	14.57
Fat	5.59	4.74	5.69	7.93	5.00
SNF	9.10	8.88	9.24	10.14	9.57
Protein	3.85	3.74	4.05	4.97	3.32
Lactose	4.40	4.32	4.31	4.28	4.31
Ash	0.85	0.82	0.88	0.89	-
Acidity	0.16	0.17	0.17	0.18	-
Chloride	0.17	0.17	0.21	0.15	0.25
Total Ca (mg/100ml milk)	168.53	150.40	159.63	190.17	-
Calories (kcal/100mg milk)	88.17	79.25	89.58	114.69	79.88

Source: Agnihotri and Prasad (1993).

2.6.1 Udder Characteristics and Factors Affecting them

Udder is the main body part of a dairy animal commonly understood to be related to its milk producing capacity. In goats, udder characteristics, milk production, milking time and rate are traits with adequate genetic variation to allow selection responses (Ricardeau, 1981; Wang, 1989; Mavrogenis et al., 1989). The knowledge of the relationships between these traits can be utilized in the design of breeding programmes to improve milkability and to identify certain morphological and physiological factors related to changes in these traits (Shook, 1989; Schutz et al., 1990; Boettcher et al., 1992).

There are few studies on the udder and teat dimensions in goats (Das and Sidhu, 1975; Mosdol, 1980; Das and Singh, 1983; Kumar et al., 1983; Narain et al., 1985; Montaldo and Martinez-Lozana, 1993) although factors affecting udder traits in goats have been studied.

The most important factors contributing significantly to the variability of the three traits (depth, width and circumference) defining udder size were lactation month, flock and yield (Labussiere, 1988). The remaining traits (cistern height, teat position, length and width) showed high repeatability and were less dependent on yield and lactation month, which made them potential candidates for genetic improvement. Moreover, cistern height, teat positon and teat angle traits are the most important for udder adaptation to mechanical milking (Labussiere, 1988). Scant cistern height, vertical teat position and minimal teat angle favour letdown and drainage of the milk, which eliminate lengthy stripping (Labussiere, 1988). Wide teat angles are responsible for teat cup slipping and inhibition of the ejection reflex (Labussiere, 1988).

Stage of lactation has been reported to significantly influence mammary traits (Fernendez et al., 1995). As lactation continued these traits diminished, as did milk yield. Also, teat size (length and width), tended to decrease with stage of lactation; while udder width and cistern height increased with parities.

Milk yield has been reported to greatly influence udder size (Fernendez et al., 1995). The traits (depth, width and circumference) defining udder size, were highly dependent on total milk yield per lactation and test day milk yield (Labussiere, 1988). However, Gootwine et al. (1980) did not find any significant correlation between udder shape and milk yield for high yielding Assal sheep. On the other hand, research reports have concluded that mammary characteristics that have low or nil genetic correlations with milk yield can be selected for without modifying milk yield (Mavrogenis et al., 1988). Udder size may be more of a limiting factor to yield in first lactation than in later ones (Schultze, 1979).

It has been found that cows with pointed teat ends had the lowest milk flow rate and highest lession scores (Seykora and Daniel, 1985). Milk yield did not differ significantly by classification of teat end shape (Seykora and Daniel, 1985). Appleman (1970) found that teat ends that were disk or inverted had wider streak canals than those with pointed or round ends. Teat with large diameter has slow milking than a small one. However, selection of a more pointed teat, although would increase resistance to mastitis, but milk yield may not increase because of a tendency to milk incompletely animals with slower milk flow (Seykora and Daniel, 1985). Increased residual milk would tend to lower total yield; hence, faster milk flow in the flatter teat ends may compensate for increased infection rate (Seykora and Daniel, 1985). All the same, the optimal shape may be the round teat-end shape, which is an intermediate and also the most prevalent shape (Seykora and Daniel, 1985).

2.6.2 Factors Affecting Milk Production Traits

For genetic evaluation and selection of sires and dams for a certain trait, it is necessary to know the genetic and non-genetic sources of variation of production traits in order to make the necessary corrections of field data. Usually, genetic and non-genetic factors affecting milk production are breeds, lactation period, herd differences, number of offsprings, age or lactation

number, season or month and year of parturition (Alderson and Pollack, 1980; Iloeje et al., 1980; Mavrogenis et al., 1989; Kala and Prakash, 1990; Mavrogenis and Papachristoforou, 1990; Rabasco et al., 1993).

The adjustment factors developed by Iloeje et al., (1980) indicate that age factors for dairy cows used for adjusting goat records should be replaced by separate factors developed for specific breeds of dairy goats. Most often, the needed factors are usually unavailable, making uniform adjustment of data difficult.

I. Season and Year Effect.

Season and year of kidding have been shown to significantly influence milk yield and length in goats (Barhat and Chowdhary, 1978; Alderson and Pollak, 1980). Data on 220 Alpine goats indicating significant effect of year (Browning et al. 1995) showed that milk production was greater in 1986 (968kg) than in the following years, 1987 - 1993 (777 - 845kg); fat yield was not influenced by lactation year. In another report (Iloeje et al., 1980), milk records of goats were affected differently in different seasons for a particular age. They further reported that season of kidding affected younger does more than their older herdmates. Kala and Prakash (1990) reported significant year effect on milk yield in some breeds of goats, but Rabasco et al. (1993) did not find any such effect.

Effect of season on milk yield was studied on Jamnapari goats (Khan et al., 1980). For 37 Jamnapari does kidding during summer (February - March) or winter (November - December), milk yield averaged 83.69 $\pm$ 3.73 and 61.81 $\pm$ 5.66 kg respectively, and lactation length 105 $\pm$ 3.72 and 94 $\pm$ 5.08 days. Daily milk yield was significantly higher for does kidding in summer than for does kidding in winter; and peak yield was not affected by season of kidding. In another report (Yadav et al., 1983), goats kidding in July - October had significantly higher lactation yields than those kidding in March - June and November - February; with does kidding

in March - June and November - Feburary having no difference. In a related report, goats kidding in October - November tended to produce more milk, especially when compared to late season kidding (Mavrogenis et al., 1984). Also, lactation length has been found to be longest for does kidding in March - June and shortest for does kidding in November - February (Mehla and Mishra, 1980).

II. Age and Parity Effect.

The effects of parity and age of doe on milk yield are well established (Mittal et al., 1977; Iloeje et al., 1980; Kennedy et al., 1981; Kala and Prakash, 1990), although they can be obscured by differences in management, season, nutrition, disease and other environmental factors (Devendra and Burns, 1983). This probably accounts for some seemingly inconsistent results, and conflicting reports as to age at maximum production.

Several authors have found significant increases in total milk production with age, reaching a peak between 30 and 50 months of age and decreasing thereafter (Steine, 1975; Alderson and Pollack, 1980; Iloeje et al., 1980; Gall, 1981; Montaldo et al., 1995). Similar trend has been reported for lactation length (Garcia, 1982; Montaldo et al., 1995). Browning et al. (1995) working with 220 Alpine does showed that lactation number affected milk yields with highest production recorded at second lactation (960kg) and lowest at seventh lactation (634kg. Does of parity 1 produced less milk than does of parity 2 and 3 (Rana et al., 1982; Yadav et al., 1983; Zeng and Escobar, 1995); thus suggesting that lactation yield shows increasing trend as the order of lactation increases.

In two herds of Beetal goats originating from different parts of Punjab in India, Amble et al. (1964) analysed 800 and 788 lactation records, and found that yield declined from the first to the second, then rose to the fifth, and declined in latter lactations. Milk production in the fifth lactation was less than in the first. The data of Mittal et al. (1977), on a much smaller number,

indicated higher yield after four years of age than in younger does. Singh and Acharya (1980), using 3,827 lactation records from 1,439 Beetal does, found that milk yield was maximal in the third lactation, and then declined in the fourth and fifth.

Kennedy et al. (1981) studied the joint effects of parity, age and season of kidding on milk and fat yields in dairy goats. They observed that differences between parities at the same age were large and significant, with does kidding at 20 - 22 months of age having maximum yield in first lactation. Milk yield in subsequent lactations tended to decrease as age at kidding increased. Thus, indicating the necessity for considering parity in developing age-correction factors.

Despite variation in details, there is a degree of consensus that milk yield reaches a maximum by four or five years old, and does not fall drastically for at least a further three years. Year or age and lactation number do not of course, always coincide, particularly in those breeds which may kid more than once a year, but almost all the breeds currently regarded as milk breeds are annual breeders (Devendra and Burns, 1983).

III. Herd Effect.

Waheed et al. (1977) in studying the feeding and management effects on herd differences in milk yield, observed that differences among herds in milk yield accounted for 27 to 37% of the total variation in milk yield. Also, Iloeje et al. (1981) reported that herd effects accounted for 22 to 23% of the total variation in milk and fat yields.

Intrasire regressions of daughters' yield on herdmates yield (Mao et al., 1972) indicate that 83 to 90% of the differences between herds are due to effects other than sires. Therefore, feeding and management factors are likely causes for a major portion of herd differences. It has been suggested (Bayley and Heizer, 1952; Mao and Burnside, 1969) that herd differences in milk yield are due to total digestible nutrients fed per day, herd size, and season of calving. Recently,

Rabasco et al. (1993) investigated the genetic and non-genetic sources of variation in yield and composition of milk in Verata goats. They reported herd differences for fat content, protein and solid yields but not for milk yield.

IV. Stimulants.

Gobran and Shpotakooski (1979) worked on the effect of insuline on the secretion of milk and reported that intramuscular and intraveinous injections of goats with insuline in the second half of the lactation increased milk yield. They also reported that injection of insuline into the mammary artery increased milk yield in the udder half supplied by the injected artery by 30 - 60% compared to the other half.

Focaut (1981) worked on the effect of hormonal induction of lactation in goats. He found that lactation can be induced in goats by injecting oestradiol-17*B* and progesterone; but the optimal dosage ratio is yet to be determined. Disenhaus et al. (1995) used multiparous lactating Alpine and Saanen goats to test the effect of recombination bovine somatotropin (BST) and galactopoiesis and metabolism on milk yield. They found that supplementation with BST significantly increased yields of milk, fat and protein compared to control (28.6, 41.6 and 23.7%, respectively).

VI. Body Weight.

There is positive and significant relationship between body weight and milk yield in goats (Mishra et al., 1980). Mishra et al. (1980) studying postpartum body weight in relation to milk yield, had the following weight classes for 68 Sirahi goats weighed within 12 hours of parturition: 24 - 26, 27 - 29, 30 - 32 and 33 - 35kg. They obtained a corresponding average of 90 days milk yield of 40.23, 48.13, 52.30 and 53.80kg.

Mukherjee et al. (1991) working on Bengal goat found that body weight at birth, 12 weeks of age and preweaning daily gain, significantly affected milk yield. They also observed

that body weights of kids at 24, 36 and 52 weeks significantly influenced milk yield of first lactating does. Also goats that were heaviest at different stages of growth had the highest preweaning daily gain and milk yield. Correlation of lactation yield with body weights at birth and at 12, 24, 36 and 52 weeks of age showed that Black Bengal goats can be selected on their body weight at birth and 12 weeks of age for milk production. Dhangar et al. (1991) worked on the effect of body weight at first calving on milk yield and concluded that milk yield increased with body weight at calving.

VI. Milking Procedures and Rates.

Comparisons between machine milking and hand milking have not shown conclusively whether differences in milking procedures influence milk output. In one such comparison, goats were assigned randomly to be hand or machine milked (Lantinger, 1969). The milking machine was that designed by Alfa Laval for milking goats in the Netherlands to operate at 30cm vacuum with 80 pulsations per minute. In 1 hour, 39 goats were machine milked to yield a total of 35kg (including 8kg strippings). In the same amount of time, 30 hand milked goats yielded 30kg of milk. Reports from other researchers (Bouillon and Ricardeau, 1975) suggest that to adapt goats quickly to machine milking, selection should be on rate of flow rather than on milk yield. In an experiment with 33 Saanens and 10 Chamois coloureds, no genetic correlation was significant between milk yield and rate of flow (machine milking) in 1- to 2-year old does in their first lactation.

Krahn and Rasmusseu (1992) worked on the influence of milking rate on milk yield of cows. They reported that milking four times a day increased milk yield by 15% in the 1st parity, 9% in the 2nd and 3% in the 3rd compared with milking twice a day. However, they noticed that cows milked four times a day had the highest incidence of diseases.

VII. Litter Size and Suckling.

Milk yield in goats is affected by the interaction of internal factors such as the genotype (Devendra, 1975) and body condition (Mackenzie, 1957) with external factors such as food supply (Devendra, 1972), season (Linzell, 1973), and exteroceptive stimuli (Cowie et al., 1968). Suckling induces prolactin secretion and prolactin plays a part in the initiation, if not the maintenance of lactation in goats (Hart, 1973). Suckling stimulus was considered the primary cause of litter size effects on milk yield in goats (Mavrogenis et al., 1984).

Litter size affects milk yield in suckled does (Browning et al., 1995), and only before weaning (Mourad, 1993; Rabasco et al., 1993). Goats with two or more kids at birth had greater efficiency for milk yield and body weight than goats with one kid (Montaldo et al., 1995). Furthermore, Hayden et al. (1979) reported that 150 day milk yield in goats increased with litter size when kids were weaned by 1 week of age. When kids were raised artificially (Subries et al., 1988 and Hernandez et al., 1989) past studies found milk yield unaffected by litter size.

It is likely that the relationship between milk yield and litter size is for the most part, due to the extent of prepartum development of the mammary gland and this will limit the response to postpartum atttempts to modify lactation performance (Hayden et al., 1979). It has been observed that placental lactogen has a significant role in the control of normal mammary development and function in goats (Hayden et al., 1979). The same workers also observed that milk yield was correlated with weekly mean of placental lactogen titres between week 11 and kidding term of hand milked goats that bore triplets or twins. The does gave 47% and 27%, respectively, higher milk yield than does of single kids.

Litter size effects on milk and fat yields may be due to modified endocrine profiles in prepartum does. Progesterone, oestrogen, and placental lactogen produced by the foetal placenta will influence mammogenesis (De Lowis et al., 1980). Concentrations of these hormones

change significantly during the middle and later stages of gestation. Positive interrelationships exist between litter size, total foetal weight, placental mass, mammary growth, and concentrations of these hormones in small ruminants (Hayden et al., 1979; Schoknech et al., 1991). Positive relationships have been observed between litter size, litter weight and lactation yield in goats (Browning et al., 1995).

VIII. Stress and Milk Secretion.

There are limited reports on the effect of environmental stress on lactation in goats. However, reports have shown that heat stress adversely affects milk production in goats (Ocfemia et. al., 1993). In a simulated experiment (Ocfemia et al., 1993), does undergoing simulated transfer to a hot humid climate were found to be poor mothers, produced weak small kids with about 50% mortality, and during lactation, partitioned more of their diet to body growth and less to milk production. Their findings further revealed that milk production during the first 2 months of lactation was highest for does in the cold room; 'hot-hot' and 'cool-hot' does had earlier peak production and lower average production. They concluded that the rapid weight loss and poor milk production of the stressed goats showed that the effect of chronic heat stress was greatest during lactation, because of the further increase of metabolic rate.

The physiological adaptations which enable tropical goats to adjust and produce milk under harsh conditions are poorly understood. An example is when milk production dramatically falls immediately after the peak of lactation due to inadequate nutrition or general adverse environmental conditions (Casoli et al., 1989; Gargouri et al., 1992). Hossaini-Hilali et al. (1993) investigated the effect of feed deprivation on fluid balance and milk secretion in the Black Moroccan goats. They reported that milk volume of 700 $\pm$ 48 ml/d decreased by 30% after the first and 57% the second day of feed deprivation. When the goats were refed, milk volume was 384 $\pm$ 81 ml/d 2 days after. Feed deprivation in European goat breeds induces a

decreased blood glucose level and a drop in milk secretion (Chaiyabutr et al., 1980; Dahlborn and Karlberg, 1986).

It appears that adaptation to harsh climatic and nutritional conditions may include the regulation of constant plasma volume and glucose concentration during feed deprivation (Hossaini-Hilali et al., 1993). Lactation is a critical period in the production cycle which involves extra demands on mechanisms regulating fluid and energy balance. Water and feed intake are expected to increase to meet requirements for milk production. Maintenance of blood volume is essential for mammary blood flow and milk precursor supply, and consequently for sustained milk secretion rate. In addition, blood glucose is critical for milk lactose sysnthesis and therefore, for total milk volume (Linzell and Peaker, 1971).

During lactation, there is a dramatic increase in glucose requirements for milk lactose synthesis (Brockman, 1986). In high yielding lactating goats, plasma glucose concentration is lower (Dahlborn and Karlberg, 1986) than in non-lactating ones. Also, in Black Moroccan goats, milk yield decreased in the same proportion as milk lactose secretion (Hossaini-Hilali et al., 1993); thus confirming that milk volume is primarily determined by lactose synthesis (Linzell and Peaker, 1971).

IX. Nutrition.

Some researchers have tried to improve intake level and milk yield of goats with limited success, by using the rationed grazing method (Masson et al., 1991) or by complementing grazing with concentrates (Garmo, 1986). During grazing, goats showed higher intakes and higher levels of milk production when fed a constant amount of concentrates even when the availability of nutrients in the pasture was highly variable (Pilla et al., 1986). Dairy goats improved their milk production when given energy (Morand-Fehr and Sauvant, 1980) or protein supplement (Hadjipanayiotou, 1987), although the response was limited by the milk potential

of the breed (Zometa et al., 1985; Gihad et al., 1987).

Morand-Fehr and Sauvant (1980) showed that protein supplements only increased milk yield when there is an insufficient supply of protein in the diet. Hadjipanayiotou (1987) found in Damascus goats that a N over-supply did not increase milk yield. Badamana and Sutton (1992) showed that the milk yield of Saanen goats was increased by an increase in the protein content of concentrates from 11% to 18%, but was unaffected by a further increase to 25%. Thomas et al. (1980) also reported that milk production of Saanen goats was increased by a protein supplement covering requirements, but reduced by over-supply of N. Rubino et al. (1995) reported that protein supplements did not improve milk production of Maltese and Rossa Mediterranean goats but rather decreased it. They attributed this result to constant positive N balance of the goats, indicating that all the goats were over-supplied with N.

Information on the effect of intake of dietary protein and energy during late pregnancy on the subsequent lactation of dairy goats is limited (NRC, 1981). Hernandez et al. (1989) reported an increase in milk production of Alpine goats at higher prepartum dietary energy intake. Sahlu et al. (1992) have also observed increased prepartum body weight gains with increased prepartum CP intake but did not examine its effect on lactation. However, the interaction between protein and energy of prepartum diets and their effects on subsequent milk production have been reported by Sahlu et al. (1992). Their observations indicate that milk production in the subsequent lactation increased quadratically in response to prepartum CP (2.59; 3.28 and 3.07 kg/d for 8.5, 11.5 and 14.5% CP, respectively). Milk production increased linearly in response to prepartum metabolizable energy concentration (2.63, 3.05 and 3.26 kg for 1.80, 2.16 and 2.53 Mcal/kgDM, respectively). The authors also observed milk composition of dairy goats to be affected either linearly or quadratically by increased prepartum CP and energy.

Abdel-Rahman and Mehaia (1996) investigated the influence of feeding different crude fibre levels on milk yield and milk composition of Najdi ewes. Their investigation revealed high milk yield in ewes weighing more than 50kg and also in twinning ewes. Protein and SNF% were significantly increased by reducing crude fibre content; whereas, fat and total solid % was significantly increased by increasing crude fibre in the diet. On the other hand, Kawas et al. (1991) observed a reduction in milk yield as ADF in feed of hay increased. Depeters and Smith (1986) fed diets of alfalfa mixed with 30 or 50% concentrate and found that milk fat was reduced at higher concentrate and milk protein was higher for early cut hay.

