Vet.Med.J.,Giza. Vol.52, No.2. (2004):231-244.

RESPONSE SURFACE AND FIXED EFFECTS MODELS OF NON-GENETIC FACTORS FOR DAIRY COWS IN SAUDI ARABIA

A.K.A. ALI; A.A. ALESSA;M.A. ALSHAIKH; R.S. ALJUMAAH; A.A. AL-HAIDARY; M. S. ALKRAIDEES.

Dept. of Animal Production; College of Agriculture; King Saud University, PO. Box 2460 Riyadh 11451. Kingdom of Saudi Arabia

Received: 10. 4. 2004.
Accepted: 24. 4. 2004.

SUMMARY

Response surface model of statistical analysis was used to quantify the relationship between non-genetic factors (NGF) such as days open (DO), days in milk (DIM), age at calving and milk production. Data included 103.776 records, each one had cow identification, non genetic traits and production traits such as total milk production, 305-milk yield and peak yield. Least square means of three farms were 10467, 11047 and 10697 liters of milk respectively. Cows calved on fall-winter season produced 10839 liters, compared with 10636 liters for cows calved in spring-summer season. Second lactation cows gave the highest production (11, 105 liters), and sixth lactation cows produced the lowest production (10, 283 liters). Significant parameters (p<.01) supported the linear and quadratic relationship between age at calving and total yield, 305-dyield and peak milk production, respectively. The DIM had a significant linear effect on milk production (p<.01). Also, quadratic representation of DIM was observed along the whole milk curve. Days open showed no linear significant effect on milk production. However, significant quadratic effect (p<.05) was found between DO and 305-d yield. The ANOVA of fixed model showed a significant effect of NGF on production traits.

INTRODUCTION

Systematic non-genetic factors have great impact on milk production. Factors such as days open (DO), age at calving (AM) and days in milk (DIM) can be accounted for, and milk production can be corrected to remove much of the variations in production associated with these factors. Therefore, studying the relationship between milk production and non-genetic factors is beneficial in determining the cut off point of adequate days open, age at calving and days in milk which achieve the optimum profitability of dairy cows.

Grusenmeyer et al. (2002) found that milking cows in late lactation is less profitable due to the decline in production as indicated by the normal lactation curves, and the loss per cow per day for each day over 150 days in milk was o .17 Ibs. for herds with production level over 16.000 Ibs. and 0.13 Ibs. for herds under 16.000 Ibs.

Regression coefficients of days open on milk production was used by Marti and Funk (1994) who found that cows had 1.1 to 1.3 more DO for each 100 kg more milk and regression coefficients from four production groups showed an antagonistic relationship between days open and production. However, DO were longer for cows with higher production. When production records were adjusted for days open, regression coefficients of days open on production was 1.3 d for each 100 kg. Moreover, milk adjusted factors for DO were similar in different production groups.

Ali et al. (2000) found that the difference in milk yield between cows with days open < 60 days and days open > 150 days was 1.021 liters of milk. This difference was larger than that found by Oltenacu et al. (1980), Funk et al . (1987) and Schaeffer et al. (1972). The difference in milk yield at early lactation decreased from 1.021 to 8.29 liters as the days open increased from 75 to 175 days, and this is probably due to the decrease in the conception impact on milking with advancing lactation. Furthermore, Linear and quadratic effects of days open on 305-day milk production was noticed by Schaeffer et al. (1972) where an open period between 60 and 90 days was found ideal in terms of efficient production. Miller et al. (1970) noted that different age adjustment factors are needed for different seasons of freshening. Therefore, simultaneous adjustment factors are needed for age at freshening and season of calving.

The objectives of this study were to examine the type of relationship between DO, DIM and age in month and milk yield. Also , the effects of farm, lactation number, DIM, AM, season of calving, milk level and year of calving on actual milk yield, peak yield and 305-day predicted milk yield of Holstein cows in Saudi Arabia were determined .

MATERIAL AND METHODS

Records of milk production and reproduction traits were collected from three dairy farms (Holstein) under the same managerial conditions of AL-Maraie Company in the central region of Kingdom of Saudi Arabia during the period from 1991 to 1999. The data consisted of 103776 records, each record included information about farm number, animal identification, lactation numbers, birth date, calving date, age at calving, actual milk yield, 305-d milk yield and days in milk. According to calving data, cows were grouped into two seasons of calving: winter (S1) for cows calved from October to March, and summer (S2) for cows calved from April to September. Milk records were also divided into two levels of milk production: level one (ML1) for cows with production ≤ 9500 liters, level two (M12) for cows with milk production > 9500 liters of milk.

Fiequency distribution of records by age in month showed the first parity included cows calved at age ≤ 21 to ≥ 32 months, whereas the second parity included cows calved at age ≤ 33 to ≥ 44 months. Each parity thereafter included cows calved at 12 months interval up to the sixth parity which included cows calved at ≤ 81 to ≥ 92 month. Age at calving was varying, therefore, age at calving within lactation was divided into four categories of three moths each. Lactation records that began with an abortion or in which milking were interrupted by injury or sickness was discarded.

Statistical Models

Data were analyzed according to following two models:

1) Response surface model was used to illustrate and quantify the linear and quadratic relationship between DO, DIM and AM; and total milk yield, 305-d yield and peak yield.

