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An Optimum Regression Model to Estimate Economic Values for Milk Yield, Milk Yield Persistency and Calving Interval in Dairy Cattle

Research Article

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ABSTRACT

Emphasis on milk yield (MY) as well as milk yield persistency (MYP) and calving interval (CI) is necessary to achieve more sustainable production in dairy cattle. Therefore the main objective of this study was to find an optimum regression model to estimate economic values for MY, MYP and CI. Using a deterministic bio-economic model, seventy five production states differing mainly in MY, MYP and CI were studied. For each production state, the total revenue comprised income from sold milk, calves of one week of age and manure. Feed costs were obtained from energy requirements for maintenance, growth, lactation and pregnancy. Non feed costs included costs of net replacement, health, artificial insemination and some others which were modeled as a function of CI. Multiple regression analyses of annual profits for production state on the means of MY, MYP and CI were used to estimate the economic values. Two different regression models were used. Both models included the linear effect of MY and the quadratic effect of MYP. However, in one model the effect of CI was linear (Model CIL) whilst it wasquadratic in the other (Model CIQ). Under both models, economic value for MY was positive (0.10 $ for model CIL and 0.32 $ for model CIQ) as was expected for the assumed milk pricing system. Economic values for MYP in the models had different signs (-118.2 $ for model CIL and 715.55 $ for model CIQ). Under model CIQ maximum profit was associated with a value of MYP greater than unity and was not consistent with the definition of persistency. Economic value of CI was negative under both models (-2.68 $ for model CIL and -6.36 for model CIQ). In the model CIQ, the profit function had a minimum value for CI (at 803 days) which was not consistent with the previously reported relationship between profit and CI. Estimates of economic values for MY, MYP and CI showed that the model CIL was superior to the model CIQ due to a lower number of fitted effects and increased consistency with the real situation of dairy systems.

KEY WORDS calving interval, economic value, milk yield, milk yield persistency, regression model.

INTRODUCTION

In selecting several traits of economic or functional importance, selection index is the chosen method of selection for maximizing genetic gain for a given breeding objective. The breeding objective includes economic values of traits that a farmer wants to improve because of their significant impacts on either revenues or costs in the production systems (Hazel, 1943; Amer *et al.* 1998). The economic value of a trait may be defined as the change in profit resulting from a unit change in that trait, assuming all the other traits remain constant (Ponzoni, 1992). In recent years, a great deal of research has been reported on economic values of traits for development of selection indices to increase efficiency of dairy production. Estimation of an economic value for each trait is needed to ensure that selection emphasis is proportional to its economic importance. The economic value of milk yield has been calculated in many studies (e.g., Groen, 1989; Dekkers, 1991; Wolfová *et al.* 2007). Although the most income from dairy cattle derives from milk production, emphasis on functional traits is also necessary to achieve sustainable production (Olesen *et al.* 2000).

Milk yield persistency is one of the determinant factors of milk production. This trait is an economically important trait in dairy cattle due to its relationship with reproduction, health and feed costs (Dekkers *et al*. 1998; Muir *et al*. 2004; Appuhamy *et al*. 2007; Togashi and Lin, 2009). Milk yield persistency is typically defined as the rate of decline in milk production after peak yield (Cole and null, 2009). There are fewer reports on the estimates of economic values for milk yield persistency than milk yield and other economically important traits. The main obstacles for estimating economic value of persistency are the need for a comprehensive data set and the difficulty of objectively assessing the economic effects of persistency components such as stress and disease resistance (Togashi and Lin, 2009). Dekkers *et al*. (1998) calculated the economic value of milk persistency using a regression model containing polynomials of milk yield persistency while milk yield and calving interval were fixed at given levels.

