Effect of Days Open on the Lactation Curve of Holstein Cattle in Saudi Arabia

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ABSTRACT : A total of 21,441 milking records of biweekly test-days were collected from six dairy farms of Almarai company, Saudi Arabia to determine the effect of days open on lactation curve and milk production during the period of 1991 to 1996. These records included cows calved in two seasons: winter, for cows calved from October to March and summer, for cows calved from April to September. Season of calving did not have a significant effect on the last biweekly points of the curve, and this is due to the effect of the evaporative cooling system. Days open had a marked effect on milk production. The difference in milk yield between cows with days open <60 days and days open >150 days was 1,021 liter. Moreover, the difference in milk yield at early lactation decreased from 1,021 to 829 liter as the days open increased from 75 to 125, due to the decrease in the effect of conception on milk production with advancing lactation. These data also showed that the middle part of the curve (105-255) was the least affected part by the variation in days open because the pregnancy effect become more obvious after five months of conception. These data showed that the dairy cattle produce more than 70% of the milk yield during the first 250 days of the lactation curve. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 3 : 277-286*)

Key Words : Days Open, Lactation Curve, Holstein Cattle, Saudi Arabia

INTRODUCTION

Days open, defined as the period from parturition to the next successful breeding, determine calving interval and influence milk production of the following lactation. Finding the relationship between milk yield and days open is important for effective control of dairy production system, and determining the part of lactation curve that is not affected by days open could be used in sire and cow evaluation instead of 305-days milk production. Both days open and calving interval have been viewed as environmental factors that need to be considered to obtain more accurate estimates of genetic merit for production traits (Smith and Legates, 1962; Wilton et al., 1967; Schaeffer and Henderson, 1972; Oltenacu et al., 1980; Sadek and Freeman, 1992). The objective of this study was to determine the effect of days open on the lactation curve and milk yield at Almarai dairy farms.

MATERIALS AND METHODS

The data included 21,441 milking records of biweekly test-days collected during the period from 1991 to 1996 on six dairy farms of Almarai company located in the central region of the kingdom of Saudi Arabia. The data was edited such that the analysis included records of age at calving ranging from 21 to 90 months for five parity groups.

Frequency distribution showed discontinuity in the data such that first parity included cows calved at age ≤ 21 to ≤ 29 mo.; second parity included cows calved at age ≤ 32 to ≤ 40 mo.; third parity included cows calved at age 44 to ≤ 53 mo.; fourth parity included cows calved between $55 \leq$ to ≤ 63 mo.; and fifth parity included cows calved at age ≤ 67 and ≤ 75 mo. Age at calving showed a wide range; therefore, age at calving within lactation was divided into three categories of four months each.

Milk records included cows calved in two seasons: winter; for cows calved from October to March and summer; for cows calved from April to September.

Lactation that began with an abortion or in which milking was interrupted by injury or sickness was discarded. Days open (DO) was the difference between the calving date and the following last reported breeding date, and if one of the breeding dates was missing, days open were computed by subtracting gestation length (280 days) from calving interval. According to the frequency distribution of the overall data, days open were classified into five categories as follows: the first category included all records with days open 30<DO1<60; three categories were 30 days each; and the last class included all records of the cows with days open 150 day or more. No records were found with days open less than 30 days.

Biweekly milk yield was analyzed according to the following model:

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$$Y_{ijklm} = \mu + F_i + L_j + AGC(L)_k + S_l + DO_m + E_{ijklm}$$

Where:

Y_{ijklm} = biweekly milk yield.

μ = overall mean.

F_i = the farm effect (i=1,..., 6)

L_j = parity or lactation number effect (j=1,...,5)

$AGC(L)_k$ = age at calving within lactation (k=1, 2, 3)

S_l = season of calving effect (l=1, 2)

DO_m = days open effect (m=1,...,5)

E_{ijklm} = error effect ~ N (0, σ^2)

Total milk yield for each cow was corrected to 305-day yield using the lactation period correction factor obtained by Al-Jumaah (1995); the corrected records were analyzed according to the model:

$$Y_{ijklmn} = \mu + F_i + L_j + AGC(L)_k + S_l + DO_m + b_n(ECY) + E_{jklmn}$$

Where:

Y_{ijklmn} = 305-d milk yield of cow n in farm i, lactation number j, age at calving k; season of calving l within lactation, days open m; b =regression coefficient of early cumulative, and ECY_n = ECY of cow n.

b_n = regression coefficient of early cumulative yield (ECY) on 305-day, (n=1,..., 5).

ECY_n = early cumulative milk yield of cow n.

E_{ijklmn} = random residual effect.

