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Genetic and non-genetic factors affecting lactation curve components of a Sudanese Butana dairy herd

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Abstract

Weekly milk yield of 1578 lactations of 249 Butana dairy cows during the period 1949–1999, were analyzed to study effects of year of calving, season of calving and cows' parity order on lactation curve components. Estimates of heritability and repeatability of these traits were also studied. Lactation curve components were estimated using the formula $Y = an^b e^{(-cn)}$. The data were classified according to years of calving into 1949–1959, 1960-1969, 1970-1979, 1980-1989 and 1990–1999 groups. The data were also classified according to season of calving into dry summer (March–June), wet summer (July-October) and winter (November-February) groups. The data were also classified according to cow's parity order into ten parity groups. General linear model was conducted to examine the significance of the tested effects. Week of peak yield and persistency of lactation curve peak significantly increased with years' advancement and the opposite trend was observed for peak yield and constants *a* and *c*. Peak yield was significantly ($P<0.05$) higher for winter group than dry summer and wet summer groups. Constants *b* and *c* significantly increased with parity order increase indicating flatter shape of lactation curve at early parities. Heritability and repeatability estimates of lactation curve components were low and ranged between 0.01–0.06 and 0.02–0.22, respectively. The study concluded that all traits those determined shape of lactation curve of Butana cows were not inheritable and were affected by environmental factors such as management systems change during years, climatic change during seasons and cow's age.

Key words: Butana, Cows, Heritability, Persistency, Repeatability

Introduction

The term lactation curve refers to the graphical representation of the relationship between milk yield and time after calving. The knowledge of pattern of lactation yield is a helpful criterion in planning of cows' nutrition and management. Lactation yield (particularly after colostrums withdrawal) when regressed on time post-calving has a curvilinear trend, because the cow produces milk in an increasing manner to reach a peak after 30 to 90 days post-partum then declines in yield gradually until advanced pregnancy causes a sharp decline (Wood, 1967). Therefore, lactation curve composes of three phases, the first phase from initial yield postpartum up to peak yield, the second phase is persistency of peak and the third phase is the decline from peak to the end of lactation which is standardized to be two months prior next calving. Wood (1967) observed that the best fit for the average lactation curve was shown by *gamma type function* $[Y_{(n)} = an^b \times e^{-(cn)}]$.

In this equation $Y_{(n)}$ was the weekly milk yield (kg) recorded during the *n*th week of lactation, *a* was a multiplier or scaling factor to represent the beginning of the lactation, *b* was the linear constant which measure the average shape of the curve during the increase phase, *c* was a linear constant that describe the rate of change of the slope of the curve during the decline phase and *e* was the base of natural logarithm. Cobby and Le Du (1978) predicted from this equation week of maximum yield, peak yield and persistency of peak yield.

The genetic and environmental factors and their interactions were reported to determine the shape of lactation curve (Santon et al., 1992 and Tekerli et al., 2000). The differences in the shape of lactation curve were greater between individual cows than between lactations of the same cow and between breeds, while relative cows showed correlation in the shape of lactation curve (Santon et al., 1992). Assessment of effects of heredity and environment on the lactation curve components of animals is greatly aided by estimates of heritability and genetic relationships (Tekerli et al., 2000). In simple term, repeatability tells how an animal will repeat a trait during its lifetime, whereas heritability tells how it will be passed to the next generation (Dalton, 1985).

This study aims to examine heritability and effects of the environmental factors as management systems change during years, climatic change during seasons and age of Butana dairy cows on their milk yield curve.

Materials and Methods

The records of 1578 lactations of 249 Butana cows used in this study were extracted from Atbara Research Station records covering the period from 1949 to 1999. The station is located in the River Nile State in the northern Sudan, at latitude 17° 42 N and longitude 33° 58 E and at altitude 345 meters above sea level.

Animals were allowed to graze on *Sorghum bicolor* (Abu-70), *Cyamopsis tetragnoloba* (Guar), *Medicago sativa* (Berseem) and *Sorghum sudanensis* (Grawia) twice daily for four hours (2 hours in the morning and 2 hours in the evening). In addition to grazing, milking cows were fed on concentrate mixture of 19% crushed sorghum grains, 20% cotton seed cakes, 60% wheat bran and 1% salt. This concentrate diet was offered daily at the rate of 4% of cow's live body weight. Animals were accommodated in groups according to their physio- logical status such as; weaned and growing calves, heifers, dry and pregnant cows, lactating cows and breeding bulls. Only natural mating was practiced. The cows were allowed to be served after two months post calving, while heifers were usually allowed at first estrus signs appearance. Breeding bulls (21 sires) were selected from progenies of the highest yielding dams in the herd. Animals were usually vaccinated against the major infectious livestock diseases in the Sudan particularly; hemorrhagic septicemia, anthrax and contagious bovine pleura pneumonia. Also monthly test for mastitis, theileriosis, and external parasites were done.

