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The Effect of Age at First Calving and Calving Interval on Productive Life and Lifetime Profit in Korean Holsteins

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ABSTRACT: This study was performed to estimate the effect of age at first calving and first two calving intervals on productive life and life time profit in Korean Holsteins. Reproduction data of Korean Holsteins born from 1998 to 2004 and lactation data from 276,573 cows with birth and last dry date that calved between 2000 and 2010 were used for the analysis. Lifetime profit increased with the days of life span. Regression of Life Span on Lifetime profit indicated that there was an increase of 3,800 Won (approximately $3.45) of lifetime profit per day increase in life span. This is evidence that care of each cow is necessary to improve net return and important for farms maintaining profitable cows. The estimates of heritability of age at first calving, first two calving intervals, days in milk for lifetime, lifespan, milk income and lifetime profit were 0.111, 0.088, 0.142, 0.140, 0.143, 0.123, and 0.102, respectively. The low heritabilities indicated that the productive life and economical traits include reproductive and productive characteristics. Age at first calving and interval between first and second calving had negative genetic correlation with lifetime profit (-0.080 and -0.265, respectively). Reducing age at first calving and first calving interval had a positive effect on lifetime profit. Lifetime profit increased to approximately 2,600,000 (2,363.6) from 800,000 Won ($727.3) when age at first calving decreased to (22.3 month) from (32.8 month). Results suggested that reproductive traits such as age at first calving and calving interval might affect various economical traits and consequently influenced productive life and profitability of cows. In conclusion, regard of the age at first calving must be taken with the optimum age at first calving for maximum lifetime profit being 22.5 to 23.5 months. Moreover, considering the negative genetic correlation of first calving interval with lifetime profit, it should be reduced against the present trend of increase. (**Key Words:** Age at First Calving, Calving Interval, Lifetime Profit, Productive Life)

INTRODUCTION

Reproduction is an important consideration in dairy farming. Good reproductive performance is important not only for the improvement of milk production but also for a better genetic progress. Therefore, recently many countries have performed genetic evaluations for reproductive traits (Abe et al., 2009). Service information could be useful reproductive measures such as days to first service, nonreturn and conception rates. However, most farms do not transcribe service information in their milk recording system although it is compulsory for birth date and calving dates to be recorded in the Republic of Korea. Therefore, information on age at first calving of heifers and calving interval which are major traits related to reproductive performance are available.

Age at first calving is an important factor in reducing cost of rearing replacements in dairy herds (Ettema and Santos, 2004). However, dystocia is detrimental to reproduction and younger, smaller heifers and older over conditioned heifers have a higher risk of dystocia (Ettema and Santos, 2004). Hence, age at first calving is a benchmark that should be properly managed in order to achieve the highest economic return and longer productive life. Calving interval also influences the productive life of a dairy cow. Although, if a cow does not calve every 365 d there is an additional cost on the system, the calving interval has continued to increase with time in all breeds in the USA and many other countries (Hare et al., 2006a). Pryce et al. (2004) pointed out an unfavorable relationship

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between milk production and calving interval. Selection for high milk yield in dairy cattle generally is accompanied by a decline in fertility (Oltenacu and Broom, 2010) which eventually appears as low reproductive performance. Questions remain about the most appropriate age at first calving and trends in calving interval required making maximum lifetime profit together with a long productive life. Therefore, the objective in the present study was to estimate the effect of age at first calving and first two calving intervals on productive life and life time profit.

MATERIALS AND METHODS

Data

Data collected from the nationwide milk recording system for Holstein dairy cattle by the Dairy Improvement Center, National Agricultural Co-operative Federation were used for the analysis. After the preliminary restrictions and eliminations pertinent to each trait such as calving interval of 300 d through 600 d, 276,573 cows remained that were born from 1998 to 2004 at lactation that calved from 2000 to 2010. The traits analyzed were age at first calving (FC), interval between first and second calving (SC), interval between second and third calving (TC), days in milk for lifetime (DIM), days of lifetime (LS), milk income for lifetime (IM) and lifetime profit by milk production (LP). Milk income from each cow was simulated by actual milk price with the Korean milk pricing system (Korea Dairy Committee, 2009). The production costs for replacement, for milk and dry period were also simulated on the basis of the statistics generated by the monthly survey bulletin (NACF, 2010) and Statistics Korea (2010). The prices and the costs were adopted as of 2010. Lifetime profit by milk production for each cow was computed as follows.

