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The influence of non-genetic factors on the shape of lactation curves in Red Sokoto goats

G. N. Akpa, E. O. Asiribo†, O. O. Oni‡ and J. P. Alawa

Animal Science Department, Ahmadu Bello University, Zaria, Nigeria

Present addresses:
† Institute for Agricultural Research, ABU, Samaru, Zaria, Nigeria.
‡ National Animal Production Research Institute, Abu, Shika, Zaria, Nigeria.

Abstract

Milk yields of 66 nursing does recorded in Zaria, Nigeria were used to characterize the lactation curve and study the influencing factors in Red Sokoto goats. Lactation curve parameters obtained by fitting the model: $Yt = at^{b}e^{-ct}$ *were subjected to statistical analysis, using herd, season, parity, litter size and litter composition of dams.*
The results indicate that the lactation curve of these goats was characterized by milk production increasing in early lactation, attaining a peak at approximately 2 to 5 weeks post partum *and thereafter declining slowly to the end of lactation. The observed total yield, peak yield, peak day and the estimated persistency defined as* $c^{-(b+1)}$ *was 79·3 kg, 1·2 kg, 20·5 and 143·2, respectively. Parameters 'a' and 'c' were strongly but negatively correlated (r = –0·53; P < 0·01). The curve parameters 'a' and 'c' differed by herd and season (P < 0·05); and parity only affected (P < 0·01) parameter 'a'. None of the factors significantly influenced parameter 'b' (P > 0·05).*
The significant herd and season effects may have practical implications in determining optimal feeding management and season of breeding to maximize total lactation yield.

Keywords: *goats, lactation curve, Red Sokoto.*

Introduction

The Red Sokoto goat is the predominant breed of goat in Nigeria. It is commonly found among the agropastoralists mainly within the northern subhumid and semi-arid zones of the country.

Available reports on the milking of indigenous African goats indicate that not much is known about their dairy characteristics. From such reports, lactation milk yield ranges between 24 and 120·3 kg and the peak week from 2 to 6 weeks; with the highest peak yield (850 g) observed in the Red Sokoto goats of Nigeria (Osinowo and Abubakar, 1989; Awgichew *et al.*, 1991; Egwu *et al.*, 1995; Ruvuna *et al.*, 1995; Akpa, 1999).

If the ever widening shortfalls in dairy product supplies are to be met through indigenous production, there is an urgent need to exploit the potential of alternative dairy animals such as goats in order to supplement milk from cows (Fasanya, 1986). Also, 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.

In goats, 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. The level of peak yield and persistency, determine to a large extent, the shape of lactation curve (Gupta and Johar, 1982; Rao and Sundareson, 1982). However, there are limited studies on factors affecting lactation curves in goats (Wahome *et al.*, 1994; Ruvuna *et al.*, 1995). Within the limits of existing studies, factors influencing lactation curves in goats include breed, season, year, parity, litter size, weight and age of doe (Madalena *et al.*, 1979; Wahome *et al.*, 1994; Ruvuna *et* *al.*, 1995). The study of the effect of these factors, for instance, season of kiddling, on lactation curve parameters and shape in goats suggest the significance of strategic seasonal breeding to maximize milk yield per doe (Gipson and Grossman, 1989; Ruvuna *et al.,* l995) The present report is therefore, on lactation curve parameters and the effect of herd, season, parity, litter size and litter composition on these parameters in Red Sokoto goats of Nigeria.

Material and methods

The data comprised 120 days of lactation records of 66 Red Sokoto does collected over 2 years (1996 to 1998) from six agropastoral goat herds. Parity of does varied from one to five. The agropastoral Fulani practise agriculture with their livestock taken out to graze every morning and penned at night The goats were herded every day from 09:00 h and returned at 17:00 h when 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 suck their dams freely for the first 6 days. Milking commenced on day 7 *post partum* and terminated at day 120 because the herd owners would not allow milking of their stock to start earlier than 1 week or go beyond 4 months *post partum*.

The date of kidding, parity and litter size of does were recorded. The sex of kids born to a doe was also recorded and from this, the litter composition of the dam per kidding was determined. The quantity of milk available per doe per test day was measured using graduated plastic cups of 50, 100 and 1000 ml capacities in the field and weighed back in the laboratory to get the kilogram equivalent.

Milk yield was determined at weekly intervals. Kids were separated from their dams at about 18:00 h 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 amount of milk collected on the test day was taken as the morning daily yield (once-a-day milking) of the doe. The daily milk yield was then estimated for each doe on the assumption that actual daily production of the does can be met if the animals were milked twice a day. Therefore, based on the concept of fixed milk yield responses to changing milking frequency (Erdman and Varner, 1995) the constant 0·6596 was derived as a weighting factor on the morning milk yield. The sampling day milk yield(S) was estimated as:

$$S = M + 0{\cdot}6596\, M$$

where, M is the morning milk yield (once-a-day milking).