ECY_1 = early 75-day cumulative milk yield;

ECY_2 = early 105-day cumulative milk yield;

ECY_3 = early 135-day cumulative milk yield;

ECY_4 = early 165-day cumulative milk yield;

ECY_5 = early 195-day cumulative milk yield.

The parameters of the lactation curve were computed using the multiphasic function of Grossman and Koops (1988).

$$Y_t = \sum_{i=1}^{n} \{ a_i b_i [1 - \tanh^2 (b_i (t - c_i))] \}$$

Where

Y_t = milk yield at t (t=days in milk).

n is number of lactation phase; tanh is the hyperbolic tangent; a_i is asymptotic total yield (L); b_i is rate of yield relative to a_i (days^{-1}); c_i is time of peak yield (days).

Function of three phases were: Initial yield computed when t=0 in the multiphasic function; Peak yield was represented by $a_i b_i$; Duration defined as the period in days required attaining about 75% of asymptotic total yield, during that phase computed as $2b^{-1}$.

Marquardt's method of nonlinear regression [Proc NLIN using Marquardt; SAS (1986)] was used to estimate the parameters because Marquardt is equivalent to performing a series of ridge regressions which correct for colinearity or mean singularity problems that arise from the correlation between the parameters of the lactation curve as given by Batts and Watts (1988).

RESULTS AND DISCUSSION

Least square means for milk yield of the first five parities were 10,013; 9,870; 10,047; 10,146 and 10,126 liters, respectively. Fitting the linear model to biweekly milk yield data (table 1) showed a significant effect for farm, parity, age at calving within lactation. Farm effect reflected the managerial conditions prevailed at the farm during lactation period. Parity effect was the second important nongenetic factor affecting the curve through the development of secretary tissues of the mammary gland. Wood (1969, 1976), Kellogg et al. (1977), Grossman and Koops (1988) and Papajcsik and Bodero (1988), showed changes in the shape of the lactation curve associated with age.

No significant effect was observed for season of calving on the last biweekly points of the curve, and this is mainly due to the effect of the evaporative cooling system used in the Al-Maraie dairy herd which eliminated a great deal of seasonal variation in milk production.

The average milk yield was 10,175 and 9,906 liter for cows calved in winter and summer. Many studies have indicated that the milk production of heat-stressed cows raised under evaporative cooling was significantly higher than the non-cooled cows. The improvement in milk production was mainly due to the increase in dry matter intake, lower rectal temperature and respiratory rate as reported by Armstrong et al. (1988), Ryan et al. (1992) and Chen et al. (1993).

Table 2 shows the relationship between DO and corrected 305-day milk yield by considering the differences in milk yield in early lactation, and shows the inhibitory effect of conception on milk yield. The differences in milk yield between cows with days open <60 days and days open >150 days was 1,021 liter of milk. These differences are larger than differences found by Funk et al. (1987), Oltenacu et al. (1980) and Schaeffer and Henderson (1972). The differences in milk yield at early lactation decreased from 1,021 liters to 829 liters as the days open increased from 75 days to 175 days, and this is due to the decrease in the conception impact on milking with advancing lactation. The coefficient of determination (R^2) on milk yield increased from 0.13 to 0.83 and this is due to the inclusion of more accumulated milk yield in the model.

Table 1. The effect of non-genetic factors: farm (F), parity (L), age at calving with lactation season of calving (S), days open (DO) and the two-way interactions

Period	FN	L	S	AGC (L)	DO	FN*L	FN*S	FN*DO	L*S	L*DO	S*DO
1	**	**	**	**	**	**	**	**	**	**	**
2	**	**	NS	**	**	**	**	**	**	**	NS
3	**	**	**	**	**	**	**	**	**	**	NS
4	**	**	NS	**	**	**	**	**	**	**	NS
5	**	**	**	**	**	**	**	**	**	**	NS
6	**	*	*	*	**	**	**	**	NS	**	NS
7	**	**	**	**	**	**	**	**	**	**	NS
8	**	**	NS	**	**	**	**	**	**	NS	NS
9	**	**	**	**	**	**	**	**	**	NS	NS
10	**	**	**	**	**	**	**	**	**	**	NS
11	**	**	**	**	**	**	**	**	**	NS	NS
12	**	*	**	**	**	**	**	**	**	**	NS
13	**	*	**	**	**	**	**	**	**	NS	NS
14	**	*	**	*	**	**	**	**	**	NS	NS
15	**	**	**	**	**	**	**	**	**	NS	NS
16	**	**	*	**	**	**	**	**	**	**	NS
17	**	**	**	**	**	**	**	**	**	NS	NS
18	**	**	**	**	**	**	**	**	**	**	NS
19	**	**	**	**	**	**	**	**	**	NS	NS
20	**	*	NS	*	**	**	**	**	**	NS	NS
21	**	**	NS	*	**	**	**	**	**	NS	NS
22	**	**	NS	**	**	**	**	NS	NS	NS	NS
23	**	**	NS	**	**	**	**	**	NS	NS	NS
24	**	**	NS	**	**	**	**	**	**	NS	NS
25	**	**	NS	**	**	**	NS	NS	**	NS	NS
26	**	NS	NS	**	**	**	NS	*	NS	NS	NS
27	**	NS	NS	**	**	NS	NS	NS	*	NS	NS
28	**	NS	NS	**	**	NS	NS	NS	NS	NS	NS
29	*	NS	NS	**	**	NS	**	NS	NS	NS	NS
30	**	**	NS	NS	NS	**	NS	NS	NS	NS	**