The model was as follows:

$$Y = \mu + b_1 (AM) + b_2 (DIM) + b_3 (DO) + b_4 (AM)^2 + b5 (DIM)^2 + b_6 (DO)^2 + \text{Cross product} + E$$

Where,

Y = represents the actual total milk yield, 305-d predicted yield and peak yield.

μ = general mean.

AM = age in month.

DIM = days in milk. = CI - day dry.

DO = days open. = CI - 285 days

$b_1, b_2, ..., b_n$ are regression coefficients.

E = Error term ~ N (0, Io²).

2) Fixed effects model

Fixed effects model was utilized to study the effect of factors such as farm, season of calving, lactation number, year effect and milk level a fixed effects model was as follows:

$$Y = \mu + FN + S + LN + ML + y + b1 (DIM) + b_2 (AM) + b_3 (AM)^2 + E$$

Where,

Y = actual total milk yield, 305-d predicted and peak yield.

μ = general mean.

FN = farm effect (1, 2, 3).

S = season of calving (1, 2).

ML = milk level (1, 2).

y = year effect (1991- 1999).

DIM = days in milk.

AM = age in month.

LN = lactation number (1, 2, ... 6).

b_1, b_2,.....,bn are regression coefficients.

E = Error term ~ N (0, Io^2).

RESULTS AND DISCUSSION

Response surface analysis (table 1) demonstrated that F-value was highly significant for linear and quadratic response of total milk yield, 305-d milk yield and peak yield. Values of R^2 were 0.46, 0.06 and 0.05 for the three traits, respectively. More variation was noticed for total milk yield where coefficient of variation was 13.12, 12.81 and 11.45 for milk yield, predicted 305-d yield and peak yield, respectively. Insignificant F-values ($p < .01$) for lack of fit of response surface model (table 2) of the three traits (milk yield, predicted 305-d yield and peak yield) represent a satisfied adequacy of applying the model to illustrate both linear and quadratic effects.

Relationship between milk yield, 305-d yield, peak yield and age in month, days in milk, days open were quantified by linear and quadratic coefficients of regression of total milk yield, 305-d yield and peak yield on age in month, days in milk and days open, (table 3). Parameter estimates and standard error of linear, quadratic and cross products regression coefficients of milk yield, 305-d predicted and milk yield on age in month, days in milk and days open are given in table 3. Intercept of linear and quadratic regression coefficients of age in month and days in milk were significant ($p < .01$) for total milk yield, 305-d predicted yield and peak yield, which suggested that both age and days in milk were important and the relationship between these yields and age or days in milk were curvilinear.

Linear regression coefficients of age in month on total milk yield, 305-d predicted yield and peak yields were positive. However, quadratic regression coefficients of age in month on the three traits were negative which indicated a diminishing response of age on month. Figure 1 depicted the curvature of milk give way with age in month effect on production traits. Schmidt and Van Vleck (1974) and Miller et al. (1967) reported that genetic evaluation procedures generally require that records have to be adjusted to common basis (mature equivalent) of age in month. This adjustment will remove the bias in genetic evaluation due to difference in age at freshening.

Linear and quadratic effects showed a significant effect ($p < .01$) for days in milk on total yield but not on peak yield (table 2). A linear relationship was observed from 200 to 400 days in milk (figure 2). Quadratic representation was noticed along the whole curve (figure 2). Positive parameter of linear and quadratic of days in milk effect was expected (table 3) probably due to the accumulation of more milk as more days the cows continue to milk. These findings were confirmed with the results of fixed effect model (table 4) which were reflected in high correlation coefficients (r =0.68) between DIM and milk yield, low numbers, birth date, calving date, age at calving, actual milk yield, 305-d milk yield and days in milk. According to calving data, cows were grouped into two seasons of calving: winter (S1) for cows calved from October to March, and summer (S2) for cows calved from April to September. Milk records were also divided into two levels of milk production: level one (ML1) for cows with production $\leq$ 9500 liters, level two (M12) for cows with milk production > 9500 liters of milk.

Frequency distribution of records by age in month showed the first parity included cows calved at age $\leq$ 21 to $\geq$ 32 months, whereas the second parity included cows calved at age $\leq$ 33 to $\geq$ 44 months. Each parity thereafter included cows calved at 12 months interval up to the sixth parity which included cows calved at $\leq$ 81 to $\geq$ 92 month. Age at calving was varying, therefore, age at calving within lactation was divided into four categories of three moths each. Lactation records that began with an abortion or in which milking were interrupted by injury or sickness was discarded.

Statistical Models

Data were analyzed according to following two models:

1) Response surface model was used to illustrate and quantify the linear and quadratic relationship between DO, DIM and AM; and total milk yield, 305-d yield and peak yield.

The model was as follows:

$Y = \mu + b_1 (AM) + b_2 (DIM) + b_3 (DO) + b_4 (AM)^2 + b5 (DIM)^2 + b_6 (DO)^2 +$ Cross product $+ E$

Where,

Y = represents the actual total milk yield, 305-d predicted yield and peak yield.

μ = general mean.

AM = age in month.

DIM = days in milk. = CI - day dry.

DO = days open. = CI - 285 days

$b_1, b_2 ..., b_n$ are regression coefficients.

