# Effect of age at first calving on longevity and fertility traits for Holstein cattle

L. Zavadilová, M. Štípková

Institute of Animal Science, Prague-Uhříněves, Czech Republic

**ABSTRACT**: Effects of age at first calving (AFC) on functional longevity of Czech Holstein cows and their reproduction traits in the first lactation were analyzed using the first lactation data of 605 538 Holstein cows first calved from 1993 to 2008. Three classes were formed for AFC: low age class (16–24 months), average age class (25–30 months), and high age class (33–46 months). Effects of AFC on length of productive life (LPL), days open (DO), days between calving and first service (CTFS), and days between first service and conception in the first lactation (FSTC) were estimated by survival and linear model analyses. It was found that LPL was on average slightly shorter for cows with higher AFC who showed also a lower proportion of higher lactations and tended to longer DO and longer CTFS in the first parity. The results of survival analysis indicate that cows with higher AFC had a tendency to shorter LPL (risk of culling 1.118) and to longer DO (risk of conception 0.758), CTFS (risk of conception 0.757), and FSTC (risk of conception 0.754) in comparison with cows with lower AFC. When the effect of fertility traits on LPL was analyzed, it was found that longer DO, CTFS, and FSTC were connected with a lower risk of culling (0.132, 0.183, 0.206) regardless of the particular AFC group. In linear model analysis, the effects of AFC group were estimated from two datasets, where the second dataset included also the missing values of fertility traits. It was found that the cows group with the highest AFC showed worse values of fertility traits (16.75, 19.69, 20.46 days) than the cows groups with lower AFC. Results of all analyses showed that a high AFC is connected with worse cow's fertility at the first lactation and with lower cow's LPL.

**Keywords**: functional traits; survival analysis; linear model; cattle

Functional traits have received increasing attention in breeding programs for dairy cattle in many countries. Functional longevity is a trait of particular interest for the breeders; it reflects fertility, health, and overall fitness of cow, not the level of cow's production. The relationship between longevity and animal health and integrity makes longevity a highly desirable trait in dairy production. When longevity of dairy cows is analyzed, age at first calving (AFC) is regularly taken into account. However, AFC has no large influence on the length of productive life, although a certain trend could be observed (Vukasinovic et al., 1997, 2001). Ducrocq (2005) found an almost linearly increasing relative risk ratio between 20 and 38 months of AFC. M'hamdi et al. (2010) observed a linear increase of relative culling risk proportional to increase of AFC with a relative risk ratio equal to 1 for calving age of 27 months. Chirinos et al. (2007) found the highest relative risk for cows with AFC over 34 months. Similarly, Bielfeldt et al. (2006) reported a higher culling risk if first calving took place when the heifers were older than 3 years. However, in the studies of Ducrocq (1994) or Ojango et al. (2005), the effect of AFC was not significant.

Decreasing AFC has a positive effect on genetic progress because the generation interval decreases (Pirlo et al., 2000). Reduction of AFC can also decrease replacement expenses (Gardner et al., 1988). To maximize lactation performance and to reduce rearing costs, average AFC in Holsteins was recommended to be ≤ 24 months with a body weight < 560 kg after calving at 24 months (Heinrichs,

Supported by the Ministry of Agriculture of the Czech Republic (Project No. MZE 0002701404).

1993; Tozer and Heinrichs, 2001). Late calvings are presumably caused by reasons associated with herd management, fertility, or other health problems and these factors are likely to increase the risk of culling (Sewalem et al., 2005). The fertility and health problems can be lifelong characteristics of particular animals and could therefore affect culling after the first calving of cows. For example, Vukasinovic et al. (2001) and subsequently other authors as Nilforooshan and Edriss (2004) and Páchová et al. (2005) speculate that the higher culling risk for cows that first calved in high age may be due to fertility problems.

Good female fertility is characterized by cows that return to cyclicity soon after calving, show strong signs of oestrus, have a high probability of becoming pregnant when inseminated at the correct time, and have the ability to carry the resulting fetus to term. Among potential measures that can be used to describe this complex trait, this study emphasizes the interval between calving and the last insemination (also called days open). Days open can be split into two partial intervals: interval between calving and first service and interval between first service and conception. The first one expresses the ability to return to cyclicity and the second one to become pregnant. For Holstein cattle in the Czech Republic, the relationship was found between indicators of fertility of cows and weight after calving and during lactation (Řehák et al., 2012) but effect of age at first calving has not been studied for the Czech Holstein population. In accordance with published estimates for Holstein cattle, heritability coefficients for fertility traits of cows and their genetic correlations correspond to literature data. Zink et al. (2012) found very low heritability, almost close to 0. The genetic correlations between days open and interval between calving and first service or interval between first service and conception were around 0.8. The genetic correlation between the above mentioned intervals was substantially lower (0.23).