X. Breed and Breeding.

Breed differences have been observed for milk yield and fat % in Gargano, Maltese and Saanen goats (Pilla et al., 1982). Milk yield in the first 175 days of lactation in the breeds averaged 207.6, 280.0 and 358.3kg and fat %, 3.87, 4.06 and 2.86, for Gargano,Maltese and Saanen goats, respectively. A comparison of milk and fat yield records of Alpine, La Mancha, Anglo-Nubian, Saanen and Toggenberg showed that Saanens had the highest average milk and fat yields for all lactations (977 and 34kg, respectively) (Alderson and Pollak, 1980). Milk production of two newly developed synthetic dairy goats (Cukurova and Taurus) were compared under subtropical conditions (Guney et al., 1992). Milk yield averaged 376 $\pm$ 13.9 and 352 $\pm$ 14.8kg for Taurus and Cukurova, respectively. Taurus goats had longer lactation length than Cukurova goats. In India, Yadav et al. (1983) studied the milk production of four Indian breeds of goats (Jamnapari, Beetal, Barbari and Black Bengal). They reported breed differences in lactation yield, thereby, suggesting differential genetic potential for milk production for these breeds. Further evaluation of the Indian breeds for dairying (Das et al., 1982) still indicated singnificant effects of genetic groups with the critical differences between group means revealing that ½ Saanen + ½ Jamnapari crossbreds produced more milk than the remaining

groups. The work of Das et al. (1982) further showed average daily yield in 2 groups (1st and 2nd - 4th lactations) of Black Bengal goats to be highest during the 1st month (222.6 ± 10.4 ml) in 1st lactation group and 339.1 ± 22.4 ml in 2nd - 4th lactation group. But Barbari, Jamnapari and ½ Saanen + ½ Jamnapari had highest daily yield during the 2nd month. The average being 551.1 ± 96.7, 562.0 ± 127.6 and 888.0 ± 269.3 ml, respectively. Black Bengal females in 1st lactation produced milk upto 6 months, and the 2nd group (2nd - 4th lactation) yielded milk upto 7 months. The Barbari, Jamnapari and ½ Saanen + ½ Jamnapari continued lactation till the 8th month. On the whole, the evaluation of the Indian breeds of goats for dairying, indicate the superiorities of Jamnapari and Barbari over others (Agrawal and Bhattacharya, 1978; Das et al., 1982; Singh and Mudgal, 1985); therefore, better for dairy purpose and development.

Upgrading local unselected goat populations with specialized breeds has been advocated and utilized as a practical method for genetic improvement of goats (Steinbach, 1987; Ricordeau et al., 1992). Comparisons between local, purebred and crossbred animals under the same environmental conditions have been done (Chawla and Bhatnagar, 1984; Steinbach, 1987). But most of these studies involved few breeds, characteristics and observations, and depended on the genetic characteristics of each local population, the breed utilized for crossing and the environmental conditions (Swan and Kinghorn, 1992).

In order to compare high-grade and low-grade goat crosses of Alpine, Granadina, Nubian, Saanen and Toggenberg sires with local Mexican goats, performance data of goats raised in a stall-fed system in northern Mexico were analysed (Montaldo et al., 1995). Alpine, Saanen and Toggenberg crosses had greater milk production, lactation length and efficiency (milk production/post kidding body weight) than Granadian and Nubian crosses or local does. High-grade Saanen were superior to low-grade Saanen for milk production and lactation length. Average increases for milk production, lactation length and efficiency over local goats for low-

grade Alpine, Saanen and Toggenberg were 46%, 10% and 41% respectively. Similar figures for high-grade were 60%, 19% and 50%, respectively.

Effect of crossbreeding on milk yield was investigated in Beetal and its crosses with Alpine and Anglo-Nubian goats in India (Rana et al., 1982). The result of the crosses revealed significant differences between genetic groups in milk yield. Total milk yield in the five groups averaged 98.26; 115.46; 107.45; 103.89 and 108.57kg for Beetal, Alpine x (Alpine x Beetal), Alpine x Beetal, Beetal x (Alpine x Beetal), and Alpine-Nubian x Beetal, respectively. Further crossbreeding study with Saanen and Malabari goats still indicate genetic group superiority on lactation yield with Saanen half breds yielding higher (117.34kg) than Malabari (49.35kg) goats in a lactation (Mukundan et al., 1983).

2.7 Lactation Curves in Goats.

Lactation curves represent the relationship between milk yield and time after kidding (Ruvuna et al., 1995). They provide valuable information on the pattern of milk production, which can be used to identify those individuals with steady production throughout the lactation period, and those with a high level of production until the peak and a substantial decline thereafter (Hassan, 1995). Knowledge of the shape of the lactation curve is necessary for the nutritional and reproductive management of lactating animals (Wood, 1980), estimation of total lactation yield, expected time of peak production, peak yield, persistency of yield (Wood, 1976) and management decisions on the level of culling (Hassan, 1995).

A parametric function describing the milk production pattern is needed to enable clear interpretation of factors that influence the lactation curve.

2.7.1 Characteristics of Lactation Curve.

A lactation curve normally has an ascending phase to a peak followed by a descending phase. A higher peak is usually followed by a sharper decrease in yield during the descending

phase, while lower peaks are followed by a slower rate of decrease in yield (Wood, 1969). Where only the parameter describing the level of production (parameter 'a') is affected by a given factor, constructed curves have similar shapes but on different levels. But where the parameters describing the ascending or descending phase are significantly influenced, then criss-crossing due to different shapes may be expected (Wahome, et al., 1994). Distinctly, the lactation curves of goats are flatter and more persistent than that of cattle (Devendra, 1980; Ruvuna et al., 1995), while showing the same configuration characterised by an initial increase with a steep fall, followed by gradual and slow decrease which is almost linear (Mukundan and Bhat, 1983). The curve can be divided into two parts, one characterised by a hump followed by almost stable straight line.

In sheep, lactational peak occurred late in high yielding breeds, while in low yielding ones, the peak was usually early or absent (Iloyd, 1963; Hassan, 1995). Also, their pattern of lactation has been described as the one having increased milk production during early lactation, reaching a peak at approximately 2 - 6 weeks after parturition and then decreasing slowly until the end of the milking period (Aboul-Naga et al., 1981; Boylan and Dangi. 1984; Sakul and Boylan, 1992; Hassan, 1995).

2.7.1.1 Dairy Goat Lactation Persistency

Persistency, the ability of the animal to continue to produce relatively at higher levels throughout the lactation, is an important factor in the economics of milk production. The shape of the lactation curve and lactation yield are mainly determined by persistency and peak yield (Gupta and Johar, 1982). Also, the persistency of lactation has been reported to be inversely proportional to the rate of decline in dairy cattle (Wood, 1969; Madsen, 1975). An animal that produces milk at a moderate but persistent level throughout the lactation may be preferred to an animal which produces a higher peak yield but has reduced persistency (Wood, 1967).

Several authors (Ludwick and Peterson, 1943; Mahadevan, 1951) have suggested various methods of measuring persistency of milk yield. However, the persistency index computed by the method of ratios (Ludwick and Peterson, 1943) is more widely used. Other methods used include, the coefficient of variation (%) among per day yields in different weeks of a lactation (Rao and Sundaresan, 1982), the ratio of 300 days yield to peak (observed maximum daily yield) (Rao and Sundaresan, 1982); and the gamma function, $S = -(b + 1) \ln c$ (Wood, 1976). These three methods were referred to as P_1, P_2 and P_3 by Rao and Sundaresan (1982), with P_1 indicating the degree of departure of the weekly yield from the average weekly yield during lactation. Higher values of P_1 and lower values of P_2 and P_3 indicate lower persistency and vice-versa.

In cattle, genetic group, parity and season of calving have been reported to affect persistency measures (Rao and Sundaresan, 1982). Crossbred cattle had higher production and greater persistency than purebred cows (Madalena et al., 1979). In Nigeria, the lactation persistency of White Fulani cattle was studied (Ibeawuchi, 1984). The results of the study indicate that first calvers are about 8% more persistent than older cows. Also, season of calving significantly influenced persistency with dry season calvers being more persistent than wet season calvers.

In sheep, crossbred ewes were reported to have higher milk yield than pure breeds in Egypt (Hassan, 1995). He further reported that the animals started their lactation at a relatively higher production level and persisted until weeks 5 - 7, when milk production started to decline. Generally, the pattern of lactation in sheep was reported as one having increased milk production during early lactation, reach a peak at approximately 2-6 weeks after parturition and then decrease slowly until the end of the milking period (Aboul-Naga et al., 1981; Boylan and Dangi, 1984; Sakul and Boylan, 1992; Hassan, 1995).

Ruvuna et al. (1995) studied lactation curve and persistency, and factors affecting them

in dairy goats. They reported that does kidding in the cold dry season had the highest initial milk, the lowest rate of increase to peak yield, and the lowest persistency. Older does had a higher rate of increase to peak lactation, a higher peak yield and lower persistency than younger does. The highest persistency was for the 2 yr-old does. Their report also showed that after 4 years of age, there was no effect of age on milk production. However, it appears there is dearth of information on lactation persistency of goats. None-the-less, higher persistency of lactation has been observed for goats kidding early in the dry season, October to November (Rabasco et al., 1993).

2.7.2 Mathematical Models in Goat Lactation Curves.

Various mathematical models have been fitted to dairy goat lactation data. The models utilized include, exponential (Brody et al., 1923), parabolic exponential (Sikka, 1950); inverse polynomial (Nelder, 1966); gamma type (Wood, 1967); grafted polynomials (Fuller, 1969); compartmental (Schaeffer et al., 1977) and maltiphasic (Grossman and Koops, 1988; Gipson and Grossman, 1989). While examining the models, Gipson and Grossman (1990) in their review, concluded that diphasic models provided the best fit. However, they suggested that the genetic and physiological basis of the phases needed further investigation and interpretation. Suffice to say that most of the existing models have been applied to animals from temperate environment. Information on the application of these models on the tropical goats is scanty. The available information on the application of some of these models on tropical African goats is presented in Table 2.5. The table showed that all the functions adequately fitted lactation curve in the goats irrespective of breeds (R^2 = 85 - 99.57%).

Table 2:5 Models used in the estimation of lactation curves in goats and their individual efficiencies.

MODEL	LOCATION	BREED	R^2	RESIDUAL	REFERENCE
Exponential	India	Malabari	86.39	0.0788	Mukundan and Bhat, 1983
		Saanen x Malabari	94.55	0.0424	,,
		Pooled data	88.16	0.0643	,,
Parabolic Exponential	India	Malabari	92.38	0.0606	,,
		Saanen x Malabari	94.52	0.0437	,,
		Pooled date	89.78	0.0501	,,
Inverse Polynomial	India	Malabari	99.23	0.373	,,
		Saanen x Malabari	99.57	0.201	,,
		Pooled data	99.39	0.209	,,
Gamma type	India	Malabari	91.54	0.0639	,,
		Saanen x Malabari	94.53	0.0437	,,
		Pooled data	88.31	0.0535	,,
	Kenya	Pooled (E.Afr. & Galla)	85	-	Ruvuna et al., 1995
		Toggenburg x E.Afr.	86	-	,,
		Toggenburg x Galla	89	-	,,
		Anglo-Nubian x E.Afr.	90	-	,,
		Anglo-Nubian x Galla	91	-	,,
		Toggenburg x E.Afr. x Galla	92	-	,,
Non-linear Modified Gamma type	Italy	Sardinian (sheep)	90.8	0.145	Cappio-Borlino et al., 1995

Among the functions in use, the gamma type function is the most popular (Table 2.5). Despite the existence of models which fit lactation curves well and which have a better biological basis (Gipson and Grossman, 1990; Stanton et al., 1992; Ferguson et al., 1993), Wood's model (1967) is still widely used (Rowland et al., 1982; Fadel et al., 1989). This has been attributed to its simplicity and usefulness to roughly determine some differences such as

high and low milk production (Pulino et al., 1993). Also, the model has been extensively studied and characterized under different production system and the parameters have biological interpretation (Ruvuna et al., 1995). On the other hand, Wood's model has been criticised because it under-estimates peak yield and over-estimates yield in the decay phase (Cobby and Ledu, 1978; Lewis Johnson and Lang Tran, 1990). The linearized form of the model was fitted to small East African goat lactation data (Wahome, 1987) and was found to under-estimate the actual yield by about 10%.

In goats, the determination of the lactation peak and other characteristics of the curve (rapidity in achieving the peak and persistence) is very important for genetic and feeding purposes. It has been suggested that models which even though appeared not too precise, but has parameters directly related to this aspect should be adopted (Capio-Borlino et al., 1995). In dairy animals, more complicated situations frequently arise and in these cases Wood's model looses its biological meaning. An example is when milk production dramatically falls immediately after the peak of lactation due to inadequate nutrition or general adverse environmental conditions (Casoli et al., 1989; Gargouri et al., 1992) or when information is lacking regarding the early stage of lactation due to the suckling of lambs (or kids) during the first 4 or 5 weeks (Gabina et al., 1993; Giaccone et al., 1993).

A non-linear modification of Wood's model focusing at preserving both the increasing and decreasing phases of the lactation curve has been proposed and used in fitting lactation curves in goats. Such modified models used a series of linear least-squares equation in interactive stages (Wahome et al., 1994; Capio-Borlino et al., 1995); and non-linear least squares using PROC NLIN of SAS (SAS, 1985) (Ruvuna et al., 1995). The modified models fitted well to dairy goats lactation curve. Infact, the modified Wood's equation as used by Capio-Borlino et al. (1995) appeared to be more flexible than the original model, inspite of being more complex

in computation. They indicated that their model was particularly useful when there is a great variance in production level, and that it may be ideal for solving the problem of early estimation for the lactation curve when there are very few initial data. This model was used to study the lactation curve of Marabari goats and their Saanen half-breeds (Mukundan and Bhat, 1983) in India. The authors reported a wide gap between the observed and the predicted weekly milk production in the initial stages of lactation upto the second week, after which the expected yields became close to the observed values. The trend of the inverse polynomial function indicate that the function might be suited to goats which start their lactation at a very low level of yield, reach the peak very early and then decline at an early stage. The function is used in fitting dairy curves in goats (Mukundan and Bhat, 1983).

The exponential function (Brody et al., 1923) was the earliest function used to fit lactation curves and it describes only the rate of decline in milk production. The function is given as: $Y_t = Ae^{-kt}$, where, Y_t is the yield in time 't' and A and k are constants to be estimated. In its logarithm form, this reduces to: $\ln Y_t = \ln A - kt$.

2.7.3 *Factors Affecting the Shape of Goat Lactation Curves.*

The factors affecting the lactation curves in dairy goats have been studied (Mukundan and Bhat, 1983; Wahome et al., 1994; Ruvuna et al., 1995). The level of peak yield, persistency and the rate of decline in the daily milk yield with the advance of lactation, determine to a large extent, the shape of the lactation curve (Rao and Sundaresan, 1982; Gupta and Johar, 1982). Persistency of lactation is inversely proportional to the rate of decline.

In East Africa, an analysis of the variation of the lactation curve of Small East African goats revealed that the parameters describing the various sections of the lactation curve were specifically influenced by period, parity, year, litter size, weight and age of the doe (Wahome et al., 1994). The authors further reported that period and year influenced the three parameters

of the lactation curve, while parity, litter size and doe weight only influenced level of production. They observed that the very dry and hot periods produced a flat curve, while the year effect produced the random criss-crossing pattern expected of the yearly variation.

Table 2.6 indicates the estimated lactation curve parameters in breeds of goats. Among breed groups, differences existed in lactation curve parameters (Ruvuna et al., 1995). The four-way crossing; Toggenberg x East Africa x Nubian x Galla goats produced the highest average peak morning milk yield (1.116 kg/d) and estimated total morning milk yield (112.582 kg). The crosses averaged at least twice as much milk yield as the indigenous breeds for both peak and total yields. Peak milk yield in the indigenous breeds was at wk 2 of lactation which was earlier than for the crosses which peaked in wk 4 to wk 8 of lactation. Ruvuna et al., (1995) further reported that all curve parameters differed with respect to breed of dam, year, season and age of dam, except season for parameter 'c' and age of dam for parametr 'a'. They also observed that indigenous East African and Galla goats ranked lowest for the average initial milk production at kidding (parameter 'a'); had the highest rate of decline after peak production; and was the least persistent. In cattle, Madalena et al., (1979) found significant breed type differences for 'a' and 'c' parameters. Crossbred cattle had higher production and greater persistency than pure bred cows. Gipson and Grossman (1989) using a diphasic model concluded that breed effect did not have a significant effect on the shape of the lactation curve in dairy goats.

However, a consistent season of calving differences in 'a', 'b' and 'c' parameters for cattle were reported by Wood (1969) and Madalena et al., (1979). Similarly, Gipson and Grossman (1989) have pointed out the importance of season of kidding differences on goat lactation curves with respect to the initial, peak, and day 305 yields. These reports suggest the significance of strategic seasonal breeding to maximize milk yield per doe (Ruvuna et al., 1995).

An interaction between age of doe and stage of lactation was reported by Ruvuna et al. (1995). As expected, older does had a higher rate of increase to peak lactation, a higher peak yield and lower persistency than younger does.

Table 2:6 Estimates of lactation curve parameters in breeds of goats using gamma-type function.

PARAMETER	BREED	MEAN	REFERENCE
a	East African	33ml	Wahome et al., 1994
	E. Afr. & Galla	0.345kg	
	(Pooled data)	0.345kg	Ruvuna et al., 1995
	Toggenburg x E.Afr.	0.721kg	,,
	Toggenburg x Galla	0.813kg	,,
	Ango-Nubian x E. Afr.	0.813kg	,,
	Anglo-Nubian x Galla	0.733kg	,,
	Toggenburg x E.Afr.x Galla	6.717kg	,,
	Sardinian (sheep)	702ml	Cappio-Borlino et al., 1995
b	East African	0.227	Wahome et al., 1994
	E. Afr. & Galla		
	(Pooled deta)	0.149	Ruvuna et al., 1995
	Toggenburg x E. Afr.	0.292	,,
	Toggenburg x Galla	0.248	,,
	Anglo-Nubian x E. Afr.	0.216	,,
	Anglo-Nubian x Galla	0.057	,,
	Toggenburg x E.Afr. x Galla	6.465	,,
	Sarinian (sheep)	1.289	Cappio-Borlino et al., 1995
c	East African	0.058	Wahome et al., 1994
	E. Afr. x Galla		
	(Pooled data)	0.082	Ruvuna et al., 1995
	Toggenburg x E. Afr.	0.049	,,
	Toggenburg x Galla	0.042	,,
	Anglo-Nubian x E. Afr.	0.028	,,
	Anglo-Nubian x Galla	0.014	,,
	Toggenburg x E.Afr.x Galla	0.066	,,
	Sardinian (sheep)	0.133	Cappio-Borlino et al., 1995

a = parameter describing the level of production;
b = parameter describing the ascending phase;
c = parameter describing the descending phase of the lactation.

2.8 ESTIMATION OF GENETIC PARAMETERS FOR DAIRY GOATS.

Estimates of genetic and phenotypic parameters for a given population must be available in order to device adequate selection schemes and optimal breeding plans that maximize the expected response to selection. In tropical Africa, genetic improvement of goats is imperative. Also, to optimize gains from environmental influences, the genetic parameters and attributes of the animals for economic traits should be appraised regularly to enable breeders determine the breeding tools of their choice (Odubote, 1996). To date, only limited published reports (see Tables 7, 8 and 9) have estimated genetic properties for metric traits in goat population reared under tropical and subtropical environment.

2.8.1 Heritabilities and Repeatabilities.

The most important property of a metric character is its heritability. Heritability gives that proportion of the total variance due to the average effects of genes. Hence it determines the degree of resemblance between relatives. However, the major role of heritability in the genetic study of metric characters is its predictive function, expressing the reliability of the phenotypic value as a guide to breeding value. It is important to note that only the phenotypic values of individuals can be directly measured. But the breeding value determines their influence on the next generation.

The extent to which observed differences in a trait are heritable is indicative of the magnitude of expected response to selection. However, there are variations in the estimates of heritabilities of traits in goat breeds (Adu et al., 1979; Ricordeau, 1981; Odubote, 1992 and 1996).