E = Error term ~ N (0, $I\sigma^2$).

2) Fixed effects model

Fixed effects model was utilized to study the effect of factors such as farm, season of calving, lactation number, year effect and milk level a fixed effects model was as follows:

$Y = \mu + FN + S + LN + ML + y + b1 (DIM) + b_2 (AM) + b_3 (AM)^2 + E$

Where,

Y = actual total milk yield, 305-d predicted and peak yield.

μ = general mean.

FN = farm effect (1, 2, 3).

S = season of calving (1, 2).

ML = milk level (1, 2).

y = year effect (1991- 1999).

DIM = days in milk.

AM = age in month.

LN = lactation number (1, 2, ..., 6).

b_1, b_2,.....,bn are regression coefficients.

E = Error term ~ N (0, $I\sigma^2$).

RESULTS AND DISCUSSION

Response surface analysis (table 1) demonstrated that F-value was highly significant for linear and quadratic response of total milk yield, 305-d milk yield and peak yield. Values of R^2 were 0.46, 0.06 and 0.05 for the three traits, respectively. More variation was noticed for total milk yield where coefficient of variation was 13.12, 12.81 and 11.45 for milk yield, predicted 305-d yield and peak yield, respectively. Insignificant F-values (p <.01) for lack of fit of response surface model (table 2) of the three traits (milk yield, predicted 305-d yield and peak yield) represent a satisfied adequacy of applying the model to illustrate both linear and quadratic effects.

Relationship between milk yield, 305-d yield, peak yield and age in month, days in milk, days open were quantified by linear and quadratic coefficients of regression of total milk yield, 305-d yield and peak yield on age in month, days in milk and days open, (table 3). Parameter estimates and standard error of linear, quadratic and cross products regression coefficients of milk yield, 305-d predicted and milk yield on age in month, days in milk and days open are given in table 3. Intercept of linear and quadratic regression coefficients of age in month and days in milk were significant (p < .01) for total milk yield, 305-d predicted yield and peak yield, which suggested that both age and days in milk were important and the relationship between these yields and age or days in milk were curvilinear.

Linear regression coefficients of age in month on total milk yield, 305-d predicted yield and peak yields were positive. However, quadratic regression coefficients of age in month on the three traits were negative which indicated a diminishing response of age on month. Figure 1 depicted the curvature of milk give way with age in month effect on production traits. Schmidt and Van Vleck (1974) and Miller et al. (1967) reported that genetic evaluation procedures generally require that records have to be adjusted to common basis (mature equivalent) of age in month. This adjustment will remove the bias in genetic evaluation due to difference in age at freshening.

Linear and quadratic effects showed a significant effect (p < .01) for days in milk on total yield but not on peak yield (table 2). A linear relationship was observed from 200 to 400 days in milk (figure 2). Quadratic representation was noticed along the whole curve (figure 2). Positive parameter of linear and quadratic of days in milk effect was expected (table 3) probably due to the accumulation of more milk as more days the cows continue to milk. These findings were confirmed with the results of fixed effect model (table 4) which were reflected in high correlation coefficients (r =0.68) between DIM and milk yield, low

Table (1): F-value of Linear, Qquadratic and cross product effect of milk yield, 30-d predicted yield, and peak yield.

Source	d f	Milk yield	Predicted 305-d yield	peak yield
		F	F	F
Linear	3	1955**	128.3**	69.99**
Quadratic	3	1745**	21.3**	55.7**
Cross product	3	612NS	2.6NS	0.79NS
Total regression	9	657.9**	50.7**	42.15**
Root MSE		1630	1503	6.2
Response mean		12431	11731	54.51
R^2		.46	.06	.05
Coeffcient of variation		13.12	12.81	11.45

** (P < .01)
NS= Non sigmificant

Table (2): Lack of fit ANOVA of response surface maodel.

Source	d f	Milk yield		Predicted 305-d yield		peak yield	
		MS	F	MS	F	MS	F
Lack of fit	6924	2672521	1.311NS	2264274	1.159NS	39.0	1.12NS
Pure Error	123	2038010		1953806		34.8	
Total	7047	2661446		2258855		38.9	

NS= Non sigmificant

Table (3): Linear and quadratic and cross products regression coefficient (± standard error) of milk yield, 305-d predicted and peak yield on age in month, lactation period (days in milk) and days open (calving interval).

	Total milk yield		Predicted 305-d yield.		Peak yield	
	Parameter	SE	parameter	SE	parameter	SE
Intercept	2778.6**	754.7	8868.6**	694.7	41.9**	2.9
Linear						
AM	47.5**	9.6	46.3**	8.8	.370**	.037
DIM	20.1**	3.6	.49^{NS}	3.3	-.001^{NS}	.014
DO	3.3^{NS}	2.5	7.23**	2.2	.001^{NS}	.009
Quadratic						
AM*AM	-.3091**	.047	-.329**	.043	-.002**	.000
DIM*DIM	0.0145**	.004	.008*	.0041	.000^{NS}	.00001
DO*DO	-.0062*	.003	-.006*	.002	.002^{NS}	.00001
Cross product						
AM*DIM	-.024^{NS}	.023	-.002^{NS}	.022	.000^{NS}	.00000
AM*DO	.051*	.025	.035^{NS}	.006	.000^{NS}	.00000
DO*DIM	-.002^{NS}	.006	-.014*	.006	.00^{NS}	.00000

AM= Age in month, DIM= days in milk and DO= days open
* (P < .05), ** (P< .01), NS = Non significant.
$Y= b_1$ AM+ B_2 DIM + b_3 DO + b_4 (AM *AM) + b_5 (DIM * DIM) + b_6 (DO*DO) + b_7 (AM*AIM) + b_8 (AM*DO) + b_9 (DIM*DO) + E.

