Phenotypic and genetic parameters of reproductive traits in Tunisian Holstein cows

Parámetros fenotípicos y genéticos de caracteres reproductivos en vacas Holstein en Túnez

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ABSTRACT

Various factors influencing reproduction in dairy Holstein cows were routinely evaluated and genetic parameters were estimated for four traits to assess fertility of artificially inseminated cows: Calving to first service interval (CFSI), calving interval (CI), calving to conception interval (CCI) and number of services per conception (NSC). Data used in this investigation consisted of records of insemination and calving events on Tunisian Holstein cows. The data included records from 1994 to 2003 in 150 herds. The aim of the study was to investigate the effects of non-genetic factors on reproductive traits and estimate their heritabilities. The factors examined were: month and year of calving, herd, parity, and year-month of calving. The effect of month and year of calving (or insemination), herd, parity and year-month of calving were included in the model and were significant ($P < 0.01$) except for the number of lactations that does not have an effect on the NSC. A decreasing efficiency in cow fertility was observed over the last years, with a longer day for first service interval. Heritability for fertility traits was low ranging from 0.027 for NSC to 0.067 for CI. The results suggested that more attention should be paid to herds with too low fertility traits and that monitoring and intervention schemes should be tested in research approaches.

Key words: fertility traits, genetic parameters, non-genetic factors, Tunisian Holstein

RESUMEN

Se evaluaron de manera rutinaria diferentes factores que influyen en la reproducción de las vacas lecheras Holstein y se estimaron los parámetros genéticos de cuatro caracteres para evaluar la fertilidad de las vacas inseminadas artificialmente: el intervalo de parto a primer servicio (IPPS), el intervalo entre partos (IP), el intervalo de parto a concepción (IPC) y el número de servicios por concepción (NSC). Los datos utilizados en esta investigación consistieron de registros de eventos de inseminación y partos en vacas Holstein de Túnez. Los registros fueron tomados desde 1994 hasta 2003 en 150 rebaños para estudiar los efectos de factores no genéticos y estimar las heredabilidades de los caracteres anteriormene señalados de fertilidad. Los factores examinados fueron: mes y año de parto, rebaño, paridad y año-mes de parto. El efecto del mes y año de parto (o inseminación), rebaño, paridad y año-mes de parto se incluyeron en el modelo y fueron significativos ($P <0,01$) con excepción del número de lactancias que no tiene un efecto sobre el NSC. Se observe una eficiencia decreciente en la fertilidad de las vacas en los últimos años, con un día más largo para el intervalo del primer servicio. La heredabilidad para los caracteres de la fertilidad fue baja en un rango de 0,027 para NSC a 0,067 para el interval entre partos. Los resultados sugieren que debería prestarse más atención a los rebaños con rasgos muy bajos de fertilidad y que los esquemas de vigilancia e intervención deberían ser evaluados con enfoques de investigación,

Palabras clave: Caracteres de fertilidad, parámetros genéticos, factores no genéticos, Holstein en Túnez.

INTRODUCTION

Knowledge of reproductive performance in Tunisian dairy herds is limited. Selection for higher yields of dairy cattle has led to a decline in fertility due to unfavorable genetic correlations between yield and fertility (Pryce *et al.*, 2004). On a herd basis, fertility in Tunisian dairy herds is not well defined and is poorly managed. It appears difficult to correct, as the levels of the standards used to measure many of the fertility indices are declining. Ben Hamouda *et al.* (2005) on Tunisian data showed that the reproductive performance of Holstein herds is poor. Tunisian Holstein is the main exotic breed used for milk production in Tunisia (Ben Salem *et al*., 2006). During the last two decades, the dairy sector in Tunisia went through major development programs to increase dairy production in order to improve farmer's lives, whose income comes from milk sales and to ensure the national self-sufficiency in milk and dairy products. In fact, these development programs are not in favor of reproductive performances of Holstein which remain low.

The deterioration in fertility of dairy cows during the last two decades currently constitutes a major problem confronted by the dairy breeders. This decline/deterioration in reproductive performance has concerned many countries (Barbat *et al*., 2005; Bosio, 2006). The results of reproductive performances conditioned largely the breeding economic profitability and its improvement is a part of the common imperatives for all types of production. The actual determination of the type of traits to be included in genetic evaluation for fertility is difficult. Earlier studies on cow reproduction possessed only calving dates from which calving intervals or days open could be computed assuming a standard gestation length (Jansen, 1986).