Survival analysis is an alternative method for analyzing traits recorded as time intervals (Eicker et al., 1996; Allore et al., 2001). In dairy cattle, survival analysis techniques are frequently used for analyzing longevity (Sewalem et al., 2005; Mészáros et al., 2008) and to predict breeding values for functional longevity (Ducrocq, 1994; Vukasinovic et al., 2001). The survival analysis was proposed also for the genetic evaluation of female fertility in dairy cattle (Schneider et al., 2005). This method can handle censoring and time-dependent covariates. Furthermore, data may be non-normally distributed what is the case for length of productive life, which usually presents right-skewed distributions. Moreover, the possibility of using also censored data in the analyses is important in order to reduce possible biases in predictions. Time-dependent covariates allow considering effects that change over the study period and help to determine the effect of such covariates at different times during the study period (Gröhn et al., 1997). Considering fertility traits, one of the main advantages of survival analysis is that it can retain the information from cows that are culled before conception or because of failure to conceive before the data recording was completed. Thus, records from pregnant (uncensored) and non-pregnant (censored) cows can be treated jointly and included in the analysis, making proper use of all the available information and would increase the accuracies of prediction and results. Schneider et al. (2005) argue that neglecting missing fertility records in the genetic evaluation for fertility results in an overestimation of sires the daughters of which were culled for reproduction problems. The worse a bull's daughter fertility is, the larger proportion of daughters is culled for fertility failure. Thus, sires are evaluated without correct information on their daughter's fertility. Therefore, such bulls appear to be better than they really are.

The objectives of this study were to estimate the impact of AFC on functional longevity of Czech Holstein cows and their fertility traits in the first lactation, to determine differences between cow groups in reproduction traits due to age at first calving, and to assess the effect of cows' fertility traits on their functional longevity.

## MATERIAL AND METHODS

### Data editing

The data on Holstein cows were extracted from the official database of the Holstein Cattle Breeders Association of the Czech Republic. The research concentrated on cows first calved in the years 1993–2008. Records with missing sire identification, incorrect calving dates, or AFC outside the range of 16–46 months were excluded. A minimal number of 10 daughters per sire and 40 cows per herd was required. After editing, the data set consisted of 605 538 records.

### Traits definition

The following traits were used: (1) length of productive life (LPL), (2) days open (DO), (3) days between calving and first service (CTFS), and (4) days between first service and conception (FSTC). Data for fertility traits were limited to the first lactation.

### Analyses definition

For analyses, two different approaches were used: survival analysis, as non-linear approach, and linear model. The first one was employed for evaluation of AFC effect on LPL and on fertility traits, and for evaluation of fertility traits effects on LPL. The linear model approach was used for estimation of AFC effects on fertility traits with and without missing records.

### Survival analysis

Using survival analysis, firstly the effect of AFC on LPL was analyzed, secondly effect of AFC on fertility traits (DO, CTFS, FSTC), and thirdly effect of fertility traits (DO, CTFS, FSTC) on LPL. In the first and third case, the depending variable was LPL. In the second case, the depending variables were fertility traits. Analyses for fertility traits were done separately for DO, CTFS, and FSTC.

LPL was expressed as the number of days between the first calving and culling, averaged 727 days, with a minimum of 5 days and a maximum of 4386 days. 8.2% of the records were right censored: cows in herds that discontinued milk recording and cows that were still alive at the time of evaluation. LPL for right censored records averaged 1028 days with a minimum of 503 days and a maximum of 4073 days. 4.2% of the records were treated as left truncated. Because voluntary culling for low production is an important reason for disposal, the current analysis was based on functional survival. Functional survival was defined as the ability to delay involuntary culling, and was approximated by correcting true longevity for within-herd-year-parity milk production ranking (see the forthcoming model explanation).

Fertility traits were used in two roles, as dependent traits and as independent effects. In the first case, they were understood as dependent trait, the principle of censored records was used not to lose data on the cows which are not pregnant. The observations for a cow without fertility records were considered as censored (Schneider et al., 2005). The censored records for cows without fertility records amounted to 42.5%. As the dependent character, fertility traits were analyzed for the effect of AFC. In the second case, as independent effect, they were used for forming classes and their influence on LPL was analyzed.

Fertility trait DO was defined as the interval between calving and conception, averaged 99.5 days, with a minimum of 21 days and a maximum of 200 days. A length of 210 days was assigned to censored records that are represented by missing DO.

Fertility trait CTFS was defined as the interval between calving and first service, averaged 76.4 days, with a minimum of 18 days and a maximum of 200 days. A length of 210 days was assigned to censored records that are represented by missing CTFS.

Fertility trait FSTC was defined as the interval between first service and conception, averaged 23.7 days, with a minimum of 0 days and a maximum of 150 days. A length of 170 days was assigned to censored records that are represented by missing FSTC.

In the case of fertility traits, missing values were replaced with a value exceeding the upper level of fertility trait to distinguish the cows, which for some reason did not get pregnant (early culling, infertility, abortion). Assignment of high value of trait penalizes cows with missing data. Therefore is it possible to include these data in the analysis, at least partially, and in such a way keep their informative value. It is a case of the analysis of the AFC effect on fertility trait, where fertility traits act as independent traits. It is obvious that one cannot accurately distinguish the cows that were not fertile and the cows that just did not have a record of fertility for other reasons, such as early culling or death. Therefore, this approach is only approximate. But the advantage is that at least some information about the file is not lost.

### Model equation

To quantify the effect of AFC, the survival analysis was employed for traits expressed as intervals in days (LPL, CTFS, FTSC, and DO). Survival analyses were performed using the Survival Kit, Version 6.0, by Ducrocq et al. (2010).