The total milk yield per doe was measured as the total yield for the 17 test-day samplings in 120 days multiplied by 7 (to reflect the weekly sampling interval). The level of peak yield and day were determined as the yield and day with the highest test-day yield during the 120 days sampling period. Persistency factor was calculated as given by Wood (1967): $c^{-(b+1)}$.

There were a total of 1418 test-day milk yield records obtained from the 66 lactating does. From the data, the lactation curve of the Red Sokoto does was estimated using a gamma-type function (Wood, 1967).

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

where, Y_t is the test-day yield (kg) on day t of lactation; a is a general scaling factor representing initial yield; b is the rate of increase to peak production; c is the rate of decline after peak production; and e is the exponential.

Therefore, estimated total yield (y) will be:

$$y = a(b + 1)/c^{b+1}.$$

The parameter b, is less than unity, implying that $(b + 1)$ is close to unity, and total yield, $y \leq a/c^{b+1}$. The peak day occurred at $t = b/c$; and y_{max} (peak) $= a(b/c)^b e^{-b}$. Total yield is a function of $c^{-(b+1)}$. Given a, variation in yield depends on variation in $p = c^{-(b+1)}$ where p is persistency.

The model was fitted using the non-linear curve fitting procedure of SAS statistical package (Statistical Analysis Systems Institute, 1989) to obtain the curve parameters.

The effect of herd, season, partity, litter size and litter composition on individual doe lactation curve parameters were determined using least squares procedures of analysis of variance (SAS, 1989). The model used was:

$$Y_{ijklm} = U + H_i + S_j + P_k + L_l + C_m + E_{ijklm}$$

where, Y_{ijklm} is the estimated curve parameter a, b, c respectively; U is overall mean; H_i is the effect of ith herd (i = 1, 2, . . ., 6); S_j is the effect of jth season of kidding (j = early dry, late dry, early wet and late

Table 1 *Means, standard errors and correlations of lactation curve parameter estimates for gamma-type model*

	Parameter			
Statistics	*a*	*b*	*c*	R^2
Average	0·586	0·316	0·023	98·3
s.e.	0·067	0·055	0·001	0·05
Correlation				
b	–0·0881		0·01145	
c	–0·5284**	0·1164		

†*a,b,c* lactation curve parameters.

Table 2 *Means and standard errors for lactation characteristics*

		Actual		Gamma	
Characteristics	No.	Mean	s.e.	Mean	s.e.
Total yield (kg)	66	79·3	2·36	83·9	0·031
Peak day	66	20·5	2·52	13·7	3·78
Peak yield (kg)	66	1·2	0·05	0·978	0·121
Persistency	66			143·2	0·02

wet); P_k is the effect of *k*th parity ($k = 1, 2, \ldots, 5$); L_l is the effect of *l*th litter size ($l = 1, 2, 3$); C_m is the effect of *m*th litter composition (*m* = male-single, female-single, all males, all females, males and females mixed); E_{ijklm} is the random error. The significant means were separated using the Duncan new multiple range test and the correlations between the curve paramenters were calculated from the raw data (SAS, 1989).

Results

Table 1 indicates the lactation curve parameter estimates for the Red Sokoto does. Wood's equation fitted the lactation curves very well with R^2 values of 98·3%. Parameters '*a*' and '*c*' were strongly and negatively correlated. Therefore animals that have a higher initial level of production will attain the peak faster and thereafter decline at a slower rate than those with a lower initial level of production. The lactation characteristics are presented in Table 2. The observed total yield to 120 days, peak yield and peak day were 79·3 (s.e. 2·36) kg, 1·2 (0·05) kg and 20·5 (s.e. 2·52), respectively. Gamma function estimated closely the observed characteristics. The estimated persistency for 120 days of lactation was 143·2 (s.e. 0·02).

Figures 1 to 3 describe the lactation patterns in the Red Sokoto goats. The lactation curves of these goats were characterized by milk production increasing during early lactation, attaining a peak at approximately 2 to 5 weeks *post partum* and thereafter declining slowly to the 120th day of lactation.