Calving interval, a key trait for the evaluation of reproductive performance, is one of the factors that affect the milk yield of dairy cows. This trait determines the benefit of improvement in persistency (Dekkers *et al*. 1998). Some researchers have reported that an excessive increase or decrease in calving interval may lead to undesirable metabolic effects which reduce the profit of production system (Muir *et al*. 2004; Dekkers *et al*. 1998; Gonzalez-Recio *et al*. 2004). These results may indicate a complicated relationship between calving interval and milk yield traits that should be investigated more precisely.

Economic values for milk yield and milk yield persistency were estimated separately in previous studies (e.g. Dekkers *et al*. 1998; Togashi and Lin, 2009; Sadeghi-Sefidmazgi *et al*. 2012) but there is no published research on the simultaneous estimation of these parameters. Furthermore, the effect of calving interval on cow profit has not been investigated considering its relationship with milk yield and milk yield persistency. Therefore, the main objective of this study was to find a regression model to combine the effects of milk yield, milk yield persistency and calving interval in an optimal way while all aspects of production and reproduction in a dairy production system are considered. The other objective of this research was to examine the sensitivity of the estimated economic values to the changes in the various inputs and costs levels.

MATERIALS AND METHODS

To find an optimum regression model to estimate economic values for MY, MYP and CI, 75 production states differing in milk yield, persistency level and calving interval were simulated by means of a deterministic model and bio-economic parameters of Holstein dairy cattle system in Iran.

Simulation of the production states

The production states were based upon lactation curves with different parameters. The incomplete Gamma function of Wood (1967) was used to describe milk production over lactation period:

$$Y_t = a \times t^b \times e^{(-ct)}$$

Where:

Y_t: is milk yield on day t.

a: is milk yield at the beginning of lactation.

b and c: are inclining and declining slopes of production curve, respectively.

Initial values for parameters of Wood's function (Ghavi Hossein-Zadeh, 2011) along with other biological and production variables are presented in Table 1. In order to simulate the various states, some marginal changes were introduced into the initial values of b and c, while a parameter was kept constant. This procedure generated 74 sets of new values for b and c which were used along with the initial values to simulate a total of 75 various states (Table 2). In each state the time for maximum yield (T_{max}) was calculated as $T_{max}= b/c$, from which the peak yield (Y_{max}) was estimated by $Y_{max}= a \times T_{max}^{\ b} \times e^{-b}$ (Wood, 1967). In order to model the effect of persistency on calving interval, the regression coefficient of calving interval on peak yield (R_{Cof}) was estimated using a linear regression model passing through origin using a data set comprising records on daily milk yield and calving intervals of 1553 (after editing for calving and milking dates) Holstein cows on a dairy farm with a reliable recording system for production and reproduction performance in Iran.

The regression coefficient of R_{Cof} was 17.19 ± 0.12 (Table 1) which was significant at P<0.01 and the R^2 of model was 0.93.

Therefore, calving interval (CI) was calculated as $CI= R_{Cof} \times Y_{max}$ and number of days in milk (DIM) was obtained from that, assuming 60 days dry period. Afterward, total lactation milk yield (*TY*) was calculated as sum of the estimated Y_t's with milk yield in the first week after calving being excluded for calf consumption. Ratio of the sum of yields from day 201 to day 305 of lactation to the sum of yields in the first 100 days was used as a milk yield persistency (*MYP*) measure (Sölkner and Fuchs, 1987).

Table 1 Biological and production variables

Variable	Value
Wood function's parameters	
a	17.2748 kg
b	0.1442
c	0.00223
Korver function's parameters	
Mature live weight	600 kg
Birth weight	42 kg
Growth rate parameter	0.004
Maximum live weight lost during the lactation	-25 kg
Number of days with minimum live weight	60 d
Pregnancy parameter	0.0187
Regression coefficient of calving interval on peak yield	17.19±0.12
Average milk fat	3.2 %
Average milk protein	3.07 %
Average calving rate	0.87 %
Average calf survival rate in the first week of life	0.95 %
Average calf birth weight	42 kg
Average age at the first calving	26.5 mo
Gestation length	279 d
Productive life	3.07 yr
Dried manure per cow per year	5475 kg
Energy content in fixed combination per kg DM during lactation period	18.36 Mcal
Energy content in fixed feed combination per kg DM during dry period	13.36 Mcal
Energy content in concentrate per kg DM	1.72 Mcal
DM content in concentrates	90 %

a: parameter relates to the level of production; *b*: parameter relates to the rate of increase to the peak yield and *c*: parameter relates to the rate of decrease in production beyond peak production.
DM: dry matter.