A Cox proportional hazard model was used with the following model equation:

$$\lambda(t) = \lambda_0(t) \times \exp\{x'(t)\beta + z'(t)\sigma\}$$

where:

$\lambda(t)$ = hazard of a cow, i.e. her probability of being culled (for fertility traits getting inseminated or pregnant) at time $t$ (traits: LPL, CTFS, FTSC, and DO, in days) given that she is alive (non-pregnant, non-inseminated) just before $t$

$\lambda_0(t)$ = baseline hazard function that represents the aging process of the whole population and loosely speaking acts like a mean

$t$ = time in days

$\beta$ = vector of regression coefficients for fixed effects

$\sigma$ = vector of regression coefficients for the random effect

$x'(t)$ = corresponding design vectors for fixed effects

$z'(t)$ = corresponding design vectors for random effects

Time-dependent covariates may affect the hazard with $x'(t)$. The Cox model permits the estimation of the regression coefficients in β without making any assumption about the form of the baseline hazard function $\lambda_0(t)$. It is possible to leave $\lambda_0(t)$ completely arbitrary.

The fixed covariates (for LPL, CTFS, FTSC, and DO) included in the model were as follows:

– time-independent effect of AFC divided into three classes (low age class: 16–24 months, average class: 25–30 months, high age class: 33–46 months);
– time-dependent effect of herd, 1865 herds; herds with at least 40 cows were considered;
– time-dependent fixed effect of the year (1993–2008)
– time-dependent fixed effect of season (January–March, April–June, July–September, and October–December).

The fixed covariates only for LPL included in the model were as follows:

– time-dependent effect DO was divided into three classes according to presence or length of DO (no DO, to 120 days, over 120 days) or into six classes (no DO, to 60 days, 61–90 days, 91–120 days, 121–150 days, over 150 days);
– time-dependent effect CTFS was divided into three classes according to presence or length of CTFS (no CTFS, until 90 days, over 90 days) or into five classes (no CTFS, until 50 days, 51–70 days, 71–90 days, over 90 days);
– time-dependent effect FSTC was divided into three classes according to presence or length of FSTC (no FSTC, until 43 days, over 43 days) or into five classes (no FSTC, 0 days (CTFS = DO), until 43 days, 54–87 days, over 87 days);
– combined time-dependent effect of lactation number (1, 2, 3, 4, 5, 6+) and stage of lactation (days) (0–90, 91–240, ≥ 240) was used;
– time-dependent effect of change in herd size in %(no appreciable change in herd size between 10 to −10%; increase ≤ 25 to > 10%; ≤ 50 to > 25%; over 50%; decrease ≥ −25 to < −10%; ≥ −50 to < −25%; below −50%) with changes on January 1st each year;
– time-dependent effect of lactation protein yield calculated within herd-year-parity class (1: between the herd-year average and +0.5 standard deviation (SD), 2: between +0.5 SD and +1 SD, 3: over +1 SD, 4: between the herd-year average and −0.5 SD, 5: between −0.5 SD and −1 SD, 6: below −1 SD, 7: nonstandard lactation, below 2000 kg of milk per lactation and/or length of lactation below 240 days) with changes at the beginning of a new lactation. Two classes were formed for parity: the first parity and second and later parities. Only yield of standard 305-days long lactation was used for forming the classes 1 to 6.

The random covariate is represented by the time-independent random effect of the sire of a cow assumed to be distributed as multivariate normal with mean of 0 and covariance matrix $\mathbf{A}\sigma^2$ where **A** is the additive relationship matrix between sires. Only sires with at least 10 daughters were considered in the analyses. For LPL, the variance of sires was 0.077, estimated in the national genetic evaluation of longevity (Plemdat, 2010). The estimated variance of sires was 0.037 for DO, 0.037 for CTFS, and 0.022 for FSTC. The variances for fertility traits were estimated in a pilot study. For estimation of variances the same dataset was used as the one described in this paper. Only sires with 10 daughters and more were included in the data set, i.e. 3717 sires. The pedigree included 4417 sires.

Analysis of dependent variable LPL was done separately for estimation of AFC effect (three classes), and effects of fertility traits, DO, CTFS, FSTC, where those were subdivided more (six classes) or less (three classes) detailedly (see model description). Also because of possible existence of interaction between AFC and fertility traits, combinations between AFC classes and DO, CTFS, FSTC classes were analyzed.

Analysis of dependent variables DO, CTFS, FSTC was done for estimation of effect of AFC (three classes).

In each specific model, the relative risk ratio (RRR) was calculated for animals in each class after accounting for the previously mentioned effects in the model. The relationship between functional longevity within levels of AFC and fertility traits was expressed as the RRR, defined as the ratio of the estimated risk under the influence of certain environmental factors relative to the reference risk, which was set to 1. Reference risk is represented by the reference level with the largest number of uncensored records. Whereas RRR values > 1 indicate a higher estimated risk associated with a given environmental factor, a relative risk < 1 indicates a lower estimated risk.

## Linear model

For linear model analysis, fertility traits were defined in the same way as for survival analysis. Missing fertility records were substituted by values higher than maximum (210 days for DO and CTFS, 170 days for FSTC) as has been done for the censored fertility records in survival analysis. The animal model was employed.

Two analyses were done: first, only records for cows with fertility records were considered, second, all cows were included into analysis. In the second analysis, the missing fertility records were replaced by a value higher than the maximal fertility record as for censored records (DO 210 days, CTFS 210 days, FSTC 170 days). The reason is that assignment of high value of trait penalizes cows with missing data. Therefore is it possible to include the data in the analysis, at least partially, and thus keep their informative value. In contrast to survival analysis, linear model analysis does not treat these deliberately supplemented data as censored. They have the same impact in analysis as true records.

