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Optimal Age at First Calving for Improved Milk Yield and Length of Productive Life in Tunisian Holstein Cows

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Abstract: The effects of age at first calving on milk production and true herd life were studied in Tunisian Holstein cows. There were 33,407 first lactation records of cows born between 1987 and 2001 from 166 herds. Firstly, age at first calving was analysed using an animal model that included herd, calving year, herd-calving year interaction, calving month and age of dam as fixed effects and the random animal additive genetic effect. Secondly, differences in first lactation and productive life milk yields and in true herd life were explained by age at first calving in addition to herd, year at first calving, herd-year at first calving interaction and month at first calving. A cow produced on the average 5669.8 kg milk (SD=1812 kg) during a 305-d first lactation period. The lifetime production of a cow was 19,496.3 (SD = 12,192 kg) kg during 3.3 lactations (SD=1.8 lactations). Coefficients of determination ranged from 14% for true herd life to 64% for first lactation milk yield. The mean of true herd life was 38.6 months (SD=24 months) and the mean of age at first calving was 28.7 months (SD=3.4 months). Posterior mean of heritability of the age at first calving derived by a Markov Chain Monte Carlo Bayesian method via a Gibbs sampling algorithm was 0.08. The reduction of age at first calving to around 24 months may result in improved 305-d and lifetime yields and a longer herd life in Tunisian Holsteins.

Key words: Age at first calving · Heritability · Milk yield · True herd life

INTRODUCTION

Milk yield has been the only breeding objective in Tunisian Holsteins. Replacement heifers are chosen on an intra herd cow index while semen is imported from the US and EU countries. Production levels were limited compared to the breed performance in countries with developed dairy industries [1-3]. Limited production levels and low to moderate genetic parameters of milk traits have been explained by unsatisfactory overall management [2-4] and harsh climatic conditions [3, 5]. In addition to ration formulation and health care, the control of reproduction is an important aspect of management. An efficient reproduction is crucial for lowered replacement costs [6] and improved milk production. Age at first calving (AFC), calving interval, days open and number of services per conception are some of the measures of reproductive efficiency. AFC determines the beginning of the cow's productive life [7]. The beginning of a cow's productive life depends on its pre- and post-pubertal growth rate and management conditions [8-11]. But as for most of fertility traits, genetic variation of AFC is low. Recent reported heritability estimates for AFC ranged from less than 10% [12, 13] to more than 30% [7, 14]. Factors affecting variations of AFC included breed, location, management (herd size, feeding resources and milk yield level) and year and season of birth of heifers [14-16].

AFC was found to have an impact on milk production and longevity traits [7, 13] reproductive traits [16, 17] and overall profitability [6, 14] of dairy cattle management. There was a slight decline in AFC mean levels in a number of Holstein populations [16]. Reported current mean levels were for example: 24 months in the US [16], 26.8 months in Iranian [13] and 25.8 in Irish cow populations [17]. Although ages at first calving of 22 to 24 months were optimal for yield, less than 24 months of age may increase dystocia incidence and unfavourably affect reproductive performance by lengthening calving intervals [16, 17]. Late first calving (>37 months) ages have impairing effects on milk production and reproduction of dairy cows as early (< 24 months) calving ages [17].

The objectives of this study were to i) examine AFC genetic variations and to ii) assess the effects of AFC on first lactation 305-d and lifetime milk yields (LMY) and longevity in Tunisian Holsteins.

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MATERIALS AND METHODS

Data: Production and pedigree files were provided by the Tunisian Genetic Improvement Centre, Livestock and Pasture Office, Tunis. Lactation records were from calving every year from 1991 to 2003. Only the first ten test-day records of each lactation record were retained. There were 33,407 final first lactation records obtained after editing for daily milk yield (> 3.0 and < 80.0 kg). Test-day yields were used to determine 305-d lactation and lifetime yields. Lifetime performance of a cow was obtained by summing up 305-d lactation yields. Records of cows with first calving before 22 and after 40 months were also omitted. Age of the dam was computed for only those (dams) born after 1970. True herd life (THL) was calculated as the date of last record minus age at first calving for cows throughout five years (1825 d) of life opportunity. A full description of the data and raw means of analyzed traits are given in Table 1. Distribution of heifers by age at first calving is illustrated by Fig. 1.