$$LP = IM-(CFC+CM+CD)$$

where:

LP = Lifetime profit due to milk production,

IM = Income from lifetime milk production,

CFC = Cost for raising calf before first calving,

CM = Production cost in milk production for lifetime,

CD = Production cost in dry period for lifetime.

Values obtained by pricing each cow's actual milk yield with average fat percentage and somatic cell count at each lactation were totalized for her IM. CFC was calculated according to age at first calving. The average farm price (2,543,000 Won; $2,312) of first calving cows (NACF, 2010) was applied to replacement cost of average age at first calving. Replacement cost (CFC) for each cow was simulated by addition or subtraction of feed cost per day according to her deviation from average age at first calving (25.7 month). CM and CD were simulated according to days in milk, days in dry and milk volume based on production cost of milk (Statistics Korea, 2010). The costs of production were estimated considering the size of the operation into account. Total costs of production based on the statistics included operating costs and overhead costs. The operating costs are composed of feed, veterinary, bedding, marketing, energy, repairs and interest on operating capital.

Statistical analysis

Simple statistics were obtained for IM, CFC, CM, CD, and LP of economic value (SAS, 2013). Genetic analysis were carried out for productive life (DIM and LS), lifetime economic (IM and LP) and reproductive performance traits (FC, SC, and TC). SC and TC were treated as different traits. Multi-trait analyses were realized to FC, SC, TC, DIM, LS, and LP traits using the animal model. The genetic parameters including heritabilities and genetic correlations were estimated by Wombat (Meyer, 2010). The statistical model is as follows.

$$y = Xb+Zu+e$$

where:

y = the vector of observation,

b = The vector of fixed effects consisting of herd and birth year for FC, DIM, LS, LP and fixed effects consisting of herd and birth year and calving year for SC and TC,

u = the vector of animal effects,

X, Z = Incidence matrices relating observations to fixed effects and random effects, respectively.

RESULTS AND DISCUSSION

General description

The structure and descriptive statistics of data used in the analysis are described in Table 1. Cows with lifetime records were mostly used for the analysis. Since reproductive performance traits were generated consecutively through lifetime, and cows with only first lactation data do not have a calving interval, the numbers of trait SC were different from the number of trait FC. Calving intervals continued to increase through 2000 to 2010 in general similar to the trend of increasing interval in the US. (Nieuwhof et al., 1989; Hare et al., 2006a). The average number of lactating cows in the herds in Korea is approximately 39. Therefore to secure enough observations in contemporary groups, calving seasons were excluded in the model for estimation of genetic parameters of the reproductive traits.

VanRaden (2002) stated that body weight of a cow along with the variation in feed and housing costs and calf prices are important factors for estimation of production cost at first calving. Moreover, reproductive performances

Table 1. Distribution and means of the reproductive and productive life traits

Birth year	No	FC	DIM	LS	Calving year	SC		TC	
						No	Mean	No	Mean
1998	36,930	780.2	1,268.8	1,985.5	2000	409	351.9		
1999	40,891	787.4	1,278.6	1,946.2	2001	13,372	403.5	347	356.9
2000	40,871	783.7	1,280.2	1,946.2	2002	21,935	409.0	9,811	392.0
2001	39,600	787.2	1,264.7	1,946.2	2003	23,383	410.5	15,963	407.5
2002	41,331	789.7	1,236.8	1,929.8	2004	23,334	411.8	18,231	414.8
2003	38,442	788.5	1,161.7	1,881.8	2005	25,815	412.1	17,613	415.6
2004	38,508	788.6	1,063.3	1,809.8	2006	25,156	416.1	18,780	413.7
					2007	25,209	415.9	18,688	417.3
					2008	8,812	447.8	18,918	420.1
					2009	499	468.3	8,698	448.2
					2010	72	454.6	1,031	472.8
Overall	276,573[1]					167,996[2]	413.8	128,080[2]	415.8

FC = Days to first calving, DIM = Days in milk for lifetime, LS = Days of lifespan, SC = Days between first and second calving, TC = Days between second and third calving.