Effects of AFC expressed as best linear unbiased estimate (BLUE) on DO, CTFS, and FSTC in the first lactation were estimated using the multivariate mixed model package DMU (Jensen et al., 1997; Madsen and Jensen, 2002).

The following linear model was used to estimate the effects:

$$Y_{ijklm} = \text{herd}_i + \text{year}_j + \text{season}_k + \text{AFC}_l + \text{animal}_m + e_{ijklm}$$

where:

$Y_{ijklm}$ = observation of fertility trait (DO, CTFS or FSTC)

$\text{herd}_i$ = fixed effect of herd *i* (1865 herds)

$\text{year}_j$ = fixed effect of year *j* of calving (1993–2008)

$\text{season}_k$ = fixed effect of season *k* (January–March, April–June, July–September, October–December) of first calving *j*

Table 1. Descriptive statistics for longevity (length of productive life, LPL) and fertility traits (days open, DO), days between calving and first service (CTFS ), and days between first service and conception (FSTC) by classes of age at first calving (AFC)

| | Classes of AFC (months) | | |
|---|---|---|---|
| | 16–22 | 23–32 | 33–46 |
| No. of all records (605 538) | 28 672 | 534 948 | 41 918 |
| No. of fertility traits records (347 847) | 17 529 | 310 119 | 20 199 |
| No. of lactations (mean ± SE) | 2.2 ± 1.34 | 2.2 ± 1.46 | 2.0 ± 1.38 |
| Calved cows (%)($1^{st}$, $2^{nd}$, $3^{rd}$)[2] | 100, 61, 33 | 100, 58, 34 | 100, 48, 28 |
| Pregnant cows (%) ($1^{st}$, $2^{nd}$, $3^{rd}$)[3] | 61, 52, 47 | 58, 58, 52 | 48, 56, 50 |
| LPL[1] (days), mean ± SE | 724.0 ± 551.02 | 722.4 ± 588.5 | 624.4 ± 566.56 |
| LPL[1](days), median | 647 | 564 | 457 |
| LPL[1] (days), min., max. | 12, 3 811 | 5, 4 386 | 15, 3 781 |
| DO (days), mean ± SE | 98.7 ± 36.82 | 99.4 ± 39.22 | 102.1 ± 37.70 |
| CTFS (days), mean ± SE | 74.4 ± 26.16 | 76.3 ± 27.24 | 79.4 ± 29.25 |
| FSTC (days), mean ± SE | 24.3 ± 32.47 | 23.1 ± 32.61 | 23.7 ± 33.08 |

SE = standard error

[1]all records, censored as well as uncensored

[2]proportions (%) of first lactation cows that calved in the second and third parity

[3]proportions (%) of pregnant cows in the first, second, and third parity

$ACF_l$ = fixed effect of age at first calving $l$ (3 classes: low age class, 16–24 months; average class, 25–30 months; high age class, 33–46 months)
$animal_m$ = random effect of animal $m$ connected with pedigree including 1 047 435 animals
$e_{ijklm}$ = random residual effect

## RESULTS AND DISCUSSION

### Descriptive statistics

Descriptive statistics for LPL, DO, CTFS, and FSTC by classes of AFC are presented in Table 1. The LPL was slightly shorter for cows that calved later on average. Cows with high AFC showed a lower proportion of higher lactations than cows that calved earlier. At the same time, high AFC cows tended to longer DO and longer CTFS in the first parity than cows in low AFC classes. For cows with medium AFC, Ettema and Santos (2004) reported lower median and mean for DO than for cows with low or high AFC. Lin et al. (1988) found no effect of AFC on the first lactation performance. However, differences in the age at first calving between AFC groups (≤ 700 days; 701–750 days; ≥ 751 days) in the paper by Ettema and Santos (2004) were substantially lower than in our study.

On average, 57% of the first calved cows had fertility records, but only 48% of cows that calved in higher age displayed some fertility trait. A more detailed classification of reproduction traits (Table 2) showed that the proportion of cows with high AFC was greater for categories representing long DO and long CTFS in comparison with cows that calved in lower age. For FSTC, an exception was found for category FSTC equal to 0, where the cows with high AFC showed high proportion.

### Survival analysis – effect of AFC

In Table 3, RRR of particular AFC classes for LPL, DO, CTFS, and FSTC are shown. The reference levels with risk ratio equal to 1 are represented by the category of cows first calved at the age of 23–32 months. For LPL, the highest risk ratio occurred for the older cows. But for fertility traits, the class of older cows showed the lowest RRR values.This implies that the cows first calved in high age had a tendency to shorter LPL and to worse fertility than cows younger at the first calving, both trends are unfavorable. With regard to longevity of Holstein cow, RRR for cows older at the first calving estimated by survival analysis was found by Vollema et al. (2000), Páchová et al. (2005) or Sewalem et al. (2005). Vukasinovic et al. (2001) reported a curvilinear effect of AFC, with slightly increased risk for cows that calve very early and, especially, very late. Similar to our results, Ducrocq (2005) or M'hamdi et al. (2010) observed a linear increase of relative culling risk proportional to the