The availability of insemination data has allowed the calculation of intervals between calving and each insemination as well as the number of inseminations. Age at first insemination, age at conception, and the intervals from calving to first service and first service to conception in each lactation have been important traits in several studies (Averill *et al*., 2004; Jamrozik *et al*., 2005; Biffani *et al*., 2005). Averill et al. (2004) affirmed that reproductive performance of a cow is an array of several traits. The heritabilities of most reproductive traits were generally below 0.10 (Kadarmideen *et al*., 2003; Wall *et al*., 2003).

The objectives were to identify non-genetic factors strongly associated with reproductive performance and to estimate genetic parameters for Tunisian Holstein female reproduction traits.

MATERIALS AND METHODS

Data Source

Data on reproductive traits were obtained from the National Center for Performance recording of Dairy Cattle under guardian of The Tunisian Livestock and Pasture Office (OEP). These comprised insemination records collected by OEP from 1994 to 2003 that were merged with pedigree, lactation, and calving performance information to be able to calculate the traits of interest. Pedigree records for individual cows were verified with records from OEP. Pedigree file of all participating animals was available and contained the ancestry of approximately 70,000 animals (about 66,000 animals and 4000 bulls). Fertility traits were defined based on data availability in a way that would describe a complete picture of a reproductive history for a cow. In order to describe herd fertility retrospectively, four fertility parameters were calculated for each cow from the insemination records: Calving to first service interval (CFSI), calving interval (CI), Calving to conception interval (CCI) and number of services per conception (NSC). Interval traits were expressed in days. The data file contained herd, number of cows, date of birth, date of insemination, date of calving, age at calving, number of lactations, number of inseminations, and genetic group (the origin of the animal).

Data preparation

Data consisted of recorded artificial insemination and calving events, however, data on several variables were missing in some cases or did not correspond to the reality. Edits performed for all traits included removal of animals having unreasonable records; 1) with more than eight lactations; 2) which calved before 1994 and after 2003; and 3) with incomplete records. Artificial inseminations before 1994 were eliminated to avoid errors at the beginning of the reproductive recording scheme. The CI that was lower than 270 days or greater than 720 days were removed. Calving to a successful insemination and CFSI which were less than 30 days or greater than 450 days were deleted. After editing, records from 150 herds with 65,549 cows for the number of inseminations per conception, calving to first service interval and calving to conception interval, and 28,777 cows for calving interval were available for analysis.

Statistical analyses of data

The data were first analyzed by the least squares techniques using the general linear model procedure (SAS, 1989), to determine the effects of the various factors on reproductive traits. CFSI, CCI and CI were analyzed using the following model.

$$Y_{ijklm} = \mu + p_i + h_j + y_k + s_l + e_{ijklm}$$

Where:

Y_{ijklm} = observations on the variable of interest;

μ = underlying constant,

p_i = fixed effect of the i^{th} lactation number,

h_j = fixed effect of j^{th} herd,

y_k = fixed effect of k^{th} year of calving,

s_l = fixed effect of l^{th} season of calving,

e_{iklm} = the random residual $N(0,\sigma^2_e)$

The model to analyze NSC was:

$$Y_{jklm} = \mu + h_j + y_k + s_l + e_{jklm}$$

Y_{jklm} = the observations on number of inseminations per conception.

μ, h_j, e_{ijklm} = as described in the previous model.

From the preliminary analysis a suitable model was identified for the final estimation of the genetic parameters. The final statistical analyses were performed with the Derivative-Free Restricted Maximum Likelihood software (Meyer 1989) and multiple-trait animal model to obtain variance components for CI, CFSI, CCI and NSC. The animal model included additive genetic merit of each cow as the only random effect. To estimate repeatability for CI, CFSI and CCI, an animal model was used to account for permanent environmental effects common to the repeated records on the same animal. Estimation of phenotypic, genetic and environmental trends was carried out for CI, CFSI, CCI and NSC. The mean additive genotype in a particular year of birth was defined as the mean predicted breeding values of cows born in that year. Consequently, changes of mean additive genotype between the years reflected additive genotypic differences.