[1] Total number of cows. [2] Total number of records.

were further assessed by simulated profit data with several biological and economic factors (Kalantari and Cabrera, 2012). The detailed costs and incomes in milk production are not recorded in Korean milk recording system. Since a large dataset of economical records may help to characterize profitability, the production costs and income were simulated. Even though simulation may not provide a precise estimation, it partly reflects real values. Replacement cost also was simulated with farm price of first calving cows in spite of controversial factors affecting farm price such as market demand. The cost of milk production and production cost during dry period were simulated according to days of production and milk volume, from estimations based on the statistics periodically collected by Statistics Korea, a reliable source of information for production costs. Lifetime profit was calculated for individuals based on milk income and production cost including feed cost and operating cost of farm which reflected differences in management type according to herd size.

The survival rates were known as 19, 10, 5, and 2% to parities 5 through 8, respectively (Hare et al., 2006b). The cows born in year 2004 had mostly 4th lactations in 2010 and 19% of the cows were supposed to have parity 5 or later. Further, 2, 5, and 10% of data from cows born in year 2001 through 2003 seemed to have been excluded in the analysis. Consequently, about 5.1% of cows in Table 2 were surmised not to have finished their latter lactation after year 2010, providing partial lifetime records (DIM, LS, IM, CM, CD, and LP). However, trivial portions were excluded in SC and TC traits. Computed economic values of income, costs and profit in Korean currency Won are provided in Table 2.

Table 2. Mean economic values[1] of production cost, milk income and lifetime profit according to number of lactations and percentage from total production cost for lifetime

No. of lactations	No. of heads	IM		CFC		CM		CD		LP
		Mean	%	Mean	%	Mean	%	Mean	%	Mean
1	59,835	6,953	83.2	2,833	33.9	5,521	66.1			-581
2	69,993	15,014	112.6	2,822	21.2	9,585	71.9	925	6.9	1,141
3	60,542	23,735	127.7	2,825	15.2	14,083	75.8	1,676	9.0	3,024
4	45,166	32,280	137.8	2,807	12.0	18,203	77.7	2,411	10.3	5,709
5	24,211	40,576	144.7	2,786	9.9	22,123	78.9	3,139	11.2	8,128
6	10,903	48,601	149.9	2,772	8.5	25,757	79.4	3,897	12.0	10,524
7	4,175	56,167	154.7	2,750	7.6	28,884	79.6	4,666	12.9	12,765
8	1,368	63,246	160.3	2,752	7.0	31,279	79.3	5,419	13.7	15,969
9	337	70,512	176.6	2,722	6.8	31,199	78.1	6,007	15.0	20,480
10	43	75,490	182.2	2,680	6.5	32,089	77.5	6,658	16.1	19,976
2.87	27,657[2]	22,513	124.9	2,818	15.6	13,191	73.2	2,019	11.2	2,502

LP = Lifetime profit due to milk production, IM = Milk income for lifetime, CFC = Replacement cost, CM = Production cost for period in milk production of lifetime, CD = Production cost for dry period in lifetime.

[1] Unit of value is 1,000 Won. [2] Total number of individuals.