Weekly milk yield data of cows recording 5-10 lactations and lactation length range of 229-331 days were used. Wood (1967) formula was used to estimate the lactation curve parameters for each cow. The formula was: $y_n = an^b \times e^{-cn}$, where y, is the milk yield (kg) on week *nth*, e is the base of the natural logarithm, a, b and c are positive parameters that determine the curve's shape.

From this equation, the following were calculated according to Cobby and Le Du (1978):

a) Week of peak yield = b/c

b) Peak yield (kg) = $a\,(b/c)^b \times e^{-b}$.

The persistency of the lactation curve = $-(b+1)\times\ln c$. where $\ln c$ is antilog of the constant c.

To study the effect of year, the data were classified into five period groups according to the years of calving. The first period extended from 1949 to 1959, the second group covered the period between 1960 and 1969, the third period extended from 1970 to 1979, while the fourth period extended from 1980 to 1989 and the last period extended form 1990 to 1999. For evaluation of effect of season of calving, the data were classified into three season groups; dry summer (those calved during months of March – June), wet summer (calvers of months between July and October) and winter (calvers during months between November and February). The data were also classified according to cow's parity order into ten parity groups (from the first to the tenth lactations).

Statistical Analysis

General linear model was conducted using *SPSS* computer software (version, 10) to examine the significance of the effects of year of calving, season of calving and cow's parity order on the studied traits. Duncan's multiple range tests was used to test the significance of differences between treatments' means.

Heritability was estimated by paternal half-sib analysis as described by (Becker, 1975). Repeatability of the studied traits was estimated by intra-cow correlation (components of variance analysis) from the first three records (1st, 2nd and 3rd lactations). Both estimates were done using Harvey's (1990) software. The animal model used was:

$$Y_{ijkl} = \mu + YC_i + SC_j + PN_k + AN_l + e_{(ijkl)}$$

Where Y_{ijkl} is the observation for each curve trait; μ is the overall mean; YC_i is the effect of the i^{th} Year of calving; SC_j is the effect of the j^{th} season of calving; PN_k is the effect of the k^{th} parity number; AN_l is the random effect of the l^{th} animal and $e_{(ijkl)}$ is the residual variation.

Results

The overall means, coefficients of variations (CV) and estimates of heritability and repeatability of the studied lactation curve components of Butana cows' herd were presented in table (1). The results illustrated that except persistency, all the traits of lactation curve showed higher CV percentages. Low heritability estimates for all of the studied traits were obtained. The results also showed that repeatability estimates of the lactation curve components were moderate for the week of peak yield and peak yield. While, low repeatability estimates were obtained for the initial milk yield (constant a of the lactation curve model), persistency of lactation curve and the rate of increase to the peak yield (constant b of the lactation curve model).

The year of calving significantly ($P<0.05$) affected all of the lactation curve components (Table, 2). Initial milk yield, rate of milk yield increase to the peak yield, rate milk yield decrease post peak yield (constant *c* of the lactation curve model) and peak milk yield significantly ($P<0.05$) decreased with year's progression. Week of peak yield and persistency of peak yield significantly ($P<0.05$) increased with years' advancement.

Table (3) showed that season of calving exerted no effect ($P>0.05$) on all of the lactation curve traits except peak yield that was significantly ($P<0.05$) higher in winter calvers than in dry and wet summer calvers those were similar.

The entire lactation curve traits were significantly ($P<0.05$) affected by cow's parity order (Table, 4). Initial milk yield of 2^nd^, 3^rd^, 4^th^, 5^th^, 6^th^, 8^th^ and 9^th^ cows' parity orders were similar and higher than the first and 10^th^ parity orders. The rate of increase to the peak (*b*), the rate of decrease post peak (*c*) and the peak milk yield increased ($P<0.05$) with increase of cows' parity order. The week and persistency of peak yield of the first parity group were the highest ($P<0.05$) and those of the 2^nd^ parity order group were the lowest ($P<0.05$) whereas those of the rest orders groups were similar ($P>0.05$). All interactions of the year of calving, season of calving and parity order did not affect the lactation curve parameters studied.

Discussion

The high CV of the studied lactation curve components (Table, 1) indicated the high discrepancies between animals. Similar observations were reported by Abate et al. (2010).

