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Effect of Non-genetic Factors on Lactation Curve of Holstein Friesian Cows in Saudi Arabia

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Abstract. The Lactation curves of Holstein Friesian dairy cows were derived using biweekly test day milk (liter/day) from 20831 milk records during the period 1996-1999 on two dairy farms of Al Maria Company in the Central Region of the Kingdom of Saudi Arabia. Incomplete gamma was fitted for five lactation periods to estimate the parameters of the lactation curve. The data were analyzed using linear models to study the effect of different non-genetic factors (Farm, Year of calving, Lactation number, Age within lactation period, Milk level, season of calving, and Days open) on the lactation curve. Farm significantly affected the lactation curve during the first 255 days of the lactation period. Cows that calved in winter had earlier peak, higher maximum milk yield and were more persistent than cows that calved in summer. Cows in first lactation were more persistent and reached peak milk yield at low level of milk. The cows were characterized by long days open, close to 150 days. Wood's equation fitted adequately lactation curve when DIM (days in milk) was close to 305 days.

Introduction

Genetic and non-genetic factors have a significant effect on test day yield and consequently on the shape of the lactation curve. The recording system in some developing countries is still in its initial stage and most of these countries import AI semen from developed countries, Therefore, pedigree and progeny information is limited and is not yet available for estimating reliable genetic parameters. Thus Test-day yield must be used to clarity the influence of non-genetic factors such as farm, Lactation number, season of calving, years of calving, milk level and days in milk on the configuration of the lactation curve.

Farm effect on milk yield includes all management conditions that exist on the some farm, throughout a lactation period. Age or parity is the second important managerial factor affects lactation through the development of the secretary mammary gland tissue. [1-4] showed changes in the lactation curve of cows with advance of age.

The effect of season of calving might influence milk production throughout an entire lactation [5, 6] and consequently influence the shape of the lactation curve [7-9].

Days in milk (DIM) affect the length of the lactation curve, Despite that effect might follows a similar pattern for all cows in the same lactation within a herd groups [6, 10].

Days open is important in determining calving interval and influencing milk production. Several researchers [11-14] emphasized the need to consider days open when estimating the genetic merit of dairy cows.

Empirical Incomplete Gamma function [15] represents a description to the configuration of milk yield throughout a lactation period. The function has the ability to generate curves of many shapes and can fit lactation curves affected by many biological and environmental factors. The function is important for predicting 305-days milk yield from incomplete records and to make comparisons between cows, with less than 305-days record, possible.

The objective of this study is to investigate the effect of non-genetic factors that affected test-day yield and the lactation curve using the incomplete gamma function.

Material and Methods

The data used in this study consisted of 20831 milk records. Biweekly tests day milk yield (liters /day) were collected during the period 1996 – 1999 from two dairy farms of Al-Marie Company in the central region of the Kingdom of Saudi Arabia. Years of calving (yc) were classified into four classes; yc1, included all records of cows calved in 1996;Yc2 included records of cows calved in 1997; yc3 included records of cows calved during 1998; and yc4 included records of cows calved during 1999. Cows were divided into two groups according to calving season, S1 for cows calved during (winter) October to March and S2 for cows calved during (summer) April until September. Milk records were divided into two milking levels; level one (ML1) included all cows with milk production≤9500 liters; level two (ML2) cows with milk production >9500 liters.

Statistical analysis included only records of calving age ranging from 24 to ≤ 75 (mo). Due to the wide range of age at calving; the calving within lactations was classified as follows:

L1: ≥ 24 to ≤ 38; L2: > 38 to ≤ 48; L3: > 48 to ≤ 58; L4: > 58 to ≤ 68; and L6: > 68 to ≤ 75 mo; The data were classified into first lactation (Ln1) and lactation group (Ln

2-5 = pooled data of lactation 2, 3, 4 and 5), This was mainly due to the different shape of the first lactation compared to 2^{nd} ,3^{rd} ,4^{th} and 5^{th} lactation for Holstein cows raised in Saudi Arabia [16,17].

According to the frequency distribution of the overall data, days open ranged 50 to 190 days. The range was classified into seven intervals twenty days each.

The effect of lactation period was examined by classifying the lactation period (days in milk) into three categories: DIM 1: for records with lactation period ≤300 days; DIM 2: for records with lactation period >300 - 405 days; DIM 3: for records with lactation period >405 days.

Biweekly test-day milk yield of the overall data and groped lactation (LN 2, 3, 4 and 5) were analyzed according to the following model:

$$Y_{ijklmno} = \mu + FN_i + YC_j + S_k + LN_l + b(AG/LN)_m + DO_n + ML_o + Error$$

$Y_{ijklmno}$ = Biweekly milk yield.
μ = Overall mean.
FN_i = Farm effect (I = 1, 2).
YC_j = Years at calving effect (j = 1996…1999).
S_k = Season at calving effect (k = 1, 2).
LN_l = Lactation number (l =1, 2, 3, 4 and 5)
$(AG/Ln)_m$ = Age within lactation as a covariate (m = 1,…,10).
DO_n = Days open effect (n = 1…7).
ML_o = Milk yield level (o =1, 2).
b = Regression of age within lactation on biweekly test day.
Error = N (0, σ^2).

Days open were not included in the above model when used in the analyses of test-day yield for first lactation. Total milk yield was analyzed with days in milk classes in the model. Means of 30-monthly test-day milk yield of the overall data, first lactation (LN1), grouped lactation (Ln2-5), season of calving (S1, S2) and DIM were computed and used as an input to fit Wood's model [15] ($y_t = At^b e^{ct}$). Marquardt's method of nonlinear regression (Proc NLIN using Marquardt [18]) was used to find the parameters and predicted values of the lactation curve using Wood's Incomplete Gamma Function. Marquardt's method is equivalent to performing a series of ridge regression, which correct for colinearity or near singularity problems that arise from the correlation between the parameter of the lactation curve as given by [19].

