Using farmers' records to determine genetic parameters for fertility traits for South African Holstein cows

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Abstract

In South Africa little attention has been given towards the improvement of fertility in dairy cows. Cows not becoming pregnant are culled because of infertility. This could be due to environmental effects (management) or a change in the genetic make-up of cows. At present, routine analyses for fertility traits for Holstein and Jersey cows are based on calving interval (CI) and age at first calving (AFC). A study has been conducted to determine the possibility of using farmers' AI records to determine the fertility of dairy cows. Farmers routinely collect insemination (AI) dates and results from pregnancy diagnosis tests for herd management purposes. All artificial insemination (AI) records (n = 69 181) in 24 646 lactations of 9 046 cows calving down in 14 South African Holstein herds were used to determine alternative fertility traits. Traits included the interval from calving to first service (CFS), the interval from calving to conception (DO), services per conception (SPC) and whether first service was within 80 days post partum (FS80d), whether cows became pregnant within 100 (PD100d) or 200 days (PD200d) post partum. Traits were significantly affected by herd, calving year, calving season and lactation number. Heritability (h^2) estimates for these traits varied between 0.04 and 0.08 but were in agreement with results from the literature. The genetic correlations between CFS and DO and CFS and PD100d were positive, 0.56 and 0.64 respectively. Selection for dairy cow fertility, despite being lowly heritable, would be aided by high levels of phenotypic variation. A fertility index could be derived from a combination of these traits to allow dairy farmers to better select for fertility.

Keywords: Muller, insemination dates, interval, days open, pregnancy rate

Introduction

Until recently, milk production, including fat and protein yield, has been the main objective for selection in most dairy-producing countries (Miglior, *et al*., 2005). In line with global tendencies, South African Holstein breeders preferred North American Holstein sires for artificial insemination(AI) from the late 1970's rather than the traditional Dutch and British Friesian types. This has been followed by a considerable increase in milk yield for cows in milk recording, i.e. from 5800 in 1984 to 9500 in 2010. At the same time, however, the calving interval (CI) of Holstein cows increased from 386 days in 1984 to 420 days in 2004 (Makgahlela, 2008). Many factors could contribute to this trend. However, the reduced reproductive performance of dairy cows have undoubtedly a significantly negative effect on the profitability of a dairy herd (Britt, 1985; Dijkhuizen *et al*., 1985). Although South African dairy farmers have been experiencing poor fertility in dairy cows for some time, little attention has been focussed upon the improvement of their fertility. At most, cows not becoming pregnant, are eventually culled because of infertility. This failure to conceive could be attributed to either environmental effects (management) or a change in the genetic make-up of cows.

Recently, Mostert *et al*. (2010) reported on genetic parameters for CI for the four major dairy breeds in South Africa. Although this is a first step towards the genetic evaluation of the fertility of South African dairy cows, Haile-Mariam *et al*. (2004) pointed out that cows that do not re-calve for any reason, including those cows culled for not becoming pregnant, for whatever reason, are not included in a genetic evaluation. Understandably, this limits the use of CI as measure of fertility in the genetic evaluation of dairy cows, as information on the perceived least fertile group of cows is excluded, possibly leading to bias and inaccurate estimated breeding values for their sires. Using calving interval as an indicator of reproduction management is also problematic from a management point of view, as this figure is based only on those cows calving down again.

Dairy farmers routinely collect and store AI dates and the results from pregnancy diagnosis tests for herd management purposes. Using these records, additional reproductive performance information can be derived for dairy cows. Traits describing fertility can also be used as herd reproduction management indicators. These traits include the following: the interval from calving date to first service (CFS), the interval from calving to conception (DO), number of services per conception (SPC), whether cows were inseminated for the first time within 80 days post partum (FS80d), whether cows were confirmed pregnant within 100 (PD100d) and 200 (PD200d) days post partum.