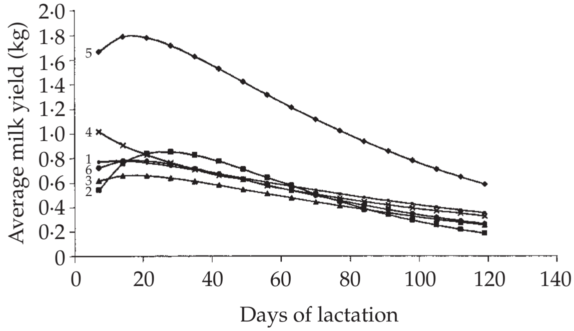

Figure 1 Effect of herd on goat lactation curves (herd number given on graph).

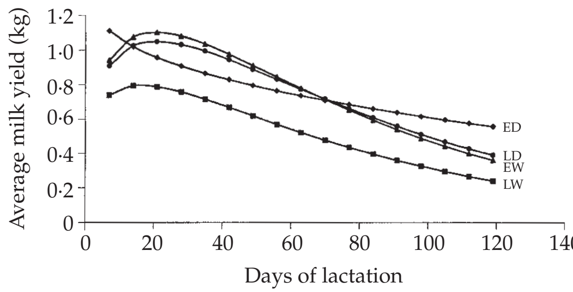

Figure 2 Effect of season of kidding on goat lactation curves: ED early dry; LD late dry; EW early wet; LW late wet.

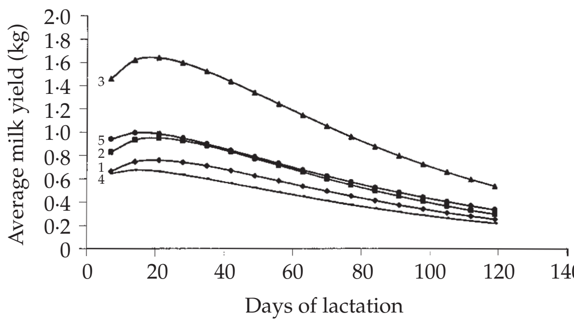

Figure 3 Effect of parity of doe on goat lactation curves (parity number given on graph).

The effect of the various factors on the estimates of lactation curve parameters '*a*', '*b*' and '*c*' are presented in Tables 3 and 4. None of the factors had a significant effect ($P > 0{\cdot}05$) on parameter '*b*'. However, herd and season of kidding significantly ($P < 0{\cdot}05$) influenced parameters '*a*' and '*c*'; while

Table 3 *Least-square means for lactation curve parameters by herd and season*

Factor	No.	*a* Mean	*a* s.e.	*b* Mean	*b* s.e.	*c* Mean	*c* s.e.
Herd							
1	10	0·656[ab]	0·188	0·119	0·093[b]	0·010[b]	0·002
2	13	0·151[b]	0·062	0·763	0·126[a]	0·029[a]	0·003
3	10	0·428[ab]	0·068	0·239	0·063	0·014[b]	0·002
4	8	1·269	0·192	–0·085	0·160	0·008[b]	0·004
5	11	1·119	0·313	0·263	0·127	0·016[b]	0·001
6	14	0·475[ab]	0·060	0·273	0·066	0·016[b]	0·002
Season							
Early dry	11	1·352[a]	0·461	–0·008	0·152	–0·004[b]	0·002
Late dry	18	0·531[b]	0·134	0·334	0·152	0·016[a]	0·004
Early wet	20	0·518[b]	0·106	0·372	0·073	0·018[a]	0·002
Late wet	17	0·486[b]	0·063	0·276	0·070	0·017[a]	0·002
Significance							
Herd		*				**	
Season		*				*	

[a,b] Figures with the same superscripts under the same factor and column are the same, otherwise they are significantly different ($P < 0{\cdot}05$).

† There were no other significant effects.

Table 4 *Least-square means for lactation curve parameters by parity, litter size and litter composition*

Factor	No.	*a* Mean	*a* s.e.	*b* Mean	*b* s.e.	*c* Mean	*c* s.e.
Parity							
1	22	0·388[e]	0·116	0·338	0·065	0·017	0·001
2	17	0·471[de]	0·082	0·355	0·108	0·018	0·003
3	13	0·877[d]	0·193	0·323	0·157	0·017	0·004
4	7	0·469[de]	0·081	0·218	0·104	0·015	0·002
5	7	0·660[de]	0·157	0·235	0·151	0·015	0·004
Litter size							
1	30	0·598	0·101	0·319	0·072	0·017	0·002
2	21	0·525	0·079	0·295	0·088	0·016	0·002
	15	0·288	0·028	0·398	0·017	0·017	0·001
Litter composition							
Male-single	14	0·414	0·074	0·196	0·079	0·008	0·002
Female-single	16	0·514	0·154	0·307	0·103	0·019	0·002
All males	12	0·228	0·107	0·575	0·205	0·025	0·004
All females	8	0·326	0·059	0·263	0·097	0·013	0·003
Males and females mixed	16	0·509	0·130	0·172	0·111	0·014	0·001
Significance							
Parity		*					

[d,e] Figures with the same superscripts under the same factor and column are the same, otherwise they are significantly different ($P < 0{\cdot}05$).