Results and Discussion

Fitting incomplete gamma function using non-linear iterative technique resulted in estimates of the parameters of the lactation curves (Table 1). Parameters of different classes were used to estimate different functions that determined the shape of the lactation curve, as described by [10,15] such as: time of peak, maximum milk yield and persistency. Parameter (A) represents the starting level of the lactation curve of each class. Records of cows classified as: first lactation, farm 1, summer calving, calved in year 1999, 300 days in milk and days open less than 50 days, started at lower levels than records of cows in other classes.

Table 1. Parameters for the lactation curves of different classes of non-genetic effects

Class	A	b	C	b/c[1]	Peak[2]	Pers[3]
Overall	25.50	0.059	0.00069	85.99	31.36	7.70
Ln 1	22.40	0.063	0.00061	103.31	28.21	7.86
Ln 2-5	27.19	0.052	0.00065	80.13	32.49	7.71
Fn 1	24.32	0.065	0.00066	99.75	30.84	7.80
Fn 2	26.05	0.055	0.00071	78.48	31.34	7.66
S 1	28.19	0.042	0.00054	78.13	32.54	7.83
S 2	24.16	0.065	0.00069	94.12	30.47	7.74
Ycd 1	26.74	0.058	0.00083	70.40	32.38	7.50
Ycd 2	26.68	0.029	0.00029	100.13	29.72	8.36
Ycd 3	25.51	0.049	0.00041	119.20	30.76	8.17
Ycd 4	16.25	0.20	0.0015	113.59	36.74	7.81
Dim 1	22.84	0.106	0.0011	90.48	33.18	7.46
Dim 2	28.53	0.029	0.00033	87.01	31.56	8.23
Dim 3	25.03	0.055	0.00055	99.16	30.56	7.90
Do 1	21.94	0.087	0.00073	119.42	29.95	7.84
Do 2	26.11	0.075	0.00091	78.39	33.63	7.47
Do 3	29.98	0.031	0.00065	48.02	32.81	7.56
Do 4	29.19	0.038	0.00069	55.58	32.79	7.55
Do 5	25.57	0.071	0.00083	85.60	32.77	7.59
Do 6	27.17	0.055	0.00061	91.15	33.05	7.81
Do 7	25.69	0.074	0.00084	87.73	33.23	7.60

A,b,c are parameter of Wood's function.
[1] b/c = Days in milk at peak.
[2] Peak yield = $a\,(b/c)^{b}e^{-b}$.
[3] Pers (persistency) = -b (b+1) ln(c).
Ln1= First lactation, Ln 2-5 = Grouped lactation (2,3,4 and 5) .
Fn 1= Farm No 9; Fn 2 = farm No 13;
S1= Cows calved in winter; S2= cows calved in summer;
Ycd 1 = Year of calving 1996; Ycd 2 = Year of calving 1997;
Ycd 3 = Year of calving 1998; Ycd 4 = Year of calving 1999.
Dim1= 300 days in milk; Dim2 days 300-405 days in milk;
Dim3 405 days in milk.
DO1=50 ≥ to ≤ 70; DO2 =70 > to ≤ 90; DO3 =90 > to ≤ 110;
DO4 =110 > to ≤ 130;
DO5 =130 > to ≤ 150; DO6 =150 > to ≤170; DO7 =170 > to ≤ 190.

Parameter b and c represents the slopes of the ascending and descending phases of the curve, respectively. Early peak was observed for records of cows in farm 2, lactation group (ln 2-5), calved in winter, calved in year 1996 and completed 405 days in milk and with days open between 50 and 70 days. Peak yield was lower for cows in farm 1, of first lactation, calved in summer, calved in year 1996, with 450 days in milk and days open ≤50 days than cows in other classes (Table 2).

Table 2. Least square mean of total milk yield for overall data and different lactation of different classes

Class	Overall	Ln2	Ln 2-5	Ln2	Ln3	Ln4	Ln5
Fn 1	10471±156[a]	9927±42[a]	10426±151[a]	10469±85[a]	10952±100[a]	10410±162[a]	10374±142[a]
Fn13	10988±149[b]	10685±49[b]	11038±140[b]	11400±64[b]	11336±80[b]	10930±128[b]	11077±103[b]
S1	11050±152[a]	10737±47[a]	10985±144[a]	11104±64[a]	11370±81[a]	11164±118[a]	10968±102[a]
S2	10409±151[b]	9875±34[b]	10479±143[b]	10766±56[b]	10918±70[b]	10177±102[b]	10483±97[b]
Ycd 1	11310±154[a]	11753±69[a]	10994±147[a]	11593±100[ac]	11290±104[a]	10909±156[a]	10969±153[a]
Ycd2	11492±152[b]	11381±55[b]	11289±147[b]	11612±83[a]	11594±113[b]	11268±142[b]	11202±136[a]
Ycd 3	11171±152[c]	11046±48[c]	11074±145[c]	11414±75[c]	11702±91[bc]	10625±138[a]	1093±115[ac]
Ycd 4	8945±161[d]	9572±76[d]	9572±155[d]	9120±102[b]	9990±113[c]	9852±167[c]	9799±164[b]
ML2	8284±154[a]	8666±54[a]	7837±148[a]	8370±90[a]	8337±103[a]	7501±139[a]	7701±137[a]
ML2	13175±151[b]	11946±37[b]	13628±142[b]	13499±52[b]	13951±64[b]	13839±100[b]	13750±84[b]
Dim1	8987±151[a]	8708±37[a]	8901±124[a]	9018±50[a]	9318±61[a]	8991±90[a]	9058±85[a]
Dim2	10025±152[b]	9463±42[b]	10066±134[b]	10230±64[b]	10408±77[b]	9933±120[b]	10294±107[b]
Dim3	13176±158[c]	12747±158[c]	13229±156[c]	13555±103[c]	13706±141[c]	13087±209[c]	12824±173[c]
Do1	10623±152[a]	.	10672±144[a]	11080±85[a]	10938±82[a]	10493±119[a]	10707±119[ac]
Do2	10840±153[b]	.	10827±145[b]	10884±77[ab]	11234±95[b]	10810±135[a]	16099±133[a]
Do3	10797±157[cb]	.	10773±150[ab]	10943±88[ab]	11095±112[ab]	10798±172[a]	10870±167[a]
Do4	10800±161[db]	.	10806±154[ab]	10963±102[ab]	11280±129[ab]	10705±193[a]	10844±177[a]
Do5	10642±159[a]	.	10659±151[a]	10775±97[b]	11104±116[ab]	10578±174[a]	10794±167[ac]
Do6	10635±169[acd]	.	10625±162[a]	10886±132[ab]	11016±148[ab]	10637±236[a]	10500±201[abc]
Do7	10769±167[ab]	.	10763±160[ab]	11014±116[ab]	11370±151[cb]	10670±239[a]	10364±192[c]