Genetic parameters for some of these fertility traits have been estimated for small data sets, i.e. 2 639 lactation records of 751 Jersey cows (Potgieter *et al*., 2004) and 3 642 lactation records of 1 375 Holstein cows (Muller *et al*., 2006). Heritability estimates were within the range of estimates from overseas studies. In Canada, a national recording scheme for fertility traits has been implemented as part of a new milk recording scheme (Jamrozik *et al*., 2005). Insemination data have been accumulated since 1997 and a national genetic evaluation program for fertility traits of cows has been developed. Van Doormaal *et al*. (2004) reported preliminary results for four fertility traits, i.e. age at first service in heifers, non-return rate to 56d in heifers and cows and the interval from calving to first service for Canadian dairy breeds. Jamrozik *et al*. (2005) also considered fertility traits such as the number of days between calving and first service, number of services, the number of days between first service to conception. Other traits included age at first service, first service non-return rate to 56 days, calving ease, calf size, the occurrence of stillbirths and gestation length.

Farmers' AI records normally used for herd management purposes, have been used in this study to determine alternative fertility traits and to estimate genetic parameters for these traits.

Material and methods

Data

All AI records (n = 69 181) of cows calving down in the period between 1991 and 2007 in 14 Holstein herds were used. A total of 24 646 lactation records from 9 046 individual cows was available. The outcome of each AI event was known. Pregnancy diagnosis was based on rectal palpation by a veterinarian, usually on a monthly farm visit. Information of veterinarian intervention at the level of individual cows were not recorded. However, it could be expected that cows would have been treated as required, i.e. for retained placentas and uterine infections. Insemination records were linked to the calving date of each cow, the lactation number, as well as dam and sire identification numbers. Fertility traits that measure the ability of cows to show heat early in the breeding period and the probability of the success of insemination and confirmation of pregnancy were derived. The traits derived included the following: the interval from calving to first service (CFS), the interval from calving to conception (DO), number of services per conception (SPC), whether the first service was within 80 days post partum (FS80d), whether cows were confirmed pregnant within 100 (PD100d) and 200 days post partum (PD200d). Non-interval traits were recorded as binary threshold traits coded as 1 = no and 2 = yes. For CFS, records below 21 days and above 250 days were deleted from the data set while for DO records below 21 and higher than 435 days were deleted.

Statistical analyses

To determine fixed effects to be included in the model, an analysis was carried out using General Linear Models (PROC GLM) procedure of GenStat Seventh Edition software (Lawes Agricultural Trust, 2007). The REML Linear Mixed Models (LMM) procedure was implemented for continous traits and the Generalized Linear Mixed Model (GLMM) procedure was used for binomial traits via a LOGIT link back transformation. Significant ($P<0.05$) fixed effects that were subsequently incorporated into the final model were herd (14 levels), year of calving (17 levels), season of calving (4 levels) and lactation number (6 levels). The GLMM models included herd as a random factor (De Vries & Risco, 2005). Estimates of least squares means and REML solutions for the significant fixed effects were also derived.

Genetic parameter estimation

Before genetic parameter estimation, records with missing sire and dam identification numbers were removed from the data set. After further edits, a data set of 16 648 records was suitable for analyses. Calving interval was not included as a fertility trait, therefore cows with no subsequent calving date or cows that were not confirmed pregnant, were also included in the analyses. Including only those cows that eventually became pregnant could introduce selection bias. The data were analysed using bivariate linear-linear and linear-threshold animal models. Fixed effects fitted were herd (14 levels), year (17 levels), season (4 levels) and lactation number (6 levels) for the same traits described above.

The model included the random effects of animal and animal permanent environment (PE). The software used was THRGIBBS1F90 (Misztal *et al*., 2009). Single chains of 250 000 cycles were run, with the first 50 000 cycles used as the burn-in period. This was followed by post-Gibbs analysis, using POSTGIBBSF90 (Misztal *et al*., 2002) to determine convergence by visual examination of plots of (co)variance by iteration. Posterior means were used to calculate the heritability and animal PE variance ratios for each trait. Genetic, animal PE and residual correlations were calculated accordingly. The following multi-trait model was therefore implemented:

$$\mathbf{y}_{ijklm} = \mathbf{f}_{ij} + \mathbf{a}_{ik} + \mathbf{c}_{ik} + \mathbf{e}_{ijklm}$$

In this model, $\mathbf{y}$ was a vector of observations for values for i^{th} trait; $\mathbf{f}_{ij}$ was the fixed effect j for the i^{th} trait; $\mathbf{a}_{ik}$ was the additive genetic effect of the k^{th} animal for the i^{th} trait; $\mathbf{c}_{ik}$ was the animal permanent environmental effect of the k^{th} animal for the i^{th} trait, and $\mathbf{e}_{ijklm}$ was the vector of randomly distributed residual effects.