Table 2 shows the changes in regression coefficient for days open (DO) on milk yield when ECY was added as a covariable in the model. Inclusion of ECY reduced the values for DO on yield. When intervals of ECY were 75, 105, 135, 165 and 195 days, the estimates of DO on milk yield decreased by 33, 13, 13, 9 and 6%, respectively.

Table 3 illustrates the significance (F-value) of the main effect on corrected records, corrected for lactation period. Days open had a highly significant effect on total milk yield for models with and without cumulative milk yield. Various biological and management factors affect the relationship between cumulative milk yield early in lactation and days open. Examples of these factors are the effect of milk production on fertility and the differential treatment for first breeding and culling of cows of low production. The association between days open and cumulative milk production of early lactation influences the length of the days open directly by affecting a cow's fertility and indirectly through management. After conception, number of days open influences production through the effect of pregnancy on milk yield because delaying conception reduces competition for nutrients from the

Table 2. Least Square Solutions (kg) for days open (DO) for milk yield with different length of early cumulative yield (ECY)

Coefficient of ECY	0	75 d	105 d	135 d	165 d	195 d
DO interval	-	33.49	29.14	24.9	21.93	19.75
<60	-1021	-1008	-1005	-997	-931	-829
60 - 90	-466	-683	-700	-732	-667	-615
>90 - 120	-289	-410	-389	-399	-364	-306
>120 - 150	-96	-222	-294	-291	-222	-182
>150	00	00	00	00	00	00
R^2	0.13	0.51	0.60	0.68	0.76	0.83

Table 3. F value for different effects of the model with and without cumulative milk yield, based on the model MY= μ +F+L+AGC (L)+MCI+DO+E

Source of variance		Model	Model+ECY1	Model+ECY2	Model+ECY3	Model+ECY4	Model+ECY5
F	4	240.57**	12.99**	3.71**	0.20^{NS}	2.27*	5.66**
L	3	4.02**	2.89**	8.12**	7.39**	7.32**	6.46**
AGC(L)	4	0.86^{NS}	5.95**	5.07**	3.74**	3.28**	2.60*
MC1	1	70.22**	2.53^{NS}	0.22^{NS}	0.88^{NS}	2.01**	7.96**
DO	4	166.36**	84.91**	83.76**	86.94**	92.06**	89.23**
ECY1	1		2368.29**	-			
ECY2	1			3011.50**			
ECY3	1				3434.65		
ECY4	1					4429.61	
ECY5							5648.71
MSE		1.994 E+06	9.517 E+05	7.651 E+05	6.104 E+05	4.445 E+05	3.16 E+05

MY=305 milk yield.

ECY1: Cumulative milk to 75 days; ECY2=ECY1+30 d; ECY3=ECY1+60 d; ECY4=ECY1+90 d; ECY5=ECY1+120 d. F=Farm effect, L=Lactation No.; AGC (L)=Age of calving within lactation; MC1=Season of lactation; DO=Days open.

fetus during a 305-day lactation (Erb et al., 1952). The inhibitory effect of pregnancy on milk yield should be minimal for the first 120 days of pregnancy (Oltenacu et al., 1980). Therefore the effect of days open on cumulative milk yield should be small. In this study, days open decreased considerably milk yield of early lactation (table 3). These results are in agreement with Auran (1974) and Schaeffer and Henderson (1972).

Milk yield for five classes of days open were 9,452, 9,725, 10,007, 10,105 and 10,362 liters respectively. Increase in days open accompanies higher production and this mainly because higher producing cows may have more breeding problems, and may be deliberately not bred back as soon as low producers. High producers also may be given more chances to conceive, whereas low producers might be culled with the same number of returns to services (Smith and Legates, 1962).