Comparable results of initial milk yield (parameter *a* of the lactation curve model) were reported by Cobby and Le Du (1978) for Holstein Friesian cows (25.5± 0.8 kg/wk). The present result was lower than 43.38 kg/wk reported by Fadlel-Moula et al. (2007) for Friesian × Kenana crossbred dairy cows at University of Khartoum dairy farm. The significant decrease of initial milk yield in the current work with years advance was in agreement with the finding of Bhutia et al. (1988) for Friesian × Sahiwal crossbred cows. The increase of value of parameter *a* with parity order increase (Table, 4) was also reported by Arik (2003) for Butana dairy cows. Similarly, Fadlel-Moula et al. (2007) observed that parameter *a* value increased with increase of parity order and it reached its maximum value in the 5^th^ lactation. The variation in the initial milk yield through different parities could be due to the fact that more alveolar cells (secretary cells) would be added at each successive pregnancy after the first lactation to reach their maximum at about the 5^th^ calving and they started to diminish gradually thereafter (Dhangar and Patel, 1991). The rate of increase to the peak yield (constant *b* of the lactation curve model) in the present study was comparable to 1.4 kg/week reported by Wood (1969) for Friesian dairy cows. The present value was higher than 0.45±0.23 kg/week reported by Fadlel-Moula et al. (2007). The increase of constant *b* with cow's parity advancement (Table, 4) was also noted by Ahunu and Kabuga (1994). The rate of decrease from the peak yield (*c* parameter) in the current study was higher than 0.0214±0.0024, 0.0112±0.0047, 0.012±0.0041 and 0.0024±0.0012 reported by Wood et al. (1980) for Friesian, Aryshire, Guernsey and Jersey cows, respectively, and than 0.05±0.02 kg/week reported by Fadlel- Moula et al. (2007). The present values of *b* and *c* constants indicated the steeper shape of lactation curve. The significant influence of year on *c* value was also reported by Fadlel-Moula et al. (2007); however, they reported that *c* value increased as years advanced. Similar effect of parity order was also reported by Fadlel-Moula et al. (2007).

The mean of week of peak yield (*n*–max) in the current study was higher than 9.04±3.69 weeks reported by Fadlel-Moula et al. (2007) for Friesian crossbred cows, and 56.60±5.47 days reported by Saeed et al. (1987) for Kenana cattle at Um-Banein research station, but lower than 15.60±7.401 weeks reported by Abate et al. (2010) for Kenana × Friesian crossbred. The current study significant effect of year of calving on n–max was also reported by Madalena et al. (1979). The present influence of cows' parity on n-max was also reported by Arik (2003). He noted that first parity order reached peak yield at later time than other parities. Comparable result to the peak yield of the current study was reported by Fadlel-Moula et al. (2007) (79.40 kg). The present significant influence of season of calving on peak yield was also reported by Bhutia et al. (1988). Consistently, Gajbhiye and Tripathi (1991) found that Murrah Buffaloes had the highest maximum peak yield when calved in winter season and the lowest peak yield when calved in summer season. Fadlel-Moula et al. (2007) and Arik (2003) also reported the present trend of increase of peak yield with parity order advancement. Persistency of peak of lactation curve in the current study was comparable to 5.37±0.757 weeks reported by Abate et al. (2010). The significant increase of persistency as years advanced (Table 2) was also reported by Arik (2003) for Butana cows and by Ahunu and Kabuga (1994) for Holstein-Friesian cows in Ghana. The significant effect of parity on persistency of lactation curve was also reported by Fadlel-Moula et al. (2007) and Arik (2003). The parity order effects on persistency of lactation curve were probably attributed to the fact that, older animals which started their lactation at a higher level had a rapid rate of decline and the regression of alveolar cells increased with advancement in age which led to decline in udder production (Wood, 1969).

Table 1: Mean heritability and repeatability of lactation curve components of Butana cows.

Traits (Number of observations, 1578)	Means± SD	C.V.%	r ± SE	h^2± S D
Initial milk yield (kg\week).	21.02 ± 20.61	98	0.07 ± 0.002	0.01 ± 0.01
Rate of increase to the peak yield (kg\week)	1.07 ± 0.54	50	0.02 ± 0.001	0.01 ± 0.01
Rate of decrease from the peak yield (kg\week)	0. 09 ± 0.05	56		0.06 ± 0.02
The week of peak yield (weeks).	11.95 ± 4.42	37	0.20 ± 0.003	0.03 ± 0.01
Peak yield (kg\week).	70.67 ± 21.57	31	0.22 ± 0.002	0.02 ± 0.01
Persistency of the lactation curve (weeks).	4.96 ± 0.77	16	0.17 ± 0.003	0.01 ± 0.01