Heritability of dairy traits in goats is moderate to high and range from 0.10 to 0.79 (Table 2.7). However, there are wide differences even for the same traits within breeds; thus suggesting large sampling variances of estimates. There are also breed differences. Heritability estimates

for reproductive performance are generally low and are of the order of 0.01 - 0.2 (i.e. litter size at birth, kidding interval, kidding rate, multiple birth; Table 2.7). But the West African Dwarf goats' litter size at birth estimates were moderately heritable (0.28 - 0.35).

Table 2.7 Heritability estimates for milk traits in goats.

TRAITS	BREED	h^2	REFERENCE
Milk yield	Indian	0.36 - 0.40	Kala and Prakash, 1990
	Damascus goats	0.29	Constantinou, 1988
	,,	0.45 ±0.08	Mavrogenis & Papachrostefoforou, 1991
	Verata	0.24	Rabasco et al., 1993
	Saanen	0.527	ACTA, 1980
Milk yield (morning yield)	Norwegian	0.40	Ronningen, 1965
Milk yield per operational year	,,	0.55	,,
1st test day milk yield	Damascus	0.45 ±0.05	Mavrogenis & Papachrosteforou, 1991
60 day milk yield	,,	0.53 ± 0.09	,,
90 day milk yield	,,	0.44 ± 0.08	,,
		0.35	Constantinou, 1988
Lactation milk yield	Norwegian	0.32	Stein, 1975
	Saanen	0.68	Ricordeau & Bouillon, 1975
1st lactation milk yield	Beetal	0.54 ± 0.12	Singh et al., 1970
	,,	0.32	Prakesh et al., 1971
	Bulgarian white	0.31	Tsoncher&Doncher. 1981
2nd lactation milk yield	,,	0.26	,,
	Beetal	029	Prakesh et al., 1971
3rd lactation milk yield	,,	032	,,
	Bulgarian white	0.14	Tsoncher&Doncher. ,1981
4th lactation milk yield	,,	0.33	,,
	Beetal	0.28	Prakesh et al., 1971
5th lactation milk yield	,,	0.16	,,
Milk flavour	Norwegian	0.25	Ronningen, 1965
Milk total solid	Indian	0.48	Kala and Prakash, 1990
	Verata	0.10	Rabasco et al., 1993
Milk SNF	Indian	0.22	Kala and Prakash, 1990
Protein yield	Verata	0.04	Rabasco et al., 1993
Fat yield	,,	0.20	,,
	Saanen	0.56	Ricordeau & Bouillon, 1975

Table 2.7 (Contd.)

Lactation butter fat yield	Norwegian	0.33	Stein, 1975
Total fat %	,,	0.29	,,
Butter fat %V (daily yield)	,,	0.10	Ronningen, 1965
Butter fat % per operational year	,,	0.22	,,
1st lactation milk fat %	Bulgarian white	0.20	Tsoncher and Doncher, 1981
2nd lactation milk fat %	,,	0.24	,,
3rd lactation milk fat %	,,	0.43	,,
4th lactation milk fat %	,,	0.31	,,
1st lactation body weight	Bulgarian white	0.48	Tsoncher and Doncher, 1981
2nd lactation body weight	,,	0.23	,,
3rd lactation body weight	,,	0.79	,,
4th lactation body weight	,,	0.48	,,
Age at 1st kidding	Beetal	0.54 ± 0.12	Singh et al., 1970
	Saanen	0.51	Ricordeau and Bouillon, 1975
1st kidding interval	Beetal	0.15 ± 0.09	Singh et al., 1970
Kidding interval (Sire-Dam)	WAD	0.03 ± 0.01	Odubote, 1996
Kidding rate	Beetal	0.12 ± 0.07	Pander and Kanaujia, 1988
Litter size at 1st kidding (Realised)	Red Sokoto	0.08 ± 0.02	Adu et al., 1979
Litter size at birth	Damascus	0.01	Constantinou, 1988
	WAD		
	(Sire group)	0.35 ± 0.05	Odubote, 1996
	(Sire-Dam)	0.32 ± 0.07	,,
		0.28 ± 0.005	Odubote and Akinokun, 1992
Multiple birth	Beetal	0.21 ± 0.15	Pander and Kanaujia, 1988
	,,	0.20 ± 0.14	,,
Birth weight	WAD	0.18 ± 0.003	Odubote and Akinokun, 1992
	,,	0.59 ± 0.45	Adebambo et al., 1994
	Anglo-Nubian	0.17	Santos et al., 1991
	Etawa grade	0.75 ± 0.39	Endang, 1989
	Jamnapari	0.46 ± 0.15	Roy et al., 1989

Table 2.7 (Contd.)

Weaning weight	German Improved Fawn	0.01	Santos et al., 1991
	WAD	0.14 ± 0.003	Odubote and Akinokun, 1992
	Jamnapari	0.47 ± 0.21	Sexena et al., 1990
	Damascus	0.02	Constantinou, 1988
	Etawah grade	0.78 ± 0.04	Endang, 1989
Body weight	Angora	0.13	Gifford et al., 1991
Adult body weight	Damascus	0.09	Constantinou, 1988
28 day weight	Anglo-Nubian	0.11	Santos et al., 1991
	German Improved Fawn	0.22	,,
56 day weight	Anglo-Nubian	0.01	,,
	German Improved Fawn	0.10	,,
112 day weight	,,	0.59	,,
	Anglo-Nubian	-0.01	,,
3 month body weight	WAD	0.29 ± 0.00[illegible]	Odubote and Akinokun, 1992
	Jamnapari	0.43 ± 0.15	Roy et al., 1989
6 month body weight	WAD	0.11 ± 0.003	Odubote and Akinokun, 1992
	Jamnapari	0.25 ± 0.1[illegible]	Roy et al., 1989
9 month body weight	WAD	0.17 ± 0.004	Odubote and Akinokun, 1992
	Jamnapari	0.13 ± 0.10	Roy et al., 1989
12 month body weight	,,	0.13 ± 0.12	,,
Sex ratio	WAD	0.72 ± 0.54	Adebanboetal., 1994
Sex combination	,,	0.69 ± 0.66	,,

Litter size at birth in sheep, cattle, pigs and mice has a low heritability of about 0.1 (Morris, 1991) but a high coefficient of variability. In sheep, too, the heritability estimates for litter size at first lambing are low while the heritability of the mean of several records is generally higher (Turner, 1969). The results of heritability studies carried out in Red Sokoto goats of Nigeria (Adu et al., 1979) suggest that the heritability of the mean of the first 2 kiddings would be lower than the heritability at first kidding if the repeatability has a negative value. Thus, selection for litter size based on the results of the first kidding would be expected to give a higher rate of response than that based on the combined data of 2 kiddings (Adu et al., 1979).

Heritability of birth weight appeared to vary from low to high (Table 2.7). The same trend was observed for other body weight traits. But generally, body weight traits are moderately to highly heritable. The high estimates of heritability of birth weight (0.59%), sex ratio (0.72%), and sex combinaions among twins and triplets (0.69) in WAD goats were attributed to high genetic variance of 0.14, 32.56 and 42.12 of these traits respectively (Adebambo et al., 1994). Singh et al.(1991) reported that heritability of postweaning survival rate in goats were not sisgnificantly different from zero. However, heritability estimates of survival rate in Beetal goats was 0.29 ± 0.14 (Pander and Kanaujia, 1988).

Heritability estimates from uncorrected records tend to be of lower magnitudes than those obtained from corrected data (Hassan, 1987), thus, indicating that environmental factors might bias heritability estimates downwards. Large variations among reported heritability estimates may in part be due to type of analysis used or the conditions under which the traits were measured. This is not necessarily due to differences in the amount of additive genetic variances present in the differnt population (Bowman, 1976). High magnitude of estimates can be attributed mainly to limited data.

Repeatability represents an upper limit of heritability of maternal influences, and not of

the heritability of early performances considered as the characteristics of the young animal (Hassan, 1987). Repeatability could be positive or negative. Negative values occur when the variances between animals are small, as compared with the within-animal variance (Adu et al., 1979). The importance of repeatability in animal breeding relies on its magnitude. For instance, in milk yield, high coefficient of variability of milk yield (32%) and repeatability (0.52) will allow flock milk production to be increased by culling (Boylan and Sakul, 1991). In goats, high estimates of repeatability had been reported for dairy, body weight and litter size traits (Table 2.8). However, some of these traits showed low repeatabilities. There were low estimates of repeatabbility for kidding interval (0.04 - 0.06), 90-day weight (0.078), 150-day weight (0.056) and 12-month body weight (0.01).

Table 2.8 Repeatabilities of milk traits in goats.

TRAITS	BREED	REPEATABILITY	REFERENCE
Milk yield	Norwegian	0.40	Ronningen, 1965
	Alpine	0.33	Iloeje et al., 1980
	LaMancha	0.29	,,
	Nubian	0.35	,,
	Saanen	0.27	,,
Butter fat %	Toggenburg	0.35	,,
Milk flavour	Norwegian	0.35	Ronningen, 1965
Kidding interval	,,	0.28	,,
	WAD	0.04 ± 0.03	Odubote and Akinokun, 1992
	,, (Sire group)	0.06 ± 0.04	Odubote, 1996
	,, (Sire-Dam)	0.04 ± 0.02	,,
Litter size at birth	,,	0.30 ± 0.03	Odubote, 1992
	,, (Sire group)	0.38 ± 0.05	Odubote, 1996
	,, (Sire-Dam)	0.33 ± 0.03	,,
Litter size	Red Sokoto	0.28 ± 0.07	Adu et al., 1979
Litter weight	,,	0.30 ± 0.11	,,
Birth weight	WAD	0.128 ± 0.92	Adebambo et al., 1994
	,,	0.22 ± 0.01	Odubote and Akinokun, 1992
Weaning weight	Etawah grade	0.53 ± 0.53	Endang, 1989
	WAD	0.16 ± 0.01	Odubote and Akinokun, 1992
30 day weight	Etawah grade	0.78 ± 0.04	Endang, 1989
90 day weight	Malian	0.19 ± 0.035	Wilson, 1984
150 day weight	,,	0.07 ± 0.035	,,
3 month body weight	WAD	0.33 ± 0.01	Odubote and Akinokun, 1992
6 month body weight	,,	0.15 ± 0.01	,,
9 month body weight	,,	0.20 ± 0.02	,,
12 month body weight	,,	0.01 ± 0.02	,,
Body weight	German Improeved Fawn	0.97	Schadlick, 1964
Loin length	,,	0.97	,,
Depth of Abdomen	,,	0.91	,,
Breath of Abdomen	,,	0.95	,,

Repeatability of birth weight using dams repeated records in WAD goats was 0.128 ± 0.92 (Adebambo et al., 1994). The estimates for body weight at all ages before one year in the same breed were moderate (Odubote and Akinokun, 1992) thus, an indication that maternal influence of the doe was important source of variation for preweaning body weight. On the other hand, kidding interval in the same breed had low repeatability which might be indicative of low genetic variance (Odubote and Akinokun, 1992). In the Yankasa sheep, high estimates of repeatabbility had been reported for birth and 3 month weights (0.23 ± 0.29 and 0.21 to 0.43, respectively) (Buvanendran et al., 1981). These high values were attributed to their closer links with the ewe. However, using the same breed, lower estimates of repeatability for birth and 3 month weights (0.14 and 0.06, respectively) compared with 6 month weight (0.19) has been observed (Hassan, 1987). On the contrary, lower estimates of repeatability of 6 months of age (0.09) was reported by Buvanendran et al. (1981). It appears that higher or lower magnitudes of repeatability of a particular trait of interest may be due to the method of estimation and the volume of data used.

In general, traits with high heritability and repeatability estimates infer that some genetic variability exists for such traits, hence alteration in them through genetic manipulation is possible (Adebambo, 1986). But traits with low heritability and repeatability estimates tend to be controlled by other factors involving strong genetic control of other complex physiological mechanisms.

2.9 SELECTION AND TRAITS RELATIONSHIPS IN GOAT BREEDING.

Selection is a differential reproduction in which some members of the population are allowed to reproduce more than others. Animals could be selected, for instance on the basis of their early and general reproductive efficiency. Fertility is of low heritability and genetic improvement based on direct selection will be relatively slow. Indirect selection based on the characters of the animal would be adequate. A review by Morris (1991) showed that realised responses to selection within a population for litter size averaged 1.3% per year in sheep, a small non-significant value in pig, and 1.6% per generation in mice. However, intensive screening in some experiments has achieved initial gains averaging 18% in sheep, 13% in cattle and 16% in pigs (Morris, 1991). Selection for ovulation rate in sheep, pigs and mice has generally been ineffective in increasing litter size, whereas selection for a combination of ovulation rate and *enbryo survival has resulted in larger litters* (Morris, 1991). In WAD goats, where moderate estimates of heritability and repeatability have been reported for litter size at birth (Odubote and Akinokun, 1992), pedigree selection or selection based on the family average should be effective in improving the trait. Osinowo and Abubakar (1989) noted that the principal reproductive trait which is known to respond to selection is litter size at birth. It is therefore, possible to select for twin bearing females in order to increase the overall kidding percentage of the flock, but unless adequate nutrition is provided this may result in a higher mortality rate (Reynolds, 1986). Improvement of the genetic base must be accompanied by good nutrition otherwise the additional potential gained at such cost during selection over a number of years, may not be realised.

Selection for body weight will be most effective and economical if carried out early in the animal's life. This is because, estimates of heritability for body weight appears to be moderate in goats, Osmanabadi (Siddiqui et al., 1981); Beetal (Madeli and Patro, 1984);

Jammapari (Roy et al., 1989); and WAD (Odubote and Akinokun. 1992); for all ages. Selection for increased growth from birth to weaning is, in part at least, selection for higher milk production from the dam (Reynolds, 1986). In Damascus goats (in Cyprus), selection methods and genetic gains of their improvement showed that for a 140 day weight of 30kg and a 90 day milk yield of 200kg, an annual genetic gain of 1.3 - 2.8% could be achieved in kid body weight and of 0.4 - 2.7% in milk yield, depending on the index used (Constantinou, 1989). Singh et al. (1992), incorporated birth weight, body weight and body measurements in selection indexes to improve body weight at 3 and 6 months of age. An index that incorporated body weight, body length, height at wither, heart girth at 3 months and body weight at 6 months gave the highest expected genetic gain at 3 and 6 months of age (Singh et al., 1992). However, it is important to note that when selecting, for instance, 3 month body weight, to increase body weight, selection should be effective but the genetic correlations with body weight at latter ages should also be considered.

Most of the reported relationships between production traits of goats were more on the phenotypic rather than genetic relationships (Table 2.9) probably due to the nature and volume of data available for analysis. Never-the-less, formulation of breeding programmes for goat based on body weight, udder and teat circumference, demands for evaluation of possible relationship between milk yield and these traits. In lactating Saanen goats, milk yield was significantly correlated with udder volume, teat diameter and angle of teat (Mikus and Mikus. 1988). In the Bulgarian white dairy goats, significant correlations of 0.13 to 0.46 were obtained between milk production and body weight (Tsonchev and Donchev, 1981). Also, Mishra et al. (1980) reported significant correlation of body weight with milk yield (0.32) in Sirohi goats in India.

Using the Damascus goats, 90 day milk yield was found to be a suitable trait for

selection since its genetic and phenotypic correlations with total milk yield were 1.01 ± 0.04 and 0.84 respectively (CARI, 1989). Relationship between doe weight and litter weight showed that litter weight tend to decline as doe weight increase (Adu et al., 1979). Birth weight is highly related to gain in dam body weight during pregnancy (Chiboka et al., 1988), implying that multiple birth bearing dams will be heavier than single birth bearing ones (Karua, 1991). Body weight relationship in Bengal goats, showed that body length accounted respectively for 65.8 and 18.5% of the variations in live weight and carcass weight in males and 52.2 and 60.8% in females; the corresponding values for heart girth were 79.7, 51.8, 65.6 and 59.3% (Islam et al., 1991)

Birth weight was positively and linearly related with survival rate in goats (Singh et al., 1991). Also, body weight and udder circumference significantly influenced the survival rate of the kids (Osuagwu and Inwang, 1988), with dams having small body weight and udder circumference recording the most dead kids. The most desirable body weight and udder circumference for kid survival in the WAD goats were suggested to be greater than or equal to 24kg and greater than or equal to 6cm respectively (Osuagwu and Inwang, 1988). The same authors also associated kid mortality to extra large teat circumference and reported teat circumference of less than 4cm to be the most desirable.

CONCLUSION

Reports on dairy goat production elsewhere outside India is highly limited. The number of animals and records involved in most studies, however, suggest large sampling variances of estimates. Gaps still exist in our knowledge of their performance, even within breeds. However, lactation performance of goats depends on body condition, nutrient intake, number of offsprings being suckled, lactation number, stage of lactation, parity, season and year of lactation as well

as on breed and genetic potentials of the animals.

In Nigeria, the dairy characteristics of the indigenous goats are yet to be exploited. Limited studies however, exist on milk yield and composition of the indigenous breeds of goats. Such studies indicate that the Red Sokoto goats have greater potentials for dairy than other breeds.

Goat lactation curve is characterised by an initial increasing phase, peak and decreasing phase, but generally flatter and more persistent than that of cattle. In tropical Africa, there is limited work on lactation curves of goats. For dairy goat development in Africa, there is therefore, the need to evaluate the indigenous African goats for dairy characteristics.

Table 2.9 Correlations between traits of goats.

ASSOCIATES	BREED	CORRELATION	REFERENCE
Lactation milk yield and body weigh	Don	0.39* (1st lactation) 0.43* (2nd lactation)	Orlyanskii and Zaporozhtsev, 1994
,,	German Improved Fawn	0.132*	Schadlick, 1964
Lacation milk yield and depth of abdomen	German Improved Fawn	0.07*	,,
Lactation milk yield and left teat length	Czechoslovakian White Polled	0.21*	Horak, 1971
Lactation milk yield and left teat circumference	,,	0.22*	,,
Lactation milk yield and teat ground clearance	,,	0.97*	,,
Lactation milk yield and milking time	Saanen an Chamois coloured	0.37*	Bouillon, 1975
Lactation milk yield and milk flavour	Norwegian	0.77*	Ronningen, 1965
Lactation milk yield and partial milk yield	Damascus	0.87 - 0.01*	Mavrogenis & Papachrostoforou, 1991
Total milk yield and 30 day yield	Beetal	0.37*	Rana et al., 1982
Total milk yield and 60 day yield	,,	0.49*	,,
Total milk yield and 90 day yield	,,	0.54*	,,
	Damascus	0.84*	CARI, 1989,
Milk production and body weight	Bulgarian white	0.13 - 0.046*	Tsoncher and Doncher, 1981
	Sirohi	0.32*	Mishra et al., 1980
Milk yield and fat %	Goats	-0.94*	Iloeje et al., 1981
		-0.86*	,,
Milk yield and fat yield	Verata	0.82*	Rabasco et al, 1993

Table 2.9 (Contd.)

Milk yield and protein yield	,,	0.68'	,,
Daily milk yield and fat %	Murcia grade	-0.09 to -0.03'	Julio, 1991
Daily milk yield and protein %	,,	-0.07 to -0.28'	,,
Fat yield and fat %	Goats	0.18'	Iloeje et al., 1981
Fat yield land protein yield	Verata	0.81'	Rabasco et al., 1993
Fat % and protein %	Murica grade	0.2 - 0.4'	Julio, 1991
Milk flavour and BF %	Nowegian	-0.28'	Ronningen, 1965
		-0.33'	,,
Teat length and diameter	Norwegian	0.75'	Mosdol, 1980

'Genetic correlation
'Phenotypic correlation

CHAPTER 3

MATERIALS AND METHODS

3.1 The Study Area.

The study was carried out in Zaria environment using agropastoral Red Sokoto goats. Zaria is within the northern guinea savannah zone of Nigeria, latitude 11° 12' N and longitude 7° 33' E at an altitude of 610m above sea level.