Table (4): ANOVA of fixed effects on total milk yield, 305-d predicted and peak yield.

		Milk yield		Predicted 305-d yield		Peak yield	
S.V	Df	MS	F	MS	F	MS	F
FN	2	2.612E+08	146.09**	2.436E+08	175.01**	7079.0	236.6**
ML	1	4.407E+09	2464.80**	3.818E+08	2743**	22184	741.4**
S	1	1.0211E+08	57.27**	1.093E+08	78.53**	3884	129.8**
Y	7	7.419E+07	41.77**	7.527E+07	54.08**	5702	190.58**
DIM	1	1.996E+10	11162.2**	1.793E+07	12.88**	17.1	.57^{NS}
LN	5	3.979E+07	22.25**	5.021E+07	36.07**	9612	154.14**
AM	1	2.303E+07	12.88**	3.388E+07	24.34**	1271	42.51**
AM*AM	1	5.166E+06	2.89^{NS}	1.162E+07	8.35**	687	22.97**
Error	11268	1.788E+06		1.392E+06		29.92	

FN= farm number, ML= milk level, S= season of calving, Y=year effect, DIM = days in milk, LN=lactation number.
* (P < .05), ** (P <.01), NS= Non significant.

correlation coefficients (r = 0.01) between peak yield and DIM (table 6) and between predicted 305-day yield and DIM (r = 0.12).

No linear effects were observed of days open on total milk yield or peak yeild (table 3). The insignificant (p > .05) effect of linear or quadratic effects of days open on peak yield (table 6) reflects the small coefficient of correlation of this trait with milk and peak production (r =0 . 16 and 0 .04). Significant (p < .05) quadratic regression parameters in table 3 for predicting total milk yield and 305-d yield support the semi-curvature relationship between actual yield and DO (figure 3). Schaeffer et al (1972) found that as days open increased, average 305-d milk yield increased in a curvilinear fashion and for 10 days increase in days open beyond 70 days, the increase in milk production became smaller.

Both days open and calving interval have been viewed as environmental factors that need to be considered to obtain more accurate estimates of genetic trait for production traits (Wilton et al. 1976 ; Oltenacu et al .1980 and Sadek and freeman , 1992). Smith and Becker (2002) found that calving interval of 13 to 13.4 month was associated with the highest average milk yield (18,498 Ibs) while a longer calving interval of 16 to 16.4 months was related to the lowest production (14, 884 Ibs). Similar results were found by Grusenmeyer et al. (2002). They reported that the highest production (16,464 Ibs) was given at 12.9 to 13.3 month calving interval class and the lowest production was related to 14.0 to 14.3 month calving interval. The ANOVA of fixed effects model showed a significant effect of non-genetic factors such as farms, milk level, season of calving, year of calving, days in milk and age of calving.

Frequency distribution of milk yield showed that the production of dairy cows ranged from 5000 to more than 20.000 liters and about 48% of the records showed a range of total production 12.000 to 14.000 liters of milk or more (Figure 4).

Least square (LS) means of milk yield, 305-d predicted and peak yield (table 5), showed that the averages of the three farms were 10467, 11047 and 10697 liters, respectively. The difference between the three farms were significant (p < .01) . LS means of two seasons of calving were 10839 and 10636 and significant differences (p < .01) were found between the Fall-Winter calving and Spring-Summer calving season. Significant differences (p < .01) also were found between two milk levels. The LS means were 9687 and 11787 liters for the two milk levels. The second lactation was characterized by the highest production (11105 liters). However, the sixth lactation had the lowest production (10283 liters). Significant differences were found among the years from 1991 to 1999. Least square means for 305-d predicted yield followed a similar pattern across

Table (5): Least square means and standard error for total milk, 305-d predicted and peak yield.

source		Total milk yield		305-day predicted		Peak yield	
		Mean	SE	Mean	SE	Mean	SE
FN	1	10467[a]	76.4	9780[a]	67.4	48.9[a]	.31
	2	11047[b]	74.9	10355[b]	66.1	51.5[b]	.31
	3	10697[c]	74.4	10039[c]	65.6	49.1[a]	.30
LN	1	10591[a]	69.2	9717[a]	61.1	43.1[a]	.28
	2	11105[b]	42.4	10339[b]	37.5	50.4[b]	.17
	3	10911[a]	64.9	10199[c]	57.3	51.5[b]	.26
	4	10821[a]	99.7	10147[d]	88.0	51.6[be]	.40
	5	10715[a]	152.1	10070[e]	134.2	51.5[cf]	.62
	6	10283[c]	242.1	98746[bf]	213.6	51.1[ag]	.99
S	1	10839[a]	70.4	10162[a]	62.1	50.5[a]	.28
	2	10636[b]	76.0	9953[b]	67.1	49.2[a]	.31
ML	1	9687[a]	78.8	9080[a]	69.5	47.5[a]	.32
	2	11787[b]	71.2	11035[b]	62.8	52.2[b]	.29
y	1	10011[a]	143	9409[a]	126	49.69	.59
	2	10419[a]	88	9720[a]	78	55.8[a]	.36
	3	10567[a]	79	9933[b]	70	46.6[a]	.32
	4	10936[a]	75	10217[a]	66	47.9[a]	.30
	5	11202[b]	75	10555[a]	66	49.9[b]	.31
	6	10969[ac]	75	10302[a]	67	49.1[c]	.31
	7	11056[a]	84	10267[ac]	76	49.9[d]	.34