Lactation curve of the first parity (figure 1) started at a low level of production, reached the peak at about sixty days, and the curve stayed close to peak level until 220 days of lactation period. First lactation curve declined after that generally until the end of lactation. The curves of third, fourth and fifth parities increased in an identical rate up to the peak; the three

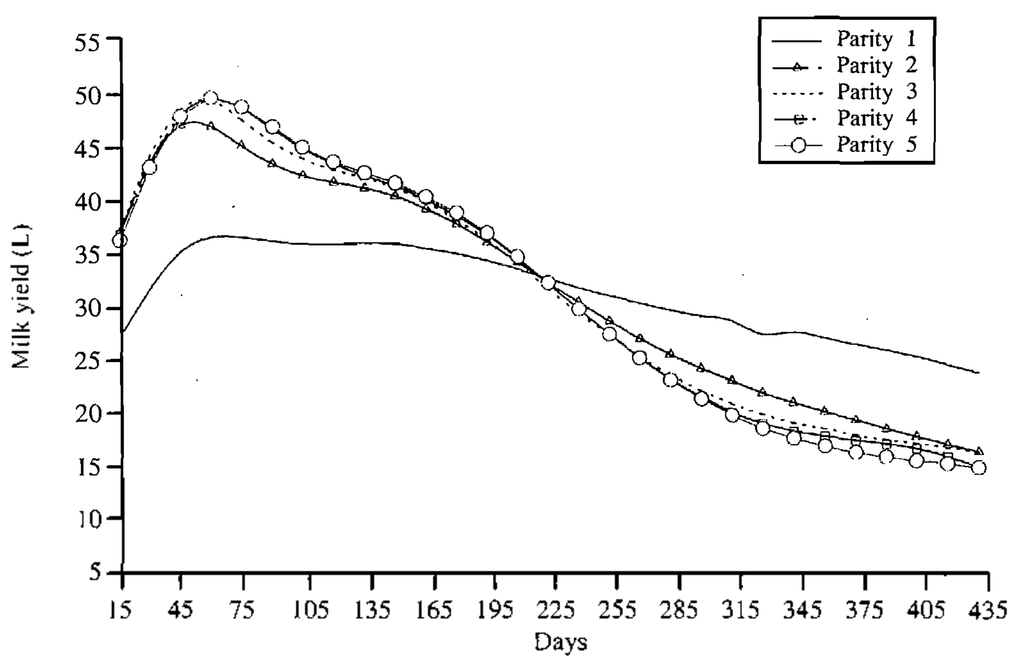

Figure 1. Lactation curves of different parities

curves decreased after that with a very close trend till the dry-off. The curve of second parity increased in an identical trend to the third lactation but with a lower peak, and continued to be lower than third lactation until 220 days of the lactation. After the intersection point between curves (at 220 days) second parity tended to show more persistency than any of other three parities.

Applying Grossman and Koops (1988) equation yielded a lactation curve with three phases. The curve points of the overall data (figure 2) is the sum of the points of the three phases. The triphasic function fitted the points of each curve and gave a curve identical to the actual data. These results are in agreement with the curves of De Boer et al. (1989).