Table 2 The mean, standard deviation, minimum and maximum of Wood's parameters for establishment of states

Parameter	*b*	*c*
Mean	0.13295	0.00199
Standard deviation	0.04058	0.00087
Minimum	0.06359	0.00050
Maximum	0.20231	0.00347

b: parameter relates to the rate of increase to the peak yield and *c*: parameter relates to the rate of decrease in production beyond peak production.

Revenues

For each production state the total revenue (per cow per year) comprised income from sold milk, calves of one week age and manure. The amounts of fat and protein percentages were considered fixed throughout the lactation and their reported values (Hosseinpour Mashhadi *et al.* 2008; Table 1) were used to calculate yearly income from sold milk:

(R_{milk}) as $R_{milk}= (365/CI) \times TY \times P_{milk}$

Where:

P_{milk}: is the price per kg milk of average fat and protein percentages.

It was assumed that all calves of both sexes were sold at the end of first week of life and required replacement heifers were bought from the market. Twin calving was not considered in the analyses. For each state the number of calving per cow per year (*NC*) was determined by $NC= 365/CI$, from which the number of calves (N_{calf}) was calculated by was calculated by:

$N_{calf}= NC \times Cr \times SR$

Where:
Cr: is the calving rate (calf born alive).
SR: the calf survival rate in the first week of life (Kahi and Nitter, 2004).

Annual calf revenue (R_{calf}) was determined by:

$R_{calf}= N_{calf} \times P_{calf}$

Where:
P_{calf}: was the price per calf.

Annual revenue from manure (R_{manure}) was assumed to be the same in production states and was determined as $R_{manure}= M_Y \times P_{manure}$

Where:
M_Y: was the amount of dried manure per cow per year.
P_{manure}: was the price per kg of dried manure.

Cow feed costs

To determine feed costs, daily energy requirement was obtained from energy requirements for maintenance, growth, lactation and pregnancy. In order to calculate energy requirements for maintenance and growth, cow's live weight at the age of t_a (day), in day t_l of lactation and day t_p in pregnancy ($LW_{ta\ tl\ tp}$) was calculated by Korver function (Korver *et al.* 1985) for which the required parameters were taken from Ghavi Hossein-Zadeh (2011) (Table 1). Daily energy requirement for maintenance was determined according to $LW_{ta\ tl\ tp}$, using equations adapted from NRC (2001). Energy requirement for growth was assumed to be 20% of the daily maintenance requirement. Net energy requirement to produce 1 kg milk of average fat and protein percentages was calculated by NRC (2001), from which daily lactation energy requirement was calculated for Y_t.

Energy requirement for pregnancy was determined for the last ninety days of gestation period on the basis of the equation adapted from NRC (2001). Energy requirement per day was partly met by a fixed feed combination consisted of 2 kg alfalfa, 1.5 kg sugar beet pulp, 2 kg molasses, 25 kg corn silage in milking period and by 2 kg alfalfa and 25 kg corn silage in dry period. Energy content of fixed feed combination and its cost are shown in Table 1 and Table 3, respectively.

Daily consumption of concentrate was a function of estimated daily energy requirement, energy supplied by the fixed feed combination and energy content of concentrate (Table 1).