The overall additive genetic trend in a trait was estimated by regressing the mean predicted breeding values on the respective year of birth for that trait. For phenotypic trends, the adjusted performance records were averaged within the year of birth and then regressed on years of birth (Wakhungu, 1988; Rege and Mosi, 1989). The difference within years between the mean predicted breeding value and the mean of the adjusted phenotypic records reflected the component due to the non-additive genetics and the environmental parameters.

RESULTS AND DISCUSSION

Summary of data for fertility traits

Table 1 presents a descriptive summary of the edited data used in the present study. The results of this study are not in agreement with the results of Vallet *et al.* (1997) who put standard objectives for CFSI of 70 days, with a percentage of cows having CFSI > 80 days greater than 15%, CCI (90 days) with a percentage of cows having CCI > 110 days greater than 15%, and CI (365 days) with a percentage of cows having CI > 365 days was greater than 15%.

Heritabilities for the four traits are shown in Table 1; they are low and ranged from 0.027 for NSC to 0.063 for CI. In previous studies heritability estimates were generally weak and ranged from 0.01 to 0.05 (Maijala, 1987; Hanset *et al.*, 1989b) using a linear model. However, genetic improvement of reproductive traits is very hard to achieve due to their low heritability. This study provides genetic parameter estimates which generally confirm the literature data: fertility traits show low heritability (<0.01) (Biffani *et al.*, 2005; Jamrozik *et al*., 2005), although some differences do exist between traits related to time period (CI, CCI and CFSI) and score traits (NSC). Averill *et al*. (2004) reported a heritability of 0.028 for female fertility using

Table 1: Descriptive statistics of reproductive indices of Tunisian Holstein cattle population.

Traits	No. of Records	Means ± SD	First quartile	Median	Third Quartile	h^2	R
NSC	65,549	2.55±1.7	1	2	3	0.027	0.034
CFSI	65,549	93.2±80.2	58	75	103	0.032	0.128
CCI	65,549	150.9±75.7	84	138	194	0.041	0.135
CI	28,777	444.2±101.5	445	445	445	0.063	0.152

NSC: Number of services per conception; CFSI: calving to first service interval; CCI: calving to conception interval; CI: calving intervals; h^2: Heritability; R: Repeatability and SD: Standard Deviation.

longitudinal binary data with Bayesian methodology. Our estimates for reproductive traits and most estimates of other researchers are comparable and low. The reproductive trait with the highest heritability (0.063) is CI. Considering this value and the lower repeatability of reproductive traits (<0.03 to 0.13) (Hayes *et al*., 1992), it is recognized that the reduction of one day on the delay of first service is accompanied by an equivalent reduction of CCI (Schneider *et al*., 1996).

Effect of non-genetic factors on the reproductive performance

The analysis of variance (Table 2) showed that the number of lactations had significant effect on CFSI, CCI and CI (P < 0.0001) with F values of 150.24, 46.90, and 5.66 respectively, but no effect was reported for NSC (P = 0.0510). Effects of herd, calving year, calving month, and the interaction between calving year and the month of calving and the genetic group on studied fertility traits were found to be statistically significant (P < 0.0001). Herd had a significant influence (P < 0.001) on traits related to time period (CI, CCI and CFSI). Similar results have been reported in literature (Kaya, 1996; Amimo *et al*., 2006).

The variation of CI from one herd to another could be attributed to differences in skills of heat detection. Effects of year of calving on CI, CCI, CFSI and NSC were significant (P < 0.001). The year of calving is important source of variation. Significant year of calving effects on fertility traits have been reported in several studies (Muasya, 2005; Amimo *et al*., 2006). The main effect for the model was also significant (P<0.001). CFSI, CCI and CI were found to be very long for the first lactation. The situation was changed during the next lactations. A decrease was reported for these traits with the lactation number between the first and the last lactations from 486 to 387 for CI, from 168 to 135 for CCI, and from 88 to 76 for CFSI (Figure 1). The NSC was slightly decreased with the lactation number from an average value of 2.50 at first lactation to 2.11 at the eighth lactation.