Table 1: Description of data and mean performances

Variables	Mean	SD	Min	Max
Data				
Number of sires	1434	-	-	-
Records[1] per sire	20.5	53.7	2	605
Records per herd	201.2	322.4	3	2478
Records per year	2227.1	1522.6	13	4239
Records per month	2787.9	361.4	2070	3281
Mean performance				
Days in milk[2]	293.6	57	90	450
305-d milk yield (kg)[2]	5669.8	1812	1231	12646
293-d milk yield(kg)[2]	5500.6	2052	1001	16168
Lactations	3.3	1.8	1	11
Lifetime milk production (kg)	19496.3	12192	1437	74129
Age at first calving(month)	28.7	3.4	22	40
True herd life (month)	38.6	24	1	126

[1]A lactation record, [2]first lactation performance

Analysis

Age at First Calving: The following animal model was used to study factors affecting variations and to estimate heritability of AFC:

$$Y_{ijklmn} = \mu + Hi + CYj + HCYij + CM_k + \beta AGE_l + A_m + e_{ijklmn} \quad (I)$$

Where:

Y_{ijklmn} = AFC,
μ = overall mean,
H_i = effect of herd I,
Cyj = effect of calving year j,
HCYij = effect of the interaction of herd by calving year,
Cm_k = effect of calving month k,
AGE_l = effect of age of the dam fitted as a covariate,
A_m = random animal additive genetic effect and
e_{ijklmn} = a residual effect with $e_{ijklmn} \sim N(0, \sigma^2_e)$.

The analysis of variance for fixed effects was done by general linear model procedure in SAS [18] and posterior mean of heritability was estimated by Bayesian analysis via Gibbs sampling [19].

Effects of Age at First Calving on Milk Yield and True Herd Life: The linear model used to study effects [18] of AFC on milk production in 305-d (MY305-d), LMY and THL was:

$$Y_{ijklm} = \mu + Hi + YFCj + HYFC_{ij} + MFC_k + AFC_l + e_{ijklm} \quad (II)$$

Where:

$Y_{ijklmno}$ = MY305-d, LMY, or THL,
μ = an overall mean, H_i= effect of herd i, YFCj= effect of year at first calving j, HYFCij = effect of the interaction of herd by year of calving,
MFC_k = effect of month at first calving k,
AFC_l = effect of age at first calving l and
e_{ijklm} = a residual effect with $e_{ijklm} \sim N(0, \sigma^2_e)$.

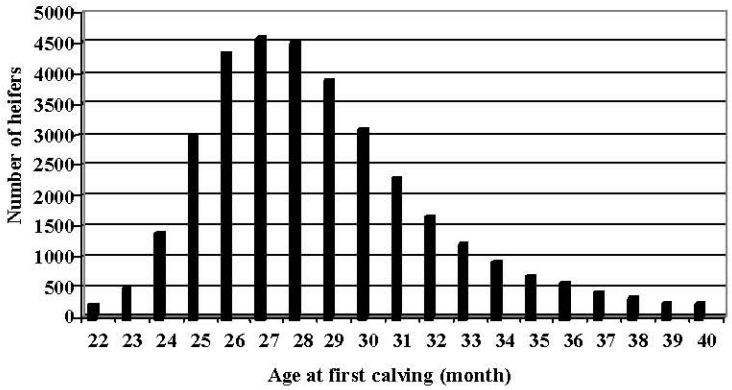

Fig. 1: Frequency of age at first calving

RESULTS

Age at First Calving: Most of heifers (76%) calved between 25 and 31 months of age with a peak occurring at 27 months of age (Fig. 1). The frequency of age at first calving looked comparable to that reported for US heifers in 1980 [16]. Mean AFC was 28.7 months (SD = 3.4 months) in this study (Table 1). This value was higher than those (24 to 26.8 months) reported for the US, Iranian (Isfahan Province) and Irish populations [13, 16; 17] but lower than those found by [20] in Brazil and Columbia (29.5 and 32.1 months, respectively). Heifers in small herds in this study (< 50 cows) had mean AFC one month greater than that for heifers in larger herds (>50 cows). Ruiz-Sánchez *et al.* [14] found mean AFC (28.9 months) in low milk yield level herds nearly 2.5 months higher than that found in high yield herds. Mean 305-d milk yield in this study was only 5669.8 kg (Table 1).

Results from the analysis of variance of AFC are given in Table 2. Except from the age of the dam, all factors were important sources of variation of AFC. Management and climatic conditions have significant impact on the onset of oestrus and conception of heifers [15]. Calving month and year, herd and calving year and herd interaction accounted for almost 38% of AFC variation.