Table 2. Proportion (%) of cows by classes of days open (DO), days between calving and first service (CTFS ), and days between first service and conception (FSTC) from the number of cows with fertility traits records

| | | Proportion (%) | | | | |
|---|---|---|---|---|---|---|
| DO classes (days) | | to 60 | 61–90 | 91–120 | 121–150 | over 150 |
| AFC class | 16–22 | 16 | 32 | 24 | 18 | 11 |
| | 23–32 | 16 | 31 | 24 | 17 | 12 |
| | 33–46 | 15 | 29 | 26 | 19 | 13 |
| | total | 16 | 31 | 25 | 18 | 12 |
| CTFS classes (days) | | to 50 | 51–70 | 71–90 | over 90 | |
| AFC class | 16–22 | 17 | 35 | 26 | 22 | |
| | 23–32 | 16 | 34 | 26 | 25 | |
| | 33–46 | 15 | 30 | 25 | 30 | |
| | total | 16 | 33 | 26 | 25 | |
| FSTC classes (days) | | 0 | 18–43 | 44–87 | over 87 | |
| AFC class | 16–22 | 54 | 20 | 20 | 6 | |
| | 23–32 | 57 | 18 | 19 | 6 | |
| | 33–46 | 60 | 15 | 18 | 7 | |
| | total | 57 | 18 | 19 | 6 | |

Table 3. Relative risk ratio for classes of age at first calving (AFC) for length of productive live (LPL), days open (DO), days between calving and first service (CTFS ), and days between first service and conception (FSTC)

| Classes of AFC (months) | LPL | DO | CTFS | FSTC |
|---|---|---|---|---|
| 16–22 | 0.934 | 1.118 | 1.125 | 1.112 |
| 23–32[1] | 1 | 1 | 1 | 1 |
| 33–46 | 1.118 | 0.758 | 0.757 | 0.754 |

[1]reference level

increase of AFC. We found that AFC threshold beyond which deterioration of LPL is observable is relatively high – 33 months. In accordance with it, Chirinos et al. (2007) found negative effect on LPL for AFC over 34 months. Similarly, Bielfeldt et al. (2006) reported a higher culling risk for AFC over 36 months. Our findings are in contrast to the results of Ducrocq (1994) or Ojango et al. (2005) that found only non-significant effect of AFC.

Our results for DO, CTFS, and FSTC showed decreasing RRR for cows that first calved in higher age (Table 3). It means that there is a lower probability to show oestrus or conceive for cows in class over 33 months of AFC. In accordance with our findings, Vacek et al. (2007) found deteriorating DO with increasing AFC when they analyzed incidence of health disorders in Czech Holstein.

## Survival analysis – effect of AFC, DO, CTFS, FSTC on LPL

Figures 1–3 present the RRRs of AFC, DO, CTFS, and FSTC, that result from the survival analysis of LPL. Without interaction between fertility traits and AFC, the reference level with RRR equal to 1 is represented by the category of cows without fertility records, i.e. the category with the maximal number of records. When the interaction between fertility and AFC was analyzed, the reference level corresponds to the age class 23–32 combined with fertility trait category without records.

For all the fertility traits analyzed, the highest RRR occurred for cows without fertility records and it was substantially lower if the cow expressed some fertility records than for classes without fertility. Comparing different classes of analyzed fertility records, it is obvious that longer DO, CTFS, and FSTC were connected with a lower RRR. For DO, cows that conceived over 120 days after calving were 1.4 times less likely to be culled comparing with cows that conceived till 120 days after calving. If cows showed DO over 150 days they were 1.8 times less likely to be culled compared with cows that showed DO till 60 days. As the length of DO increased, the relative risk ratio decreased. For CTFS and FCTS, a same linear relationship was found but the differences between classes were less expressive in comparison with DO. For FCTS, cows that conceived later than 87 days after the first service were 1.5 times less likely to be culled compared with the group that conceived at the first service.

The ability of the cow to conceive and maintain pregnancy is among the most important components of dairy herd management for maintaining high production and longevity of dairy cows. Our results are opposite to findings reported by Sewalem et al. (2008) that found the highest risk of culling for cows with the highest unfavourable value of reproduction trait days open. Similarly Beaudeau et al. (1994) also reported that cows with longer DO showed increasing risk of culling. RRR decreasing with prolonging DO could be explained by voluntary culling used by breeders. If the possibility exists that the cow might conceive breeders probably postpone the culling of non-pregnant cows although DO and consequently the calving interval are prolonged. Therefore cows with a longer calving interval also show a longer LPL. It introduces the idea that increasing DO has a positive effect on longevity but this is not true. Similarly, Ajili et al. (2007) found that in Tunisia the cow is culled for reproductive reasons only when her milk production becomes low and probably the cost for keeping her in the herd gets very high.

We suppose that there is no interaction between AFC and the analyzed fertility traits.

For all fertility traits, RRR was the highest for the class of cows old at the first calving (Figures 1–3). If DO, CTFS or FSTC was longer, RRR of cows young at the first calving approached to RRR of the average AFC class. But the ranking of RRR for AFC classes remained the same for each class of fertility groups.