Results and discussion

Descriptive statistics.

Cows eventually became pregnant in most lactations (0.85±0.36). The interval from CFS was 77±30 days with 64% of first services occurring within 80 days post partum (Table 1). The interval from calving to conception (DO) was high and variable at 134±74 days. Only in 36 and 71% of all lactations were cows confirmed pregnant within 100 and 200 days post partum, respectively. The number of services per conception (SPC) was 2.55±1.79 indicating less than average insemination efficiency of 0.39. Haile-Mariam *et al. (*2004) reported a lower (better) SPC of 1.85. Although average values for some traits were acceptable, large levels of variation were observed as indicated by high standard deviations. The coefficient of variation for interval traits was 0.39 and 0.70 for CFS and SPC respectively. Observed values for these traits are the result of a complex interplay among several elements such as the decision policy of the dairy farmer, physiology, nutrition, health management of cows after calving, environmental factors and genetics. Therefore, a considerable spread of values was expected.

Table 1. Number of records, means and SD, coefficient of variation (CV), minimum and maximum values for traits interval from calving to first service (CFS), interval from calving to conception (DO), number of services per conception (SPC), whether cows were inseminated for the first time within 80 days post partum (FS80d), whether cows were confirmed pregnant within 100 days post partum (PD100d) and whether cows were confirmed pregnant within 200 days post partum (PD200d).

Variables	CFS (days)	DO (days)	SPC	FS80d	PD100d	PD200d
Number of records	16605	14255	14255	16648	16648	16648
Mean	77.3	133.9	2.55	0.64	0.36	0.71
Standard deviation	29.9	74.3	1.79	0.48	0.48	0.45
CV (%)	38.7	55.5	70.2	75.2	133.7	64.0
Minimum	21	21	1	1	1	1
Maximum	250	435	8	2	2	2

Although the CFS intervals were less than 100 days in 82% of lacations, first AI success rate was less than 40%. This causes a long interval from first AI to conception resulting in an exeptionally high number of days open and consequently a long CI. Only 42% of DO intervals were concluded within 100 days post calving, while 18% dragged on for longer than 200 days after calving.

The effect of herd, year of calving, season of calving and lactation number on fertility traits is presented in Table 2. Herd had the largest effect on the variation within traits. This is probably related to management style and inseminator proficiency.

Table 2. Total sums of squares depicting the effects of herd, year of calving, season of calving and lactation number on fertility traits in South African Holstein cows (CFS = interval from calving to first service; DO = interval from calving to conception, SPC = services per conception; FS80d = percentage of cows inseminated within 80 days post

partum, PD100d = percentage of cows confirmed pregnant with 100d post partum, PD200d = percentage of animals confirmed pregnant within 200d post partum).

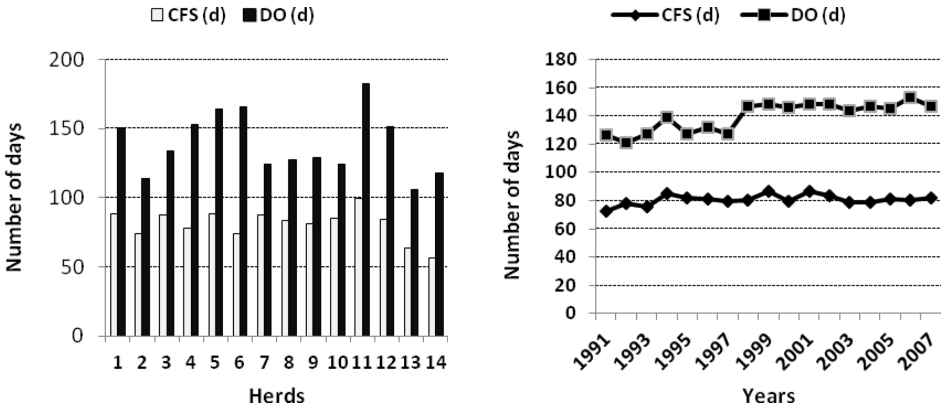
Traits	Fixed effects			
	Herd	Calving year	Calving Season	Lactation number
Degrees of freedom	13	16	4	5
CFS	2598201.2**	118646.4**	25816**	75172.7**
DO	1259070**	2273999**	21501[1]	331422**
SPC	1473.72**	1059.98**	27.903[1]	34.05[1]
FS80d	487.64**	41.39**	6.09**	11.81**
PD100d	119.71**	25.44**	9.15**	14.68**
PD200d	196.92**	37.32**	7.54**	32.31**