Table 2: Mean squares of main factors affecting age at first calving in Tunisian Holsteins

Source of variation	DF	Mean squares	Pr > F
Herd	142	181.26	0.0001
Calving year	14	111.52	0.0001
Calving month	11	49.91	0.0001
Herd x calving year	671	84.68	0.0001
Age of dam	1	15.93	0.1411
Coefficient of determination		38.4%	

Heritability estimates of AFC ranged from 0.052 to 0.127 (Fig. 2). The average estimate of this parameter was 0.08 (SD = 0.002). Mean estimates of additive and residual variances were 0.59 (SD= 0.01) and 6.78 (SD = 0.01), respectively. Heritability estimates falls in the low side of the range of estimates reported for AFC in the literature, from less than 10% to nearly 40% [7, 12,-14].

Variation of Milk Yield with Age at First Calving: Mean squares of factors affecting variation of 305-d and LMY yields are given in Table 3. All factors included in the model were important sources of variation of milk production. AFC effect was the second most important next to herd effect in explaining 305-d yield variation but was the most important effect in explaining LMY.

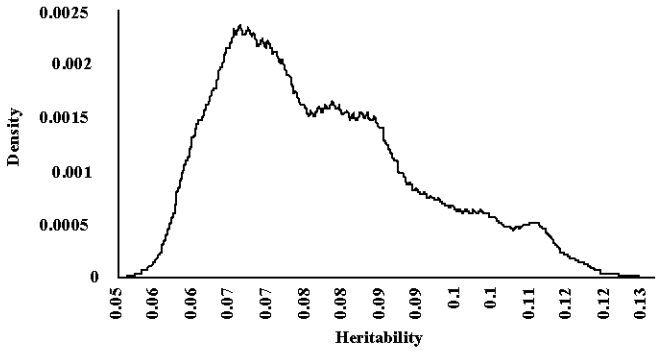

Fig. 2: Posterior density function of heritability

Table 3: Mean squares of main factors affecting 305-d[1] and lifetime milk yields and true herd life in Tunisian Holsteins

	305-d milk yield		Lifetime milk yield		True herd life	
Factor	Mean square	Pr	Mean square (x10^{-8})	Pr	Mean square	Pr
Herd	131697327	0.0001	17.6	0.0001	3357	0.0001
Calving year	3751013	0.0004	18.5	0.0001	9992	0.0001
Calving month	5620996	0.0001	3.9	0.0001	2815	0.0001
Herd x calving year	6742860	0.0001	1.9	0.0001	857	0.00001
AFC	59712147	0.0001	143.7	0.0001	66426	0.0001
Residual	1106131	-	1.2	-	514	-
R^2	64%		21%		14%	

[1] First lactation yield, AFC: age at first calving, R^2: coefficient of determination