[1] b/c = Days in milk at peak.
[2] Peak yield = $a (b/c)^{b} e^{-b}$.
[3] Pers (Persistency) = -b (b+1) ln(c).
Ln1= First lactation, Ln 2-5 = Grouped lactation (2,3,4 and 5) .
Fn 1= Farm No 9; Fn 2 = Farm No 13;
S1= Cows calved in winter; S2= Cows calved in summer;
Ycd 1 = Year of calving 1996; Ycd 2 = Year of calving 1997; Ycd 3 = Year of calving 1998;
Ycd 4 = Year of calving 1999;
ML 1= Milk level ≤ 9500 liters; ML 2 = Milk level > 9500 liters.
Dim1= 300 days in milk; Dim2 days 300-405 days in milk; Dim3 405 days in milk.
DO1=50 ≥ to ≤ 70; DO2 =70 > to ≤ 90; DO3 =90 > to ≤ 110; DO4 =110 > to ≤ 130;
DO5 =130 > to ≤ 150; DO6 =150 > to ≤170; DO7 =170 > to ≤ 190;

Farm effect

Fitting the linear model to biweekly test-day yield (Tables 3,4 and 5) showed a significant ($P < 0.01$) effect due to farm during the first seventeen tests i.e. the first 255 days. Least square means (Table 2) showed significant ($P < 0.01$) differences between total milk yield across lactation’s of farm 1 and farm 2. The differences in milk yield between the two farms were 758, 941, 384, 520 and 703 liter for lactation’s 1 to 5 respectively.

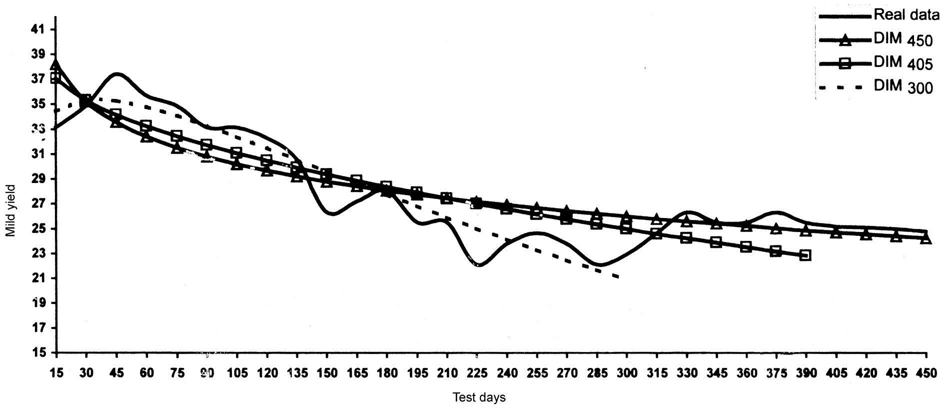

Fig. 1. Lactation curve of the overall data for the classes of days in milk.

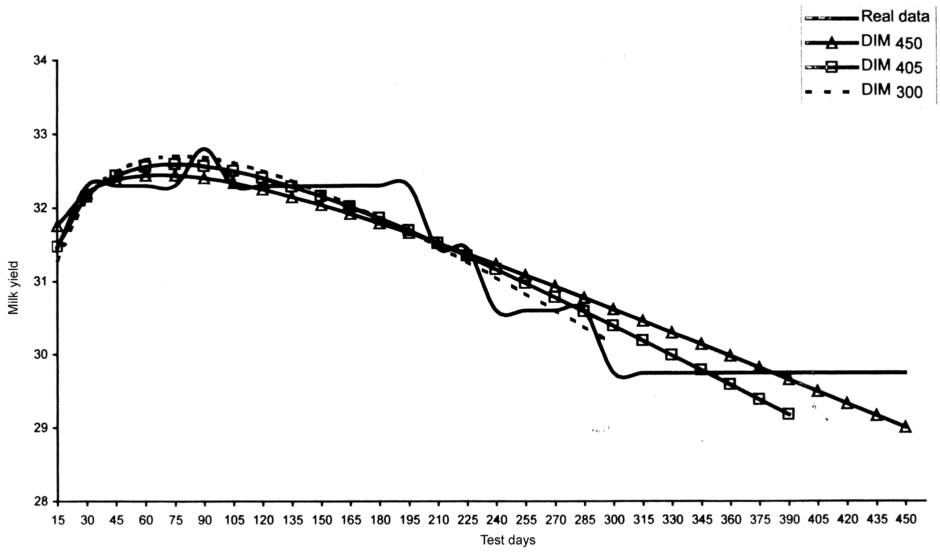

Fig. 2. Lactation curve of the lactation group (LN 2-5) for the classes of days in milk.