The climatic condition of the area is relatively dry, with mean annual rainfall of about 736 to 1377mm, occuring between the months of April to September. The dry season begins around the middle of October with dry cold harmattan weather that ends in February. This is followed by relatively hot dry weather from March to some time in April when the rains begin. The mean annual minimum and maximum daily temperature ranges between 14°C to 24° C during the harmattan and from about 19°C to 36°C during the hot season. The relative humidity varies between 17 and 35 in the dry season, and 63 to 80 in the wet season. Zaria has a savannah vegetation dominated by various Acacia species with sparse ground cover of annual grasses, herbs, dwarf shrubs, and perennial grasses on a few plains.

3.2 The Animals and Management.

Although a total of 10 agropastoral Fulani goat herds were studied, only 6 herds were used in the final analysis. Four herds were discarded due to incomplete records resulting from the attitude of the Fulani pastoralists during the course of the study. From the remaining 6 herds a total of 92 does were used with parity varying from 1 - 5. For dairy characteristics that required complete 120 days lactation data, only 66 does met this condition and were therefore, the only does whose information were used for such analysis. On the average, there were 15.3 $\pm$ 4.75 lactating does per herd throughout the period of the study.

The goats were under the agropastoral management. The agropastoral Fulanis practise agriculture with their livestocl: taken out to graze every morning by children (youths) and penned at night. The goats were herded every day from 9.00 h and brought back at 17.00 h. On return from grazing, the animals were penned in small open sided shades called 'rumpas' by tethering. Dams were allowed to nurse their kids in the mornings after milking and in the evenings before the does were put in 'rumpas' overnight. New born kids were left to suckle their dams freely for the first 6 days postpartum to enable the kids take advantage of colostrum.

Before setting out for grazing every morning, the goats were given water mixed with potash (Kanwa) especially in the rainy season, and during grazing, animals were taken to water sources (i.e. ponds, rivers, streams or brooks) around the grazing area at about 13.00 to 14.00 h. The main differences in management between herds were the nature and timing of supplementations to the animals.

3.3 The Measurements.

Red Sokoto goat herds were studied, making use of mainly agropastoral Fulani herds, between June, 1996 and February, 1998. All measurements commenced from day 7 postpartum and were taken for at least one lactation length of 120 days per doe. Milking commenced on day 7 postpartum and terminated at day 120 because the herd owners would neither allow milking of their stock to start earlier than one week nor go beyound 4 months postpartum. The date of kidding, parity and litter size of does were recorded. The sex of the kid born to a doe was also recorded, and from this, the litter composition of the dam per kidding was determined.

On day 7 postpartum, the day of commencement of milking, the udder size (udder height, circumference and distance between the two teats) and teat size (teat length and circumference) were taken. The udder and teat measurements were done using flexible tape as follows in cm: udder circumference (UC) - measured at the widest point of the udder round it. Udder height

(UH) - measured from the rear attachment of the udder to the front of it where it blends with the body. Distance between two Teats (DT) - was measured between the base of two teats. Teat Length (TL) - was measured as the distance from the upper part of the teat, where it hangs perpedicularly from the udder to the tip of the teat. Teat Circumference (TC) - was measured at the widest point round the teat.

During milking, lactating does were kept calm by providing supplements in a calabash for them. Three main supplements were given as follows: bran of maize or guinea corn (dusa), beans pods, and whole cotton seeds. The quantity of milk available per doe per test day was measured using graduated plastic cups of 50, 100 and 1000ml capacities on the field and weighed back in the laboratory to get the kilogram equivalent.

Milk yield was determined at weekly intervals. The first milk yield record was taken on day 7 postpartum and weekly thereafter. Kids were separated from their dams at about 18.00h on the evening preceeding the day of milking. On the test day, the two halves of the udder of each lactating doe were hand-milked for all herds from 06.00 to 09.00 h, and the milk yield was recorded to the nearest gram. The total volume of milk collected on the test day (once-a-day milking) for the individual does was used to estimate the daily yields for that week. First, it was considered that the actual daily production of the does can be obtained if the animals were milked twice a day; and based on the concept of fixed milk yield responses to changing milking frequency (Erdman and Varner, 1995), the constant 0.6596 was estimated and used to correct for the actual daily milk yield as follows:

$$S = M + 0.6596M$$

where, S is the sampling day milk yield and M is the morning milk yield (once-a-day milking) per doe. Milk recording was terminated at 120 days postpartum.

Milk yield characteristics were measured as follows:

Average Daily Yield - as average of all test day yields within the 120 days postpartum.

First Test Day Yield - as milk yield at day 7 postpartum.

Peak Yield - as the yield with the highest test day yield.

Ascending Phase Yield - as the yield between the first test day and peak yield.

Days in Ascending Phase - as the number of days between the first test day and peak day.

Total Yield - as 120 days postpartum milk production.

Last Test Day Yield - as milk yield at day 120 postpartum.

3.4 The Description of Data.

Data consisting of udder traits and lactation records between 1996 and 1998 of Red Sokoto does milked once a week in the mornings while nursing a kid were analysed.

3.4.1 Udder Traits Records.

A total of 92 records were generated for each trait, corresponding to the number of does milked during the study period. Each record was taken on the first test day sampling before the does were milked.

3.4.2 Lactation Records.

There were a total of 1418 morning lactation records. No evening milk records were available for this study because the management of the flocks was such that the evening milk was left for the kids to suckle as recommended by Cartwright et. al. (1983), Tallau et. al. (1986) and Ruvuna et al. (1988).

3.5 Statistical Analysis.

The lactational persistency was derived from the persistency index method computed by the application of ratio developed by Ludwick and Peterson (1943). The lactation period was divided into four equal periods of 30 days each. The total 30 days milk yield of each period for

each lactating doe was calculated. Only does that had lactation records up to 120 days were used. The following ratios were obtained.

$$R_1 = \frac{X_2}{X_1}; \quad R_2 = \frac{X_3}{X_2}; \quad R_3 = \frac{X_4}{X_3}$$

where X_1, X_2, X_3, X_4, refer to the total milk yield in the four consecutive periods. These ratios were added and weighting factors calculated as:

$$W_1 = \frac{R_1}{R_1 + R_2 + R_3}; \quad W_2 = \frac{R_2}{R_1 + R_2 + R_3}; \quad W_3 = \frac{R_3}{R_1 + R_2 + R_3}$$

By using W_1, W_2, W_3, the persistency index of each lactating doe was determined.

Persistency index:

$$\mathbf{PI} = (W_1 . X_2/X_1 + W_2 . X_3/X_2 + W_3 . X_4/X_3) 100$$

The data was thereafter subjected to least squares analysis with unequal subclass observations.

The correlations among traits were estimated as follows:

$$r = \frac{\Sigma XY - \frac{\Sigma X \Sigma Y}{n}}{\sqrt{[\Sigma X^2 - \frac{(\Sigma X)^2}{n}][\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}]}}$$

where,

r = simple correlation coefficient;

n = number of observations;

X, Y = two traits whose nature of association was to be determined at a time.

All correlation coefficients and test of significance were done using SAS (1989).

The effect of herd, season, parity, litter size and litter composition on individual doe milk yield characteristics, udder and teat characteristics, persistency and lactation curve parameters, respectively, were determined using least squares procedures of analysis of variance

(SAS, 1989). All effects were assumed to be fixed with a random error that is normally and independently distributed, mean zero and homogeneous variance. A generalised example of models used in the analyses of variance, which were of a similar nature, was:

Yijlmn = U + Hi + Sj + Pl + Lm + Cn + Eijlmn

where;

U = Overall mean;

Hi = effect of the ith herd (I = 1 .... 6);

Sj = Effect of the jth season of kidding (j = 1 (early dry= Oct. - Dec.), 2 (late dry = Jan. - Mar.), 3 (early wet = April - June), 4 (late wet = July - Sept.);

Pl = Effect of the lth partiy (l = 1, ..., 5);

Lm = Effect of the mth litter size (m = 1, ..., 3)

Cn = Effect of the nth litter composition (n = 1, ..., 5)

Eijlmn = Random error.

Significant means were separated using Duncan Multiple Range Test.

3.5.1 Estimation of Milk Yield.

The average milk yield (MA) for a 17 week lactation for each doe was computed as:

$$MA = {}^{1}/17 \sum_{t={}^{t}1}^{17} Y_t$$

where t is the week of lactation; and Y_t is the milk yield in week t of lactation.

3.5.2 Estimation of Lactation Curves.

Lactation curves of Red Sokoto does were estimated from the data using Gamma function, Inverse polynomial, Parabolic exponential and Exponential models. The individual models were fitted using PROC NLIN of the SAS statistical package (SAS, 1985) to obtain the

curve parameters.

Milk yields during each week of lactation were used to fit lactation curves using the four models as follows:

Gamma type (Wood, 1967); $Y_t = at^b e^{-ct}$

where Y_t is the average yield (kg) in week t of lactation; a is a scaling factor representing initial average yield; b is the rate of increase to peak production; c is the rate of decline after peak production and e is the exponential. The peak week was computed as b/c; and peak yield as $YP = a(b/c)^b e^{-b}$. The peak week, b/c was derived as follows:

$$\frac{dy}{dt} = abt^{b-1} e^{-ct} + at^b (-c) e^{-ct}$$

$$\frac{dy}{dt} = 0$$

Implying, $abt^{b-1} e^{-ct} - at^b c\, e^{-ct} = 0$

$$abt^{b-1} e^{-ct} = act^b e^{-ct}$$

$$bt^{b-1} = ct^b$$

$$b = ct$$

$$t = b/c$$

The peak yield (YP) was derived as follows:

$$YP = at^b e^{-ct}$$

Substituting for t, $YP = a\,(b/c)^b e^{-c(b/c)}$

$$= a\,(b/c)^b e^{-b}$$

Parabolic exponential (Sikka, 1950); $Y_t = ae^{bt+ct2}$

Exponential (Brody et al., 1923); $Y_t = ae^{-ct}$

Inverse polynomial (Nelder, 1966); $Y_t = t[bo + b_1 t + b_2 t^2]^{-1}$

where the parameters bo, b_1 and b_2 describe the rate of rise, the general slope and the rate of decline from the peak, respectively. The above equation after simplification becomes:

$$\frac{1}{Y_t} = bot^{-1} + b_1 + b_2t$$

The predicted peak week was estimated as $(bo/b_2)^{1/2}$ while the peak production was estimated as:

$$[2(bob_2)^{1/2} + b_1]^{-1}$$

The peak week was derived as follows:

$$\frac{dy_t}{dt} = (b_0 + b_1t + b_2t^2)^{-1} + t (- 1) (b_0 + b_1t + b_2t^2)^{-2} (b_1 + 2b_2t)$$

$$\frac{dy_t}{dt} = 0$$

Implying, $(b_0 + b_1t + b_2t^2)^{-1} - t (b_0 + b_1t + b_2t^2)^{-2} (b_1 + 2b_2t) = 0$

$$(b_0 + b_1t + b_2t^2)^{-1} = t (b_0 + b_1t + b_2t^2)^{-2} (b_1 + 2b_2t)$$

$$1 = \frac{t (b_1 + 2b_2t)}{(b_0 + b_1t + b_2t^2)}$$

Implying, $t (b_1 + 2b_2t) = b_0 + b_1t + b_2t^2$

$$b_1t + 2b_2t^2 = b_0 + b_1t + b_2t^2$$

$$b_2t^2 = b_0$$

$$t = (b_0/b_2)^{1/2}$$

The peak production was derived as follows:

$$YP = t (b_0 + b_1t + b_2t_2)^{-1}$$

Substituting for t, $YP = (b_0/b_2)^{1/2} (b_0 + b_1 (b_0/b_2)^{1/2} + b_2 (b_0/b_2))^{-1}$

$= (2 (b_0 b_2)^{1/2} + b_1)^{1/2}$

The average curve was computed by obtaining the production of all the lactations at each week. For each model, correlation coefficients were calculated between fitted and observed curve characteristics. The curve characteristics were compared by looking at the fitting ability of each model. Also, paired t-test was done to compare the fitted with actual observed curve characteristics.

.3.5.2.1 Choice of Models

The models were chosen because of their practical applicability, ease of use with precise measure of fitness. Above all, the models fit into our present field conditions, because researchers can use them with minimum errors and difficulties. The models have biological interpretation required for field application such as in estimating initial, peak and total yields; peak week, rate of rise to and rate of decline from the peak production. The models are not complex in computation and can be used by any scientist with the basic knowledge of regression.

Therefore, the suitability of the models was assessed using the general goodness of fit (R^2)and their predictive abilities.

(a) Coefficient of determination (R^2) as a measure of fitness

This measures the amount of variability accounted for by the fitted model. Adequacy of the model is indicated by high R^2 values, while low values indicate inadequacy. An R^2 value of 70% and above indicate a good measure of fitness (Olorunju, 1991).

(b) Predictive abilities of models

The ability to predict accurately the lactation events in the goats will aid in early selection, production planning and economic decision making. Therefore, the model that is able

to make the most accurate prediction when compared to the actual will be more reliable; and will be an asset to both the farmer and breeder (Oni, 1997). The predictive ability was assessed in terms of the errors (%) in estimation of total, initial and peak yields; peak week and average weekly yields over the lactation period of 17 weeks by the models. The errors (%) in estimation was obtained for each characteristic by subtracting the predicted from the actual. The resulting value was divided by the actual and multiplied by 100. This gives an estimate of the % deviation of the predicted milk production characteristic from the observed. With this estimation it will be possible to tell whether the predicted yield characteristic is lower or higher than the actual observation; and in terms of peak week, whether the predicted time of peak will be early, delayed or same as the observed using the models.

3.5.2.2 Assessment of Dairy Curves Models.

The lactation curve models were compaired in terms of their suitability in describing the lactation curves of Red Sokoto goats under Zaria conditions. The criterion used was the coefficient of determination, R^2. This determines the amount of variability accounted for by the fitted model. High R^2 values indicate adequacy while low values indicate inadequacy of the model. Generally, an R^2 of about 70% or above is considered a good measure of fitness. Apart from R^2, the models were also assessed by their ability to correctly predict some production indicators on the actual data, such as, initial production, peak production and peak week, and total production per lactation. A good model is expected to have high correlation between the observed and the predicted production indicators.

CHAPTER 4

RESULTS

4.1 Milk Yield Capacity.

The least squares means for milk yield characteristics are presented in Table 4.1. The results indicate that total milk yield was 79.827kg; Daily yield 0.664kg; Peak week yield 8.464kg; Peak week 4.0; Initial yield 0.946kg; and Day 120 yield 0.432kg. The number of days, daily yield (kg) and total yield (kg) during the ascending phase was 24.0, 0.916 and 17.758, respectively. Measures of milk yield capacity in Red Sokoto goats exhibited a high variability, varying from 38.6 to 74.5. The most variable characteristics were number of days and total yield ascending phase, and week of peak production (Table 4.1).

Table 4.1 Least squares means for lactation milk yield characteristics in Red Sokoto goats.

Character	Mean	SE	CV(%)
Initial yield (kg)	0.946	0.034	45.7
Peak week yield (kg)	8.464	0.360	54.7
Peak week	4.0	0.360	69.8
Total yield (kg)	79.827	2.390	38.6
Daily yield (kg)	0.664	0.210	38.9
Day 120 yield (kg)	0.432	0.015	44.5
No. Of days Ascend.	24.0	2.31	74.5
Daily yield Asced. (kg)	0.916	0.034	47.6
Total yield Ascend. (kg)	17.758	1.02	74.0

Milk yield characteristics were significantly ($P<0.05 - 0.001$) influenced by herd, season, parity, litter size and litter composition of dam (Tables 4.2 - 4.5). Observations on individual characteristics indicate non-significant ($P>0.05$) effect of all the factors on peak

week (Tables 4.2 & 4.5). Also, herd had no effect (P>0.05) on initial yield and day 120 yield, respectively, and season of kidding on peak week yield (Table 4.2).

Litter size and litter composition of dam significantly (P<0.05) influenced only the Day 120 yield (Table 4.3). But they did not significantly (P>0.05) influence the ascending phase yield characteristics (Table 4.5). On the other hand, parity significantly (P<0.01) affected ascending phase, daily yield but not number of days and total yield.

Table 4.2 Least squares means (± s.e.) for milk yield characteristics by herd and season of kidding.

Factor	N	Initial Yield, g	Peak Week yield (kg)	Peak week	Total Yield (kg)	Daily Yield (kg)	Day120 yield (kg)
Herd			*		*	*	
1	12	0.704 ±0.083	5.3±0.51^{b}	5.0 ± 1.48	58.3 ± 4.97^{b}	0.486 ± 0.042^{b}	0.349 ± 0.031
2	20	1.003 ±0.075	11.2 ± 1.37^{a}	5.0 ± 0.44	94.6 ± 8.42^{a}	0.774 ± 0.072^{a}	0.444 ± 0.050
3	10	0.824 ±0.030	7.1 ± 0.33^{b}	3.8 ± 0.70	80.7 ± 2.19^{ab}	0.672 ± 0.018^{ab}	0.447 ± 0.020
4	10	1.033 ±0.071	7.6 ± 0.68^{ab}	2.0 ± 1.00	76.0 ± 8.93^{ab}	0.634 ± 0.074^{ab}	0.456 ± 0.031
5	18	1.193±0.102	10.1± 0.54^{ab}	3.4 ± 0.71	92.6 ± 3.28^{a}	0.774± 0.027^{a}	0.528 ± 0.027
6	22	0.967±0.070	7.8 ± 0.44^{ab}	3.7 ± 0.64	76.5 ± 3.47^{ab}	0.643± 0.029^{ab}	0.404 ± 0.028
Season		*			*	*	*
Early dry	14	0.838±0.08^{b}	7.5 ± 0.83	4.7 ± 1.21	69.4 ± 5.82^{b}	0.563 ± 0.049^{b}	0.369 ± 0.024^{b}
Late dry	22	1.163±0.083^{a}	11.0 ± 0.35	6.3 ± 0.44	107.5 ± 9.66^{a}	0.839 ± 0.062^{a}	0.664 ± 0.049^{a}
Early wet	35	0.940±0.045^{ab}	8.6 ± 0.46	3.7 ± 0.37	82.0 ± 2.92^{ab}	0.683 ± 0.024^{ab}	0.441±0.015^{b}
Late wet	21	0.966±0.074^{ab}	7.8 ± 0.46	3.4 ± 0.67	75.7 ± 3.64^{ab}	0.636 ± 0.031^{ab}	0.396±0.029^{b}

* $P<0.05$;

a, b, Column means under the same factor with different letters differ significantly.

Table 4.3 Least squares means (± s.e.) for milk yield characteristics by parity, litter size and litter composition.

Factor	N	Initial yield (kg)	Peak week yield kg)	Peak week	Total yield (kg)	Daily yield (kg)	Day 120 yield (kg)
Parity		**	*		**	**	*
1	30	0.724 ± 0.046^{b}	6.6 ± 0.34^{b}	4.9 ± 0.68	63.9 ± 2.65^{b}	0.525 ± 0.022^{b}	0.347 ± 0.016^{b}
2	24	1.132 ± 0.086^{a}	9.6 ± 0.71^{ab}	3.2 ± 0.68	87.3 ± 4.03^{a}	0.729 ± 0.034^{a}	0.418 ± 0.027^{a}
3	15	1.175 ± 0.069^{a}	11.3 ± 1.21^{a}	3.8 ± 0.85	99.4 ± 7.01^{a}	0.832 ± 0.058^{a}	0.562 ± 0.041^{a}
4	13	0.858 ± 0.049^{ab}	7.1 ± 0.59^{ab}	3.8 ± 1.01	75.8 ± 6.34^{ab}	0.633 ± 0.053^{ab}	0.440 ± 0.043^{ab}
5	9	0.857 ± 0.079^{ab}	7.1 ± 0.46^{ab}	3.7 ± 0.84	76.8 ± 6.58^{ab}	0.646 ± 0.056^{ab}	0.455 ± 0.052^{ab}
Litter size					*		*
1	41	0.949 ± 0.052	8.3 ± 0.47	3.9 ± 0.49	74.4 ± 2.77^{b}	0.616 ± 0.023	0.382 ± 0.015^{b}
2	34	0.916 ± 0.042	8.5 ± 0.68	4.0 ± 0.63	83.6 ± 4.76^{b}	0.700 ± 0.040	0.479 ± 0.031^{ab}
3	17	1.071 ± 0.037	9.6 ± 0.20	5.3 ± 0.48	106.9 ± 2.42^{a}	0.890 ± 0.024	0.622 ± 0.014^{a}
Litter composition					*		*
Male(single)	23	0.892 ± 0.088	7.1 ± 0.58	4.5 ± 0.87	70.2 ± 3.15^{b}	0.587 ± 0.026	0.380 ± 0.020^{b}
Female ,,	18	0.815 ± 0.061	7.3 ± 0.73	3.3 ± 0.74	63.1 ± 4.76^{b}	0.541 ± 0.040	0.312 ± 0.019^{b}
All males	13	0.733 ± 0.058	6.5 ± 0.38	2.5 ± 0.62	65.4 ± 6.06^{b}	0.548 ± 0.051	0.354 ± 0.045^{b}
All females	17	0.896 ± 0.039	6.8 ± 0.23	3.8 ± 1.49	81.2 ± 2.95^{ab}	0.679 ± 0.025	0.467 ± 0.017^{ab}
Male & Female	21	0.924 ± 0.227	13.4 ± 4.70	6.3 ± 2.40	106.4 ± 9.97^{a}	0.888 ± 0.249	0.636 ± 0.208^{a}

* $P<0.05$; ** $P<0.01$

a,b columns means with the same factor having different letters differ significantly.