**P<0.01; *P<0.05; [1]Not significant

Interval from calving to first insemination and days open

The intervals CFS and DO as affected by herd and calving year is presented in Figure 1. The interval CFS increased overall from 1991 to 2007 although the linear trend was small (0.24 days per year) and not-significant ($P > 0.05$; $R^2 = 0.11$). The largest increase occurred from 1991 to 1994 when the annual increase was 3.5 days ($R^2 = 0.75$; $P < 0.05$). From 1995, the interval CFS did not change over time probably indicating herd managers' ability to maintain this interval although not improving either. De Vries & Risco (2005) also showed that the number of days from calving to first service increased by from 84 days in 1983 to 104 days in 2001 for Holstein cows in the US.

Herd had the biggest contribution to the total variance for DO (Table 2). This variation could be attributed to differences in the voluntary waiting period used in each herd, the inseminators' skills regarding heat detection and AI, as well as conscious management decisions, i.e. postponing first inseminations until a positive energy balance is reached. The largest difference ($P < 0.001$) between two herds in DO was 77.8 ± 6.8 days. The interval DO increased (1.84 days per annum, $P < 0.01$) from 127 days in 1991 to 153 days in 2006. However, the largest increase occurred from 1991 to 1998 after which DO varied little. From this it seems that farmers have adopted a specific strategy regarding the voluntary waiting period and insemination protocols to maintain a DO of about 147 days. This would, however result in extended lactations because of longer calving intervals.



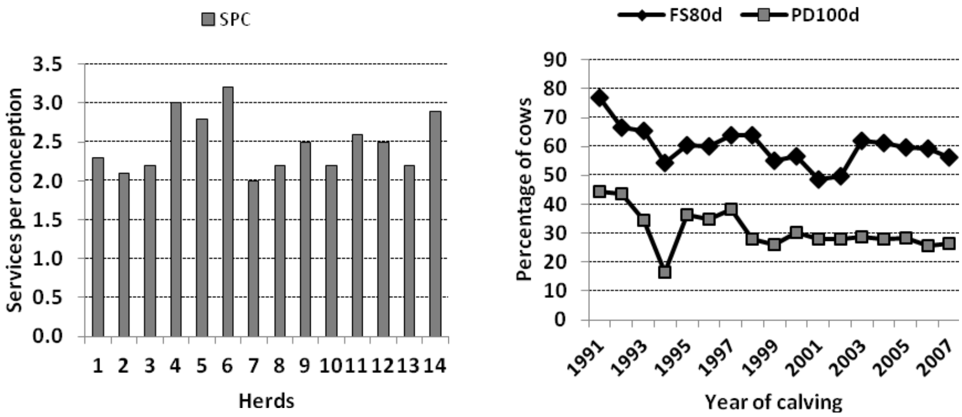
(a) (b)

Figure 1. The interval between calving date and first insemination date (CFS) and (days open (DO) for all Holstein cows as affected by (a) herd and (b) calving year.

Parity affected ($P < 0.05$) the total variance for the interval CFS as well as DO. The interval CFS decreased from 84 days for parity 1 cows to 78 days for parity 3 cows, after which the interval CFS increased to 82 days. This trend is consistent with that of Berry *et al.* (2011) who reported a decline ($P < 0.05$) in the average number of days from calving to first service for cows in parity 1 to 5 of 79, 77, 75, 75 and 74 days respectively. The reason for this trend is not clear, however, physiological stress at first calving could affect young cows, partly explaining the observed longer interval CFS. The second plausible explanation is the fact that after the first parity, animals continue to grow whereby the dietary energy intake is partitioned to meet the requirements for maintenance, continuation of growth, lactation and reproduction.The average (± SE) DO increased from136 ± 2 days for parity 1 cows to 145 ± 4 days for cows in parity 6. A possible explanation for this trend is that dairy producers may give more insemination opportunities to high yielding cows to conceive and may deliberately delay inseminations after calving for these cows.