Table 4. Estimated effects[1] of the classes of age at first calving (AFC) on days open (DO), days between calving and first service (CTFS), and days between first service and conception (FSTC) (for number of records see Table 1)

| Traits | Classes of AFC (months) | | |
|---|---|---|---|
| | 16–22 | 23–32 | 33–46 |
| **Only fertility records** | | | |
| DO | −3.75 ± 0.420** | −2.26 ± 0.296** | 0 |
| CTFS | −3.06 ± 0.282** | −1.70 ± 0.196** | 0 |
| FSTC | −0.82 ± 0.357* | −0.60 ± 0.248* | 0 |
| **Including missing fertility records** | | | |
| DO | −16.75 ± 0.309** | −11.47 ± 0.205** | 0 |
| CTFS | −19.69 ± 0.229** | −13.48 ± 0.152** | 0 |
| FSTC | −20.46 ± 0.268** | −14.40 ± 0.178** | 0 |

[1]estimate ± standard error
*$P < 0.05$, **$P < 0.001$

## Linear model – effect of AFC on fertility traits

Results of both analyses (Table 4) showed negative estimates for low and average AFC classes, cows old at the first calving showed a worse fertility than cows in the other classes. The effects of AFC group estimated only for cows with fertility records had lower absolute values than those estimated on the basis of all records when missing records were replaced by the maximal value of traits. The second analysis provided results with higher statistical significance than the first analysis. For an analysis of effects, the second approach, when all records including missing fertility records were taken into account, is better than the first approach because of the increase of values of estimates and enhancement of their statistical significance. When the fertility traits are analyzed, the disadvantage of the linear model is its inability to properly distinguish between pregnant and non-pregnant cows. Hence, records of pregnant and non-pregnant cows have to be treated alike, or the records of non-pregnant cows have to be excluded or extended by projection (Schneider et al., 2005). In our analysis, each AFC class is penalized by a different proportion of missing fertility records. Replacement of missing values by the maximal value of trait takes into account different proportions of cows without fertility records in each class and at the same time the large number of records empowers the statistical significance of the results.

Also, the results obtained by a linear model confirm the fact that the group of cows that calved for the first time in high age has a lower fertility

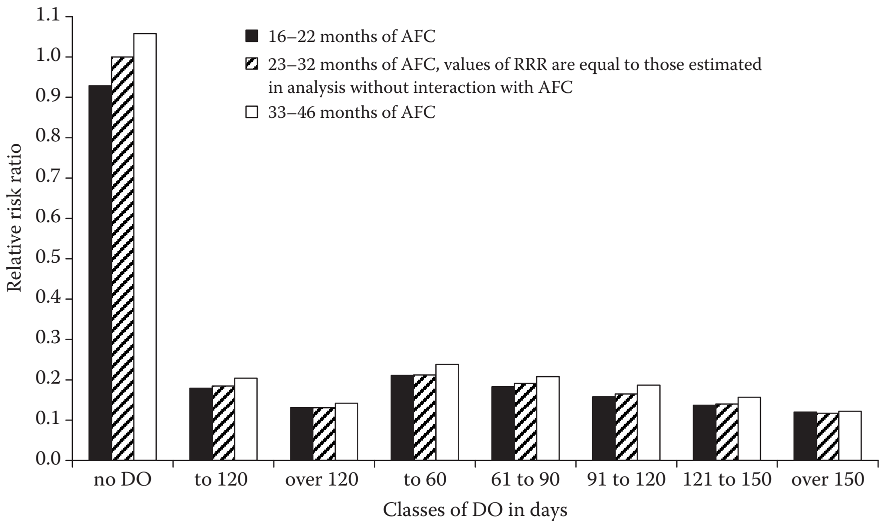


Figure 1. Relative risk ratio (RRR) for length of productive life and classes of days open (DO) separately (dashed column) and according to different age at first calving (AFC)

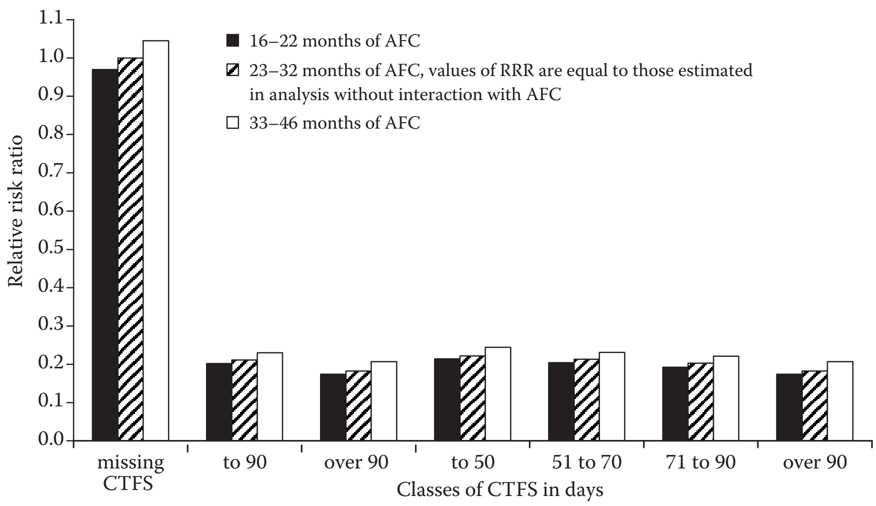


Figure 2. Relative risk ratio (RRR) for length of productive life and classes of days between calving and first service (CTFS) separately (dashed column) and according to different age at first calving (AFC)

than other groups of cows. Our findings are consistent with results of Dematawewa and Berger (1998) that found significantly longer days open in groups of cows older than 28 months at first calving. Hodel et al. (1995) found that among first lactation cows, those with AFC of more than 32 months had poorer fertility than cows that calved at an earlier age.