Table 4.4 Least squares means (± s.e.) for ascending phase milk yield characteristics by herd and season.

Factor	N	No. of days	Daily yield (kg)	Total yield (kg)
Herd				*
1	12	32.2 ± 9.69	0.686 ± 0.084	13.6 ± 1.92[a]
2	20	28.6 ± 2.65	0.948 ± 0.077	27.1 ± 2.70[b]
3	10	20.1 ± 4.47	0.808 ± 0.038	15.8 ± 2.29[a]
4	10	12.3 ± 5.25	1.026 ± 0.068	11.5 ± 2.86[a]
5	18	18.4 ± 4.17	1.107 ± 0.117	16.3 ± 1.62[a]
6	22	23.3 ± 4.12	0.962 ± 0.067	17.1 ± 2.10[b]
Season		*		
Early dry	14	29.3 ± 7.54[a]	0.837 ± 0.082	18.6 ± 3.01
Late dry	22	42.0 ± 15.39[b]	1.007 ± 0.059	24.2 ± 2.68
Early wet	35	21.0 ± 2.22[a]	0.891 ± 0.046	16.8 ± 1.11
Late wet	21	21.4 ± 3.87[a]	0.977 ± 0.071	16.1 ± 2.12

* $P<0.05$

a, b, column means under the same factor with different letters differ significantly.

Season significantly ($P<0.05$) influenced number of days in the ascending phase, but it had no effect on ascending phase daily and total yields (Table 4.4) while herd had no effect on the ascending phase daily yield ($P>0.05$).

The herd effect on milk yield characteristics showed that herds 1 and 3 produced lower peak-week yield than the rest with the highest peak-week yield coming from herd 2 (11.2kg), followed closely by herd 5 (10.1kg; Table 4.2). Although with no significant difference ($P > 0.05$) the pattern for initial yield was similar to that of peak week yield. The total and daily yields were lower for herd 1 and higher for herds 2 and 5 which did not differ significantly from herds 3 and 6.

The season effect indicates that does that kidded during the late dry season were superior to early dry season kidders but not to early wet and late wet season kidders, with respect to initial yield, total yield and daily yield. However, day 120 yield clearly showed late dry season kidders to be superior to does kidding in other seasons (Table 4.2). Although season of kidding appeared to have no significant effect on peak-week yield and peak week, late dry season clearly demonstrated higher values for these characteristics than the other seasons.

The effect of parity on milk yield characteristics indicated that parity 3 performed best for all characteristics measured except for peak week (Table 4.3). However, the performance of does in their 3rd parity was not significantly ($P>0.05$) different with those in their 2nd, 4th and 5th parities but with the ones in their 1st, for all milk yield characteristics ($P<0.001$ - 0.05).

Litter size and litter composition only affected day 120 yield significantly ($P<0.05$). Does giving birth to males and females combined, did better than single kidders (male or female) and all males multiple kidders but not for all female multiple kidders. Litter size 3 had the highest milk yield performance at day 120. There was a non-significantly ($P>0.05$), increase

in performance with increase in litter size for peak week yield, peak week, total yield and daily yield.

The ascending phase milk yield characteristics were variably affected by herd and season of kidding (Table 4.4). The herd effect was only expressed in the total yield with herd 2 performing better (27.1kg) than the rest (11.5 - 17.1kg). Season only affected the number of days in the ascending phase with early dry and late dry, having similar performance, but late dry being better (42 days) than early wet (21.0 days) and late wet (21.4 days).

Table 4.5 Least squares means (± s.e.) for ascending phase milk yield characteristics by parity, litter size and litter composition.

Factor	N	No. of days	Daily yield (kg)	Toal yield (kg)
Parity			**	
1	30	28.7 ± 4.48	0.678 ± 0.043^{b}	15.8 ± 1.17
2	24	17.0 ± 3.31	1.133 ± 0.087^{a}	16.9 ± 2.52
3	16	24.2 + 5.96	1.131 ± 0.072^{a}	21.4 ± 2.41
4	13	22.2 ± 5.83	0.814 ± 0.049^{ab}	18.9 ± 3.57
5	9	26.0 ± 5.86	0.855 ± 0.061^{ab}	18.3 ± 3.91
Litter size				
1	41	22.8 ± 3.00	0.931 ± 0.053	15.9 ± 1.19
2	34	25.0 ± 4.31	0.875 ± 0.039	18.9 ± 3.57
3	17	29.8 + 3.35	1.003 ± 0.053	27.7 ± 2.31
Litter composition				
Male (single)	23	28.4 ± 5.59	0.879 ± 0.088	15.8 ± 1.19
Female ,,	18	16.5 ± 3.17	0.823 ± 0.070	13.3 ± 2.87
All males	13	16.3 ± 4.30	0.762 ± 0.053	9.8 ± 1.98
All females	17	22.8 ± 11.21	0.827 ± 0.040	16.1 ± 3.88
Male & Female mixed	21	39.7 ±15.30	0.884 ± 0.022	27.1 ± 6.16

** P<0.01

a,b columns means under the same factor with different letters differ significantly.

Table 4.6 Phenotypic correlations between the lactational milk yield characteristics in goats.

Characteristic	Daily yield	Peak yield	Peak week	Initial yield	Day 120 yield	Total (Ascend.)	Daily (Ascend.)	No. of days (Ascend.)
Total yield	0.99**	0.87**	0.06	0.66**	0.82**	0.62**	0.62**	0.04
Daily yield	-	0.86**	0.05	0.66**	0.82**	0.61**	0.62**	0.04
Peak yield	-	-	-0.08	0.79**	0.58**	0.51**	0.77**	-0.10
Peak week	-	-	-	-0.33*	0.07	0.64**	0.40**	0.95**
Initial yield	-	-	-	-	0.46**	0.29*	0.98**	-0.30*
Day 120 yield	-	-	-	-	-	0.42**	0.38*	0.04
Total (Ascend.)	-	-	-	-	-	-	0.68**	0.23
Daily (Ascend.)	-	-	-	-	-	-	-	0.37*

* P<0.05, ** P< 0.01

Correlation coefficients between milk yield characteristics are shown in Table 4.6. Highly positive and significant (P<0.01) correlations (r = 0.42 - 0.99) were found among various milk yield characteristics. However, negative and significant (P<0.05 - 0.01) correlation (r = 0.40 to -0.30) were observed among peak week and initial yield; initial yield and number of days in the ascending phase; and ascending phase daily yield and number of days in the ascending phase. Other correlations were close to zero or not significant and two of such relationships were negative (peak yield and peak week; peak yield and number of days in the ascending phase).

4.2 Udder Characteristics.

The udder and teat characteristics averaged, UC 38.8, UH 17.1, DT 11.5, TC 7.2 and TL 5.2 cm in agropastoral Red Sokoto goats (Table 4.7). The traits were of low to high variability (13.7 - 42.9%). The lowest variability was recorded for UC; while the highest was for TC.

Table 4.7 Least squares means (± s.e.) for udder characteristics (cm) in Red Sokoto goats.

Character	Mean(cm)	SE	CV (%)
Udder circumference (UC)	38.8	0.91	13.7
Udder height (UH)	17.1	0.45	16.1
Distance betw. The 2 teats (DT)	11.5	0.55	28.6
Teat circumference (TC)	7.2	0.57	42.9
Teat length (TL)	5.2	0.30	34.7

Season of kidding, parity, litter size and litter composition significantly (P<0.05) affected

udder and teat characteristics (Table 4.8). Season of kidding affected all characteristics, while parity, litter size and litter composition did not affect DT and TC, TC and TL, and DT and TL, respectively.

Does kidding in early and late wet seasons had larger UC and longer UH than does kidding in the early dry season, and late dry season for only UH (Table 4.8). On the other hand, early dry season had larger TC and longer TL than the rest of the seasons.

The observed differences in parity of does (Table 4.8) indicated that UC and UH was larger and longer, respectively for 3rd, 4th and 5th parities than for 1st and 2nd parities; while TL was longer for 3rd parity and shorter for 1st parity. Increased litter size also increased the dimensions of UC, UH and DT in Red Sokoto goats. Multiparous does kidding all males had the largest UC while the smallest was for the same category of does but having their kids as mixed males and females. The UH was longer for multiple kidders irrespective of sex composition than for single kidders.

The correlations observed amongst udder and teat characteristics were positive and range from moderate to high but highly significant ($P<0.01$); (Table 4.9). Their correlation with milk yield characteristics, though significant, were low to moderate. Teat circumference, though positive, was not significantly ($P>0.05$) correlated with initial yield, peak yield, daily yield and total yield, respectively.

Table 4.8 Least squares means (± s.e.) for udder characteristics by season,parity, litter size and litter composition.

Factor	N	UC	UH	DT	TC	TI
Season		*	*	*	*	*
Early dry	14	35.5±1.77^{b}	16.1±0.20^{b}	11.5±0.35^{bc}	13.6±1.10^{a}	8.3±0.08^{a}
Late dry	22	38.8±1.93^{ab}	16.5±0.71^{b}	9.6±0.32^{c}	6.1±0.47^{b}	4.7±0.41^{b}
Early wet	35	39.1±1.14^{a}	17.3±0.62^{ab}	12.0±0.76^{b}	7.3±0.65^{b}	5.2±0.38^{b}
Late wet	21	40.0±0.09^{a}	18.0±0.14^{a}	18.2±0.11^{a}	5.1±0.21^{b}	4.0±0.00^{b}
Parity		*	*			*
1	30	37.6±1.48^{b}	16.0±0.59^{b}	10.9+0.62	7.0±0.58	4.6±0.33^{b}
2	24	37.6±1.10^{b}	17.0±1.33^{b}	12.6±1.98	7.0±0.81	5.4±0.57^{ab}
3	15	40.9±2.27^{a}	17.4±074^{ab}	11.8±1.07	8.9±1.40	6.3±0.79^{a}
4	13	41.0±1.97^{a}	19.8±0.65^{a}	11.3±0.82	7.8±1.39	5.8±0.54^{ab}
5	9	40.0±1.08^{a}	19.0±0.55^{a}	11.1±0.35	6.9±0.33	5.6±0.38^{ab}
Litter Size		*	*	*		
1	41	37.9±1.10^{b}	16.0±0.55^{b}	10.7±0.54^{b}	7.4±0.70	5.3±0.39
2	34	39.5±1.76^{ab}	18.0±0.67^{ab}	12.4±1.29^{ab}	6.9±0.80	5.0±0.54
3	17	42.7±2.18^{a}	19.3±0.98	14.7±1.66^{a}	6.7±1.36	5.3±0.72
Litter Composition		*	*		*	
Male (single)	23	36.0±1.38^{bc}	15.6±0.55^{b}	9.9±0.33	6.7±0.86^{b}	5.2±0.41
Female ,,	18	37.5±1.68^{b}	14.7±0.61^{b}	10.7±0.93	9.0±1.63^{a}	5.5±0.77
All males	13	44.0±2.12^{a}	20.0±0.71^{a}	12.0±1.41	5.5±0.35^{b}	5.0±0.71
All females	17	35.0±0.71^{a}	18.0±0.71^{a}	8.5±3.18	11.5±1.77^{a}	7.5±1.77
Males & Female (mixed)	21	34.1±0.64^{a}	19.0±1.41^{a}	10.0±0.00	6.0±0.03^{b}	6.2±0.71

* P<0.05

a,b,c means with different letters under the same column and factor differ significant.

Table 4.9: Correlations between udder and milk yield characteristics.

Character	UC	UH	DT	TC	TL
Initial yield	0.35*	0.39*	0.38*	0.04	0.11
Peak yield	0.25*	0.53**	0.29*	0.17	0.26*
Daily yield	0.21	0.52**	0.34*	0.14	0.29*
Total yield	0.21	0.51**	0.33*	0.14	0.29*
UC	-	0.73**	0.52**	0.50**	0.46**
UH	-	-	0.75**	0.61**	0.70**
DT	-	-	-	0.38*	0.45**
TC	-	-	-	-	0.91**

* P<0.05; ** P<0.01.

4.3 Lactation Persistency

The weighting factors employed in the computation of persistency indices are shown in Table 4.10. The overall mean values for the 120 days lactation period were W_1 (0.3353), W_2 (0.3248) and W_3 (0.3406).

The mean values of the persistency index in each non-genetic component of variation along with their coefficient of variations are presented in (Table 4.11). The mean persistency of lactation in the goats was 84.0 with a variation of 14.5%. Season of kidding significantly (P < 0.05) influenced persistency in Red Sokoto goats. On the other hand, parity, litter size and litter composition of does did not significantly (P>0.05) affect lactation persistency.

Table 4.10: Weighting factors for non-genetic sources of variation in lactation persistency of goats.

Factor	N	W_1	W_2	W_3
Season				
Early dry	11	0.2903 ± 0.0279	0.4065 ± 0.0238	0.3028 ± 0.0212
Late dry	18	0.3494 ± 0.0305	0.3374 ± 0.0270	0.3136 ± 0.0265
Early wet	20	0.3511 ± 0.0140	0.3055 ± 0.0100	0.3448 ± 0.0097
Late wet	17	0.3106 ± 0.0111	0.3294 ± 0.0100	0.3599 ± 0.0123
Parity				
1	22	0.7427 ± 0.0738	0.3273 ± 0.0120	0.3301 ± 0.0163
2	17	0.3514 ± 0.0224	0.3220 ± 0.0196	0.3266 ± 0.0104
3	13	0.3194 ± 0.0217	0.3456 ± 0.0169	0.3382 ± 0.0180
4	7	0.3675 ± 0.0314	0.2677 ± 0.223	0.3648 ± 0.0241
5	7	0.2840 ± 0.0225	0.3339 ± 0.0215	0.3820 ± 0.0128
Litter size				
1	30	0.3341 ± 0.0133	0.3329 ± 0.0110	0.3341 ± 0.0096
2	21	0.3320 ± 0.0157	0.3175 ± 0.0130	0.3508 ± 0.0153
3	15	0.3353 ± 0.0119	0.2930 ± 0.0239	0.3440 ± 0.0196
Litter composition				
Male (single)	14	0.3306 ± 0.0133	0.3573 ± 0.0135	0.3118 ± 0.0132
Female „	16	0.3425 ± 0.0232	0.3178 ± 0.0172	0.3396 ± 0.0160
All males	12	0.3380 ± 0.0240	0.3054 ± 0.0109	0.3568 ± 0.0265
All females	8	0.3687 ± 0.0113	0.2930 ± 0.0281	0.3387 ± 0.0179
Male & female (Mixed)	16	0.3152 ± 0.0354	0.3605 ± 0.0295	0.3243 ± 0.0639
Overall		0.3353 ± 0.0099	0.3248 ± 0.0080	0.3406 ± 0.0078

Table 4.11: Least squares means (± s.e.) for lactation persistency by non-genetic factors in goats.

Factor	N	Index	CV
Season		*	
Early dry	11	86.7 ± 5.79[a]	13.4
Late dry	18	95.8 ± 5.25[a]	18.2
Early wet	20	83.9 ± 1.59[b]	10.0
Late wet	17	75.8 + 1.64[c]	8.9
Parity			
1	22	87.4 ± 3.22	16.5
2	17	80.5 ± 2.76	12.8
3	13	82.0 ± 2.78	12.3
4	7	88.4 ± 5.20	14.4
5	7	81.3 ± 4.39	14.3
Litter Size			
1	30	83.1 ± 1.86	13.3
2	21	85.2 ± 3.26	17.5
3	15	85.4 ± 3.08	7.2
Litter Composition			
Male (single)	14	86.9 ± 3.42	15.3
Female (single)	16	79.3 ± 1.89	8.2
All males	12	76.1 ± 3.61	10.6
All females	8	87.1 ± 1.49	3.0
Male & Female (mixed)	16	90.0 ± 15.45	34.4
Overall		84.0 ± 1.57	14.5

* P<0.05

The effect of season of kidding indicate that does kidding in the dry season were more persistent than the ones kidding in the wet season. However, the late dry season kidders were the most persistent (95.8) and the least was for late wet season (75.8).

Although the effect of parity, litter size and litter composition was not significant on lactation persistency, there were established trends in them. Lactation persistency decreased from 1st to 2nd then increased to 4th and decreased to the 5th. For litter size, persistency increased with litter size. Does that kidded male singles were 7.6% more persistent than their counterparts whose kids were females. Multiple kidders with litter composition of both male and female were 2.9 and 13.9% more persistent than all females and all males, respectively. All female kidders were 11% more persistent than all male kidders.

Does at their 1st parity were 6.9, 5.4 and 6.1% more persistent than does of 2nd, 3rd and 5th parities, respectively and 1% less persistent than does at the 4th parity. Litter size 3 was 2.3 and 0.2% more persistent thant litter size 1 and 2, respectively; while liter size 2 was 2.1% more than litter size 1.

4.4 Lactation Curve:

4.4.1 Suitability of Models in Describing Pattern of Lactation.

The observed milk yield characteristics for Red Sokoto goats is given in Table 4.12. The results from the table indicate that total production was approximately 77 to 82kg with daily yield of 0.653 to 0.679kg; initial production 0.913 to 0.979kg; peak yeild, 1.154 to 1.256 kg; and peak week 3 to 5 weeks. The level of variability in milk yield characteristics ranged from 25 to 70% with the maximum variability observed for week at peak production.

Table 4.13 shows the fitted curve parameters and the predicted yield characteristics. Three of the models, Inverse polynomial, Parabolic exponential and Gamma-type fitted well the lactation data of agropastoral Red Sokoto goats in Zaria (R^2 = 85.5 - 98.1%). However, the most efficient of them is the Gamma-type (R^2 = 98.1%).

Table 4.12 Observed estimates for yield characteristics of 120 days lactation data in Red Sokoto goats.

Character	N	Mean	SE	CV (%)
Initial production (kg/d)	66	0.946	0.033	45.2
Peak yield (kg)	66	1.205	0.051	52.2
Peak week	66	4.0	0.360	70.0
Daily yield (kg)	66	0.666	0.013	25.1
Total yield (kg)	66	79.300	2.360	38.3

Table 4.13 Predicted estimates for curve and yield characteristics by functions (means ± s.e.).

Character	N	Gamma	Parabolic	Inverse Polynomial	Exponential
a	66	0.428±0.034	0.984±0.036	1.9×10^{-5}±0.0016	1.277±0.036
b	66	0.446±0.053	0.008±0.002	0.0001±0.0000	-
c	66	0.018±0.001	-0.000±0.000	0.0000±0.0000	0.007±0.005
R^2	66	98.1±0.07[d]	94.2 ± 0.22[e]	85.5 ± 0.05[f]	69.3 ± 0.53[g]
Peak yield (kg)	66	1.148±0.090	-	1.390±0.024	-
Peak week	66	3.5 ± 0.54	-	3.0 ± 1.96	-
Total yield(kg)	66	83.9±0.31	73.4 ± 0.22	103.6±0.29	81.4 ± 0.16

d,e,f,g, within row, means with different superscripts are significantly different (P<0.0.1).