Different letter in columns means significant at ($p < .01$)
FN= farm number
LN= lactation number.
Y= year effect.
S = season of calving,
ML= Milk level

farms, lactation numbers, season of calving, years of calving and milk levels.

In the last decade, milk production of dairy cows in AL-Maraie Company has increased from 6.000 -7,000 to 10,000 -11,000 liters. This increase was the result of the continuous health improvement, management and the use of high quality semen from progeny tested bulls from the ABS Al Company. Another study of different dairy farms in Saudi Arabia (Al Jumaah, 1995) found that least square means of milk yield of the first four parities and overall data were 6653, 7659, 7482, 6988 and 7614 liters , respectively. Lactation period for the four parities and overall data were 358, 367, 350, 363 and 364 days respectively. In this study, first lactation gave the least peak of 43.1 liters and the fourth lactation had the highest peak of 51.6 liters (table 5). Furthermore, no significant differences were found between cows calved in winter and those calved in summer.

High producing cows had a peak 52.2 liters and low producing ones had a peak of 47.5 liters. Differences between peaks across different years of calving explain the different shapes of the lactation curves for different years of calving AI Seaf et al. (2003) showed that cows that calved in winter had earlier peak, high maximum milk yield and more persistent milking than cows calved in summer. Cows in first lactation were more persistent and reached peak milk yield at low levels of milk.

Conclusions

Least square means of non-genetic factors are necessary to compute correction factors to adjust lactation yield records for largely environmental effects of age at calving and days open. Standard 305-d lactation period with adequate days open and dry period 60-80 days will enable each farmer to have on average calving interval of !2-13 months. obtaining maximum total production and more live time production. Adjustment of 305-day records for mature equivalent and for days open appears necessary and would not introduce genetic bias. Response surface methodology can determine an adequately the cut off point of DO and illustrates the relationship between productive traits and both age and days in milk.

Table (6): Phenotypic correlation coefficients among non-genetic factors and yields

	MY	Pj5	PE	AM	DIM	DO
MY	1.00	.76	.50	.22	.68	.16
Pj5	.76	1.00	.73	.38	.12	.12
PE	.50	.73	1.00	.56	.01	.04
AM	.22	.38	.56	1.00	-.02	.09
DIM	.68	.12	.01	-.02	1.00	.12
DO	.16	.12	.04	.09	.12	1.00

MY=milk yield, PJ5=predicted 305-d yield, PE=peak yield
AM=age in month, DIM= days in milk, DO= days open.