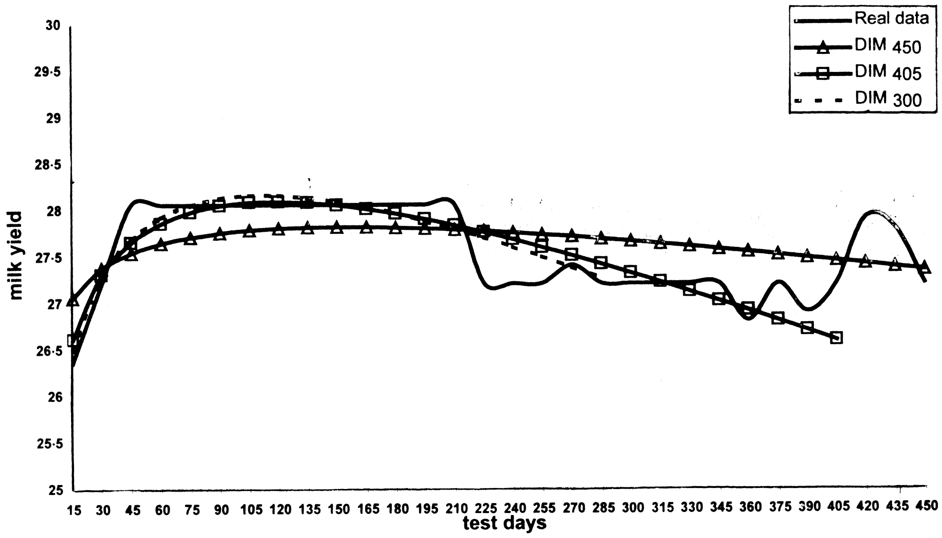

Fig. 3. Lactation curve of the first lactation (LN 1) for the classes of days in milk.

Milk yield of a dairy farm is a composite value of the cows in that farm (herd). Consequently, individual cow effect, other non-genetic factors and the quality of overall management influence farm yield. [20] Pointed out that changes in heard milk level were mainly due to change in ration, change in heifer raising program and the shape of the lactation curve. Several studies [7,16,21,22] showed a significant effect to farm on shape of the lactation curve and milk yield. Furthermore, all previous research, [23-25] concerned with estimating genetic parameters, took into account herds differences and corrected for them combined with year and season (herd- year-season).

Age effect

Age is a major factor that affects biweekly test-day milk yield. (Table 2) shows a significant effect of age on milk yield as indicated by the increase in lactation number and advancing age within lactation. The increase in milk yield with the advancing of age was explained to be partially due to the increase in body weight, resulting in a larger digestive system and larger secretary tissues in the mammary gland. [1- 4, 26] showed changes in the shape of the lactation curve associated with age. A similar age effect within lactation was observed for the lactation group (Table 3). Age at calving within first lactation (Table 4) showed significant effect in early and middle stages of lactation. [27] Suggested that the effect of age on milk production could be divided into two parts: during the first and second lactation’s, where yield was directly related to age of calving, while during subsequent lactation’s there is an inverse relationship between milk yield and age at calving.

Table 3. Effect of farm number (Fn), season at calving(S), lactation number (LN),milk level (ML),days in milk (DIM), years of calving (Ycd), age in lactation (Ag/LN) and days open on overall data

M	Mean	Fn[1]	S[2]	LN[3]	ML[4]	Dim[5]	*Ycd*[6]	Ag/LN[7]	DO[8]
M1	34.74	**	**	**	**	**	**	**	**
M2	35.67	**	**	**	**	**	**	**	**
M3	36.32	**	**	**	**	**	**	**	**
M4	36.70	**	**	**	**	**	**	**	**
M5	36.71	**	**	**	**	**	**	**	**
M6	36.78	**	**	**	**	**	**	**	**
M7	36.71	**	**	**	**	**	**	**	**
M8	36.70	**	**	**	**	**	**	**	**
M9	36.65	**	**	Ne	**	**	**	**	**
M10	36.41	**	**	Ne	**	**	**	**	**
M11	36.24	**	**	Ne	**	**	**	**	Ne
M12	36.20	**	**	Ne	**	**	**	**	Ne
M13	36.08	**	**	Ne	**	**	**	**	Ne
M14	35.74	**	**	Ne	**	**	**	**	Ne
M15	35.55	**	**	Ne	**	**	**	**	Ne
M16	35.25	**	**	Ne	**	**	**	**	Ne
M17	34.78	**	**	Ne	**	**	**	**	Ne
M18	34.88	Ne	**	Ne	**	**	**	**	Ne
M19	34.89	Ne	**	Ne	**	**	**	**	Ne
M20	34.56	Ne	**	Ne	**	**	**	**	Ne
M21	34.51	Ne	**	Ne	**	Ne	**	**	Ne
M22	34.55	**	**	Ne	**	Ne	Ne	**	Ne
M23	34.66	**	Ne	Ne	**	Ne	**	**	Ne
M24	34.75	**	**	Ne	**	Ne	**	Ne	Ne
M25	34.75	Ne	**	Ne	**	**	**	Ne	Ne
M26	35.05	**	Ne	Ne	**	**	**	Ne	Ne
M27	34.92	**	**	**	**	**	**	**	Ne
M28	35.07	Ne	**	Ne	**	**	**	Ne	Ne
M29	35.25	**	**	Ne	Ne	**	Ne	Ne	Ne
M30	35.26	Ne	Ne	Ne	**	**	Ne	Ne	Ne
My	10903	**	**	**	**	**	**	**	**

M1-M30 = Test day.