Lactation curves of different parities for different

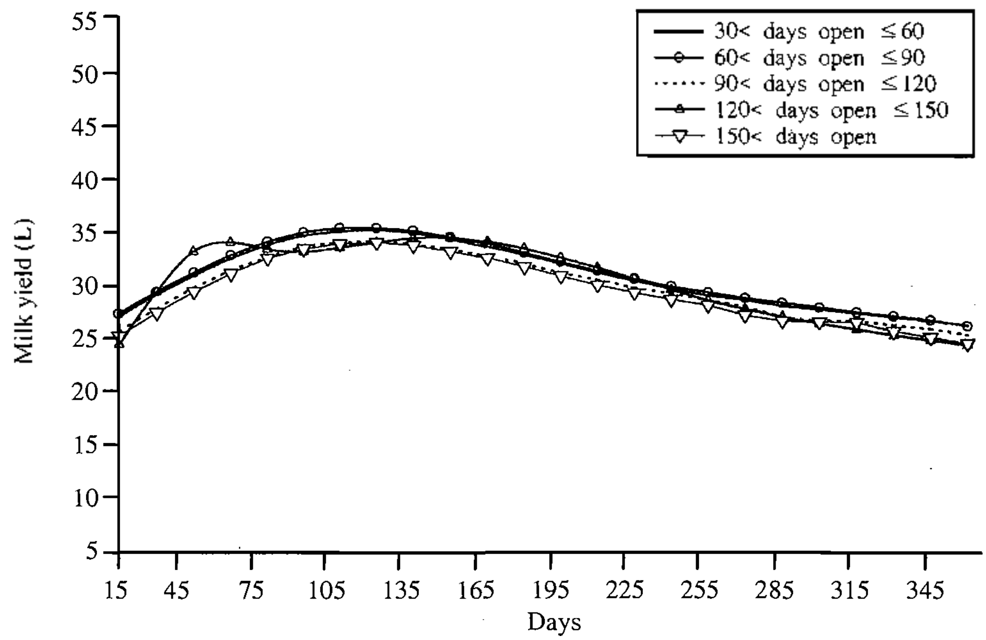

Figure 2. Lactation curves of the 1st parity for five classes of days open

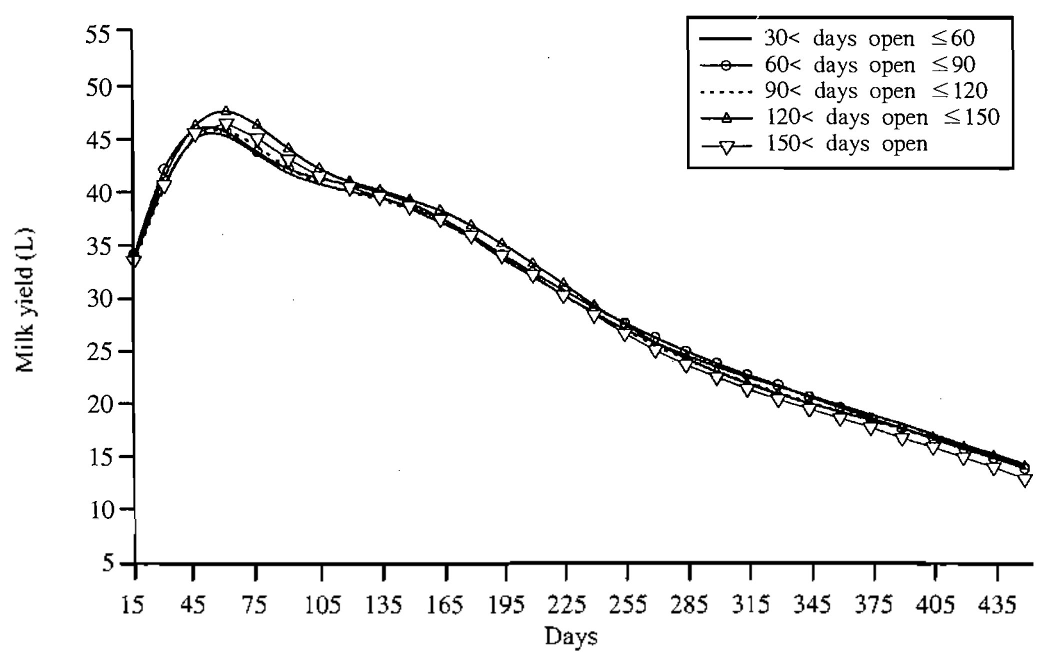

Figure 3. Lactation curves of the 2nd parity for five classes of days open

classes of days open (figure 3-6) show the variation between curves of different days open at early and late lactation. The middle part of the curves (105-255 d) is the part least affected by variation in days open and this is mainly due to the pregnancy effect which becomes more obvious after five months of conception. The interaction between milk yield and reproductive performance had been illustrated by Nebel and Mcgilliard (1993) since selection for milk has increased blood concentration of somatotropin and prolactin, stimulators of lactation, and decreased insulin, a hormone that is antagonistic to lactation and may be important for normal follicular development. Also, negative energy balance during early lactation may alter hypothalamic secretion of GnRH and its effect on gonadotropin secretion, and therefore ovarian secretion