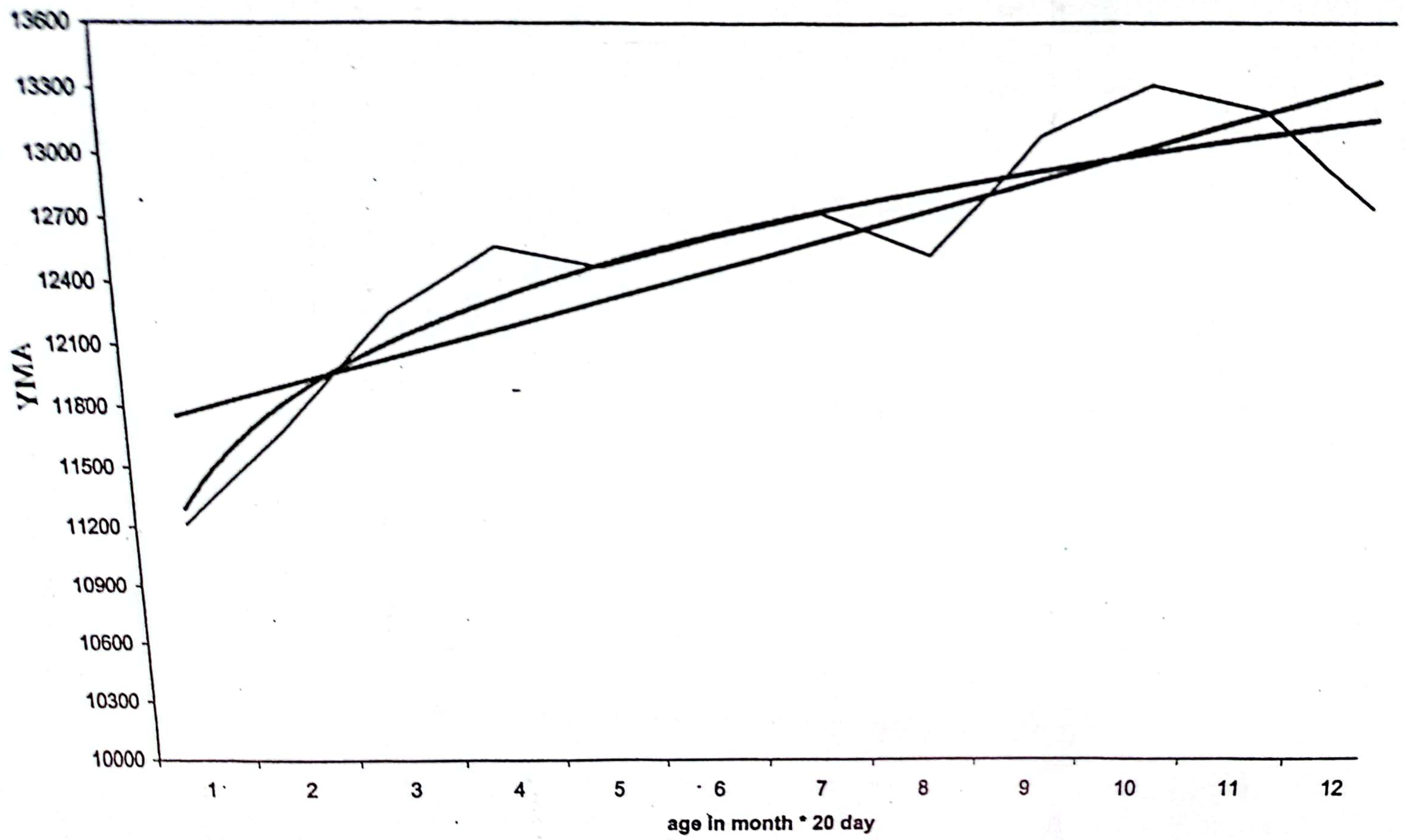

Fig. (1) Relationship between Age in month and actual milk yield (AMY).

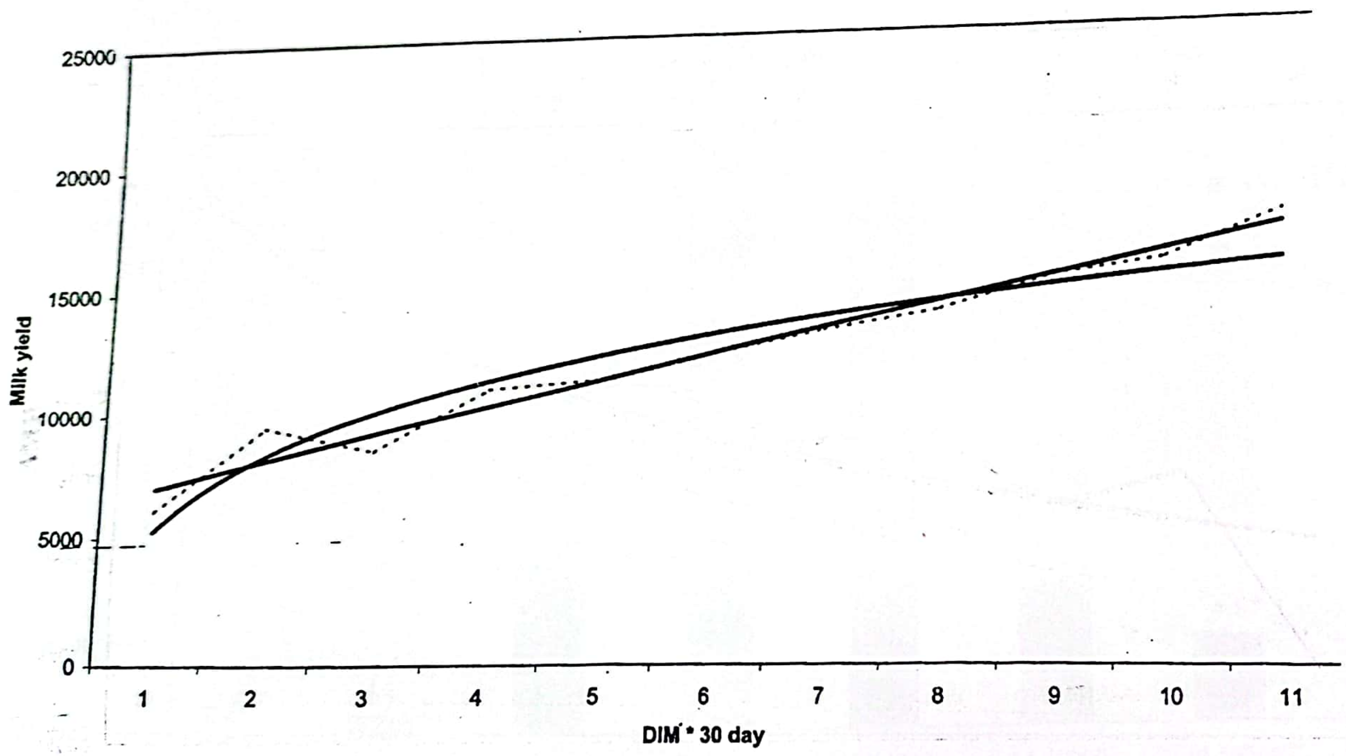

Fig. (2): Relationship between DIM and milk yield .