Table 3 Economic variables

Variable	Value (US $)
Price	
Milk of 3.2% fat and 3.07 % protein	0.43/kg
Calf at the age of 7 days of life	350/head
Replacement heifer	2900/head
Culled cow	1300/head
Manure	0.01/kg
Cost	
Fixed feed combination in lactation period	4.1/d
Fixed feed combination in dry period	3.1/d
Concentrate	0.44/kg DM
Health in open cows	0.67/d
Health in pregnant cows	0.01/d
Insemination	18.17/service
Calf non-feed	4.79/head
Annual fuel and electricity	6.96/cow
Annual labor	141.12/cow
Annual hygiene	28.81/cow
Annual repair and depreciation of building	222.48/cow
Annual repair and depreciation of equipment	17.52/cow

DM: dry matter.

Main components of the dairy ration were consisted of corn silage, alfalfa, cotton seed, soybean meal, cotton seed meal, barley grain, canola meal, wheat bran, fat powder, beet pulp and feed additives. Total feed cost per cow per lactation (T_{feed}) was calculated on the basis of fixed feed combination and concentrate consumptions through calving interval and consequently annual feed cost (C_{feed}) was determined by $C_{feed}= (365/CI) \times T_{feed}$.

Cow non-feed costs

Non-feed costs were in cluded, these comprised the costs of net replacement, health, artificial insemination, hygiene, fuel and electricity, labor, repair and depreciation. Annual net replacement cost was determined as the difference between price of a replacement heifer and a culled cow that is divided by cow productive life. In order to model the effect of calving interval on health cost this was partitioned into two parts differing by associated daily costs, namely days open and gestation period and consequently health costs per cow per year.

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In order to model the effect of calving interval on health cost this was partitioned into two parts differing by associated daily costs, namely days open and gestation period and consequently health costs per cow per year (C_{health}) was determined by:

$$C_{health}= ([C_{do}\times(CI-g)+(C_g\times g)]/CI) \times 365$$

Where:
C_{do}: is daily health cost for days open.
g: is gestation length.
C_g: is daily health cost for the gestation period.

Assuming constant gestation length, calving interval was a function of days open which was in turn depended on the waiting period and the number of inseminations per conception. To link between calving interval and artificial insemination costs, the number of inseminations per conception (S) was determined as:

$$S= [CI - g - w] / h$$

Where:
w: was the waiting period.
h: was the estrous length, with assumed values of 50 and 20 days, respectively.

Artificial insemination cost per cow per year was calculated using S and cost per service (Table 3).

Calf rearing costs

Milk produced by cow in the first three days after calving was totally fed to the calves. Over the remaining days to day seven they consumed milk equivalent to nine percent of their body weight which was calculated as a function of birth weight and daily weight gain.

The rearing cost of a calf in the first week of life comprised feed and non-feed costs (Table 3). Calf rearing costs per cow per year was calculated as a function of calf survival rate during the first week of age, pregnancy rate and calving interval.

Economic value of traits

In order to estimate economic values for milk yield, milk yield persistency and calving interval, multiple regression analyses of annual profits to the total milk yield, milk yield persistency and calving interval of states were performed. Profit was estimated from differences between revenues and costs for each production state. Two different regression models were used. Both models were included the linear effect of milk yield and the quadratic effect of milk yield persistency.

However, in one model the effect of calving interval was of linear order (Model CIL) and in the other one of quadratic order (Model CIQ). The regression coefficient in these models gives an estimate of economic value for a trait when its linear effect is included. For traits whose quadratic effects are fitted, the first derivative of the regression profit equation in respect to that trait generates a function whose value at the population mean gives an estimate of its economic value. In this case, economic value of a trait would be a function of its mean.

Sensitivity analysis

Effects of 20% changes in the price of milk and in the cost of feed on the estimated economic values were investigated.

RESULTS AND DISCUSSION

Overall characteristics of production states

Each of 75 production states had a specific lactation curve differing from others in terms of length of lactation and milk yield persistency. The mean, standard deviation, minimum and maximum of milk yield, milk yield persistency, calving interval and profit of all production states are shown in Table 4.