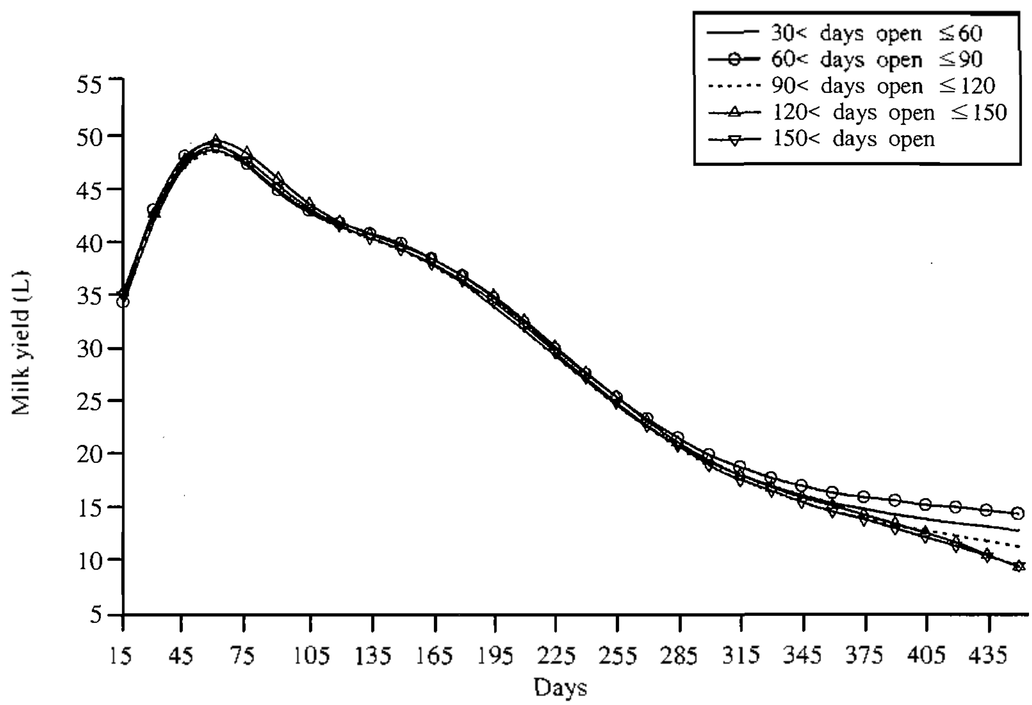

Figure 4. Lactation curves of the 3rd parity for five classes of days open

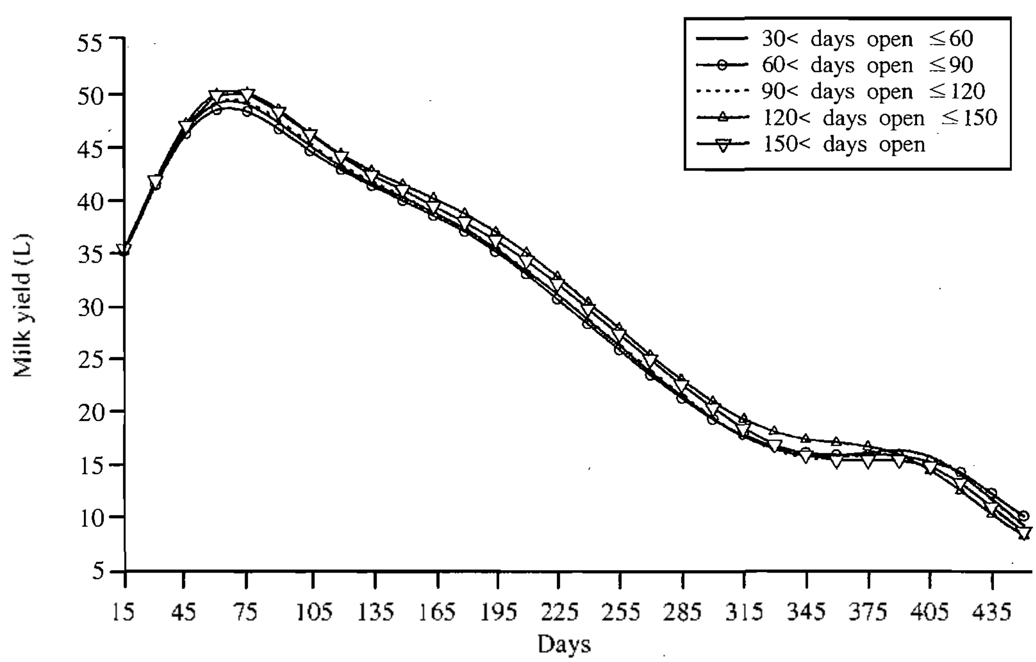

Figure 5. Lactation curves of the 4th parity for five classes of days open

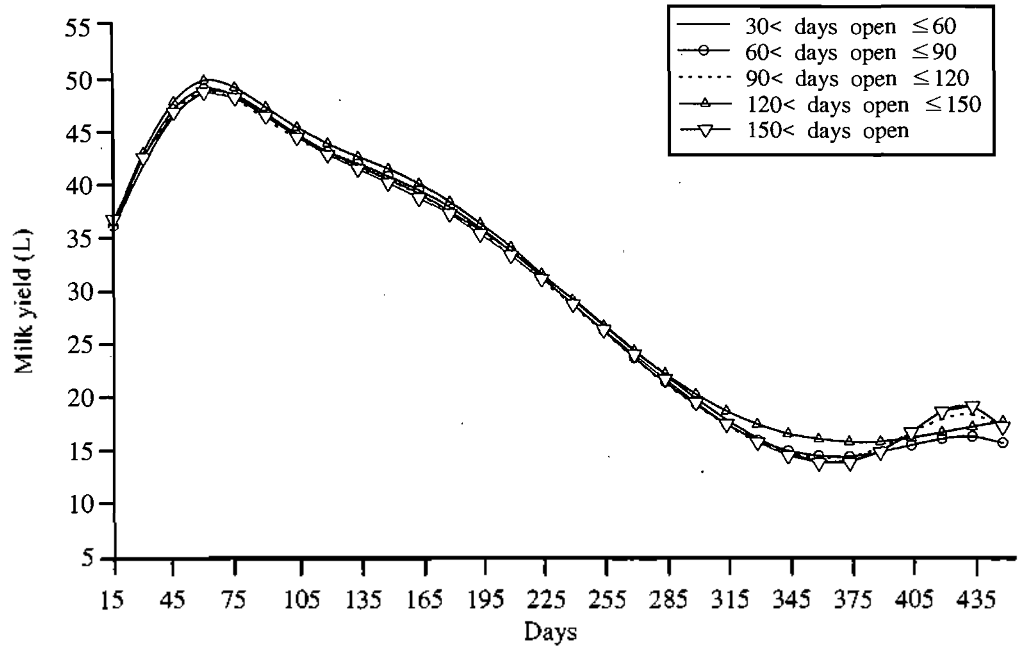

Figure 6. Lactation curves of the 5th parity for five classes of days open

Table 4. Initial yield* of different lactations by five classes of days open

Days open	Lactation L1	L2	L3	L4	L5
			Phase I		
1	21.1	18.6	0.3	16.1	16.1
2	19.7	20.3	17.1	1.9	11.7
3	25.9	23.3	21.6	3.9	11.9
4	21.5	22.8	17.2	20.8	11.1
5	17.7	5.6	30.4	8.2	10.2
Average	21.2	18.1	17.3	10.2	12.2
			Phase II		
1	0.1	5.2	17.0	2.1	0.2
2	0.3	0.1	0.1	28.9	0.3
3	3.6	0.0	0.1	16.5	0.0
4	0.6	0.8	1.1	2.2	0.0
5	2.6	20.5	14.8	14.9	0.0
Average	1.4	5.3	6.6	12.9	0.1
			Phase III		
1	8.1	6.0	12.2	9.9	12.7
2	8.9	10.3	12.5	0.3	16.4
3	3.1	7.7	8.0	5.3	17.4
4	8.8	8.1	10.4	5.0	18.5
5	9.5	2.9	5.8	6.3	21.1
Average	7.7	7.0	9.8	5.4	17.22

* $Y_t = \sum_{i=1}^{n} \{ a_i b_i [1 - \tanh^2(b_i(t - c_i))] \}$, computed at t=0.

of progesterone which affects expression of estrus.

The estimates for functions of parameters for different lactations and different days open of each phase of the triphasic functions are given in tables 4 to 8. These estimates included initial, peak, and 305-day yields; time of peak yield and duration of each phase. Estimates of functions of parameters were similar to overall yield class within parity except for combination with a few observations. Across lactation and across days open classes (table 4, 5 and 8), Phase