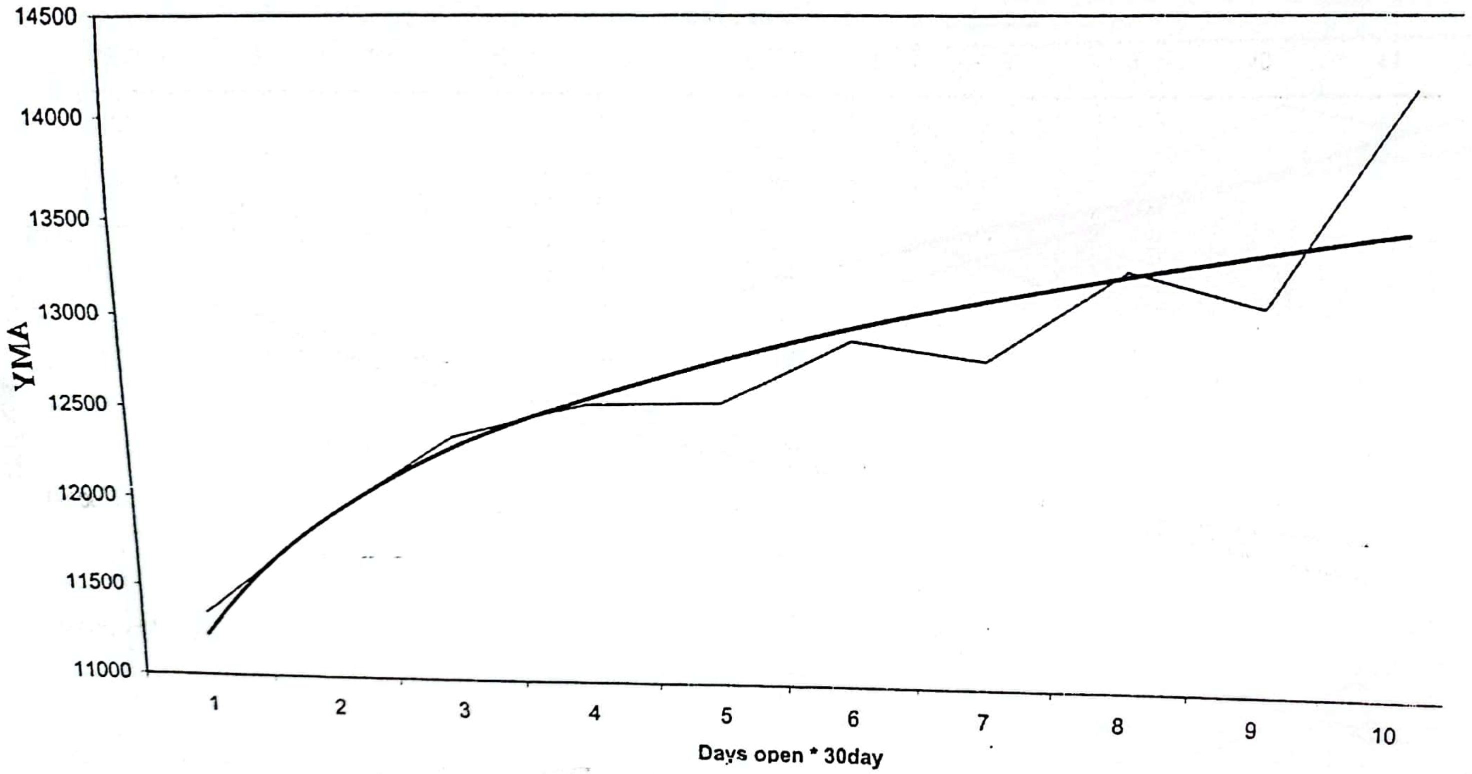

Fig. (3): Relationship between actual milk (AMY) yield and days open.