In each of the milk yield characteristics, Gamma-type model was found to fit them more closely than any of the other models (Initial production 0.946 vs 0.903kg; Peak yield 1.205 vs 1.147kg; Peak week 4.0 vs 3.5 weeks; and Total yield 79.33 vs 83.98kg). However, Gamma-type model closely under-estimated initial production by 4.3% (Table 4.14). This under-estimation was also observed to a larger extent in the Inverse polynomial (9.6%). On the other hand, Exponential and Parabolic exponential over-estimated initial production level by 27.3 and 8.4%, respectively. The Gamma-type model also under-estimated peak yield (5.8%), peak week (12.5%), but over-estimated total yield (4.7%). However, the over- or under-estimation of the yield characteristics by other models was at least twice that of Gamma-type excepting for Exponential model that over-estimated total yield by only 2.2%.

Figure 1 shows the fittings of the models to the actual yield in the Red Sokoto goats. Initial level of production for the observed was under-estimated by Gamma and Inverse polynomial but over-estimated by Exponential and Parabolic exponential models. The actual

peak production was under-estimated by the models excepting Invese polynomial that over-estimated it. A close observation of the data, indicates that there were obvious over-estimation of the actual by Gamma-type model at week 3, 7, and 17; and under-estimation at week 1-2, 4 & 11-12, respectively. The percentage over-estimation in these periods ranged between 2 & 7% while the under-estimation was between 2 & 5% (Table 4.15). The model closely estimated morning milk yield data in Red Sokoto goats at week 5-6, 8-10 and 13-16, respectively. These were the weeks at which deviations from the actual yield were close to or zero.

For Parabolic exponential, it over-estimated actual yield at week 1-2, and 7-13 while under-estimating it at week 3-6 and 14-17, respectively. The over- or under-estimation of the actual yield varied between 2 - 12 %. The Inverse polynomial over-estimated yield at week 2-5 and 16-17, and under-estimated it at week 1 and 7-14, respectively; while closely estimating yield at week 6 and 15, respectively. Its over-estimation was 2-23% and under-estimation, 2-10%. For the Exponential model, it only estimated actual yield closely at week 12, while over-estimating it at a decreasing rate at week 1 and 2; and at increasing rate at week 13-17. The under-estimation were at week 3-11 with percentage under-estimation of 2-15%. The percentage over-estimation for this model was 3-28%.

From Table 4.15 and Figure 1, there was the indication to prefer Gamma-type model to any of the remaining three models (Exponential, Parabolic exponential and Inverse polynomial). This was further enhanced when we consider the rate at which the peak was maintained to the end of lactation period, in conformity with actual yield.

Table 4.14 Observed, fitted and % deviations (d) of models from observed yield characteristics.

Character	N	Actual	Gamma	d	Parabolic	d	Inverse	d	Exponential	d
Initial Production (kg)	66	0.946	0.903	+ 4.3	1.030	-8.4	0.850	+9.6	1.219	-27.3
Peak yield (kg)	66	1.205	1.147	+ 5.8			1.390	-18.5		
Peak week	66	4.0	3.5	+12.5			3.0	+25		
Total yield (kg)	66	79.33	83.98	- 4.7	73.35	+6.0	103.56	-24.2	81.49	-2.2

- Over-prediction of the observed yield by model
+ Under-prediction of the observed yield by model

Table 4.15 Observed, fitted and % deviations (d) of models from daily yield (kg) data of Red Sokoto goats.

Week	Observed	Gamma fitted	d	Parabolic fitted	d	Inverse fitted	d	Exponential fitted	d
1	0.946	0.896	+5	1.029	-8	0.846	+10	1.228	-28
2	1.029	1.095	- 7	1.062	-3	1.261	- 23	1.162	-13
3	1.129	1.162	-3	1.095	+3	1.361	- 23	1.112	+ 2
4	1.212	1.162	+5	1.095	+12	1.311	- 10	1.062	+15
5	1.145	1.145	0	1.095	+5	1.212	- 8	1.012	+13
6	1.095	1.095	0	1.079	+2	1.095	0	0.963	+13
7	1.029	1.046	-2	1.046	-2	1.012	+ 2	0.929	+10
8	0.979	0.979	0	1.012	-3	0.913	+ 7	0.880	+10
9	0.913	0.913	0	0.946	-3	0.846	+ 7	0.846	+ 7
10	0.846	0.846	0	0.896	-5	0.780	+ 7	0.797	+ 5
11	0.797	0.780	+2	0.830	-3	0.714	+ 8	0.763	+ 4
12	0.730	0.714	+2	0.747	-2	0.664	+ 7	0.730	0
13	0.664	0.664	0	0.680	-2	0.631	+ 3	0.697	- 3
14	0.614	0.614	0	0.597	+2	0.581	+ 3	0.664	- 5
15	0.548	0.548	0	0.531	+2	0.548	0	0.631	- 8
16	0.498	0.498	0	0.465	+3	0.514	- 2	0.614	-12
17	0.431	0.465	-3	0.398	+3	0.498	- 7	0.581	-15

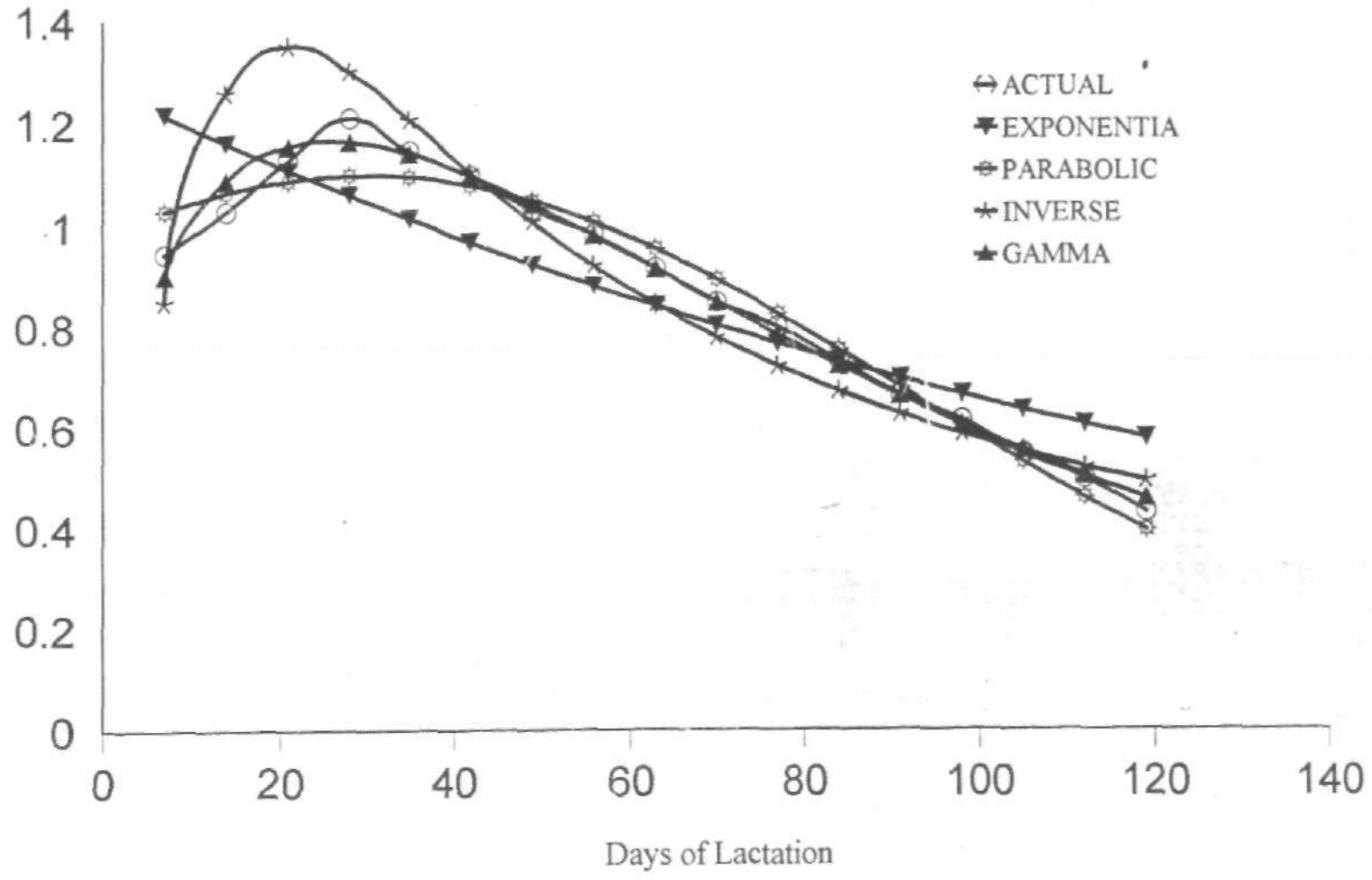


Fig. 1: Fitted Models to milk yield in Red Sokoto Does

4.4.2 Shapes of Lactation Curve for Gamma-type model

Table 4.16 indicates the lactation curve parameter estimates for Red Sokoto does. Wood's equation fitted very well the lactation curves with R^2 values of 97 to 99%. Parameters `a` and `c` were strongly and negatively correlated. Therefore, animals that have higher initial level of production after attaining the peak will decline at a slower rate than those with lower initial level of production.

Table 4.16 Statistics of lactation curve parameter estimates for gamma-type model.

	Parameter			
Statistics	a	b	c	R^2
Average	0.837	0.221	0.018	98.1
± SE	0.066	0.053	0.001	0.07
Correlation				
b	-0.0879	-	0.01043	
c	-0.5263**	0.1043	-	

** P<0.01
a, b, c, lactation curve parameters.

Figures 2 to 6 describe the lactation patterns in Red Sokoto goats. The lactation curves of these goats were characterised by increased milk production during early lactation, attaining a peak at approximately 3-5 weeks postpartum and thereafter, decline slowly to the end of lactation.

The effect of the various factors on the estimates of lactation curve parameters `a`, `b` and `c` are presented in Table 4.17 and 4.18. All factors had no significant (P>0.05) effect on

parameter `b`. However, herd and season of kidding significantly ($P<0.01$-0.05) influenced parameters `a` and `c`; while parity only affected parameter `a` significantly ($P<0.05$). Litter size and litter composition had no influence on the curve parameters ($P>0.05$).

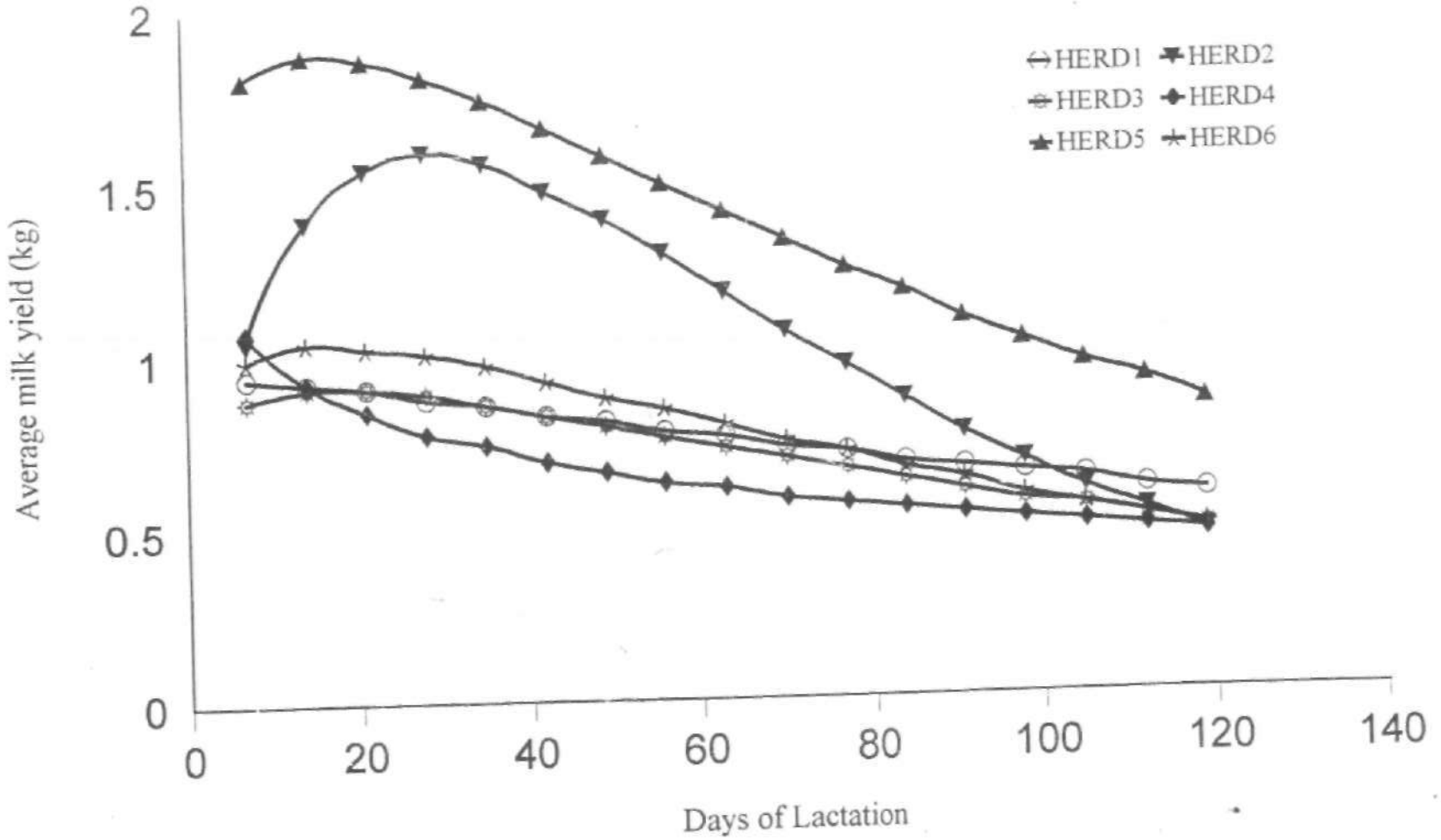


Fig. 2: Effect of Herd on Goat Lactation Curves

Table 4.17 Least squares means for lactation curve parameters by herd and season.

Factor	N	Parameter (± s.e.) a	b	c
Herd		*		**
1	10	0.940 ± 0.188^{ab}	0.024 ± 0.093	0.005 ± 0.002^{b}
2	13	0.335 ± 0.062^{b}	0.668 ± 0.126	0.024 ± 0.003^{a}
3	10	0.713 ± 0.068^{ab}	0.144 ± 0.063	0.009 ± 0.002^{b}
4	8	1.555 ± 0.192^{a}	-0.180 ± 0.160	0.003 ± 0.004^{b}
5	11	1.403 ± 0.313^{a}	0.168 ± 0.127	0.011 ± 0.001^{b}
6	14	0.759 ± 0.060^{ab}	0.178 ± 0.066	0.011 ± 0.002^{b}
Season		*		*
Early dry	11	1.636 ± 0.461^{a}	-0.181 ± 0.152	-0.001 ± 0.002^{b}
Late dry	18	0.815 ± 0.134^{b}	0.239 ± 0.152	0.011 ± 0.004^{a}
Early wet	20	0.802 ± 0.106^{b}	0.277 ± 0.073	0.013 ± 0.002^{a}
Late wet	17	0.770 ± 0.063^{b}	0.181 ± 0.070	0.012 ± 0.002^{a}

* P<0.05; ** P<0.01

a,b,c, Figures with the same superscripts under the same factor and column are significantly the same, otherwise they are different.

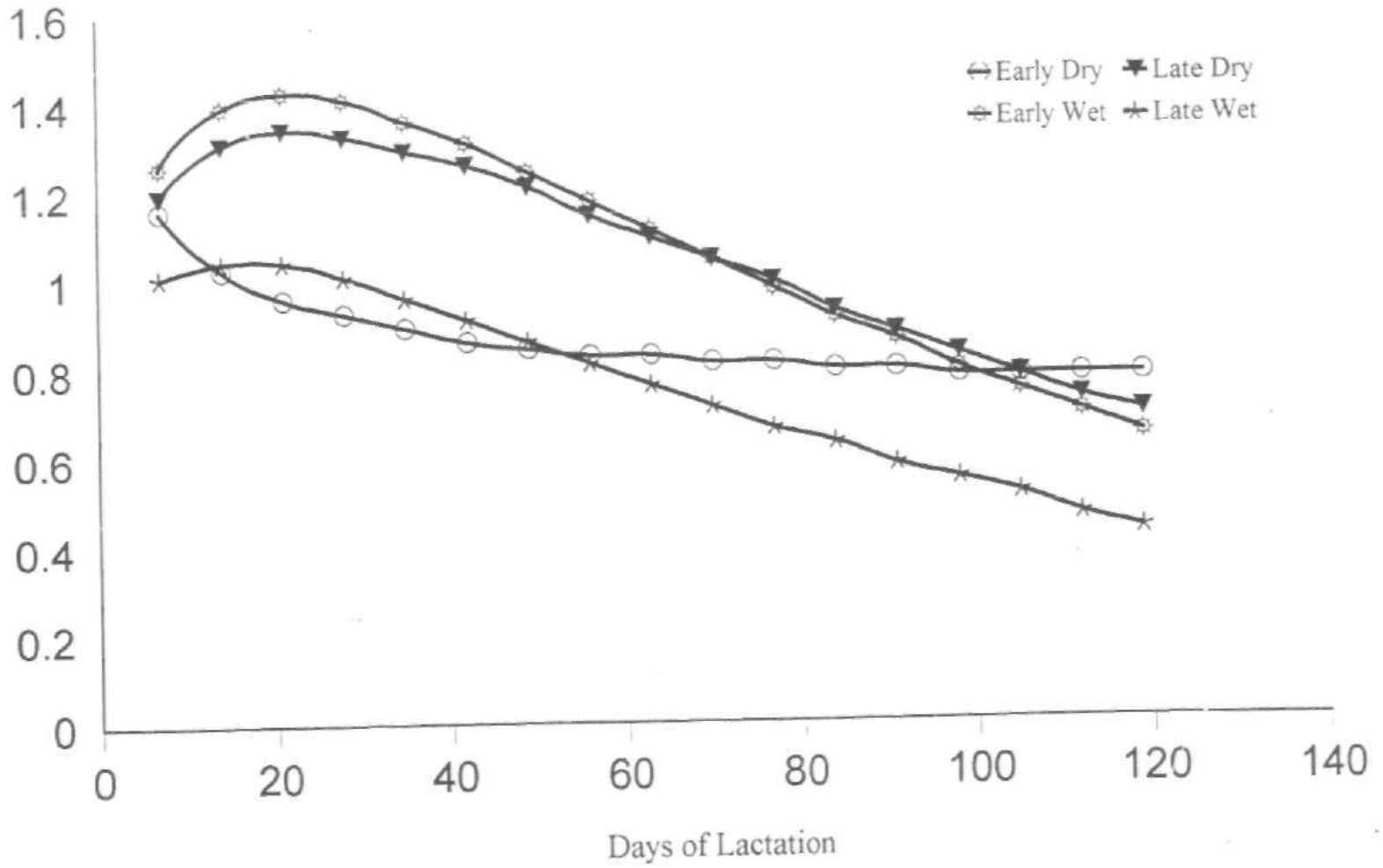


Fig. 3: Effect of Season of Kidding on Goat Lactation Curves

The patterns of lactation in the different herds studied are presented in Fig. 2. Herds 2 and 5 produced higher peaks. Herd 2 also had higher rate of increase to peak although non-significantly. The random criss-crossing patterns of the herd effect are due to the variations in the peak production level and time; and the declining rates. The curves for herds 1 and 4 are peculiar in that they lack the rising phase to peak.