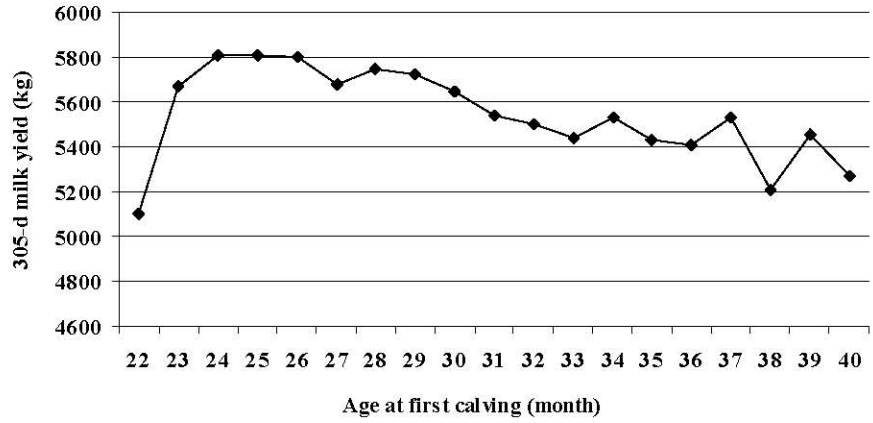

Fig. 3: Effect of age at first calving on 305-d milk yield

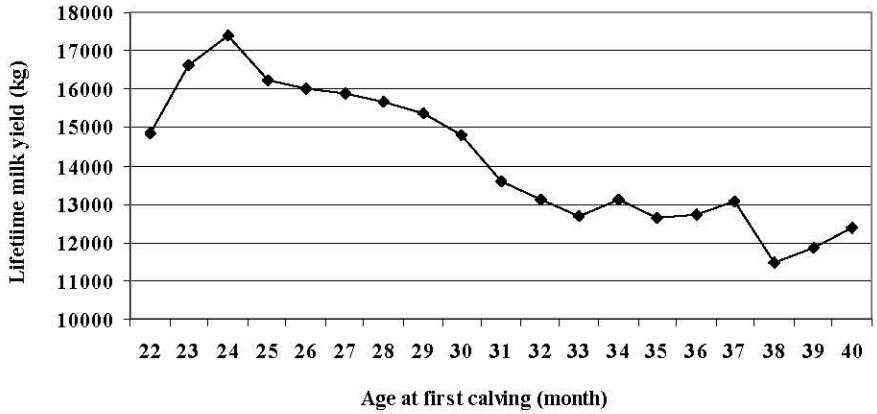

Fig. 4: Effect of age at first calving on lifetime milk yield

Milk production levels by calving age for 305-d and lifetime periods are illustrated by Fig. 3 and 4, respectively. Less than 24 months and greater than 26 months of calving ages were associated with low 305-d and lifetime yields. Age at first calving at 24 months seemed to be the optimal age for improved lifetime milk production. Age at first calving between 24 to 26 months of age at calving seemed to result in increased milk yield in the first lactation.

Variations of True Herd Life with Age at First Calving: Mean herd life was 38.6 months (SD = 24 months) for Holstein cows under Tunisian conditions (Table 1). A cow averaged 3.3 lactations (SD=1.8 lactations) during her life time in the herd. Results of the analysis of variance of THL with AFC are given in Table 3. As for LMY, AFC was the most important factor that affected THL. Low and high calving ages (<23 and > 25 months) seemed to reduce cows' longevity and AFC of 23 months was optimal for a lengthy productive life. Effects of AFC on THL are illustrated by Fig 5. Results on optimal AFC ages for longer longevity differ from [13] who reported a positive but small correlation between AFC and longevity.

DISCUSSION

Milk production levels of Tunisian Holsteins remain lower than the breed performances in temperate regions. Advanced causes of limited production of Holsteins in Tunisia were overall management, climatic conditions (heat stress) and health care [1-3, 5]. AFC is an important management factor that has an impact not only on first lactation yield but also on yields on subsequent lactations, calving intervals, lifetime production, longevity traits and consequently on the overall profitability of dairy management [6]. Heinrichs *et al.* [11] concluded a study on Holstein heifer management by "nutrition, housing and management factors that affect health and growth of calves have long-term effects on the animal at least through first calving". Although, the effect of

age at first calving on longevity is not clear [6], there is an agreement on the fact that young ages at calving (22-24 months) are good for milk and increased longevity. Unfortunately in Tunisia most of cows have their first calving beyond 24 months of age.

The average AFC from this study (mean =28.7 months, SD=3.4 months) was higher than some estimates [13, 16, 17] and lower than others [20]. The present estimate was relatively high compared to reported optimal calving ages for improved productive and reproductive performances [8, 6, 13, 17] because less than 7% of heifers calved for the first time at ages less than 24 months (Fig 1). Late calving ages may suggest limited management of calf heifers by Tunisian farmers. First conceptions depend on heifers' body weights at insemination. Such a weight is a result of pre-pubertal growth rate which is a crucial management result that may affect heifers' future careers [8-11]. Actually, heritability of AFC from this data was low (0.08) indicating that AFC is mostly an environmental factor in agreement with the most recent reports on AFC heritability estimates [13]. Herd (management) and calving year were the most important sources of variation of AFC (Table 2). Together, they accounted for around 66% of the total variation (38.4 %) in AFC, explained by the model that included herd, calving year, calving month, herd x calving year interaction and age of the dam. The calving month also was an important factor that may affect the AFC of heifers in Tunisian Holsteins although the frequencies of calving were nearly uniform over the year in Tunisia [2].

Effects of AFC on THL and LMY were comparable (Table 3, Fig. 3, 4 and 5) but were slightly different from that on 305-d milk yield where delayed first calving seemed to result in increased first lactation milk production [6]. The best performances were obtained for calving ages that were 24-26, 23-24 and 24 months of calving ages for 305-d milk yield, THL and TMY, respectively. That is, 24 months of age may be a reasonable management practice for improved performances of Holstein cows in Tunisia, which is similar to that advanced in most of previous reports (e.g., 13). However, only a small fraction of heifers had their first calving around 24 months of age in this study (Fig. 1) and most of them calved for the first time at ages greater than 24 months which may in part explain limited production performances of Tunisian Holstein cows. The improvement of production performances necessarily requires the reduction of age at first calving. This may be achieved by the improvement of growth rates and health care of calf heifers to have them inseminated at 14 to 15 months of age.

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