As presented in Figure 2, an elongation of CFSI, CCI and CI were observed for many years. CI was prolonged from 13 to 17 months from 1994 to 2003, with a noteworthy increase in 1997 (Figure 2). Fluctuation of CFSI showed that the number of cows inseminated at less than 50 days of postpartum decreased appreciably during the last years. It can partially explain the prolongation of calving interval. Hence there could be a factor that contributes to larger CI. It may be due to selection for yield or it may be due to poor management, such as poor conception rates, poor expression or detection of oestrus and poor nutrition. These results agree with those of Sewalem *et al*., (2002) who studied reproductive performance of Canadian dairy herds. An increase in the NSC was noticed during the period

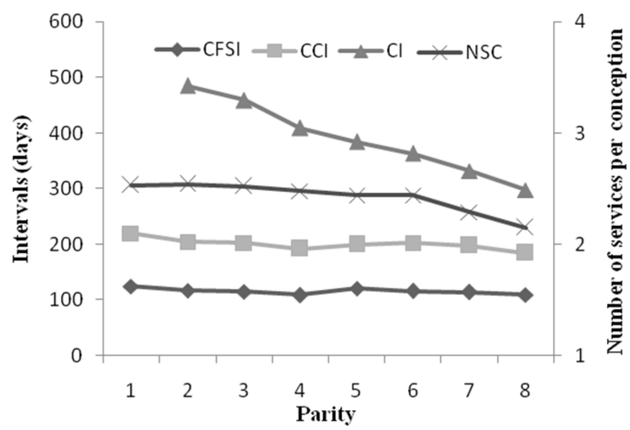

Figure 1. Relationship between calving to first service interval (CFSI), calving to conception interval (CCI), calving interval (CI) and number of services per conception (NSC) with parity.

Table 2. Effect estimates for selected factors included in the final model.

Source of Variation	Degree of Freedom	NSC		CFSI		CCI		CI	
		F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
H	125	28.99	<0.0001	26.64	<0.0001	18.15	<0.0001	15.34	<0.0001
LN	7	2	0.0510	149.68	<0.0001	46.36	<0.0001	5.73	<0.0001
CY	9	77.79	<0.0001	83.03	<0.0001	43.70	<0.0001	74.72	<0.0001
CM	11	37.72	<0.0001	28.34	<0.0001	60.98	<0.0001	7.33	<0.0001
CY*CM	99	4.18	<0.001	9.92	<0.0001	12.65	<0.0001	2.29	<0.0001
GG	16	5.69	<0.0001	4.87	<0.0001	8.13	<0.0001	189.61	<0.0001

Herd (H), lactation number (LN), calving year (CY), calving month (CM) interaction calving year-calving month (CY*CM) and genetic group (GG) from 1994 to 2003. The NSC ranges from 1.5 in 1994 to 2.5 at 2002 with a peak at 1996 when the NSC exceeds 2.7. A reduction has also been reported between 2002 and 2003 in which the NSC decreased again to reach a value lower than 2. Prolongation of CFSI, CCI and CI was as a result of the important number of belated returns (returns over 35 days exceeded 65 % of the set of returns). Chevallier and Humblo (1998) claimed that these returns were the cause of calving interval elongation. The frequency of longer intervals, superior in Holstein Population, suggested an elevated embryonic mortality at a later stage (Boichard *et al*., 2002). Shrestha *et al.* (2004) explained that higher CFSI by the absence of heat detection at the onset of appropriate reproduction period. On the contrary, an elongation of these intervals with lactation number has been reported by Erb *et al*. (1985). Interval between calving and first insemination decreased (Ogan, 2000) or increased (Cilek and Tekin, 2007) with lactation number. Other authors noticed the same trend in dairy cattle compared to beef cattle (Gregory *et al.,* 1999b). Fertility was known to decrease with the increase of lactation number in dairy cattle (Weller and Ron, 1992) which was the case in this study.

