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# Age Optimization of First Calving to Achieve the Best Reproductive Performance in Holstein Dairy Cattle

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**Abstract**—The objective of the present study was to investigate the associations between age at first calving and reproductive performance in Holstein dairy cattle. A total of 4655 reproductive records of Holstein dairy cattle collected between 2013–2018 were used to study the effect of age at first calving (AFC) on dry period (DP), days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC) and dystocia. Heifers were classified into five age groups based on the age of the first calving 20–22, 23–24, 25–26, 27–28 and 29–32 months, and subsequently, the effect of AFC classes on the studied traits was tested. The effects of AFC on DP, CI, DO, and CTFS were evaluated using the general linear model procedure. Also, a logistic procedure was used to investigate the effect of AFC on NSC and dystocia. Age at first calving significantly affected all the traits investigated except for DP and CTFS. The results of this study showed that decreased AFC led to improvement of reproductive trait. Also, AFC less than 23 months led to an increased incidence of dystocia. It is therefore recommended that the age of first calving should be between 23 and 24 months.

**Keywords:** days open, dystocia, relationship, reproduction

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## INTRODUCTION

Reproductive performance of dairy cattle is evaluated by several factors such as age at first calving, days open, calving interval and number of services per conception [1]. Reproductive traits are considerably affected by different management practices in herds and other environmental factors [2].

One possible approach to reduce the cost of dairy cattle rearing is to shorten the length of the nonproductive period of the dairy heifers, which can be achieved by lowering the age at first calving [3]. However, some authors have reported antagonistic relationships between reproductive performance and lower AFC. Also, it has been reported that early calving harms the longevity and milk yield [4]. Therefore many dairy producers face the challenge of keeping favorable reproductive performance in their cattle at lower levels of AFC.

It is, therefore, crucial to weigh the possible benefits of reduced AFC, such as shorter generation interval, greater cumulative production per month of age, decreased feed costs, and lower overhead costs, for an unfavorable circumstance of increased dystocia, lower conception rates, reduced milk production per lactation, the prices of increased nutrient density in the ration, and diminished longevity [5]. Lower feed efficiency would be assumed after calving from first lactation cows, which are still growing rapidly when entering milk production [6]. Krpálková et al. (2014) evaluated the associations of variable intensity in rearing dairy heifers with age at first calving (AFC), reporting that conception at first and overall services was greatest in herds with AFC ≥ 800 days and the shortest calving interval (396 days) and days open (105 days) were found in the middle AFC group (799–750 days).

Nilforooshan and Edriss (2004) reported a positive effect of reducing age at first calving on milk yield and productive life. However, reducing age at first calving to 21 months of age had a negative effect on yields of milk and milk fat.

Therefore, age at first calving is an important consideration that should be appropriately monitored in order to obtain longer productive life and the highest economic return. The objective of this study was to estimate associations between AFC and reproduction traits in a commercial dairy herd.

**Table 1.** Characteristics of the data structure

| Trait | Min | Max | CV | SD | Mean | N |
|---|---|---|---|---|---|---|
| DP, day | 17 | 123 | 32.18 | 21.97 | 68.26 | 2303 |
| CI, day | 298 | 760 | 11.85 | 49.49 | 417.63 | 1974 |
| DO, day | 40 | 214 | 12.91 | 18.48 | 142.58 | 1968 |
| CTFS, day | 40 | 171 | 47.62 | 30.66 | 64.38 | 1967 |
| NSC | 1 | 14 | 48.75 | 0.78 | 1.60 | 4655 |
| AFC, mo | 17 | 47 | 9.89 | 2.42 | 24.46 | 4655 |

Age at first calving (AFC) dry period (DP), days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC).