Table 5. Peak yield* of different lactations by five classes of days open

Days open	Lactation L1	L2	L3	L4	L5
			Phase I		
1	38.9	32.1	13.1	35.9	39.0
2	38.8	39.6	39.6	9.6	23.1
3	37.2	39.1	40.4	13.9	22.6
4	36.7	37.5	36.4	35.4	22.2
5	33.1	13.6	19.2	18.4	20.7
Average	36.4	32.8	29.7	22.6	25.5
			Phase II		
1	9.4	14.9	38.4	16.1	9.5
2	12.9	13.1	12.8	40.9	9.6
3	13.1	7.5	11.3	36.5	8.2
4	32.7	19.0	11.8	22.8	5.9
5	13.2	33.5	26.2	27.3	5.1
Average	16.3	17.6	20.1	28.7	7.7
			Phase III		
1	17.9	14.7	22.4	20.7	23.6
2	19.4	19.1	22.9	8.0	40.0
3	11.0	16.6	18.9	15.6	38.9
4	15.6	16.8	21.4	14.0	38.0
5	18.8	12.7	15.9	15.6	37.2
Average	16.5	16.0	20.3	14.8	35.5

* Peak yield=$a_i b_i$.

Table 6. Time of peak* of different lactations by five classes of days open

Days open	Lactation L1	L2	L3	L4	L5
			Phase I		
1	137.6	113.0	394.2	118.9	142.2
2	131.6	142.0	139.7	66.9	45.4
3	108.3	140.9	133.1	77.8	47.4
4	137.2	140.9	138.5	87.1	52.8
5	123.1	82.8	103.1	105.4	55.8
Average	127.6	123.9	181.7	91.2	68.7
			Phase II		
1	382.6	414.2	132.1	350.9	416.5
2	371.9	413.6	400.7	120.3	407.3
3	553.8	419.4	410.5	160.8	417.7
4	786.1	737.8	406.6	243.3	432.4
5	342.5	194.4	209.8	202.2	883.2
Average	487.4	433.9	311.9	215.5	511.4
			Phase III		
1	43.3	40.1	40.0	41.7	45.1
2	40.6	41.3	42.4	37.5	145.5
3	40.6	41.3	42.4	37.5	145.5
4	42.5	44.1	44.0	38.1	149.9
5	41.6	38.1	44.2	45.9	163.4
Average	42.8	41.8	43.4	40.9	132.5

* Time of peak=C_i.