The question of interest was whether impaired LPL connected with increased AFC is caused by decreased reproductive efficiency. The results of the study showed that high AFC is related with a shortened LPL. At the same time, the high AFC is associated with a worsening reproduction (prolonged DO, etc.) at the first lactation. Thus our results confirm the assertion made by several authors (e.g. Vukasinovic et al. (2001), Nilforooshan and Edriss (2004), Páchová et al. (2005)) that explained the shorter longevity of cows first calved at high age by impaired fertility. However, other results also suggest that worsened fertility of cows in the first lactation is associated with prolonged longevity. This finding contradicts previous results for high AFC. But not all cows with impaired fertility calved for the first time in high age, which may explain this inconsistent results. Assertion, that the longer the DO the better the longevity, is inconsistent with the findings by Sewalem et al. (2008). These findings can be explained by the fact that in the Czech Republic, the late conception is not the preferred reason for culling of cows and therefore a positive relationship between LPL and DO is likely given by a herd management of Holstein cattle.

## CONCLUSION

Results of this study confirm that the high AFC is connected with worse cow's fertility at the first

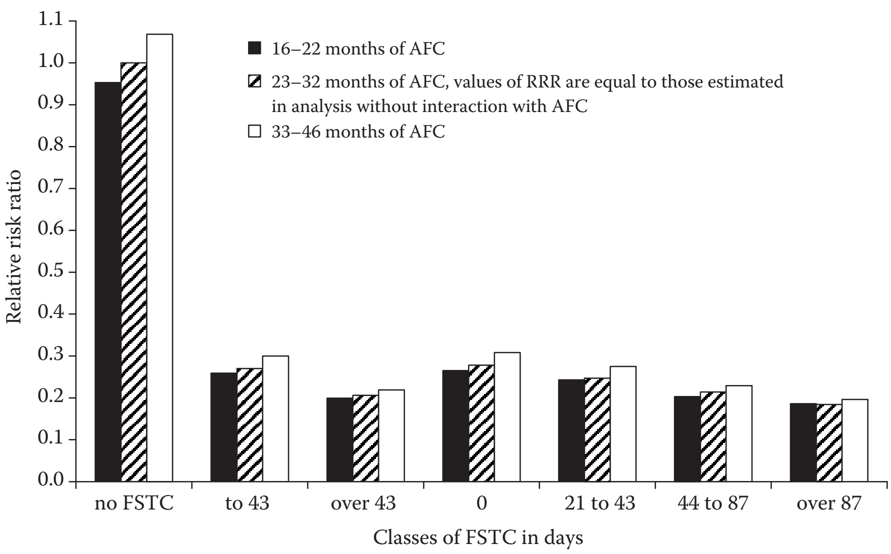


Figure 3. Relative risk ratio (RRR) for length of productive life and classes of days between first service and conception (FSTC) separately (dashed column) and according to different age at first calving (AFC)

lactation and with lower cow's LPL caused mostly by mentioned bad fertility of cows that calved in the high AFC. Positive (unfavourable) relationship between analyzed fertility traits and longevity of cows was found. This is probably given by herd management of Holstein cattle in the Czech Republic.

**Acknowledgement**

The authors thank J. Wolf (Institute of Animal Science, Prague, Czech Republic) for helpful comments and editorial help with the manuscript.

## REFERENCES

Ajili N., Rekik B., Ben Gara A., Bouraoui R. (2007): Relationships among milk production, reproductive traits, and herd life for Tunisian Holstein-Friesian cows. African Journal of Agricultural Research, 2, 47–51.

Allore H.G., Warwick L.D., Hertl J., Gröhn Y.T. (2001): Censoring in survival analysis: a simulation study of the effect of milk yield on conception. Preventive Veterinary Medicine, 46, 223–234.

Beaudeau F., Ducrocq V., Fourchon C., Seegers H. (1994): Effect of disease on productive life of French Holstein dairy cows assessed by survival analysis. Journal of Dairy Science, 78, 103–117.

Bielfeldt J.C., Tolle K.H., Badertscher R., Krieter J. (2006): Longevity of Swiss Brown cattle in different housing systems in Switzerland. Livestock Science, 101, 134–141.

Chirinos Z., Carabano M.J., Hernández D. (2007): Genetic evaluation of length of productive life in the Spanish Holstein-Friesian population: model validation and genetic estimation. Livestock Science, 106, 120–131.

Dematawewa C.M.B., Berger P.J. (1998): Genetic and phenotypic parameters for 305-day yield fertility and survival in Holsteins. Journal of Dairy Science, 81, 2700–2709.

Ducrocq V. (1994): Statistical analysis of length of productive life for dairy cows of the Normande breed. Journal of Dairy Science, 77, 855–866.

Ducrocq V. (2005): An improved model for the French genetic evaluation of dairy bulls on length of productive life of their daughters. Animal Science, 80, 249–256.

Ducrocq V., Sölkner J., Mészáros G. (2010): Survival Kit v6 – a software package for survival analysis. In: Proc. 9th World Congress on Genetics to Livestock Production. Leipzig, Germany.

Eicker S.W., Grohn Y.T., Hertl J.A. (1996): The association between cumulative milk yield, days open and days to first breeding in New York Holstein cows. Journal of Dairy Science, 79, 235–241.

Ettema J.F., Santos J.E.P. (2004): Impact of age at calving on lactation reproduction health and income in first-parity Holsteins on commercial farms. Journal of Dairy Science, 87, 2730–2742.