Number of services per conception and insemination success

The number of services per conception as affected by herd is presented in Figure 2. Overall, the mean number of services per conception (SPC) was high with large variation between herds, i.e. from 2.0 to 3.2. This means that AI efficiency ranged from a low of 0.31 to 0.50. Furthermore, a linear trend ($P < 0.01$) was observed from 1992 to 2006 with the average number of services per conception increasing from 2.1 to 2.9. Specifically from 1998 onwards the number of services per conception was more than 2.5, indicating a insemination efficiency below 40%. According to an Australian survey (Morton *et al*., 2003), farmers experience reproduction problems in their herds with average SPC of above 2.32. In the present study SPC was higher than 2.3 in more than 50% of herds. Jamrozik *et al*. (2005) found that the number of services (NS) for first parity and older Holstein cows in Canada was 1.64 ± 1.09 and 2.14 ± 1.50, respectively. In that analysis, actual SFC higher than 10 was assigned to 10. This would have reduced the mean values indicating better reproductive performance by dairy farmers.



(a) (b)

Figure 2. Services per conception as affected by herd (a) and the annual trend (b) in the percentage of cows inseminated within 80 days post partum (FS80d) and confirmed pregnant by 100 days post partum (PD100d).

A poor conception rate at first service is reflected as a service efficiency below 0.50. This results in a lower percentage of cows pregnant by 100 days in milk and consequently the extension of the interval DO and CI. Although 0.64 of first inseminations were within the first 80 days after calving, a considerable number of first inseminations occurred much later. The reason for this could be ascribed to the management of cows immediately following calving i.e. cows having uterine infections or reproductive problems such as cystic ovaries not observed early by managers. Uterine infections could be caused by a number or factors such as calving environment (wet and dirty conditions), the birth weight of calves (sire selection), the presentation (position) of calves during the birth process, and retained placentas because of nutritional imbalances. This could be addressed by examining cows on a daily basis during the first 10 days of lactation.

A survey in Ireland by Mackey *et al*. (2007) of 19 Holstein-Friesian dairy herds showed that fertility performance was generally poor with the interval to first service being 84.4 ± 35.4 days and first insemination success rate 40.6 ± 0.68%. The 100-day in-calf rate was 46.0 ± 0.68% and CI 404 ± 65 days. By back-calculation, i.e the difference between CI and gestation length (González-Recio *et al*. 2006), the number of days open could be calculated. For a CI of 404 days DO would be *c*. 124 days which is slightly lower (134 ± 74 days) than that observed in the present study. Mackey *et al*. (2007) also noted that the major cause of the poor reproductive performance in Irish dairy herds was due to the prolonged interval to first service and the poor success rate at first AI. The result of this is that only 46% of cows were confirmed pregnant by 100 days-in-milk, although this varied considerably between herds, i.e. 16.4 to 70.8%. In the present study first AI success rate varied between herds from 24 to 50%. Other researchers (Royal *et al*., 2000; Grosshans *et al*., 1997) found first AI success rates of 39.7 and 48.5% respectively.

Genetic parameters estimated using a series of threshold trait analyses are reported in Table 3. The 95% highest posterior density (HPD) confidence interval for the binomial trait FS80d additive genetic variance ranged from a minimum of -0.0393 to a maximum of 0.1816, depending on the two-trait combination. Heritability estimates ranged from 0.04 ± 0.01 to

0.10 ± 0.02 for FS80d depending on the bivariate trait combination. The additive genetic variance (σ_a^2) for FS80d for the combination of FS80d and CFS was very low, resulting in the low heritability of 0.04 ± 0.01 for the two-trait analysis of FS80d with CFS.

Table 3. Mean variance components, posterior standard deviations (PSD), 95% highest posterior density (HPD) confidence intervals and variance ratios for fertility traits in South African Holstein cows using two-trait linear–threshold analyses.