## MATERIALS AND METHODS

### *Data and Records*

In this study, a total of 4655 reproductive records of Holstein dairy cows collected from 2013 to 2018 were used to assess associations between age at first calving and reproductive performance in Holstein dairy cattle. The data was covered by the breeding center in Iran and the records were registered regularly by experts of the breeding center of the country. At birth, the relevant information about newborns such as sex, birth type, birth date, birth weight, sir ID and dam ID were recorded. The traits included in this study were age at first calving (AFC), season and year of calving, days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC) and dystocia. Dystocia was registered as, 0 = non assisted, 1 = difficult farmer assistance. Data were first edited using Excel software. Data less or greater than 3 standard deviations from the average were deleted as outlier data and were removed from further analyses. Age at first calving was defined to be 20 to 32 months of age. Calving age out of this range was excluded.

### *Statistical Analysis*

In this study, cows with AFC between 20 and 32 months of age were considered for further analysis. Heifers were classified into 5 age groups based on the age of the first calving (20–22, 23–24, 25–26, 27–28 and 29–32 months) and the effect of AFC classes on the studied traits was tested by SAS 9.4 software. The effects of AFC on dry period, calving interval, days open, and days between calving and first service (CTFS) were evaluated using the general linear model procedure. Also, logistic procedure was used to investigate the effect of AFC on number of services per conception (NSC) and dystocia. Fixed effects were first tested and finally, the effects of the year and season of calving were entered into the statistical model. The mean comparison between different AFC classes probe was performed with Tukey test at a probability level of 0.05.

## RESULTS

The descriptive statistics for the traits studied are presented in Table 1. Minimum and maximum of coefficients of variation (CV) among the considered traits were for age at first calving and number of services per conception, respectively. The mean age of the first calving and calving interval for this population was 24.46 months and 417.63 days, respectively. Year of calving was significantly associated with all reproductive traits except for DP and NSC (Table 2). All studied traits, except for DP were significantly influenced by season of calving (Table 3). Heifers calving in the summer showed the lowest AFC.

Days open (DO), calving interval (CI), number of services per conception (NSC), and dystocia differed significantly ($P < 0.001$) among groups of AFC (Table 4). Heifers with AFC less than 24 months had significantly lower calving intervals than other classes, but no significant difference was observed between the first two classes. A similar trend was obtained in days open in that, with increasing AFC, the number of days open increased. Also, the number

**Table 2.** Least squares means ± S.E for traits studied in different classes of calving year

| AFC, day | NSC | Dystocia | CTFS, day | DP, day | DO, day | CI, day | Calving, yr |
|---|---|---|---|---|---|---|---|
| *** | ns | *** | ** | ns | *** | *** | |
| $756.98 + 2.56^{a}$ | $1.62 \pm 0.038$ | $0.05 \pm 0.009^{c}$ | $67.28 \pm 1.13^{a}$ | $67.86 \pm 0.65$ | $151.06 \pm 4.92^{ab}$ | $426.33 \pm 4.96^{ab}$ | 2013 |
| $754.61 + 2.38^{a}$ | $1.67 \pm 0.036$ | $0.069 \pm 0.009^{bc}$ | $65.95 \pm 1.04^{a}$ | $67.91 \pm 0.57$ | $164.06 \pm 4.50^{a}$ | $438.90 \pm 4.52^{a}$ | 2014 |
| $762.98 + 2.68^{a}$ | $1.61 \pm 0.040$ | $0.066 \pm 0.01^{c}$ | $62.76 \pm 1.18^{bc}$ | $68.05 \pm 0.68$ | $144.85 \pm 5.11^{b}$ | $421.07 \pm 5.14^{bc}$ | 2015 |
| $715.62 + 2.34^{b}$ | $1.54 \pm 0.035$ | $0.078 \pm 0.008^{bc}$ | $62.84 \pm 0.98^{b}$ | $68.65 \pm 0.53$ | $135.46 \pm 4.20^{b}$ | $409.62 \pm 4.23^{c}$ | 2016 |
| $716.89 + 2.54^{b}$ | $1.62 \pm 0.038$ | $0.126 \pm 0.009^{a}$ | $62.43 \pm 1.44^{c}$ | $68.95 \pm 0.57$ | $125.48 \pm 6.21^{c}$ | $375.39 \pm 6.26^{d}$ | 2017 |
| $710.81 + 3.02^{b}$ | $1.53 \pm 0.045$ | $0.096 \pm 0.011^{b}$ | $61.92 \pm 2.43^{c}$ | $67.83 \pm 0.66$ | $100.30 \pm 5.76^{c}$ | $368.78 \pm 7.98^{d}$ | 2018 |

Age at first calving (AFC) dry period (DP), days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC).