CFC was not much influenced by the number of lactations. CM, CD, IM, and LP gradually increased as the number of lactations increased as well as their standard deviations (not shown). For one lactation, the production cost exceeded milk income, resulting -581 (-$528.18) of LP because of a short productive life and large portion of CFC. The percentage of CM and CD generally increased as the number of lactations increased. Milk income increased faster than total production cost from 83 to 182.2% through 1 to 10 lactations, resulting in a continuous increase of lifetime profit (LP). Longevity of cows turned out to be most important because several lactations of income (IM) exceeded the production cost and made the replacement costs (CFC) small portion out of the total production cost. The percentage of CFC from total production cost reduced from 33.9 to 6.5% through 1 to 10 lactations and overall average was 15.6% of the total production cost, which tallys with the US cost of replacement (15% to 20%) (Cole et al., 2013). Furthermore, percentage of milk income from total production costs significantly increased from 83.2 to 182.2% while the number of lactations increased 1 through 10. It occurred not only by the influence of reduced portion of replacement cost (CFC) but also by the increment of added value in profitability of mature cows. VanRaden (2002) reported that the value of an additional lactation above the mean number of lactations was estimated to be $236 which was significantly lower than our estimation of 2,476.8 Won (approximately $2,252) average increase per lactation. It was conjectured that this difference was mostly due to different situations of dairy enterprise including milk pricing and marketing system in Korea. The mean lactation number was 2.87 which was similar to that of US. (VanRaden, 2002).

Lifetime profit function may not be linear over days of life span, but it had a linear shape over days in lifetime in Figure 1. Longevity has a large influence in determining lifetime profit (VanRaden, 2002). Productive life in the US was defined as the lactating period of a cow to 84 months, but credit for days in milk was restricted to the first 305 days of each lactation (VanRaden and Klaaskate, 1993; Pollott, 2011). Among many possible types of measurements for productive life, days in milk for lifetime (DIM) and days of life span (LS) were used to analyze and Figure 1 shows this relationship of LS and LP. Generally the LP increased in proportion to the days of life span. Regression of LS on LP indicated that 3,800 Won (approximately $3.45) of lifetime profit increased per day in life span. Lifetime profits fluctuated and had lower variation in animals with a relatively short life span. It was conjectured that cows with short life span had similar pattern for CFC, CM, CD, and IM with their group mates, resulting lower variation in LP. However, animals with long life span showed large individual difference in lifetime profit. This could indicate that care of each cow is necessary for improving net return and thus an important factor in maintaining farm profits.

Analysis of the traits

Involuntary culls, such as culls due to health or reproductive defects, have a profound effect on the economics. The primary reason for culling in dairy cattle was due to failure to conceive, which accounted for 44% of culls in first lactation animals (Esselmont and Kossaibati, 1997) and is a major factor in extending age at first calving. Figure 2 shows the distribution of ages at first calving and life span (days) of cows according days to first calving. Age at first calving was distributed between 730 (23.9) to 790 d (25.9 month). Mészáros et al. (2008) reported that the effect of age at first calving did not have a large influence on the length of productive life, and Nilforooshan and Edriss

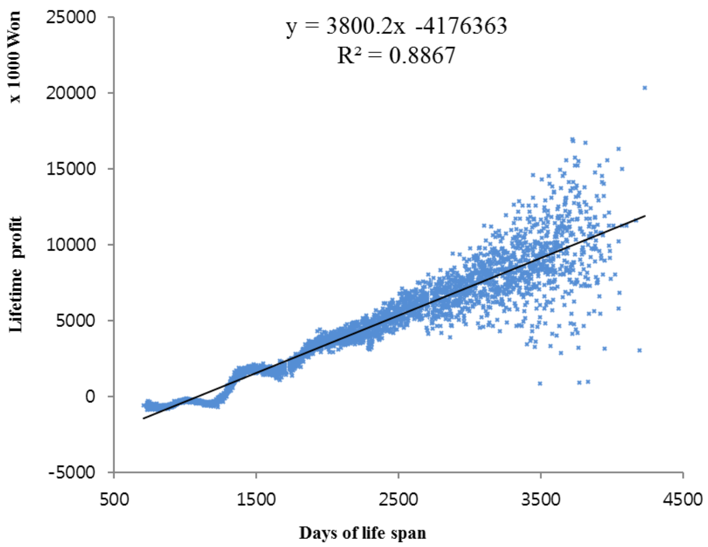

Figure 1. Distribution of lifetime profit (1,000 Won) according to days of life span.