My = Total milk yield.

Fn 1= Farm No 9; Fn 2 = Farm No 13;
S1= Cows calved in winter; S2= Cows calved in summer;
Ycd 1 = Year of calving 1996; Ycd 2 = Year of calving 1997;
Ycd 3 = Year of calving 1998; Ycd 4 = Year of calving 1999.
Ag/LN = Age within lactation as a covariate 1 to 10.
Dim1= 300 days in milk; Dim2 days 300-405 days in milk;
Dim3 405 days in milk.
DO1=50 ≥ to ≤ 70; DO2 =70 > to ≤ 90; DO3 =90 > to ≤ 110;
DO4 =110 > to ≤ 130; DO5 =130 > to ≤ 150; DO6 =150 > to ≤170;
DO7 =170 > to ≤ 190.

Season and year of calving

Season and year of calving significantly (p<. 01) effected the first 300 days of the lactation curve (Tables 3,4 and 5). The effect of season of calving on biweekly test yield led to an increase of total milk yield in winter calving (Table 2).

Table 4. Effect of farm number (Fn), season at calving(S), lactation number (LN), milk level (ML), days in milk (DIM), years of calving (Ycd) and age in lactation (Ag/LN) on LN 1

M	Mean	Fn	S	My	Dim	Ycd	AG/LN
M1	30.86	**	**	**	**	**	**
M2	31.76	**	**	**	**	**	**
M3	32.63	**	**	**	**	**	**
M4	32.86	Ne	**	**	**	**	**
M5	32.91	**	**	**	**	**	**
M6	32.83	**	**	**	**	**	Ne
M7	32.93	**	**	**	**	**	Ne
M8	33.03	**	**	**	**	**	Ne
M9	33.10	**	**	**	**	**	Ne
M10	32.75	**	**	**	**	**	**
M11	32.80	**	**	**	**	**	**
M12	32.64	**	**	**	**	**	**
M13	32.66	**	**	**	**	**	**
M14	32.54	**	**	**	**	**	**
M15	32.38	**	**	**	**	**	**
M16	32.27	**	**	**	**	**	**
M17	32.04	**	**	**	**	**	**
M18	32.05	Ne	**	**	**	**	**
M19	32.67	Ne	**	**	**	**	**
M20	31.59	Ne	**	**	**	**	Ne
M21	31.61	Ne	**	**	**	**	**
M22	31.61	Ne	Ne	**	Ne	**	**
M23	31.77	Ne	Ne	**	**	**	**
M24	31.46	Ne	Ne	**	Ne	**	Ne
M25	31.32	Ne	Ne	**	Ne	Ne	Ne
M26	31.93	Ne	Ne	Ne	Ne	Ne	Ne
M27	31.14	Ne	Ne	Ne	Ne	Ne	Ne
M28	31.71	Ne	Ne	Ne	Ne	Ne	Ne
M29	32.61	Ne	Ne	Ne	Ne	Ne	Ne
M30	31.44	Ne	Ne	Ne	Ne	Ne	Ne
My	9950	**	**	**	**	**	**

M1-M30 = Test day.

My = Total milk yield.

Fn 1= Farm No 9; Fn 2 = farm No 13;
S1= Cows calved in winter; S2= cows calved in summer;
Ycd 1 = Year of calving 1996; Ycd 2 = year of calving 1997;
Ycd 3 = Year of calving 1998; Ycd 4 = year of calving 1999.
Ag/LN = Age within lactation as a covariate 1 to 10.
Dim1= 300 days in milk; Dim2 = 300-405 days in milk;
Dim3 = 405 days in milk.

Lactation curve for cows calved in winter season (Fig. 4) started with high level at 52 liters, showed no peak and decreased rapidly to dry off at 26 liter .The curves of actual data and three days in milk classes (DIM1, DIM2 and DIM3) were very close among all lactation periods.

Lactation curve for summer calvings (Fig. 5) started at low level 25 liter and reached a peak at 35 liter (Table 1). The differences in Least square means of total milk yield of two seasons of calving were 862, 338, 452, 987 and 485 liter for lactations 1 to 5 respectively. The effect of season of calving is stimulus to milk yield due to the time of the year in which lactation was initiated and caused by season of production [1, 28] corrected the incomplete gamma function to adjust for spring hump seasonally.

Despite significance differences exist between year of calving across lactations (Table 2), cows calved in year 1999 produced less milk than cows calved in other years; since the cows were milking in progress or milked more than 150 days and have reached the dry off before 300 days in milk. Thus month of calving and the year in which the cow was freshened affected the lactation curve.

In Saudi Arabia, heat stress is one of the major limiting factors for dairy production; a cow that freshens in summer faces the heat stress of summer early in lactation when the cow has the urge to produce milk and the lactation curve is in the ascending phase. On the other hand, a cow that calves in winter would make the last part of the descending phase of the lactation curve in summer. Least square means of total milk yield (Table 5) showed a significant differences (p <. 01) between the two seasons. [9] Found that evaporative cooling could alleviate seasonal differences in milk production in dairy farms in Saudi Arabia. Year of calving showed a highly significant (p<01) effect on biweekly test yield, up to 360 d for first lactation and up to 390 d for lactation group. These results are similar to the findings of [21, 29].