**Table 3.** Least squares means ± S.E for traits studied in different classes of calving season

| Calving year | AFC, day | NSC | Dystocia | CTFS, day | DP, day | DO, day | CI, day |
|---|---|---|---|---|---|---|---|
| | *** | *** | *** | *** | ns | *** | *** |
| Spring | 740.42 + 2.46[b] | 1.6663 ± 0.03620[b] | 0.11 ± 0.009[a] | 65.39 ± 1.07[a] | 67.80 ± 0.55 | 170.05 ± 4.63[a] | 445.02 ± 4.65[a] |
| Summer | 722.11 + 1.74[c] | 1.5240 ± 0.02563[c] | 0.081 ± 0.006[b] | 60.88 ± 0.83[b] | 68.49 ± 0.39 | 128.02 ± 3.60[b] | 402.68 ± 3.63[b] |
| Automn | 740.78 + 2.1[b] | 1.5712 ± 0.03093[c] | 0.064 ± 0.0078[b] | 65.78 ± 1.01[a] | 67.98 ± 0.50 | 124.97 ± 4.33[b] | 400.59 ± 4.37[b] |
| Winter | 760.21 + 2.62[a] | 1.7793 ± 0.03850[a] | 0.06 ± 0.0097[b] | 68.50 ± 1.22[a] | 68.70 ± 0.62 | 164.42 ± 5.29[a] | 439.21 ± 5.32[a] |

Age at first calving (AFC) dry period (DP), days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC).

**Table 4.** Least squares means±S.E for traits studied in different classes of AFC

| AFC | NSC | dystocia | CTFS, day | DP, day | DO, day | CI, day |
|---|---|---|---|---|---|---|
| | *** | *** | Ns | Ns | *** | *** |
| 20-22 | 1.27 ± 0.035[d] | 0.19 ± 0.01[a] | 63.37 ± 1.23 | 70.52 ± 0.55 | 131.78 ± 5.32[c] | 405.69 ± 5.35[a] |
| 23-24 | 1.29 ± 0.20[d] | 0.049 ± 0.005[c] | 63.91 ± 0.79 | 67.98 ± 0.37 | 132.26 ± 3.42[c] | 407.63 ± 3.45[a] |
| 25-26 | 1.69 ± 0.026[c] | 0.049 ± 0.007[c] | 65.02 ± 0.94 | 67.10 ± 0.55 | 147.97 ± 4.06[b] | 422.66 ± 4.08[b] |
| 27-28 | 2.29 ± 0.042[b] | 0.06 ± 0.01[c] | 64.70 ± 3.86 | 68.00 ± 1.78 | 149.61 ± 16.15[ba] | 427.53 ± 16.27[b] |
| 29-32 | 3.382 ± 0.050[a] | 0.05 ± 0.014[c] | 66.40 ± 1.57 | 67.66 ± 0.71 | 187.69 ± 6.89[a] | 463.19 ± 6.86[c] |

Age at first calving (AFC) dry period (DP), days between calving and first service (CTFS), days open (DO), calving interval (CI), number of services per conception (NSC).

of services per conception was highest in the group 32 ≥ AFC ≥ 29 months. The latest AFC (32 ≥ AFC ≥ 29 months) and earliest AFC 22 ≥ AFC ≥ 20 months) groups had the highest and lowest calving interval, respectively. The highest incidence of dystocia was found in the earliest AFC group (22 ≥ AFC ≥ 20 months) and the lowest frequency of dystocia was detected for heifers with 26 ≥ AFC ≥ 23 months.

## DISCUSSION

The present study evaluated association of AFC and reproductive traits of Holstein dairy cattle. The reason for less CV for AFC may be due to less variation and effect of outside environment on this trait. Nilforooshan and Edriss (2004) reported minimum and maximum coefficients of variation for age at first calving and productive life, respectively.