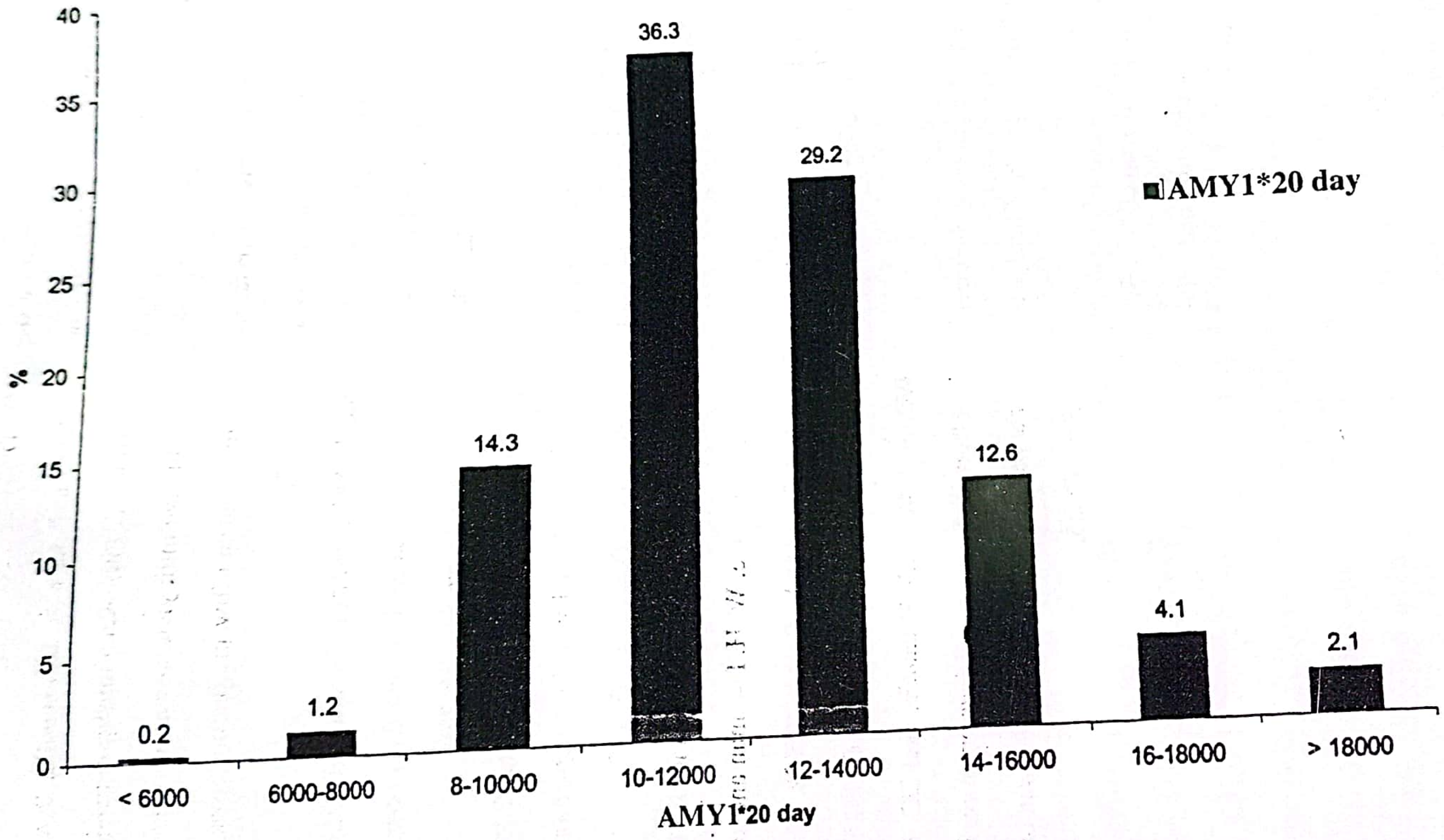

Fig. (4): Frequency distribution of milk yield.

REFERENCES

Ali, A.K.A, A. AL-Haidary, M.A. AL Shaikh, M. H. Ga-mil, and E. Hayes. (2000). Effect of Days open on the lactation curve of Holstein cattle in Saudi Arabia. Asian-Aus. J. Anim. Sci., 13:227-286.

Al Seaf, M.A., Al Shaikh, M.S., Al Kraidees and A. AL-Haidary. (2003). Effect of non-genetic factors on lactation curve of Holstein Friesian Cows in Saudi Arabia. J. King Saud Univ. Vol. 15, Agric. Sci (2), pp. 115 - 131.

Al Jumaah, R.S. (1995) Lactation curve of Holstein Friesian Cows in the Kingdom of Saudi Arabia M.Sc Thesis, King Saud University.

Funk, D.A., A.E. Freeman, and P.J. Berger (1987). Effect of previous days open and pervious days dry and present days open on lactation yield. J. Dairy Sci., 70: 2366.

Grusenmeyer, D., J. Hillers and G. Williams (2002). Evaluating dairy herd reproductive status using DHI records. Internet (2002).

Marti, C.F., and D.A. Funk. (1994). Relationship between production and days open at different levels of herd production. J. Dairy Sci., 77: 1682.

Miller, P.L.D., Van Vleck, and C.R. Henderson (1967): Relationships among herd life, milk pnoduction and calving interval. J. Dairy Sci., 50: 1283.

Miller, P.D., W.E. Lentz, and C.R. Henderson (1970). Joint influence of month and age of calving on milk yield of Holstein cows in the Northeastern United States. J. Dairy Sci., 53: 351.

Oltenacu, P.A., T.A. Rounsaville, R.A. Milligan and R. L. Hintz. (1980). Relationship between days open and cumulative milk yield at various intervals from parturition for high and low producing cows. J. . Dairy Sci., 63: 1317.

Sadek, M.H. and A.E. Freeman (1992). Adjustment factors for previous and present days open considering all lactation. J. Dairy Sci., 75: 279.

Schaeffer, L.R., R.W. Everett, and C.R. Henderson (1972). Effect of days dry and days open on Holstein milk production. J. Dairy Sci., 55: 107.

Schmidt, G.H. and L.D. Van Vleck (1974). Principles of Dairy Science. W. H. Freeman and company.

Smith, J.F. and D.A. Becker (2002). The reproductive status of your dairy herd. Guide D-302 Extension report.

Wilton, J. W., E.B. Burnside, and J.C. Rennie (1967). The effect of days dry and days open on the milk and butterfat production of Holstein-Friesian cattle. Can. J. Anim. Sci., 47: 85.