† There were no other significant effects.

parity significantly ($P < 0{\cdot}05$) affected only parameter '*a*'. Litter size and litter composition had no influence on the curve parameters ($P > 0{\cdot}05$).

The patterns of lactation in the different herds studied are presented in Figure 1. Herds 2 and 5 produced higher peaks. Herd 2 also had a higher rate of increase to peak although this was not significant. The random criss-crossing patterns of the herd effect are due to the variations in peak production level and time, and rates of decline. The curve for herd 4 is peculiar in that it lacks the rising phase to peak.

The lactation curves for the different seasons are presented in Figure 2. The season effect demonstrated that the higher the initial production level the higher the peak yield with slower rate of decline. Late dry and early wet seasons 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 a curve without the rising phase but which was highly persistent to the end of lactation.

Parity significantly ($P < 0{\cdot}05$) influenced the curve parameter '*a*' but not '*b*' and '*c*' (Table 4), resulting in curves of similar shapes but different production levels (Figure 3).

Discussion

The outstanding efficiency of the Wood model in this study further emphasizes why the model has been used in most lactation curve studies. Ruvuna *et al.* (1995) used the model to provide a good fit to goat lactation data in Kenya, East Africa. It was also used to understand the main factors that influence production levels and general forms of lactation curves (Carles, 1986; Wahome, 1987; Wahome *et al.*, 1994).

The peak yield observed in this study agrees with earlier reports on tropical goats (Morand-Fehr and Sauvant, 1978; Devendra, 1980; Osinowo and Abubakar, 1989; Egwu *et al.*, 1995). Also, the observed peak day conforms to the range reported for tropical goats (Ruvuna et al., 1995) and sheep (Iloyd, 1963; Hassan, 1995). The observed total yield agrees with an earlier report on the same breed of goat (Osinowo and Abubakar, 1989) but it was higher than those of Adal goats (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). The persistency over the 120-day lactation peroid in the Red Sokoto goats was high (143·2) and signifies the ability of these does to maintain their milk production throughout the lactation period. The estimate is comparable with that of 128·0 reported for a single Friesian cow lactation chosen at random and calculated from 24-h production on 1 day a week over a 305-day period (Wood, 1967). However, it is far higher than the ones reported for East African goats and their crosses (2·87 to 4·50) with the same 120-day lactation period (Ruvuna *et al.*, 1995).

The strong negative correlation between parameters '*a*' and '*c*' 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.

A similar trend to that observed in the lactation curve characteristics of Red Sokoto goats has been reported by other workers on goats (Mukundan and Bhat, 1983) and sheep (Sakul and Boylan, 1992; Hassan, 1995). The described pattern also agrees with reports that lactation curves of goats are flatter and more persistent than those 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 characterized by herding on a daily basis, there are between herd differences in the nature and timing of food supplementation to the animals. Also, the Fulani agropastoralists practise some level of selection based on the 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 food both in terms of quality and quantity. During the late dry season, there are a variety of crop residues available; while in the early wet season, there is an abundance of grazable materials for the animals. Therefore, does kidding in these seasons do not experience nutritional stress during lactation unlike does in the other 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 pasture available for grazing. Effects of season of kidding on lactation curve parameters and shape in goats have also been reported in other studies (Gipson and Grossman, 1989; Ruvuna *et al.*, 1995) and suggest that strategic seasonal breeding is important to maximize milk yield per doe (Ruvuna *et al.*, 1995).

The high persistence of the early dry season lactation may be explained by 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 a 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 parity effects to the present ones have been reported for lactation curves of East African goats by Wahome *et al.* (1994). Parity 3 had the highest level of production, followed by parties 2 and 5. The lowest production level was for does of parity 4. Parities l, 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-significant, higher litter size gave rise to a lower level of milk production. This 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 noting 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 disavantage due to their relatively poor body condition and body reserves to mobilize for milk following kidding when compared with the single litter does (Wahome *et al.*, 1994).

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).

Conclusion

Shapes of the lactation curve provided by the gamma-type model strongly suggest that animals with a higher initial level of production, are likely to attain the peak faster and thereafter decline at a slower rate than those with a lower initial level of production. Factors influencing the shape of the lactation curve in the Red Sokoto goats were herd, season and parity.

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