Table 7. Duration* of different lactations by five classes of days open

Days open	Lactation L1	L2	L3	L4	L5
			Phase I		
1	334.3	292.8	302.4	249.1	281.6
2	303.1	329.5	284.6	92.4	104.2
3	351.8	375.3	319.9	124.9	112.2
4	359.4	383.4	300.9	228.3	120.1
5	295.2	162.6	231.1	219.3	125.0
Average	328.8	308.7	287.8	182.8	148.6
			Phase II		
1	243.7	743.5	274.5	415.6	316.9
2	283.2	188.2	244.0	397.2	229.2
3	882.9	192.2	249.3	338.5	204.0
4	592.6	645.3	435.6	265.7	162.5
5	468.5	506.1	527.3	496.3	209.8
Average	494.2	455.1	346.1	382.7	224.5
			Phase III		
1	91.2	79.2	97.6	91.9	108.8
2	86.1	99.5	103.9	31.3	286.9
3	67.9	94.3	88.4	71.8	312.3
4	115.6	99.4	103.6	74.8	351.8
5	95.1	55.9	81.3	90.0	412.7
Average	91.2	71.7	95.0	90.3	294.5

* Duration=$2/b_i$.

Table 8. 305-day yield* of different lactations by five classes of days open

Days open	Lactation L1	L2	L3	L4	L5
			Phase I		
1	9362.6	7119.8	908.4	7358.9	8712.9
2	8911.7	9485.3	8882.3	841.8	2053.0
3	8857.9	9820.1	9517.3	1597.0	2014.1
4	9069.4	9493.8	8364.2	6480.9	2272.1
5	7446.2	1950.9	3661.5	3422.9	2210.3
Average	8729.6	7573.9	6266.7	3940.3	3452.5
			Phase II		
1	493.9	2883.4	8403.3	2461.9	575.9
2	1001.4	222.5	536.3	10335.4	314.0
3	1961.6	122.2	432.0	8840.6	165.4
4	629.9	660.2	1336.5	4194.9	39.7
5	2290.6	9041.7	6972.7	7199.9	17.2
Average	1275.5	2586.0	3536.2	6606.5	222.4
			Phase III		
1	1423.4	1031.2	1834.9	1638.5	2161.2
2	1448.5	1599.4	1989.8	24282	9027.3
3	689.5	1358.9	1468.2	1000.9	9142.0
4	1501.8	1439.6	1903.1	946.7	9346.7
5	1519.7	665.9	1163.2	1246.2	9656.7
Average	1316.6	1219.0	1671.8	1016.8	7866.8

* $MY_{305} = \sum_{i=1}^{n}\{a_i(\tanh(b_i(305-c_i)) - \tanh(b_i(a-c_i)))\}$.

I of the triphasic function contributed the most for functions of initial yield, peak yield and 305-day yield days open have not affected the yield functions (initial, peak yield and 305-day) of the first phases and this mainly because phase I is nearly completed before most cows become pregnant. Phase II contributed the best especially for initial yield. Phases II and III were nearly equal and intermingled in contributions for peak yield and 305-day yield. Odd values of yields functions for different classes of days open were mainly due to a short lactation curve of that class or to unusual increase of the curve at the end of the lactation.

Phase II affected mainly the time of peak since phase II contributed the most on time of peak (table 6). Duration is a function useful to distinguish persistency (Grossman and Koops, 1988). Phases I and II played a major role in determining the values of duration for different parities and different days open classes (table 7). These results differ from De-Boer et al. (1989) who showed that phase III contributed the most, and phase I has least value for all the functions of the lactation curve. The discrepancy between those two studies may be due to the differences in data that represented Israeli Holstein cows that were raised under different climatic conditions. In this study the curve of the first phase declined considerably after 250 days whereas the second phase started and continued to be in a low phase up to 200 days of lactation, and the third phase declined rapidly after the first 100 days. The dairy cows in Almarai farm produced more than 70% of the milk yield during the first 250 days of lactation, which continued upto 375 days. Dairy farms in the Kingdom of Saudi Arabia do not dry their cows on 305-day of milk. Long lactation periods (>305 day) in Holstein cows raised in the Kingdom of Saudi Arabia is mainly due to: 1. low conception rate, Salah and Mogawer (1990a) found a low conception rate (45%) in two herds of Holstein cattle in the Kingdom. 2. Long days open, in another study, Salah and Mogawer (1990b) estimated the average days open as long as 140 days.

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