Linear Trait	Item	FS80d	PD100d	PD200d
Days Open (DO)	Additive Genetic PSD	0.5634	0.0148	0.0423
	Additive genetic lower HPD	-0.0393	0.0477	-0.0160
	Additive genetic upper HPD	0.1816	0.1058	0.1498
	Additive genetic variance (σ_a^2)	0.0711	0.0768	0.0669
	Environmental variance (σ_e^2)	1.0000	1.0000	1.0000
	Animal permanent environmental variance (σ_{pe}^2)	0.0811	0.0900	0.1046
	Direct heritability (h^2)	0.06±0.05	0.07±0.01	0.06±0.04
	Permanent environment effect (c^2_{pe})	0.07±0.05	0.08±0.01	0.09±0.04
Calving to First Service (CFS)	Additive genetic PSD	0.0112	0.0195	0.0221
	Additive genetic lower HPD	0.0185	0.0517	0.0554
	Additive genetic upper HPD	0.0623	0.1281	0.1420
	Additive genetic variance (σ_a^2)	0.0404	0.0899	0.0987
	Environmental variance (σ_e^2)	1.0000	1.0000	1.0000
	Animal permanent environmental variance (σ_{pe}^2)	0.0039	0.0658	0.1256
	Direct heritability (h^2)	0.04±0.01	0.08±0.02	0.08±0.02
	Permanent environment effect (c^2_{pe})	0.01±0.01	0.06±0.02	0.10±0.02
Services per Conception (SPC)	Additive genetic PSD	0.0207	0.0207	0.0221
	Additive genetic lower HPD	0.0746	0.0746	0.0554
	Additive genetic upper HPD	0.1558	0.1558	0.1420
	Additive genetic variance (σ_a^2)	0.1152	0.1152	0.0987
	Environmental variance (σ_e^2)	1.0000	1.0000	1.0000
	Animal permanent environmental variance (σ_{pe}^2)	0.0329	0.0329	0.1256
	Direct heritability (h^2)	0.10±0.02	0.07±0.01	0.06±0.01
	Permanent environment effect (c^2_{pe})	0.14±0.02	0.07±0.02	0.10±0.02

The 95% highest posterior density (HPD) confidence intervals for the categorical trait PD100d additive genetic variance ranged from a minimum of -0.03928 to a maximum of 0.18160 depending on the two-trait combination (Table 3). Heritability estimates ranged from 0.07 ± 0.01 to 0.08 ± 0.02 for PD100d depending on the two-trait combinations. Earlier work by Potgieter *et al.* (2004) reported an estimate of heritability of 0.05 ± 0.02 for PD100d using a linear animal model.

Heritability estimates ranged from 0.04 - 0.10 for FS80d, from 0.07 – 0.08 for PD100d and from 0.06 – 0.08 for PD200d. Corresponding ranges for pe^2 were respectively 0.01 – 0.14, 0.06 – 0.08 and 0.09 – 0.10. Potgieter *et al.* (2004) found a heritability estimate for DO of 0.04±0.02 in South African Jerseys using a linear animal model. Dematawewa & Berger

(1998) also reported a heritability estimate of 0.04 for DO in Holsteins using a linear animal model. Restricting DO to be between 50 and 250 days, Van Raden *et al*. (2004) found a heritability of 0.037 for DO in US Holsteins. Oseni *et al*. (2004) estimated heritability estimates for DO of between 0.03 and 0.06 in US Holsteins with different editing criteria, and concluded that DO was strongly influenced by management protocols.

Potgieter *et al.* (2006) reported a heritability for CFS of 0.01±0.02 using a linear animal model in a study conducted on reproduction parameters for South African Jerseys. Wall *et al*. (2003) reported a heritability of 0.04 for days from calving to first service. The heritability estimates for CFS were slightly higher than the estimates in previous studies, although agreeing with the estimate of Jamrozik *et al*. (2005).

Heritability estimates ranged from 0.05±0.02 to 0.07±0.02 for CFS depending on the bivariate combination. Wall *et al*. (2003) reported a heritability of 0.02 for number of inseminations per conception. González-Recio *et al*. (2005) found that heritability of SPC ranged between 0.038 and 0.050 using ordinal censored threshold and sequential threshold models. In study conducted by , Potgieter *et al.* (2006), a heritability of 0.04±0.02 for SPC was derived using a linear animal model. Veerkamp *et al*. (2001) reported a heritability estimate of 0.03 for SPC using a linear model. Fitting a negative binomial model, Tempelman & Gianola (1999) estimated a heritability of 0.02 for SPC. The estimates derived in this study are slightly higher than previously published values, although, in general, studies using threshold models tend to give a slightly larger heritability of SPC.