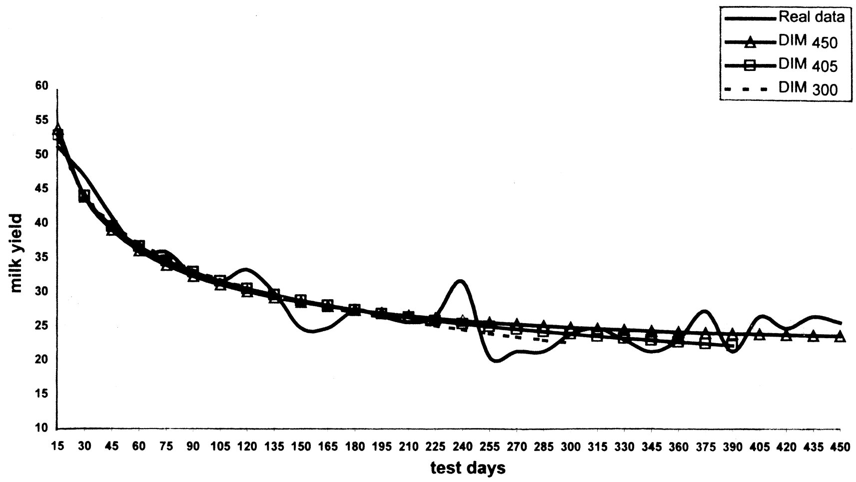

Fig 4.. Lactation curve of the season 1 (winter) for the classes of days in milk.

Days in milk effect

Lactation curve of Wood's model for actual data and three classes of days in milk (DIM1=300, DIM2=405 and DIM3=450) of overall data are shown in (Fig. 2). The lactation curves for overall data showed the closeness of 300-day lactation curve to the curve of the actual data. The curve of DIM2 showed discrepancy from the real data in the first part of the (first 150 days) and the last part of lactation (>240 days). This discrepancy increased for the same periods for the curve of DIM3. The curve of first lactation, (Fig. 3) showed adequate fit for Wood’s model, the closeness of predicted value to the actual data for lactation of 300 and 405 days, and poor fit of Wood’s model to the curve 450 days. Similar results were observed for lactation group (Fig. 2).

Table 5. Effect of farm number (Fn), season at calving (S), lactation number (LN), milk level (ML), days in milk (DIM), years of calving (Ycd), age in lactation (Ag/LN) and days open on Ln 2-5

M	Mean	Fn	S	Ln	My	Dim	Ycd	AG/LN	Do
M1	36.62	**	**	Ne	**	**	**	**	**
M2	37.52	**	**	**	**	**	**	**	**
M3	38.00	**	**	Ne	**	**	**	**	*
M4	38.45	**	**	Ne	**	**	**	**	**
M5	38.42	**	**	Ne	**	**	**	**	**
M6	38.53	**	**	Ne	**	**	**	**	Ne
M7	38.35	**	**	Ne	**	**	**	**	Ne
M8	38.29	**	**	Ne	**	**	**	**	Ne
M9	38.21	**	**	Ne	**	**	**	**	**
M10	38.07	**	**	Ne	**	**	**	**	Ne
M11	37.72	**	**	Ne	**	**	**	**	Ne
M12	37.70	**	**	Ne	**	**	**	**	**
M13	37.54	**	**	Ne	**	**	**	**	**
M14	37.11	**	**	Ne	**	**	**	**	**
M15	36.89	**	**	Ne	**	**	**	**	**
M16	36.53	**	**	Ne	**	**	**	**	Ne
M17	36.07	Ne	**	Ne	**	**	**	**	Ne
M18	35.96	Ne	**	Ne	**	**	**	**	Ne
M19	35.96	Ne	**	Ne	**	**	**	**	Ne
M20	35.43	Ne	**	Ne	**	**	**	**	Ne
M21	35.26	Ne	**	Ne	**	Ne	**	**	Ne
M22	35.21	**	**	Ne	**	Ne	Ne	**	Ne
M23	35.17	**	Ne	Ne	**	Ne	**	**	Ne
M24	35.25	Ne	**	Ne	**	Ne	**	Ne	Ne
M25	35.16	Ne	**	Ne	**	**	**	Ne	Ne
M26	35.32	Ne	Ne	Ne	**	**	**	Ne	Ne
M27	35.11	Ne	**	**	**	**	Ne	**	Ne
M28	35.25	Ne	**	Ne	**	**	Ne	Ne	Ne
M29	35.34	**	**	Ne	Ne	Ne	Ne	Ne	Ne
M30	35.36	Ne	Ne	**	**	**	Ne	Ne	Ne
My	11335	**	**	**	**	**	**	**	Ne

M1-M30 = Test day.

My = Total milk yield.

Fn 1= Farm No 9; Fn 2 = farm No 13;
S1= Cows calved in winter; S2= cows calved in summer;
Ycd 1 = Year of calving 1996; Ycd 2 = year of calving 1997;
Ycd 3 = Year of calving 1998; Ycd 4 = year of calving 1999.
Ag/LN = Age within lactation as a covariate 1 to 10.
Dim1= 300 days in milk; Dim2 = 300-405 days in milk;
Dim3 =405 days in milk.
DO1=50 ≥ to ≤ 70; DO2 =70 > to ≤ 90; DO3 =90 > to ≤ 110;
DO4 =110 > to ≤ 130; DO5 =130 > to ≤ 150; DO6 =150 > to ≤170;
DO7 =170 > to ≤ 190.

However, the curve of Wood’s model and actual data of first lactation showed low level of milk yield along the entire lactation period. [20] pointed out that lactation curves can be developed by using the average test-day data on milk yield (test-day yield) grouped in monthly intervals of DIM within parity groups (1, 2 and≥ 3).