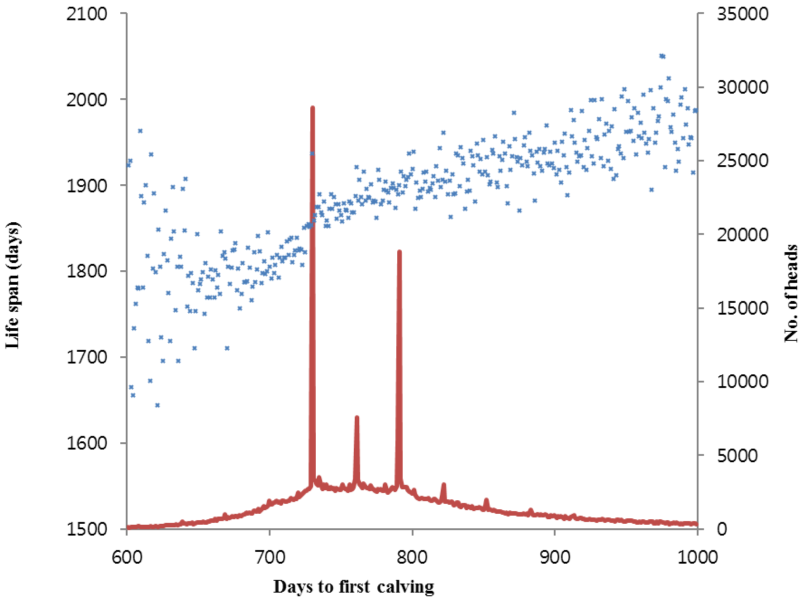

Figure 2. Frequency of age (days) at first calving and life span (days) according to days to first calving.

(2004) found a slight positive phenotypic correlation (0.052) between age at first calving and lifetime in Iranian Holsteins. Life span in the present study, however, linearly increased with increased age at first calving and a further increase in days of life span was larger than those in age at first calving as shown in Figure 2. A greater variation was observed in life span when first calving occurred before 700 d (23.0 month). Simerl et al. (1991); Ettema and Santos (2004) found greater frequency of dystocia in first calving for older (>27 month) heifers as well as for younger (<22 month) heifers. Less variation in life span was coincidently found between 671 (22) and 823 d (23 month). The results suggested that first calving at proper mature age provided healthy body condition for lifetime and early calving is harmful to longevity as found by Pirlo et al. (2000); Haworth et al. (2008).

Economic losses from impaired fertility are mainly due to a loss of production as a result of prolonged calving intervals (Van Arendonk et al., 1989; Olori et al., 2002) but also includes increased insemination costs, reduced returns from calves born and higher replacement costs (Bagnato and Oltenacu, 1994). Nilforooshan and Edriss (2004) stated that age at first calving significantly affected traits, including milk yield, fat percentage, lifetime and productive life. The production costs (CM and CD) included various expenses occurred by low reproductive performance that directly influenced lifetime profit. Milk income and lifetime profit were treated as traits to estimate genetic parameters and to predict breeding values (Pe´rez-Cabal and Alenda, 2003). The genetic relationship among the reproductive traits, productive life traits and lifetime economic traits are shown in Table 3.

Heritabilities of the reproductive traits (FC, SC, and TC) were low in general with the range of 0.088 to 0.142, similar to other reproductive traits (Weigel and Rekaya, 2000; Jamrozik et al., 2005; Windig et al., 2006). Genetic correlations of FC with SC and TC were low as -0.060 and 0.080, respectively although a high genetic correlation was obtained between calving intervals. Genetic correlations of age at first calving with DIM, LS, IM and LP were low as 0.084, 0.131, 0.093 and -0.080, respectively. Heritability of productive life and economical traits were low, similar to

Table 3. Heritabilities and genetic correlations of reproductive traits and economic traits

	FC	SC	TC	DIM	LS	IM	LP
FC	0.111						
SC	-0.060	0.088					
TC	0.080	0.989	0.142				
DIM	0.084	0.037	0.410	0.140			
LS	0.131	0.018	0.409	0.948	0.143		
IM	0.093	0.074	0.429	0.921	0.880	0.123	
LP	-0.080	-0.265	0.081	0.439	0.457	0.581	0.102

FC = Days to first calving, SC = Days between first and second calving, TC = Days between second and third calving, DIM = Days in milk for lifetime, LS = Days of lifespan, IM = Gross income from milk production, LP= Lifetime profit.