SD = Standard Deviation; C.V. = Coefficient of Variation; h^2 = Heritability estimate; r= Repeatability estimate

Table 2: Effect of year of calving on lactation curve components of Butana cows

Year	No	Initial milk yield (kg\week)	Rate of increase to peak yield (kg\week)	Rate of decrease from peak yield (kg\week)	Week of peak yield (weeks)	Peak yield (kg\week)	Persistency of lactation curve (weeks).
1949-1959	129	28.63^a	1.03^b	0.10^a	11.2^b	84.71^a	4.79^c
1960-1969	492	21.34^b	1.14^a	0.10^a	11.9^b	80.37^b	4.98^b
1970-1979	250	22.46^b	1.01^b	0.10^a	11.6^b	66.71^c	4.89^b
1980-1989	293	18.53^b	1.02^b	0.09^b	12.1^a	60.86^d	4.97^b
1990-1999	152	15.93^c	1.01^b	0.08^c	12.9^a	52.81^e	5.15^a
SE	-	2.72	0.07	0.007	0.57	2.75	0.10
		S*	S*	S*	S*	S*	S*

No = Number of observations; SE = Standard error of means; NS = Treatment effect is not significant (P>0.05); S* = Treatment effect is significant (P<0.05); a, b, c, d and e = Means on the same column with different superscripts are significantly (P<0.05) different

Table 3: Effect of season of calving on the lactation curve components of Butana cows

Seasons	No	Initial milk yield (kg\week)	Rate of increase to peak yield (kg\week)	Rate of decrease from peak yield (kg\week).	Week of peak yield (weeks).	Peak yield (kg\week).	Persistency of lactation curve (weeks).
Dry summer	480	20.19	1.09	0.10	11.8	69.3^b	4.94
Wet summer	313	19.99	1.05	0.09	12.2	68.3^b	5.00
Winter	523	22.39	1.05	0.09	11.9	73.2^a	4.96
SE		0.99	0.03	0.002	0.21	1.01	0.04
		NS	NS	NS	NS	S*	NS

Dry summer (March – June), wet summer (July–October) and winter (November–February)

Table 4: Effect of Butana cows' parity order on lactation curve components

Parity order	No	Initial milk yield (kg\week)	Rate of increase to peak yield (kg\week)	Rate of decrease from peak yield (kg\week)	Week of peak yield (weeks)	Peak yield (kg\week)	Persistency of lactation curve (weeks)
1st	196	14.45^b	1.02^b	0.071^c	14.8^a	56.85^d	5.38^a
2nd	229	26.70^a	0.93^b	0.090^b	10.6^c	66.65^c	4.71^c
3rd	218	20.96^a	1.08^a	0.099^a	11.5^b	71.09^b	4.88^b
4th	171	21.96^a	1.08^a	0.098^a	11.3^c	75.80^b	4.87^b
5th	135	22.16^a	1.13^a	0.099^a	11.7^b	77.08^a	4.93^b
6th	123	21.72^a	1.13^a	0.096^a	11.8^b	77.44^a	4.99^b
7th	98	18.99^b	1.17^a	0.099^a	12.3^b	74.32^b	5.05^b
8th	78	19.62^a	1.08^a	0.094^a	11.7^b	73.90^b	4.94^b
9th	42	20.62^a	1.12^a	0.092^a	12.9^b	70.66^b	5.08^b
10th	26	18.21^b	1.22^a	0.111^a	11.6^b	84.43^a	4.93^b
SE		2.24	0.06	0.005	0.47	2.26	0.08
		S*	S*	S*	S*	S*	S*

The low heritability estimates of lactation curve components in the current study (Table, 1) indicated that most of the variations in these parameters could be attributed to environmental and managerial causes. So the improvement of these parameters is linking with improving system of herd feeding and management. However, Solkner and Fuchs (1987) observed moderate heritability (0.17–0.22) for persistency and accordingly they reported that the moderate estimates of heritability of persistency have encouraged interest in selecting for desirable shape of lactation curve. They also stated that there was clearly a significant genetic component of lactational persistency but estimates of heritability vary widely due to differing methods of measuring persistency. The moderate repeatability estimates of the week of peak yield (0.20) and peak yield (0.22) were consistent with the findings of Tekerli et al. (2000). They noted that higher producing cows in the past are correctly expected to be higher producing cows in the future.

The present study concluded that Butana is a promising dairy cow. The components of their lactation curves were not inheritable; however, they were slightly repeatable during the life of the animal. The results also concluded that these components were significantly affected by the environmental factors such as managerial changes during years, seasonal variations and age of the cows. The improvement of these parameters can be achieved by improving the environmental factors rather than selection.

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