Table 4 The mean, standard deviation, minimum and maximum of MY, MYP, CI and profit of production states

	MY (kg)	MYP	CI (d)	Profit ($/cow/yr)
Mean	8961.80	0.9052	458.00	95.46
SD	1202.46	0.0900	51.33	21.08
Minimum	6891.37	0.7599	379.00	46.90
Maximum	10912.00	1.0681	552.00	119.32

MY: milk yield; MYP: milk yield persistency; CI: calving interval and SD: standard deviation.

Sorting the production states by lactation length in descending order revealed that the declining slope of lactation curves decreased steadily and their shapes became flatter from 1st through 75th production state.

Also, the magnitude of the persistency measures of various production states increased gradually and approached to unity indicating better persistency. In the 75th state this was slightly greater than unity. Therefore, first production state showed the lowest persistency and the last showed highest persistency.

Milk production decreased from the first through the last production state. Differences in milk production were due to the differences in the amount of peak production, lactation length and milk yield persistency. This indicated the need for simultaneous attention to the production of milk, milk yield persistency and calving interval (lactation length) in the breeding programs.

Figure 1 shows the change in annual profit of dairy production system over 75 states. Considering that production states were different in term of milk yield persistency, this figure indicates that annual profit is a non-linear function of persistency.

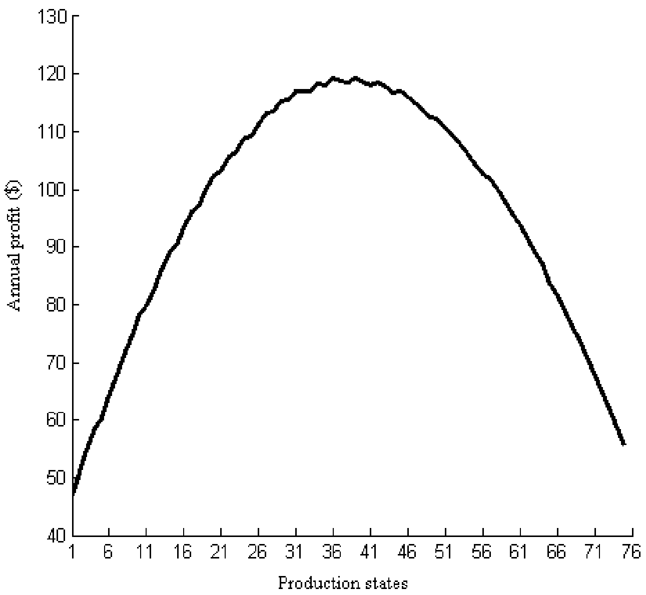

Figure 1 Annual profit of dairy production system over seventy-five states sorted by milk yield persistency in ascending order

Economic values of traits under model CIL

Multiple regression coefficients of profit for milk production, persistency and calving interval under model CIL are shown in Table 5. Defining the economic value of a given trait as the partial derivative of profit with respect to that trait, the regression coefficients of milk production and calving interval in model CIL give the appropriate economic values.

The economic value for milk was positive as was expected in dairy production system in Iran where the milk revenue mainly depends on the milk volume with no limit or quota on milk production. The results of Shadparvar and Nikbin (2008) also showed a linear relationship between milk production and profit in Iran. Sadeghi-Sefidmazgi *et al.* (2009) also reported a positive economic value (0.11 $) for milk yield in Iran.

According to the definition of economic value and because of the presence of quadratic order of persistency in the regression model, the economic value of this trait was a function of its mean and the first derivative of the profit equation generated the following function:

$EW_{MYP}= 1970.1 - (2307.90\times\overline{MYP})$

Where:
EW_{MYP}: is obtained function in order to determine economic value of milk yield persistency.
$\overline{MYP}$: is the mean of milk yield persistency.