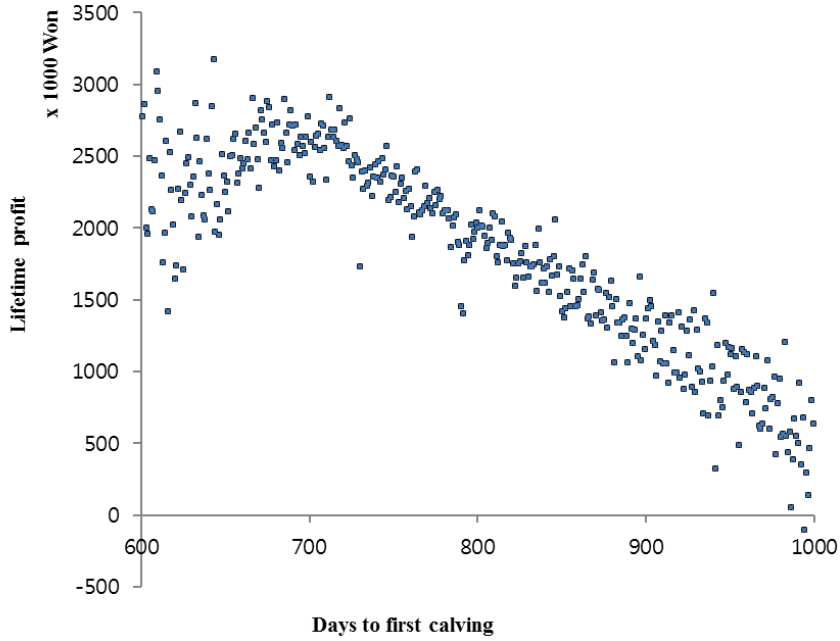

Figure 3. Distribution of lifetime profit according days to first calving.

reproductive traits, with a range of 0.102 to 0.143. Since the traits of productive life and profitability are functions of reproduction, health and production performance, it was natural to have low heritability of these traits. The results indicated that increasing age at first calving has a positive effect on productive life and milk income, which is not in agreement with the results of Nilforooshan and Edriss (2004). Similar to the positive relationship of age at first calving and life span as shown in Figure 2, genetic correlations of FC with DIM and LS were positive as 0.084 and 0.131, respectively. A negative genetic correlation was obtained between age at first calving and lifetime profit. Even though reducing age at first calving may decrease productive life, it showed a positive genetic effect on lifetime profit. A negative genetic correlation was observed between SC and LP (-0.265). Longer interval between first and second calving (SC) had negative genetic effect on lifetime profit. On the contrary, TC had a positive and lower genetic correlation with lifetime profit. The results showed that SC was more closely related with lifetime profit in an opposite direction to TC.

The economics of age at first calving are very challenging to quantify because there are many factors that could affect a cow's lactations over a lifetime (Kalantari and Cabrera, 2012). A simple rough approach was adopted to calculate the cost of replacement, which is a part of production costs for lifetime. Figure 3 shows the relationship of ages at first calving with the simulated lifetime profits. Lormore (2005) showed a cumulative income over feed cost advantage was maintained across the first lactation (and herd lifetime) for heifers calving at 22 vs 24 months of age. A conjectural peak of lifetime profit coincidently was located around 690 d (22.6 month) at first calving in Figure 3. Even though extended ages at first calving increased life span as previously shown, linearly reduced lifetime profits were observed. Hypothetically reduction of age at first calving can also decrease replacement cost and increase lifetime profit. In Figure 3, lifetime profit declined from approximately 2,600,000 (2,363.6) to 800,000 Won ($727.3) when age at first calving increased from 680 (22.3 month) to 1,000 d (32.8 month). Nilforooshan and Edriss (2004) stated that there were negative effects of age at first calving on productive life and optimum age at first calving for milk yield was 24 months. Results in the present study suggests that for lifetime profit care regarding age at first calving must be taken and that the recommended age at first calving was 22.5 to 23.5 months.

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