Variation of fertility traits according to calving season

The analysis of seasonal variation of the reproductive performances must be interpreted in the light of the reciprocal influences. During the same year, changes in management and feeding systems, temperature, humidity, and photoperiod can be observed. The contradictory results in opposition to the effect of season can be explained by the effect of each independent factor or the combination of many of them at the same time. Figure 3 showed that intervals increased during the hottest and the coldest periods of the year. An elongation of all intervals was observed from June to August and from the first fifteen days of November to the first fifteen days of February. Figure 3 showed a fluctuation in the number of inseminations during the year, an increase in the NSC during two periods; colder and hotter when NSC reached 3.5 and 3 services, respectively. In the temperate regions, fertility is maximal in spring and minimal in summer and winter. This was in agreement with the finding of Cilek (2009).

Westwood *et al.* (2002) noticed that the anoestrus length of the post-partum was longer when cows calved in winter, while Eldon and Olafsson (1986) confirmed that it was shorter for dairy cows calving in autumn. Fertility may be affected (Gregory *et al.*, 1999b) or may not be affected (Hageman *et al*., 1991) as per seasonal variations. In tropical and subtropical areas, many authors reported a reduction in fertility in summer usually coinciding with the prolonged periods of elevated temperature (Weller and Ron, 1992). According to Hansen and Aréchiga (1999), the effect of temperature on cow reproductive performance would be translated by a decrease of heat. The modifications of the photoperiod were not alien to the variations of reproductive performances. Berthelot *et al.* (1991) mentioned the specificities of species, mechanisms of action as well as its effects on the puberty, calving, uterine involution and anoestrus postpartum.

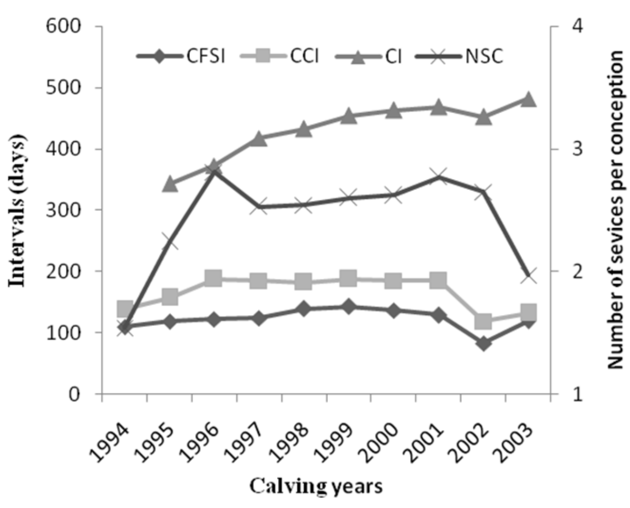

Figure 2. Phenotypic trends of calving to first service interval (CFSI), calving to conception interval (CCI), calving interval (CI) and number of services per conception (NSC) over a ten year period.

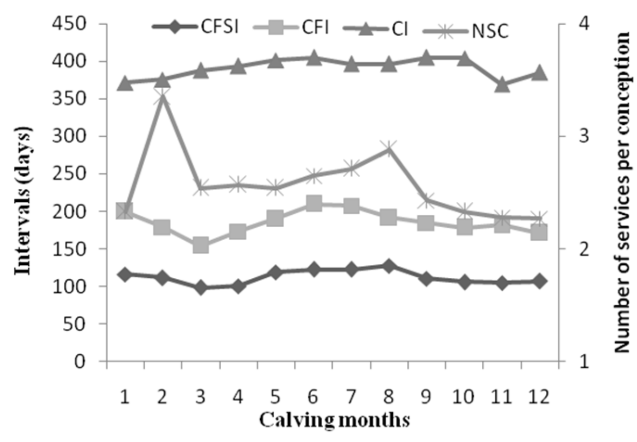

Figure 3. Seasonal variations of calving to first service interval (CFSI), calving to conception interval (CCI), calving interval (CI) and number of services per conception (NSC).

CONCLUSION

Female fertility is a complex set of traits related to genetic and environmental factors. Fertility traits showed low heritability. Reproductive performances changed with the age of the cow often depending on previous performances. Heritability estimates for NSC, as a trait of the cow being inseminated was 2.7 % and was 3.2%, 4.1% and 6.3% for CFSI, CCI and CI, respectively. There were a deterioration of the non return rates and the elongation of the calving interval for several years. Months during the year, lactation number, and herd affected fertility traits. In order to improve or at least stop the deterioration trend in fertility, more emphasis on fertility traits in selection is necessary.

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