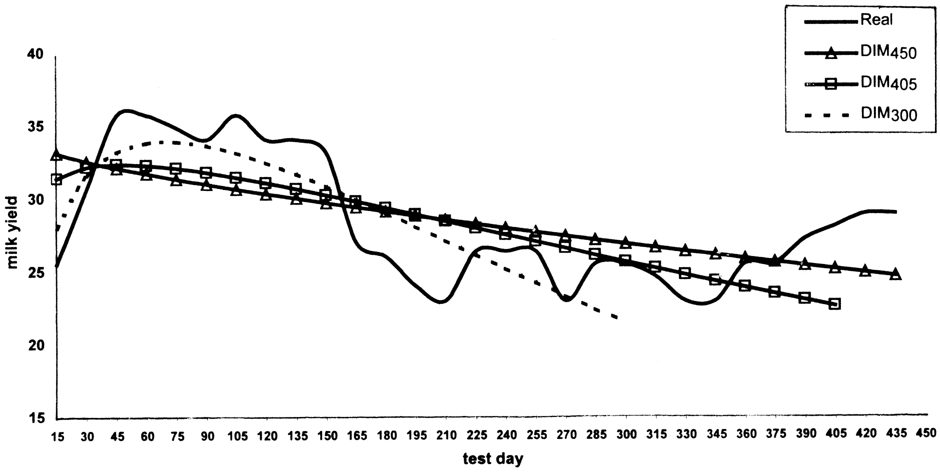

Fig. 5. Lactation curve of the season 2 (summer) for the classes of days in milk.

Residual mean square (RMS) of non-linear fitting of Wood's model for overall data and different lactation numbers, season of calving, milk level and days open for different days in milk (DIM1, DIM2 and DIM3) are given in (Table 6). RMS within each class increased with the increase of length of DIM, and for overall data the RMS values were 2.38, 6.54 and 7.70 for DIM1, DIM2 and DIM3, respectively. Small RMS values are an indication of the adequacy of Wood's model for fitting lactation curve and predicting 305- day milk yield.

Dairy cows raised in Saudi Arabia are characterized by long days in milk (> 305 day) due to: 1- low reproductive performance; [30] found the conception rate was as low as 45% in two herds of Holstein cows and [17] found that dairy cow could have up to 150 days open before getting pregnant. 2- dairy cows are allowed to stay in the herd as long as they are making profit.

Calving interval and days open

Calving interval is defined as the period from parturition to the following parturition, which is the sum of gestation length and days open. In this study, the variation in calving interval was found to be mainly due to differences in days open length. The significance of days open of overall data and lactation group at early stage of lactation is mainly due to carry over effect of previous days open. [14] pointed out to the effect of previous and present days open on lactation yield. In the present study grouped lactation (Ln 2-5) (Table 5) showed a significant effect for days open for the period >

165 to 225 days while was mainly due to pregnancy effect. [13] found that the inhibitory effect of pregnancy should be minimal for the first 120 days of pregnancy. [17] reported that the difference in milk yield between cows with days open <60 days and days open >150 days was 1021 liter. Moreover, the difference in milk yield at early lactation decreased from 1021 to 829 liter as the days open increased from 75 to 125 days.

Residual mean square (Table 6) increased with increasing the length of days open which reflected the increasing variation of milk yield with the increased length of days open. Several researches [12-14, 31] indicated that a long calving interval increase the total current yearly production and total life time production of a cow but did not increase average daily production for her productive life time. Cows which have long calving intervals, such as the dairy cows in Saudi Arabia, usually live longer and produce more than cows with short calving interval, but average daily production is higher for the frequently freshening cows (cows with short calving intervals).

Table 6. Residual mean square of non linear fitting of Wood's function

		DIM 1	**DIM 2**	**DIM 3**
	Overall	2.38	6.54	7.70
LN	LN 2-5	0.11	0.12	0.19
	LN	0.07	0.10	0.63
	S1	6.68	6.77	7.25
S	S2	17.55	18.87	20.06
	ML1	6.56	25.21	26.26
ML	ML2	2.93	4.65	6.72
	DO 1	4.09	6.65	6.94
	DO 2	4.09	6.65	6.94
	DO 3	17.25	16.32	18.47
DO	DO 4	33.3	33.7	34.6
	DO 5	25.02	25.45	27.99
	DO 6	44.00	51.03	52.96
	DO 7	53.10	63.60	66.09

Dim1= 300 days in milk; Dim2 = 300-405 days in milk;
Overall data , Ln1= First lactation and Ln 2-5 = Grouped lactation (2,3,4 and 5)
S1= Cows calved in winter; S2= Cows calved in summer.
ML 1= Milk level ≤ 9500 liters; ML 2 = Milk level > 9500 liters.
DO1=50 ≥ to ≤ 70; DO2 =70 > to ≤ 90; DO3 =90 > to ≤ 110;
DO4 =110 > to ≤ 130; DO5 =130 > to ≤ 150; DO6 =150 > to ≤170;
DO7 =170 > to ≤ 190.

Milk level

The pattern of the lactation curve (Fig. 6) of the three classes of DIM for the first milk level showed close fitness of Wood's curve to the actual data in the first 200 days in milk after that the curve showed more variation and more discrepancy from the real data for curve of DIM2 and DIM3. The same pattern was observed in the lactation curves for second milk level (Fig. 7).

The differences in least square means of total milk yield, (Table 2) between high and low producing cows were 3280, 5129, 5614, 6338 and 6049 for lactations 1 to 5 respectively.

The diverse feeding and management condition as well as annual climate changes in Saudi Arabia may also explain the significant effect. [9] found a highly significant effect of milk level along all lactation. Moreover, the difference between winter and summer calving were more obvious along the curve of high producers than low producers, because high producers have a high metabolic rate than low or average producers. [32].