The resultant curves on the effect of season is presented in Fig. 3. The season effect demonstrated that the higher the initial production level the higher the peak yield with slower rate of decline. Late dry season and early wet produced higher peaks. These seasons fall within the hot-dry period and hot wet period of the year respectively. Early dry, the cold dry period (Harmattan) of the year produced curve without the rising phase but highly persistent to the end of lactation.

Parity significantly ($P<0.05$) influenced only the curve parameter `a`, but not `b` and `c` (Table 4.18). This led to the production of curves of similar shapes but different production levels (Fig.4). Increasing litter size produced curves with decreasing production levels, but non-significantly (Fig. 5). However, the production level for litter size 3 was moderately more persistent than that of litter size 2. But litter size 1 produced curve that was consistently of higher persistence than litter size 2 and 3.

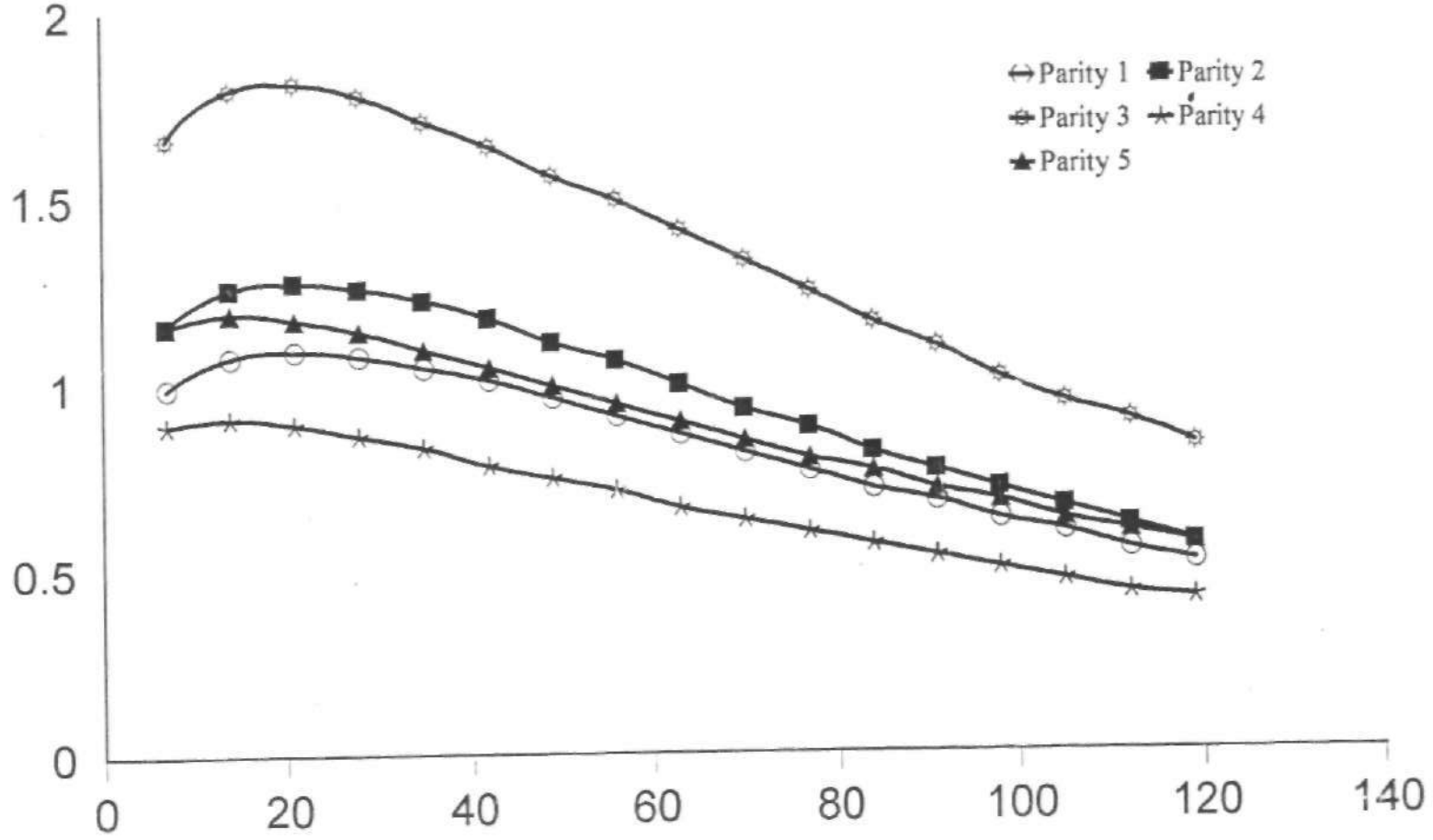


Fig. 4: Effect of Parity (P) of Doe on Goat Lactation Curves

Table 4.18 Least squares means for lactation curve parameters by parity, litter size and litter composition.

		Parameter (± s.e.)		
Factor	N	a	b	c
Parity		*		
1	22	0.672 ± 0.116[e]	0.243 ± 0.065	0.012 ± 0.001
2	17	0.755 ± 0.082[dc]	0.264 ± 0.108	0.013 + 0.003
3	13	1.161 ± 0.193[d]	0.228 ± 0.157	0.012 ± 0.004
4	7	0.753 ± 0.086[dc]	0.123 ± 0.104	0.010 ± 0.002
5	7	0.944 ± 0.157[dc]	0.140 ± 0.151	0.010 ± 0.004
Litter Size				
1	30	0.882 ± 0.101	0.224 ± 0.072	0.012 ± 0.002
2	21	0.813 ± 0.079	0.200 ± 0.088	0.011 ± 0.002
3	15	0.572 ± 0.028	0.303 ± 0.017	0.012 ± 0.001
Litter Composition				
1	14	0.698 ± 0.074	0.101 ± 0.079	0.008 ± 0.002
2	16	0.760 ± 0.154	0.212 ± 0.103	0.014 ± 0.002
3	12	0.512 ± 0.107	0.480 ± 0.205	0.020 ± 0.004
4	8	0.610 ± 0.059	0.168 ± 0.097	0.008 ± 0.003
5	16	0.793 ± 0.130	0.077 ± 0.111	0.009 ± 0.001

* P<0.05

d,e, Figures with the same superscripts under the same factor and column are significantly the same, otherwise they are different.

The lactation pattern for litter composition is presented in Fig. 6. There was an interaction between litter composition and stage of lactation. Although does that kidded single females had higher production levels at the early lactation stage than single male kidders, single male kidders were more stable in production leading to the higher level of production observed for them at the decay phase. In the multiple kidders, does that kidded all females were more persistent than does that kidded mixture of males and females. Litter composition 5, mixture of males and females, produced a curve without the rising phase, following the already established trend in curve parameters.

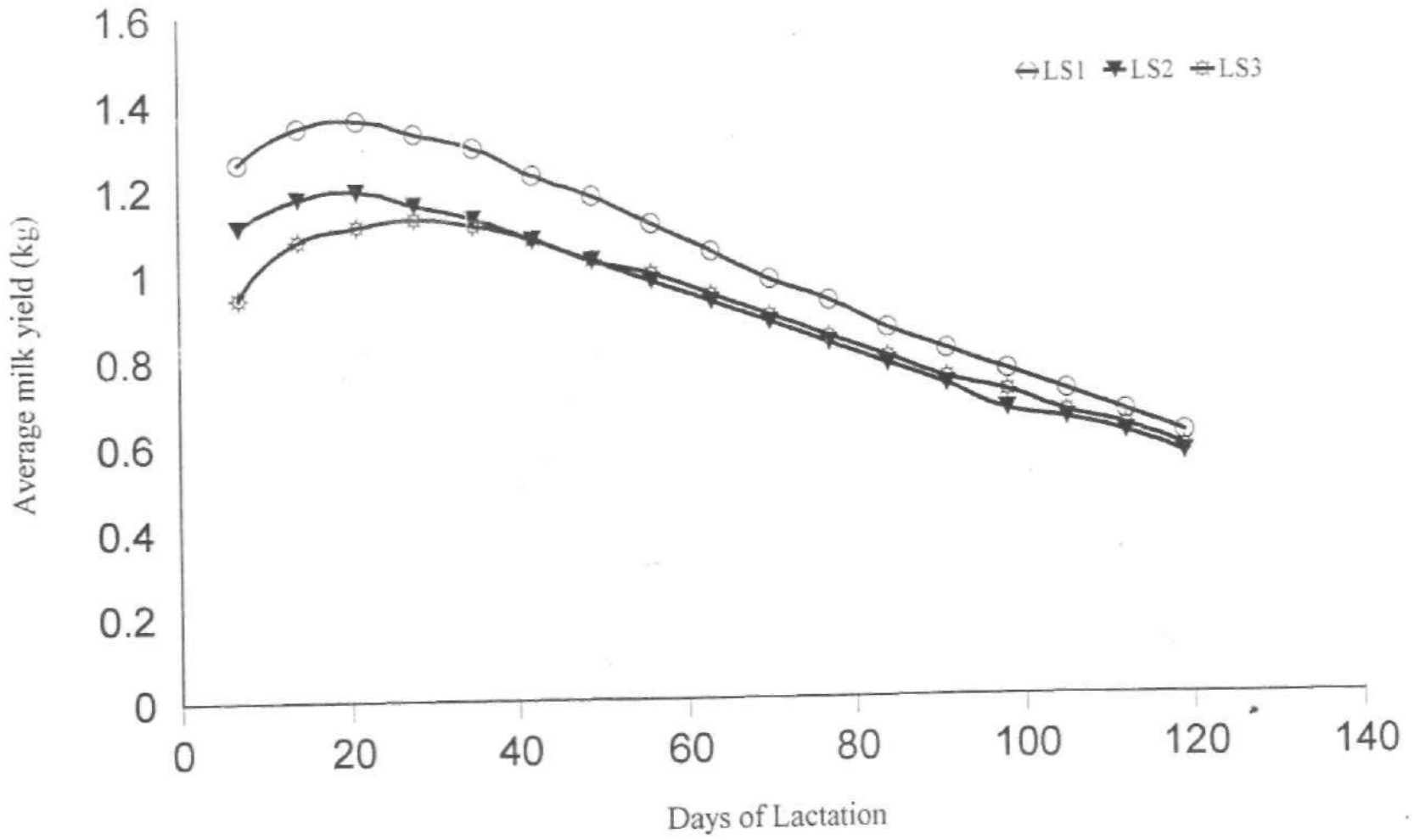


Fig. 5: Effect of Litter Size (LS) on Goat Lactation Curve

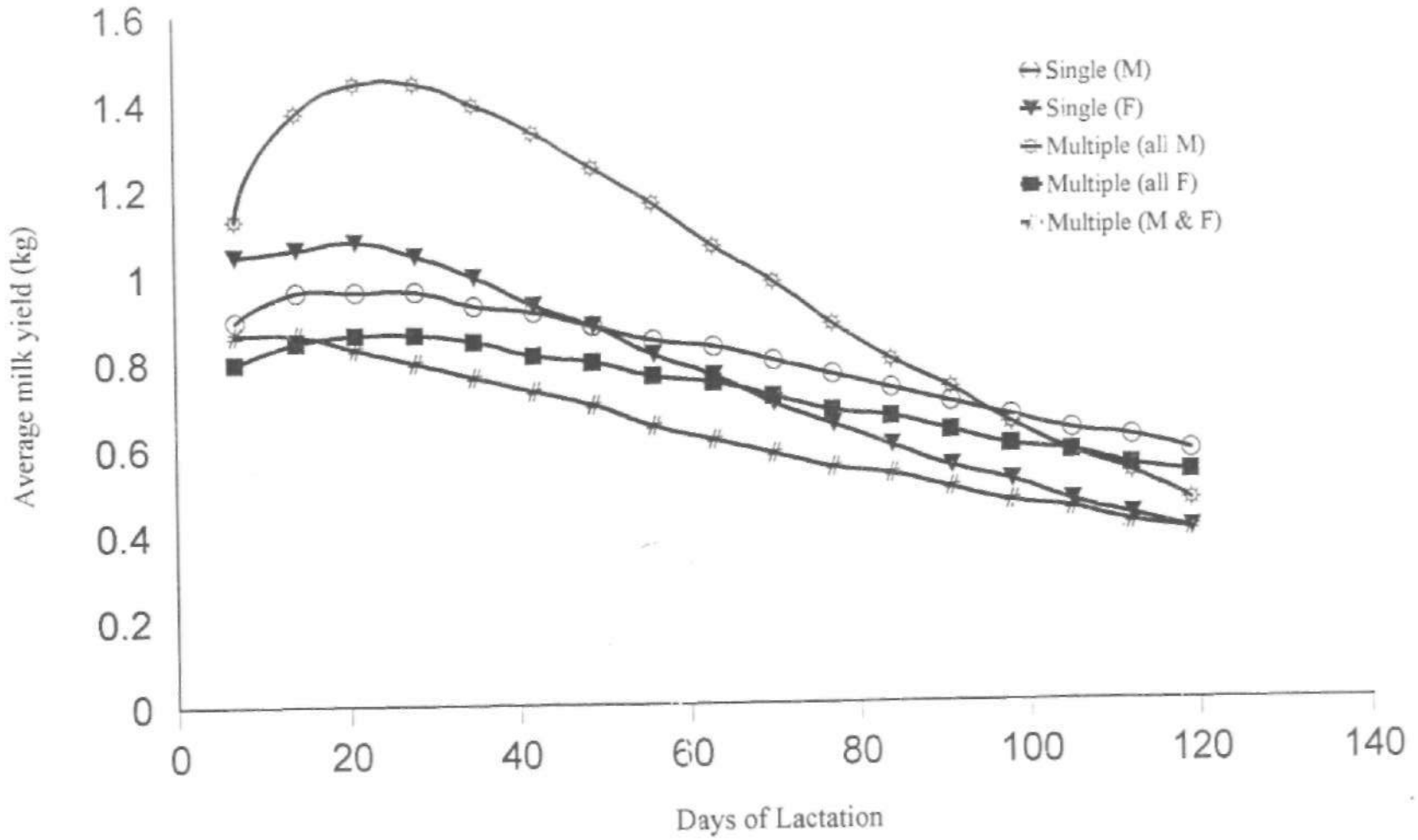


Fig. 6: Effect of Litter Composition at Birth on Goat Lactation Curves

CHAPTER 5

DISCUSSION

5.1 Milk Yield Capacity.

The peak yield in this study is consistent with earlier studies involving tropical goats (Morand-Fehr and Sauvant, 1978; Devendra, 1980; Osinowo and Abubakar, 1989; Egwu et al., 1995). The observed peak week conformed to the range, reported by Ruvuna et al. (1995) for East African goats and their crosses, and in sheep by Iloyd (1963) and Hassan (1995). The results on total yield agrees with existing reports on the same breed of goats (Osinowo and Abubakar, 1989). The present yields are higher than those reported for Ethiopian Adals (Awgichew et al., 1991), East African and Galla goats (Ruvuna et al., 1995), and Nigerian Sahel and West African Dwarf goats (Egwu et al., 1995). It was however, lower than that reported for Blended goats of Tanzania (Das, 1989).

The observed levels of variability in the present study suggest non-homogeneity of these milk yield characteristics which should respond to selection. The high variability of ascending phase total yield and number of days; peak week and peak yield further suggest the possibility of developing a dairy goat breed/strain from the Red Sokoto goats by selecting high yielding animals.

The effect of herd on milking capacity in Red Sokoto goats was variable and was only observed for peak yield, daily yield and total yield. The herd effect on these traits may be attributed to variations mainly in nutrition and management, and to some extent the strain of does. Waheed et al. (1977) in studying the feeding and management effects on herd differences in milk yield, observed that differences among herds accounted for 27 to 37% of the total variations in milk yield. Also, intra-sire regression of daughters' yield on herdmates yield (Mao et al., 1972) have indicated that 83 to 90% of the differences between herds were due to effects

other than sires. However, non-significant effect of herd on milk yield had been reported for Verata goats in Spain (Rabasco et al., 1993).

Season and year of kidding were shown to significantly affect milk yield and lactation length in goats (Barhat and Chowdhargy, 1978; Alderson and Pollak, 1980). In the Red Sokoto goats different seasons of kidding affected milk yield characteristic differently. Similar trend was reported for milk records of goats in USA (Iloeje et al., 1980). A greater lactation performance was observed for late dry season (January to March) in this study. Iloeje et al. (1980) observed that does kidding in January to March produced larger milk yields than their herdmates that kidded in latter months of the year.

In Jamnapari does kidding in summer (February to March) or Winter (November to December), daily milk yield was significantly higher in summer than in winter kidders (Khan et al., 1980). The authors also reported non-significant effect of season on peak yield as was observed in this study. Similarly, Salah et al. (1991) reported non-significant effect of season on milk yield.

The significant effect of parity on milk yield characteristics observed in Red Sokoto goats has also been reported in other breeds (Kala and Prakash, 1990; Salah et al., 1991). The observed lowest yield in 1st parity and highest yield in 2nd and 3rd parities for the milk yield characteristics agreed with previous reports on milk yield in goats (Yadav et al., 1983; Julio, 1991; Zeng and Escobar, 1995). Also, in a total of 7 lactations, Mavrogenis and Papachrostoforou (1991) observed milk yield to be greatest in the 2nd and 3rd lactations.

The observed trend of increased performance in milk yield characteristics with increased litter size supports the fact that goats with multiples produced more milk than goats with singles (Rabasco et al., 1993; Montaldo et al., 1995; Browning et al., 1995). This is probably due to increased levels of placental lactogen in goats with multiple kids (Hayden et al., 1979). The

significant effect of litter size and litter composition on day 120 milk yield tend to suggest that suckling stimulus may be necessary for maintenance of milk production in late lactation stages in these goats. Suckling stimulus has been considered the primary cause of litter size effects on milk yield in goats (Mavrogenis et al., 1984). Suckling induces prolactin secretion and prolactin plays a part in the initiation and maintenance of lactation in goats (Hart, 1973).

The significant herd effect in the ascending phase total yield was purely a cummulative effect reflecting the level of relationship existing between the ascending phase number of days and daily yield. The relationship exisiting between number of days and daily yield in the ascending phase for the present study was significantly negative. However, it appears herd 2 deviated slightly from this norm, leading to the cummulative effect as observed in the ascending phase total yield.

The effect of season on the number of days in the ascending phase was a reflection of feed availability in both quality and quantity. The present study was carried out on agropastoral Fulani goat herds that are purely range animals, and the period between October and March in Zaria is characterized by availability of abundant crop residues which the animals make use of while on range. This enabled the goats to fairly meet their nutritional requirement to express their production potentials. This condition is different from that of the wet seasons when the movement of the goats is restricted due to arable crop farming leading to reduced feed availability to the animals. In the Black Moroccan goats, feed deprivation was reported to decrease milk yield (Hossaini-Hilali et al., 1993). Also, in European breeds of goats, feed deprivation induces a decreased blood glucose level and a drop in milk secretion (Chaiyabutr et al., 1980; Dahlborn and Karlberg, 1986).

The observed differences in the ascending phase daily yield were in conformity with the results obtained for other milk yield characteristics in this study, thus, depicting the 3rd parity

as the stage when the does are at their top milk production. Although the 1st parity had the highest number of days in the ascending phase, it gave the lowest milk yield within the same period. This observation is in line with the established negative relationship between number of days in the ascending phase and initial yield, peak yield, and daily yield in the ascending phase, respectively, in this study. Thereby suggesting that does at their first parity start their initial milk yield at lower level but take longer time to attain the peak. While later parities take shorter time to attain the peak but at higher initial level of production.

Most of the characteristics for milk yield capacity in Red Sokoto goats were positively correlated. Therefore, selection to improve any one of such traits may lead to improvement on the others. The inter-relationships between total yield, daily yield, initial yield and final yield (day 120 yield) which were positive with correlation coefficients ranging from 0.66 to 0.99, indicate that these variables measure the milking capacity of the goats. Positive relationships between milk yield characteristics have been reported by Stein (1975), Mittal (1979) and Montaldo et al. (1995).