Gardner R.W., Smith L.W., Park R.L. (1988): Feeding and management of dairy heifers for optimal lifetime productivity. Journal of Dairy Science, 71, 996–999.

Gröhn Y.T., Ducrocq V.P., Hertl J.A. (1997): Modeling the effect of a disease on culling: An illustration of the use of time-dependent covariates for survival analysis. Journal of Dairy Science, 80, 1755–1766.

Heinrichs A.J. (1993): Raising dairy replacements to meet the needs of the 21st century. Journal of Dairy Science, 76, 3179–3187.

Hodel F., Moll J., Kuenzi N. (1995): Analysis of fertility in Swiss Simmental cattle – genetic and environmental effects on female fertility. Livestock Production Science, 42, 95–103.

Jensen J., Mantysaari E.A., Madsen P., Thomson R. (1997): Residual maximum likelihood estimation of (co)variance components in multivariate mixed linear models using average information. Journal of the Indian Society of Agricultural Statistics, 49, 215–236.

Lin C.Y., McAllister A.J., Batra T.R., Lee A.J., Roy G.L., Vesely J.A., Wauthy J.M., Winter K.A. (1988): Effects of early and late breeding of heifers on multiple lactation performance of dairy cows. Journal of Dairy Science, 71, 2735–2743.

Madsen P., Jensen J. (2002): A user's guide to DMU. A package for analysing multivariate mixed models. Version 6, release 4.4. Danish Institute of Agricultural Sciences, Tjele, Denmark.

Mészáros G., Wolf J., Kadlečík O. (2008): Factors affecting the functional length of productive life in Slovak Pinzgau cows. Czech Journal of Animal Science, 53, 91–97.

M'hamdi N., Aloulou R., Brar S.K., Bouallegue M., Ben Hamouda M. (2010): Study on functional longevity of Tunisian Holstein dairy cattle using a Weibull proportional hazards model. Livestock Science, 132, 173–176.

Nilforooshan M.A., Edriss M.A. (2004): Effect of age at first calving on some productive and longevity traits in Iranian Holsteins of the Isfahan Province. Journal of Dairy Science, 87, 2130–2135.

Ojango J.M.K., Ducrocq V., Pollott G.E. (2005): Survival analysis of factors affecting culling early in the productive life of Holstein-Friesian cattle in Kenya. Livestock Production Science, 92, 317–322.

Páchová E., Zavadilová L., Sölkner J. (2005): Genetic evaluation of the length of productive life in Holstein cattle in the Czech Republic. Czech Journal of Animal Science, 50, 493–498.

Pirlo G., Miglior F., Speroni M. (2000): Effect of age at first calving on production traits and on difference between milk yield returns and rearing costs in Italian Holsteins. Journal of Dairy Science, 83, 603–608.

Plemdat (2010): Genetic evaluation of dairy cattle longevity. Available from http://iserv.plemdat.cz/store/Longevity.pdf (accessed Jan 10, 2010).

Řehák D., Volek J., Bartoň L., Vodková Z., Kubešová M., Rajmon R. (2012): Relationships among milk yield, body weight, and reproduction in Holstein and Czech Fleckvieh cows. Czech Journal of Animal Science, 57, 274–282.

Schneider M. del P., Strandberg E., Ducrocq V., Roth A. (2005): Survival analysis applied to genetic evaluation for female fertility in dairy cattle. Journal of Dairy Science, 88, 2253–2259.

Sewalem A., Kistemaker G.J, Ducrocq V., Van Doormaal B.J. (2005): Genetic analysis of herd life in Canadian dairy cattle on a lactation basis using a Weibull proportional hazards model. Journal of Dairy Science, 88, 368–375.

Sewalem A., Miglior F., Kistemaker G.J., Sullivan P., Van Doormaal B.J. (2008): Relationship between reproduction traits and functional longevity in Canadian dairy cattle. Journal of Dairy Science, 91, 1660–1668.

Tozer P.R., Heinrichs A.J. (2001): What affects the costs of raising replacement dairy heifers: a multiple-component analysis 1. Journal of Dairy Science, 84, 1836–1844.

Vacek M., Stádník L., Štípková M. (2007): Relationships between the incidence of health disorders and the reproduction traits of Holstein cows in the Czech Republic. Czech Journal of Animal Science, 52, 227–235.

Vollema A.R., Van Der Beek S., Harbers A.G.F., De Jong G. (2000): Genetic evaluation for longevity of Dutch dairy bulls. Journal of Dairy Science, 83, 2629–2639.

Vukasinovic N., Moll J., Künzi N. (1997): Analysis of productive life in Swiss Brown cattle. Journal of Dairy Science, 80, 2572–2579.

Vukasinovic N., Moll J., Casanova L. (2001): Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland. Journal of Dairy Science, 84, 2073–2080.

Zink V., Lassen J., Štípková M. (2012): Genetic parameters for female fertility and milk production traits in first-parity Czech Holstein cows. Czech Journal of Animal Science, 57, 108–114.

Received: 2012–03–02
Accepted after corrections: 2012–08–23

*Corresponding Author*

Ing. Ludmila Zavadilová, Institute of Animal Science, Přátelství 815, 104 00 Prague 10-Uhříněves, Czech Republic
Tel. +420 267 009 608, fax +420 267 710 779, +420 267 711 448, e-mail: zavadilova.ludmila@vuzv.cz