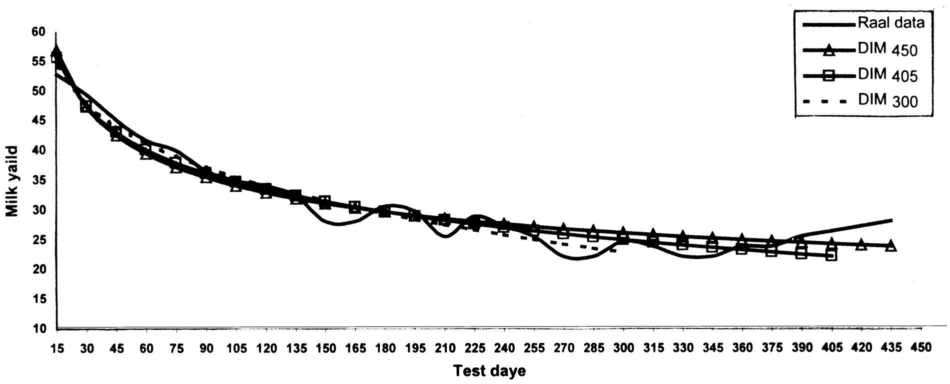

Fig 6. Lactation curve of the milk level 2 (>9500 liter) for the classes of days in milk.

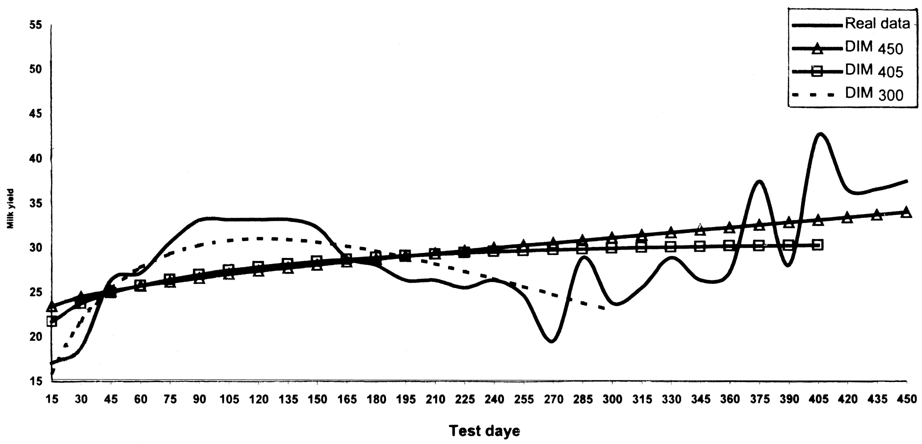

Fig. 7. Lactation curve of the milk level 1 (≤ 9500) for the classes of days in milk.

Residual Mean square (Tables 1-6) increased with the increase of days in milk and values decreased at high milk level. Residual mean square (RMS) for high producing cows were 2.93, 4.65 and 6.72 for the three classes of days in milk, respectively; and their corresponding values for low producing cows were 6.56, 25.21 and 26.26, respectively.

Conclusion

In conclusion, cows in Farm 2 produced more milk. Cows calved in winter produced more milk, reached the peak earlier, had a higher maximum milk and were more persistent than summer calving.

Cows in first lactation were more persistent and reached the peak late at low level of milk. Most cows in these studies have long lactation period exceeding 300 days, and long day open close to 150days. High producing cows have less variation along the entire lactation curve. Wood's equations are more adequate to cows with standard 305 days lactation curve.

Days open adjustment must be made on the records. Cow with long days open, and long calving interval should have records adjusted downwards, and cows with short days open should have record adjusted upwards.

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تأثير العوامل غير الوراثية على منحنى الحليب لبقر الهولستين فريزيان في المملكة العربية السعودية

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(قدم للنشر في ١٢/٢/ ١٤٢٢؛ وقبل للنشر في٢٨/١١/ ١٤٢٢هـ)

الملخص البحث. في دراسة لمنحنى الحليب لبقر الهولستين فريزيان استخدم ٢٠٨٣١ سجلاً لاختبار يوم حليب كل خمسة عشر يوماً. جمعت هذه السجلات في الفترة من ١٩٩٦ إلى ١٩٩٩ م من مزرعتين لبقر الحليب لشركة المراعي في المنطقة الوسطى من المملكة العربية السعودية. استخدمت معادلة جاما الناقصة مع خمسة مواسم حليب لتقدير ثوابت منحنى الحليب باستخدام المعادلة الخطية لمعرفة تأثير العوامل غير الوراثية (مثل المزرعة ،سنة الولادة، رقم موسم الحليب، العمر داخل موسم الحليب، مستوى الإنتاج و عدد الأيام المفتوحة) على منحنى الحليب. وجد أن هناك تأثير معنوي للمزرعة في ٢٥٥ يوم الأولى من موسم الحليب ووصلت البقر التي ولدت في الشتاء مبكراً لأقصى إنتاج كما تميزت بمثابرة أعلى عن البقر التي ولدت في فصل الصيف. ووجد أن البقر الصغيرة في العمر كانت أكثر مثابرة من غيرها ولكن بمستوى إنتاج منخفض. كما تميزت البقر تحت الدراسة بأن لها موسم حليب يمتد إلى ٤٥٠ يوما وتميزت أيضاً بأيام مفتوحة تصل إلى ١٥٠ يوما. أعطت معادلة جاما الناقصة تمثيلاً ملائماً لمواسم الحليب التي كانت طول موسم الحليب فيها تقترب من ٣٠٥ أيام.