5.2 Udder Characteristics.

The dimensions measured in the present study had higher values and were less variable than previous measurements on the same breed of goats (Akpa et al., 1998). This is probably because the present results involve only lactating does while the previous report encompassed lactating and dry does. The main body part of a dairy animal commonly understood to be related to its milk producing capacity is the udder. The variabilities of udder dimensions in the present study indicate strongly that in goats, udder characteristics have adequate variation to allow selection response (Ricardeau, 1981; Mavrogenis et al., 1989). The measured udder and teat characteristics, though characteristic of Red Sokoto goats, were comparable to other dairy goat breeds like Black Bengal of India (Kumar et al., 1983) and crosses of Alpine, Criolla,

Granadina and Nubian of Mexico (Montaldo and Martinez-Lozano, 1993).

The observed influence of season of kidding on udder and teat characteristics was simply a reflection of milk production levels of the does at the various seasons. Reports have shown that lactation season and yield contribute significantly to the variability of traits defining udder size (Labussiere, 1988). Also, in sheep, milk yield has been reported to greatly influence udder size (Fernendez et al., 1995).

That increasing parity, increased udder and teat sizes are supportive of the previous reports on goats (Akpa et al., 1998) and sheep (Fernendez et al., 1995). However, the present results tend to define the limit to such an increasing relationship, since the values for the measured traits were about the same for 3rd, 4th and 5th parities.

The observed influence of litter size and litter composition on udder size traits (UC; UL) is a reflection of milking ability of the various categories of does. Milk yield increased with increased litter size, and udder size characteristics were positively correlated with milk yield characteristics in the present study. It has been argued that the relationship between milk yield and litter size is for the most part, due to the extent of prepartum development of the mammary gland and function which is significantly controlled by placental lactogen (Hayden et al., 1979).

The low correlations observed between the teat size (TC and TL) and milk yield characteristics in Red Sokoto goats supports the conclusion that mammary characteristics (excepting udder size) can be selected for, without modifying milk yield because genetic correlations with milk yield are nil or at best low (Mavrogenis et al., 1988). The correlations of daily and total milk yields with TC and UC were positive but non-significant. These levels of relationship appear logical, since the different measurements and udder volume are functions of milk secreting activity of the mammary gland and the quantity of milk produced and stored in normal udder (Kumar et al., 1983). Other workers have reported significant correlations

between milk yield and udder measurements (Das and Sidhu, 1975; Mavrogenis et al., 1989; Montaldo and Martinez-Lozano, 1993). Therefore, the result of the present study indicates that the prediction of milk yield from external measures of the udder can be based on udder height, distance between the two teats and teat length; and udder circumference, only for initial and peak yields.

The correlations between the traits that determine udder size (UC, UH and DT) were high and positive. This positive correlation amongst udder and teat size characteristics would suggest that as udder height increases, udder circumference and teat length and circumference would correspondingly increase. This trend would make wide udders desirable since cistern height and teat position and angle may increase (Fernandez et al., 1995). In previous studies with sheep (Fernandez et al., 1995), udder size traits were also found to be highly correlated because of their relationship with milk yield.

5.3 Lactation Persistency

The overall mean weighting factors of W_1 (0.3353), W_2 (0.3248) and W_3 (0.3406) for Red Sokoto goats were close to those reported for Sudanese cows, W_1 (0.337), W_2 (0.342), W_3 (0.322) (El Amin and Osman, 1971). There were considerable differences between them and those of white Fulani cows, W_1, (0.38), W_2 (0.347), W_3 (0.272) (Ibeawuchi, 1984). The fair consistency in the estimates of the weighting factors is probably an indication that the lactation length in Red Sokoto goats goes on well beyong 120 days. It is also an indication of slow rate of decline for lactation in these goats; and therefore, a pointer to their great potentials as dairy animals.

The persistency index of 84.0 was high and thus, signifies the possibility for all selected does on this basis to maintain their milk production throughout the lactation period. The present estimate is about the same as that reported for White Fulani cattle (83.8) (Ibeawuchi,

1984). The low variability of lactation persistency (14.5%) in the present study conforms closely to that reported for White Fulani cows, 11.0 (5.7 - 18.8%) (Ibeawuchi, 1984). This is an indication that possible faster progress could be made by selecting does for milk production on the basis of individual performance since heritability of milk yield in goats is moderate to high. 0.24 - 0.53 (ACTA, 1980; Constantinou, 1988; Kala and Prakash, 1990; Mavrogenis and Papachrostoforou, 1991; Rabasco et al., 1993). An animal that produces milk at a moderate but persistent level throughout lactation may be preferred to an animal which gives a higher peak yield but has reduced persistency (Wood, 1967). The results of this study indicate that selection for further improvement in milk yield could subsequently be made on these bases. It seems possible therefore, that Red Sokoto goats could be graded according to their milk producing ability into high, medium and low producers.

The prevailing conditions of food supply in the different seasons of the year were the probable causes of seasonal variations in the observed lactation persistency. It is probable that persistency of milk yield in these goats could be improved considerably through an all year round feeding of high quality feeds and good management. This was exemplified in the late dry season (95.8) persistency because at this time of the year, there exist abundance of crop residues and crop harvest wastes which the goats feed on. Rabasco et al. (1993) observed higher persistency of lactation for goats kidding early in the dry season, which agrees with the present finding.

The superiority in persistency for does kidding in the dry season may be explained by the fact that peak yield and the period of decline in milk yield in the present study occurred during the period of optimum food supply when quality and quantity of grazing and browsing was most favourable. Does kidding in the dry season were apparently not exposed to nutritional stresses during lactation as does kidding in the wet season. The significant effect of season was also

observed in White Fulani cows where dry season (October - March) calvers were more persistent than wet season (April - September) calvers (Ibeawuchi, 1984).

Although parity did not significantly affect lactation persistency in the present study, a trend towards a greater persistency in the first parity compared to subsequent parities, excepting the 4th parity was observed. Similar diminishing trend of persistency with increasing age was observed by Bouloc (1992) and Montaldo et al. (1997) in goats and Schultz et al. (1990) in three breeds of dairy cattle. The present study on the other hand, showed an increasing trend for persistency with increase in litter size, which may be a reflection of the suckling stimulus (Mavrogenis et al., 1984) and / or increased levels of placental lactogen (Hayden et al., 1979) in goats with multiple kids to maintain a higher performance in milk yield.

5.4 *Lactation Curves*

5.4.1 Suitability of Models in Describing Pattern of Lactation.

The suitability of the models in describing efficiently the lactational pattern in the Red Sokoto goats supports the fact that models of lactation curves allow the evaluation of genetic and environmental factors on conponents of milk production such as persistency (Gengler. 1996), maximum production and days to maximum production (Gipson and Grossman, 1990).

In cattle, the efficiency of estimation (R^2 = 93-98%) indicated in the present study have also been found for Gamma-type model fitted to lactation data by Yadav et al. (1977). In goats, almost comparable values have been reported for Malabari and their Saanen half-breds, R^2 = 85-92% (Mukundan et al., 1983). However, in the same study, the Inverse polynomial model accounted for 99.4% of the variability in the lactation curve data (Mukundan et al., 1983).

That the coefficients of determination for the Wood model ranged from 98.03 - 98.17, is an indication that error variances were a small proportion of total variances. These figures are greater than previous estimates on African goats (Wahome et al., 1994; Ruvuna et al., 1995)

using the same model but similar to those estimates by Montaldo et al. (1997) for goats in Mexico.

The outstanding efficiency of the Wood model in the present study further emphasizes why the model has been used in most lactation curve studies. The model has the basic features of lactation curves with only three parameters that allows the calculation of some key measurements such as average production, maximum production and days to maximum production (Wood, 1967). In studies performed on goats (Gipson and Grossman, 1989; Williams, 1993) differences between squared error of the Wood model and other models containing more parameters, were relatively small. This suggests that the use of the Wood model may be sufficient to study factors affecting lactation curves in goats (Montaldo et al., 1997). Wood's model has been demonstrated to provide a good fit to goat lactation data (Ruvuna et al, 1995) and was used to understand the main factors that influence production levels, and general forms of the lactation curves (Carles, 1986; Wahome, 1987; Wahome et al., 1994). In cattle, the model has been demonstrated to adequately represent lactation yields of dairy cattle (Wood, 1976; Madalena et al., 1979; Wood, 1980). Abubakar and Buvanendran (1980) and Rao and Sundareson (1979) fitted the model to tropical or crosses of tropical cattle: while Olorunju (1991) in describing the production curve of Bunaji cows in Nigeria, concluded that the Gamma-type model was better than the Inverse polynomial model.

5.4.2 Shapes of Lactation Curve for Gamma-type model

The strong negative correlation between parameters ` a` and `c` probably suggests that Red Sokoto goats selected for high initial milk yield may be highly persistent in milk production. This is because lactation persistency is negatively correlated with rate of decline.

Similar trend observed in the lactation curve characteristics of Red Sokoto had been reported by other workers on goats (Mukundan et al., 1983), and sheep (Sakul and Boylan, 1992; Hassan, 1995). The described pattern also agree with the report that lactation curves of goats are flatter and more persistent than that of cattle (Devendra, 1980; Ruvuna et al., 1995).

Two reasons, management and within herd improvement may be advanced for the effect of herd on the shape of lactation curves in Red Sokoto goats. Although the agropastoral Fulani herd is generally characterised by herding on daily basis, there are between herd differences in the nature and timing of supplementations to the animals. Also, the Fulani agropastoralists practise some level of selection based on individual farmers' acquired knowledge through personal experience or descendant; thus leading to differences in productivity between the herds.

The superiority in the lactation pattern of does kidding in the late dry and early wet seasons may be explained by the availability of feed both in quality and quantity. During the late dry season, there are varieties of crop residues available; while in the early wet, there is an abundance of qualitative grazable materials for the animals. Therefore, does kidding in these seasons do not experience nutritional stress during lactation unlike does in the other 2 seasons, especially the late wet season. During the late wet season, there is restricted-grazing due to arable land cropping, thereby reducing the quantity and quality of available pasture for grazing. Effect of season of kidding on lactation curve parameters and shape in goats have been reported (Gipson and Grassman, 1989; Ruvuna et al., 1995) and the results suggest the significance of strategic seasonal breeding to maximize milk yield per doe (Ruvuna et al., 1995).

The highly persistent pattern of the early dry season lactation curve may be explained on the basis of the fact that the declining phase of milk production coincided with the period of low or minimal nutritional stress due to the onset of availability of varieties of crop residues resulting from crop harvest.

There was a criss-crossing pattern in the season effect. Wahome et al. (1994) obtained criss-crossing pattern of lactation curves when the parameters describing the ascending or descending phases were significantly influenced by any given factor of consideration due to different curve shapes. They also observed that factors affecting only the parameter describing the level of production resulted in curves having similar shapes but on different levels.

Similar results on parity effect had been reported for lactation curves of East African goats by Wahome et al. (1994). Parity 3 had the highest level of production, followed by parities 2 and 5. The lowest production level was for does of parity 4. Parities 1, 2 and 3 had their production peaks at week 3 while parities 4 and 5 had theirs at week 2. All these point to the fact that it may not be necessary to cull does purely on the basis of performance before parity 5. However, preliminary culling for herd replacement can make use of lactation performance at parity 3 in Red Sokoto goats.

Although non-significantly, higher litter size gave rise to lower level of milk production which differed from most other reports on lactating goats (Ehoche and Buvanendran, 1983; Mavrogenis et al., 1984; Mourad, 1993; Rabasco et al., 1993; Browning et al., 1995; Montaldo et al., 1995). However, the reports of Madrid-Bury et al. (1982) and Wahome et al. (1994) support the present observed trend. It is worth of note that the present report is from a true range condition where the stress of pregnancy and lactation would be expected to be much greater for a doe carrying twins or triplets. Therefore, the twin or triplet bearing does would be expected to be at a disadvantage due to relatively poorer body condition and body reserves to mobilise for

milk following kidding when compared to the single litter does (Wahome et al., 1994).

The relationship existing between twin and triplet bearing does with stage of lactation leading to triplet bearing does showing higher level of production at later lactation stages could be due to suckling effect. It has been reported that litter size affects milk yield in suckled does (Browning et al., 1995), and only before weaning (Hernandez et al., 1989; Mourad, 1993; Rabasco et al., 1993). It appears that the stress created by twins and triplets on lactating does is about the same, thereby, further justifying the present trend observed for twin and triplet kidders under agropastoral Fulani herds, which results in higher production level for triplet kidders at later stages of lactation

The curves developed from the gamma-type model as influenced by the various factors encountered in the present study suggest that the nature of the curves could provide a basis for planning and adjustment in the management of herds, particularly with regards to culling and assessment of the nutritional and health status of animals. These findings may also provide a basis for developing unbiased methods of comparison among animals with incomplete lactation records for genetic evaluation purposes (Guo and Swalve, 1995).

CONCLUSIONS.

Milk yield capacity of Red Sokoto goats in the present study exhibited high variability, the most variable characteristics being number of days and total yield in the ascending phase and week of production. Factors influencing milk yield characteristics were herd, season, parity, litter size and litter composition of the dam being milked. These factors were highly and positively inter-related.

Variability in udder characteristics and correlations of udder and teat characteristics with milk yield characteristics were low to high. The season of kidding affected all udder characteristics.

Persistency in milk was greatly influenced by season of kidding but not by parity, litter size or litter composition of the dam being milked. Dry season kidders were more persistent in milk than wet season kidders. Lactation persistency/ persistency in milk increased with litter size.

Although the pattern of lactation was adequately described by all models, excepting the exponential model used in this study, the best fit was provided by the gamma-type model which also accounted for the least over- and under-estimation of milk yield characteristics, on the average, of all the models studied in connection with milk yield. It however slightly underestimated initial production (by 4.3%).

Shapes of the lactation curve provided by the gamma-type model suggest strongly that animals with a higher initial level of production, are likely to decline at a slower rate after attaining the peak than those with lower initial level of production.

SUGGESTIONS FOR FURTHER STUDIES

From the results of this work the following suggestion are hereby made:

1. Studies to investigate the optimum nutritional requirement for optimum dairy performance of Red sokoto goats should be instituted. The identified optimum regime should be adopted in further investigations involving genetic improvements.
2. There is need to institute further studies aimed at genetic improvement of dairy performance of Red Sokoto goats.

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APPENDIX

Appendix 1 : Actual and estimates of 120 days milk yield (kg) by models

Days	Actual	Exponential	Parabolic	Inverse	Gamma
7	0.946	1.219	1.030	0.850	0.903
14	1.029	1.164	1.066	1.262	1.090
21	1.129	1.110	1.088	1.355	1.157
28	1.212	1.060	1.098	1.304	1.165
35	1.145	1.012	1.094	1.107	1.140
42	1.095	0.965	1.076	1.102	1.095
49	1.029	0.921	1.046	1.005	1.039
56	0.979	0.879	1.004	0.918	0.977
63	0.913	0.839	0.951	0.843	0.912
70	0.846	0.801	0.891	0.777	0.847
77	0.797	0.765	0.823	0.720	0.782
84	0.730	0.730	0.752	0.670	0.721
91	0.664	0.696	0.678	0.626	0.661
98	0.614	0.665	0.604	0.587	0.606
105	0.548	0.634	0.531	0.552	0.555
112	0.498	0.606	0.461	0.521	0.504
119	0.431	0.578	0.396	0.494	0.459

Appendix 2 : Gamma function estimates of 120 days milk yield (kg) by herd

Days	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5	Herd 6
7	0.946	1.046	0.880	1.079	1.809	0.996
14	0.929	1.394	0.913	0.929	1.875	1.046
21	0.913	1.543	0.913	0.846	1.859	1.029
28	0.880	1.593	0.896	0.780	1.809	1.012
35	0.863	1.560	0.863	0.747	1.743	0.979
42	0.830	1.477	0.830	0.697	1.660	0.929
49	0.813	1.394	0.797	0.664	1.577	0.880
56	0.780	1.294	0.763	0.631	1.494	0.846
63	0.763	1.178	0.730	0.614	1.411	0.797
70	0.730	1.062	0.697	0.581	1.328	0.747
77	0.714	0.963	0.664	0.564	1.245	0.714
84	0.680	0.863	0.631	0.548	1.178	0.664
91	0.664	0.763	0.597	0.531	1.095	0.631
98	0.647	0.680	0.564	0.514	1.029	0.581
105	0.631	0.597	0.548	0.498	0.963	0.548
112	0.597	0.531	0.514	0.481	0.913	0.514
119	0.581	0.465	0.481	0.465	0.846	0.481

Appendix 3 : Gamma function estimates of 120 days milk yield (kg) by season

Days	Early dry	Late dry	Early wet	Late wet
7	1.162	1.195	1.261	1.012
14	1.029	1.311	1.394	1.046
21	0.963	1.344	1.427	1.046
28	0.929	1.328	1.411	1.012
35	0.896	1.294	1.361	0.963
42	0.863	1.261	1.311	0.913
49	0.846	1.212	1.245	0.863
56	0.830	1.145	1.178	0.813
63	0.830	1.095	1.112	0.763
70	0.813	1.046	1.046	0.714
77	0.813	0.996	0.979	0.664
84	0.797	0.929	0.913	0.631
91	0.797	0.880	0.863	0.581
98	0.780	0.830	0.797	0.548
105	0.780	0.780	0.747	0.514
112	0.780	0.730	0.697	0.465
119	0.780	0.697	0.647	0.431

Appendix 4 : Gamma function estimates of 120 days milk yield (kg) by parity

Days	Parity 1	Parity 2	Parity 3	Parity 4	Parity 5
7	0.996	1.162	1.660	0.896	1.162
14	1.079	1.261	1.792	0.913	1.195
21	1.095	1.278	1.809	0.896	1.178
28	1.079	1.261	1.776	0.863	1.145
35	1.046	1.228	1.709	0.830	1.095
42	1.012	1.178	1.643	0.780	1.046
49	0.963	1.112	1.560	0.747	0.996
56	0.913	1.062	1.494	0.714	0.946
63	0.863	0.996	1.411	0.664	0.896
70	0.813	0.929	1.328	0.631	0.846
77	0.763	0.880	1.245	0.597	0.797
84	0.714	0.813	1.162	0.564	0.763
91	0.680	0.763	1.095	0.531	0.714
98	0.631	0.714	1.012	0.498	0.680
105	0.597	0.664	0.946	0.465	0.631
112	0.548	0.614	0.896	0.431	0.597
119	0.514	0.564	0.830	0.415	0.564

Appendix 5 : Gamma function estimates of 120 days milk yield (kg) by litter size

Days	Litter size 1	Litter size 2	Litter size 3
7	1.261	1.112	0.946
14	1.344	1.178	1.079
21	1.361	1.195	1.112
28	1.328	1.162	1.129
35	1.294	1.129	1.112
42	1.228	1.079	1.079
49	1.178	1.029	1.029
56	1.112	0.979	0.996
63	1.046	0.929	0.946
70	0.979	0.880	0.896
77	0.929	0.830	0.846
84	0.863	0.780	0.797
91	0.813	0.730	0.747
98	0.763	0.670	0.714
105	0.714	0.647	0.664
112	0.664	0.614	0.631
119	0.614	0.564	0.581

Appendix 6 : Gamma function estimates of 120 days milk yield (kg) by litter composition

Days	Single (male)	Single (female)	Multiple (males)	Multiple (female)	Multiple (male and female)
7	0.896	1.046	1.129	0.797	0.863
14	0.963	1.062	1.377	0.846	0.863
21	0.963	1.079	1.444	0.863	0.830
28	0.963	1.046	1.444	0.863	0.797
35	0.929	0.996	1.394	0.846	0.763
42	0.913	0.929	1.328	0.813	0.730
49	0.880	0.880	1.245	0.797	0.697
56	0.846	0.813	1.162	0.763	0.647
63	0.830	0.763	1.062	0.747	0.614
70	0.797	0.697	0.979	0.714	0.581
77	0.763	0.647	0.880	0.680	0.548
84	0.730	0.597	0.797	0.664	0.531
91	0.697	0.548	0.730	0.631	0.498
98	0.664	0.514	0.647	0.597	0.465
105	0.631	0.465	0.581	0.581	0.448
112	0.614	0.431	0.531	0.548	0.415
119	0.581	0.398	0.465	0.531	0.398