Substituting the mean persistency of 0.9052 (Table 4) in above function gave -118.20 \$ as its economic value. A negative economic value for persistency indicated that at its current level an increase in the value of that trait will lead to lower profit. Since the second derivative of the profit function with respect to persistency was negative, the profit function must have a maximum value in terms of persistency. Equating the above equation to zero and solving for *MYP* led to 0.854 as the optimum value for persistency which maximizes the profit. Determining the optimum value of persistency is important in breeding for this trait. If the mean persistency in a population is less than the optimum value, the economic value of persistency would be positive and selection should be used to improve this trait. However, with higher mean persistency the economic value would be negative and selection should be directed toward reducing the mean of this trait. Negative economic value for calving interval indicated that increase in calving interval will reduce profit 2.68 \$ per day. Economic value for calving interval in Iran reported by Sadeghi-Sefidmazgi *et al*. (2012) -0.72 \$ per day.

Economic values of traits under model CIQ

Based on model CIQ, economic value of milk production was positive similar to model CIL. Economic value for persistency and its optimum value were estimated as 715.55 \$ and 1.09, respectively. Contrary to model CIL, economic value of persistency in this model was positive. Similar to model CIL, the regression coefficient of the quadratic effect of persistency in model CIQ indicates that second derivative of profit with respect to this variable is negative and there must be an optimal persistency that maximizes the profit (Table 5). The main reason for the different signs of the economic value of persistency in two models was due to the estimated optimal value of trait which was higher in model CIQ than model CIL.

But according to the definition of persistency measure in this study, maximum acceptable value for persistency could be unity (Sölkner and Fuchs, 1987), hence model CIQ cannot be accepted.

Because quadratic order of calving interval was used in model CIQ, the first derivative of profit equation based on this trait generated a function as follows:
$EW_{CI}= -14.79 + (0.0184 \times \overline{CI})$

Where:
EW_{CI}: is obtained function to determine economic value of calving interval.
$\overline{CI}$: is the mean of calving interval.

Replacing the population mean for calving interval in the above equation gave -6.36 \$ per day as an estimate of the economic value. Because second derivative of profit equation based on calving interval was positive, the profit function had a minimum value at a specific value of calving interval. Equating the above equation to zero and solving for CI gave 803 days as the value of calving interval which minimizes the profit function. Mathematical interpretation of this value is that increasing the mean calving interval up to 803 days (2.2 years) will reduce the profit and after that the profit would increase by lengthening calving interval. In the current study the maximum value of calving interval was assumed to be 552 days and practically this value would never be exceeded. Therefore, it seems that model CIQ is not consistent with real conditions in dairy systems, although all effects fitted in model CIQ were statistically significant.

From previous studies (Van Arendonk and Dijkhuizen, 1985; Nebel and McGilliard, 1993; Dekkers *et al*. 1998; Arbel *et al*. 2001; Gonzalez-Recio *et al*. 2004) a non-linear relationship between calving interval and profit was revealed. They emphasized that although profit increases by reducing calving interval, however at intervals smaller than a certain level, several problems would occur which in turn would cause the profit to decrease. Mathematical interpretation of the results from these studies is that profit function must have a maximum value at a specific calving interval so that any deviation from this value reduces the profit. Therefore, the nature of non-linear relationship between profit and calving interval reported in previous studies is different from what was found in this study under model CIQ.

Table 5 Estimate (±SD) of multiple regression coefficients of profit for MY, MYP and CI

Model	Intercept	MY	MYP	MYP^2	CI	CI^2
CIL	$-424.74^{**}\pm158.29$	$0.10^{**}\pm0.00$	$1970.91^{**}\pm183.59$	$-1153.95^{**}\pm67.91$	$-2.68^{**}\pm0.09$	--
CIQ	$-147.43^{ns}\pm146.00$	$0.32^{**}\pm0.04$	$4198.40^{**}\pm461.58$	$-1923.80^{**}\pm160.87$	$-14.79^{**}\pm2.36$	$0.0092^{**}\pm0.0017$

MY: milk yield; MYP: milk yield persistency and CI: calving interval.
CIL and CIQ are regression models containing linear order and quadratic order of calving interval, respectively.
NS: non significant (P> 0.05); * P<0.05 and ** P<0.01.