For fixed effects evaluated, dry period was not significantly influenced by year and season of calving. Also the year of calving was not significantly associated with the number of services per conception. Hammoud et al. (2010) reported that season of calving had significant effect on CTFS ($P < 0.01$), DO and CI ($P < 0.05$), but had insignificant effect on NSC. Dákay et al. (2006) reported that year had significant influence on AFC. Also, Mengistu et al. (2016) reported that season of calving was not significant on reproductive traits while, calving interval and days open significantly influenced by year of calving.

Mean age at first calving of this population (24.46 months) was less than those reported by Nilforooshan and Edris (2004) in Iranian Holsteins of the Isfahan Province (26.8 months), Hammoud et al. (2010) in Friesian cows under semiarid conditions in Egypt (30.6 months) and Eastham et al. (2018) in UK Holstein and Holstein-Friesian dairy cows (29.1 months). Our estimate of AFC was slightly greater than the recommended value for AFC. The AFC in Holsteins is recommended to be under 24 months to maximize lactation performance and to reduce rearing costs [11, 12].

In our study optimal reproductive performance was detected for the AFC ranging between 23 to 24 months as AFC below 23 months of age exhibited higher incidence of dystocia. Pirlo et al. (2000) found 23 to 24 months of AFC as the biologically optimum age for obtaining maximum income from dairy cattle farming. Thompson et al. (1983) reported that AFC below 22 months of age resulted in higher incidence of difficult calving, recommending this age as biological threshold for cattle. Although, reduction of age at first calving, theoretically, can increase the number of calves per cow, dystocia can act as a limiting factor that may reduce the livability of calves [13, 14]. Simerl et al. (1991) reported the incidence of dystocia to be greater

for younger (<22 months) heifers as well as for older (>27 months). Pirlo et al. (2000) reported that later calving of heifers is preferred by cattle farmers as they expect that early calving would result in negative influence on milk yields and lifespan. Wathes et al. (2008) reported that optimal fertility and keeping best performance were achieved in the AFC range of 24 to 25 months. Also, Krpálková et al. (2014) reported that the group with the earliest AFC (24.5 months) had the lowest number of completed lactations and the lowest profitability.

Results of this study showed that AFC had significant effect on all reproductive traits except for DP and CTFS. Our results showed that increased calving interval was associated with increased AFC which was in agreement with that reported by Eastham et al. (2018) in UK Holstein and Holstein-Friesian dairy cows who found that those heifers with lower AFC had better fertility in order to conceive and calve at a young age which could then result in successive good fertility and a low calving interval. However, they recommended evaluating the percentage of animals by known class of AFC to have calved again. Also Froidmont et al. (2013) in heifers calving for the first time in Belgium found the same association between AFC and CI.

Though the effect of AFC on CTFS was not significant, heifers with AFC lower than 24 months had the shortest CTFS. Hammoud et al. (2010) found the influence of AFC on CTFS highly significant and reported that cows with AFC more than 36 months had the longest CTFS ($92.6 \pm 4.5$) and cows had AFC less than 29 months of age had $87.8 \pm 2.7$ days CTFS. Zavadilová and Štípková (2013) reported that cows with higher AFC tended to experience longer DO and longer CTFS in the first parity. Penev et al. (2014) found influence of AFC on reproduction traits in a way that cows calving after the 26th month had higher number of services per conception.

## CONCLUSIONS

Results of this study show that the high AFC is associated with unfavorable fertility at the first lactation. Optimal reproductive performance was observed for the AFC ranging between 23 to 24 months. AFC below 23 months of age was associated with a higher incidence of dystocia.

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## COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving animals or human participants performed by any of the authors.

## CONSENT TO PARTICIPATE

Not applicable.

## DATA AVAILABILITY

The datasets analysed during the current study are not publicly available due to restrictions set by data provider but are available from the corresponding author on reasonable request.

## AUTHOR CONTRIBUTIONS

Conceptualization, methodology, supervision, review and editing: Mohsen Gholizadeh; formal analysis, investigation and writing—original draft preparation: Mohammad-Zaman Dastranj, review and editing: Hasan Hafezian.

## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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