Judging from the heritability estimates and computing time, interval traits seem to be effective for genetic improvement of reproductive traits. This study included some records in which calving date of next parity is reported, but pregnancy diagnosis and calving date of next parity are unnecessary for deriving a trait like CFS. Depending on data availability and appropriate data editing criteria, CFS might be more suitable for genetic evaluation than DO.

Table 4 reports genetic, permanent environmental and residual correlations among fertility traits in South African Holsteins using several linear-linear and linear-threshold analyses. Direct genetic correlations between the reproductive traits ranged from 0.99 between DO and PD100d to -0.98 between DO and PD200d. The interval trait DO also had favourable relationships, i.e. with FS80d and PD200d indicating that increasing DO would have resulted in fewer cows inseminated within the first 80 days post-partum and also fewer cows confirmed pregnant within 200 days post calving.

The interval trait CFS had a positive genetic correlation with PD100d (0.64±0.01) indicating that increasing the average number of days to first service would increase the number of cows confirmed pregnant by 100 days post-partum; although, reducing the number of cows confirmed pregnant by 200 days post-partum. The favourable genetic relationships between SPC and PD100d (-0.88±0.16) and between SPC and PD200d (-0.90±0.15), demonstrated that increasing the number of services, fewer cows will be confirmed pregnant by 100 and 200 days post-partum.

Results indicated positive associations between common environments in later lactations for DO and PD100d, CFS and PD100d. These results indicate that fewer DO and fewer days for CFS can result into higher pregnancy rates at PD100d. Negative relationships could be observed for SPC and PD100d, SPC and PD200d, which meant that more SPC was associated with lower pregnancy rates at PD100d and PD200d. The level of management in herds may be partially the reason for these relationships. In herds with a lower level of management the reproductive performance of cows will be lower.

Table 4. Genetic, permanent environmental and residual correlations between fertility traits in South African Holsteins using linear – linear and linear-threshold analyses.

Linear Traits	Type of Correlation	FS80d	PD100d	PD200d
Days Open (DO)	Genetic	-0.50±0.01	0.99±0.01	-0.98±0.02
	Permanent Environmental	-0.34±0.02	0.99±0.01	-1.00±0.01
	Residual	-0.25±0.01	0.97±0.01	-0.99±0.01
Calving to First Service (CFS)	Genetic	0.03±0.01	0.64±0.01	-0.36±0.01
	Permanent Environmental	0.12±0.01	0.42±0.03	-0.19±0.02
	Residual	0.04±0.01	0.49±0.01	-0.15±0.01
Services per Conception (SPC)	Genetic	0.01±0.14	-0.88±0.16	-0.90±0.15
	Permanent Environmental	0.14±0.18	-0.93±0.18	-0.93±0.16
	Residual	0.09±0.01	-0.91±0.01	-0.77±0.01

Table 5. Genetic correlations (above diagonal) and residual correlations (below diagonal) between binary and linear traits indicative of fertility in South African Holsteins.

Traits	Traits	FS80d	PD100d	PD200d
Binary traits	FS80d	-	0.54±0.16	0.60±0.15
	PD100d	0.42±0.17	-	0.95±0.20
	PD200d	0.12±0.02	0.97±0.02	-
	Traits	**DO**	**CFS**	**SPC**
Linear traits	DO	-	0.56±0.11	0.03±0.01
	CFS	0.28±0.01	-	0.99±0.19
	SPC	0.04±0.01	0.81±0.02	-

In general, high genetic correlation estimates were obtained between the different fertility traits. CFS showed medium to large estimated correlations with most of the fertility traits, but close to zero with FS80d. This indicates that a strong genetic relationship exist between a cow's ability to recover its normal reproduction function after calving and the ability to conceive after exhibiting heat**.**

Conclusion

Several fertility traits were examined using on-farm insemination and pregnancy records. Estimated genetic parameters were in a close agreement with results from other studies. Heritability estimates of most reproductive traits were 0.10 or below. Genetic correlations between different fertility parameters indicated that it is unlikely that a single fertility trait would serve well for selection purposes under all conditions. This means that different traits should be combined in a fertility index to improve the fertility in dairy cows. Virgin heifer traits can be measured relatively early in the cow's life and should probably also be included in a fertility index. Further research in developing such an index is warranted.

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