This difference could be due to simultaneous inclusion of persistency and calving interval in the regression model. Therefore, the results of this model do not contradict previous studies. Comparison of the results of models used in this study showed the model CIL was superior to the model CIQ due to lower number of effects fitted in the model and also more consistency with the true situation of dairy systems.

Sensitivity analysis

The effects of 20% changes in the price of forage, concentrate and milk on the economic values of milk yield, milk yield persistency and calving interval under model CIL are shown in Table 6.

Table 6 The effects of changes in the price of forage, concentrate and milk on the economic values of MY, MYP and CI under model CIL

	MY	MYP	CI
Base	0.1000	-118.2000	- 2.6700
+20% Change in forage price	-0.0003	-2.1000	-0.0067
-20% Change in forage price	0.0003	2.1100	67.0000
+20% Change in concentrate price	-0.0178	2.4000	0.3600
-20% Change in concentrate price	0.0178	-2.4000	- 0.3600
+20% Change in milk price	0.0459	14.1500	- 0.7700
-20% Change in milk price	-0.0459	-14.1500	0.7700

MY: milk yield; MYP: milk yield persistency and CI: calving interval.
CIL is regression model containing linear order of calving interval.

The price of milk had the greatest effect on the economic values of the traits. This may be due to higher impact of milk sales on profit of production system. Increase in milk price led to higher economic importance of milk yield and milk yield persistency which are directly linked to the income of system. Change in the forage price had the lowest effect on the economic values because the most portion of cow requirements were supplied by concentrate intake which was more expensive than forage. Increase in the concentrate price was associated with reduced economic value of milk production and increased economic importance of non-production traits i.e. calving interval and milk yield persistency.

Contrary to what was stated about increase in concentrate price, increase in forage price reduced the economic values of all traits. This was relevant to feeding management in the studied systems.

As explained above, daily energy requirement was supplied by forage and concentrate with forage intake being fixed and concentrate consumption being variable according to energy requirement.

Therefore, increasing forage price regardless of the change in the importance of production traits will reduce economic values of all traits including calving interval and milk yield persistency.

CONCLUSION

Multiple regression models provide a general tool to estimate the economic values of traits. However, the included effects in these models might impact on the consistency of results in real situations. Considering the simplicity of the model and consistency in real conditions, model CIL seems to be an optimum due to lower number of effects fitted in the model and also more consistency with the real situation of dairy systems. Sensitivity analysis showed economic importance of traits was affected positively by milk price and increasing the concentrate price in future may reduce the importance of milk yield in favor of calving interval and milk yield persistency.

REFERENCES

Amer P.R., Mpofu N. and Bondoc O. (1998). Definition of breeding objectives for sustainable production systems. Pp. 97-104 in Proc. 6th World Cong. Genet. Appl. Livest. Prod. Armidale, NSW, Australia.

Appuhamy J.A.D.R.N., Cassell B.G., Dechow C.D. and Cole J.B. (2007). Phenotypic relationships of common health disorders in dairy cows to lactation persistency estimated from daily milk weights. *J. Dairy Sci*. **90,** 4424-4434.

Arbel R., Bigun Y., Ezra E., Sturman H. and Hojman D. (2001). The effect of extended calving intervals in high-yielding cows on milk production and profitability. *J. Dairy Sci*. **84,** 600-608.

Cole J.B. and Null D.J. (2009). Genetic evaluation of lactation persistency for five breeds of dairy cattle. *J. Dairy Sci*. **92,** 2248-2258.

Dekkers J.C.M. (1991). Estimation of economic values for dairy cattle breeding goals-Bias due to sub-optimal management policies. *Livest. Prod. Sci*. **29,** 131-149.

Dekkers J.C.M., Ten Hag J.H. and Weersink A. (1998). Economic aspects of persistency of lactation in dairy cattle. *Livest. Prod. Sci*. **53,** 237-252.

Ghavi Hossein-Zadeh N., Nejati-Javaremi A., Miraei-Ashtiani S.R., Kohram H. and Honarvar M. (2011). Bio-economic model to evaluate twinning rate using sexed embryo transfer in dairy herds. *Animal*. **5,** 1705-1719.

González-Recio O., Pérez-Cabal M.A. and Alenda R. (2004). Economic value of female fertility and its relationship with profit Spanish dairy cattle. *J. Dairy Sci*. **87,** 3053-3061.

Groen A.F. (1989). Economic values in cattle breeding. I. Influences of production circumstances in situations without output limitations. *Livest. Prod. Sci*. **22,** 1-16.

Hazel L.N. (1943). The genetic basis for constructing selection indexes. *Genetics*. **28,** 476-490.

Hosseinpour Mashhadi M., Emam Jomeh Kashan N., Nassiry M.R. and VaezTorshizi R. (2008). Prediction breeding value and genetic parameter in Iranian Holstein bulls for milk production traits. *Pakistan J. Biol. Sci*. **11,** 108-112.

Kahi A.K. and Nitter G. (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. I. Derivation of economic values using profit functions. *Livest. Prod. Sci*. **88,** 161-177.

Korver S., Van Arendonk J.A.M. and Koops W.J. (1985). A function for live-weight change between two calvings in dairy cattle. *Anim. Prod*. **40,** 233-241.

Muir B.L., Fatehi J. and Schaeffer L.R. (2004). Genetic relationships between persistency and reproductive performance in first-lactation Canadian Holsteins. *J. Dairy Sci*. **87,** 3029-3037.

NRC. (2001). Nutrient Requirements of Dairy Cattle. 7th Ed. National Academy Press, Washington, DC, USA.

Nebel R.L. and McGilliard M.L. (1993). Interactions of high milk yield and reproductive performance in dairy cows. *J. Dairy Sci*. **76,** 3257-3268.

Olesen I., Groen A.F. and Gjerde B. (2000). Definition of animal breeding goals for sustainable production systems. *J. Anim. Sci*. **78,** 570-582.

Ponzoni R.W. (1992). Genetic Improvement of Hair Sheep in the Tropics. Food. Agric. Org. United National, Rome, Italy.

Sadeghi-Sefidmazgi A., Moradi-Shahrbabak M., Nejati-Javaremi A., Miraei-Ashtiani S.R. and Amer P.R. (2012). Breeding objectives for Holstein dairy cattle in Iran. *J. Dairy Sci*. **95,** 3406-3418.

Sadeghi-Sefidmazgi A., Moradi-Shahrbabak M., Nejati-Javaremi A. and Shadparvar A.A. (2009). Estimation of economic values in three breeding perspectives for longevity and milk production traits in Holstein dairy cattle in Iran. *Italian J. Anim. Sci*. **8,** 359-375.

Shadparvar A.A. and Nikbin S. (2008). Optimum model for analyzing lifetime profitability of Holstein cows. *Asian-australas. J. Anim. Sci*. **21,** 769-775.

Sölkner J. and Fuchs W. (1987). A comparison of different measures of persistency with special respect to variation of test-day milk yields. *Livest. Prod. Sci*. **16,** 305-319.

Togashi K. and Lin C.Y. (2009). Economic weights for genetic improvement of lactation persistency and milk yield. *J. Dairy Sci*. **92,** 2915-2921.

Van Arendonk J.A.M. and Dijkhuizen A.A. (1985). Studies on the replacement policies in dairy catlle: III. Influence of variation in reproduction and production. *Livest. Prod. Sci*. **13,** 333-349.

Wolfová M., Wolf J., Kvapilík J. and Kica J. (2007). Selection for profit in cattle: I. Economic weights for purebred dairy cattle in the Czech Republic. *J. Dairy Sci*. **90,** 2442-2455.

Wood P.D.P. (1967). Algebraic model of the lactation curve in cattle. *Nature*. **216,** 164-165.