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REGULAR ARTICLES

Fertility subindex for improving fertility performance in Iranian Holstein cows

Heydar Ghiasi · Abbas Pakdel · Ardeshir Nejati-Javaremi · Oscar González-Recio

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Abstract Different fertility indices were constructed for improving fertility performance in Iranian Holstein dairy cows. Number of inseminations per conception and days from calving to first insemination, each weighted by its economic value, were included as breeding goals in the aggregate genotype definition. Different fertility indices (FI) were constructed with different combinations of available fertility traits: number of inseminations to conception (INS), days from calving to first service (DFS), interval between first and last insemination (IFL), and days open (DO). The fertility index (FI_1) that included INS and DFS had the greatest genetic gain for INS (−0.39 insemination), DFS (−7.47 days), and profit ($4.3) per generation. Genetic gain for profit, DFS, and INS including only DO showed slight differences regarding FI_1. A selection index that included only INS (DFS) presented the larger (smaller) genetic gains for INS and smaller (larger) for DFS, which were −0.40 (−0.034) and −0.975 (−11.18) inseminations and days, respectively. The result of this study showed that recording INS and DFS are preferable traits for including in a fertility subindex. DO can be used in the absence of other fertility traits.

Keywords Fertility index · Subindex · Genetic gains · Fertility traits

Introduction

In previous decades, breeding programs have placed most emphasis on milk production (De Jong 1998). Unfavorable genetic correlations exist between milk production and fertility, causing a considerable impairment of fertility in dairy cows worldwide (Liu et al. 2007). A cow with good fertility performance should have the ability to re-cycle after calving and the ability to become pregnant after insemination. Fertility is a complex trait, and different related measurements may be recorded in dairy herds. Such measures include days from calving to first service (DFS), number of inseminations to conception (INS), calving interval (CI), days open (DO), interval between first and last insemination (IFL), pregnancy rate (PR), or success to first insemination (SF) (Jorjani 2007). Fertility measurements can be classified in three groups: (1) SF, IFL, PR, and INS measure the ability of cows to become pregnant, (2) DFS is related to the ability of the cow to show heat post-calving, and (3) CI and DO are combination of the two former trait complexes (González-Recio and Alenda 2005). Previous studies reported that INS is an important fertility trait, and weaker genetic correlations between DFS and INS indicate that the ability of a cow to re-cycle and the ability to become pregnant are genetically different traits (González-Recio and Alenda 2005; Ghiasi et al. 2011). Therefore, DFS and INS should be included in the aggregate genotype, and it is important to determine which combination of fertility measurements should be used in a selection index to achieve greater genetic gains for fertility performance. It is

H. Ghiasi (✉)
Department of Animal Science, Faculty of Agricultural Science, Payame Noor University, Tehran, Iran
e-mail: ghiasei@gmail.com

A. Pakdel
Department of Animal Sciences, Isfahan University of Technology, Isfahan, Iran

A. Nejati-Javaremi
Department of Animal Science, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran

O. González-Recio
Departamento de Mejora Genética, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Madrid, Spain

common to construct subindices for improving performances where more than one measurement is recorded in dairy cattle breeding, e.g., subindex for udder performance (Boettcher and Van Doormaal 1999), subindex for calving ability (Cole et al. 2007), subindex for fertility performance (De Jong 1998) subindex for health resistance, and subindex for fitness (Šafus et al. 2005). The aim of this study is to propose a subindex to enhance fertility of Iranian Holstein cows.

Material and method

Fertility selection indices were constructed using the following aggregate genotype:

$$H = v_1 \times \mathrm{INS} + v_2 \times \mathrm{DFS}$$

where v_1 and v_2 are the economic values of INS and DFS. In the aggregate genotype, DFS is related to the cow's ability to recycle after calving and INS is related to the cow's ability to become pregnant after insemination. Traits were included in eight fertility indices (FI) according to their availability and their genetic correlation with traits in the aggregate genotype. Single trait or two combinations of different traits were used in constructing fertility indices. In fertility indices with a single trait, the objective was to test the effect of selection based on one cow's ability (DFS or INS) to another cow's ability. DO is a trait related to both cow fertility abilities; therefore, in the fertility indexes that included only DO, the aim was to test the effect of selection exclusively for DO on genetic gains in INS and DFS. Where there were combination of different traits, only two combinations were used. In such fertility indices, combinations of traits were chosen so that each trait in the selection criteria was representative of one trait in the aggregate genotype (for example, IFL was representative of INS). Fertility indices were as follows:

$$\mathrm{FI}_1 = b_1 \times \mathrm{INS} + b_2 \times \mathrm{DFS}$$

$$\mathrm{FI}_2 = b_1 \times \mathrm{INS} + b_2 \times \mathrm{IFL}$$

$$\mathrm{FI}_3 = b_1 \times \mathrm{IFL} + b_2 \times \mathrm{DFS}$$

$$\mathrm{FI}_4 = b_1 \times \mathrm{DO}$$

$$\mathrm{FI}_5 = b_1 \times \mathrm{DFS}$$

$$\mathrm{FI}_6 = b_1 \times \mathrm{IFL}$$

$$\mathrm{FI}_7 = b_1 \times \mathrm{INS}$$

$$\mathrm{FI}_8 = b_1 \times \mathrm{INS} + b_2 \times \mathrm{DO}$$

Index weights were calculated by the following equation according to (Hazel 1943):

$$\mathbf{b} = \mathbf{P}^{-1}\mathbf{G}\mathbf{v} \quad (1)$$

with **b** is the vector of the index coefficients, **P** is the genetic variance-covariance matrix among traits included in the selection index, **G** is the genetic variance-covariance matrix between traits in the selection index and traits in the aggregate genotype, and **v** is the vector of economic values of traits included in the aggregate genotype that were −\$82 and −\$2.08 per cow per year for INS and DFS, respectively. These values were previously calculated in the same population by Ghiasi (2011; Doctoral Thesis dissertation; Unpublished) using economic information from ten large Iranian herds in year 2008. Economic data included cost of production of 1 kg milk, price of 1 kg milk, price of 3-month-old calf (male and female), cost of raising a 3-month-old calf, price of heifer, cost of raising a heifer, average salvage value of a culled dairy cow, average cost of doses of semen, cost of hormonal treatment for reproductive purposes, average veterinary fee per insemination, and average cost of genetic counselor. Economic values were derived using a profit function methods and differentiating a profit equation with respect to the traits of interest. In this study, multiple-trait EBV were used in the selection index as a source of information. Therefore, to use a selection index in such a situation required some changes when constructing selection indices, as follows: the **P** matrix should be the genetic variance-covariance matrix between traits in the selection index instead of the phenotypic variance-covariance matrix as described by Schneeberger et al. (1992). An assumption of this procedure is that the genetic variance-covariance matrix of traits in the selection index and traits in the aggregate genotype is known without error. Genetic parameters obtained by Ghiasi et al. (2011) using 72,124 records from 27,113 cows in 15 large Iranian herds with parities from one to six were used in this study (Table 1).

Expected genetic gains

Expected genetic gains for those traits in the aggregate genotype ($\boldsymbol{\Delta}\mathbf{G_j}$) and for profit ($\boldsymbol{\Delta}\mathbf{Pr}$) for each proposed fertility index were predicted as follows:

$$\Delta \mathrm{G_j} = \left(\mathrm{G_j}'\mathrm{b} / \sigma_\mathrm{I}\right) \times \mathrm{I} \quad \Delta \mathrm{Pr} = \sum\left(\Delta \mathrm{G_j} \times \mathrm{v_j}\right)$$

where $\mathbf{G_j}$ is the *j*th column of the matrix **G** related to *j*th trait in aggregate genotype, $\boldsymbol{\sigma_I}$ is the standard deviation of the selection index calculated as $\boldsymbol{\sigma_I}=\sqrt{(\mathbf{b}\ \ \mathbf{P}\ \mathbf{b})}$, **i**=selection intensity that was equal one in this study, and v_j is the economic value of *j*th trait in aggregate genotype.

Observed genetic gains

After these indices were constructed, they were ranked according to expected genetic gains. In order to determine if the order of fertility indices will change based on observed genetic gains after using these indices in population, a simulated population was obtained for each of the fertility indices for five generations using Dairy Herd sim.1 software (Honarvar et al. 2010).

Observed genetic gains were computed as the difference between the mean genetic breeding value of the population in the fifth generation and base generation.

The selection intensity for computing observed genetic gains was 1.34, which was higher than those assumed in the prediction of expected genetic gains. Although the selection intensity was different when computing expected and observed genetic gains, this does not affect the ranking of the fertility indices because it is constant for all fertility indices compared.

Observed genetic gains were computed for INS and DFS in the aggregate genotype and also for IFL and DO.

Results and discussion

Expected genetic gains

Expected genetic gain for traits in the aggregate genotype and profit are shown in Table 2. FI_7, which included only INS as selected trait, had the largest and lowest genetic gains for INS and DFS, respectively, among the different fertility indices evaluated. In contrast, FI_5 that included only DFS had lowest and largest genetic gains for INS and DFS, respectively. Therefore, using FI_7 or FI_5 would place larger emphasis on only one of the two aspects of fertility. Therefore, FI_5 or FI_7 may be chosen depending on what trait needs larger genetic improvement in the population. If becoming pregnant is a major problem in a population, then FI_7 can be used to overcome to this problem, while if ovarian cyclicity post-calving is a major problem in a population, FI_5 would be preferred. The index (FI_1) that included INS and DFS achieved similar genetic gain for both INS and DFS as those obtained in FI_5 for DFS and FI_7 for INS. Furthermore, the genetic gain for profit in FI_1 was the largest one among all the fertility indices evaluated.

Days open is a trait that can be routinely obtained from milk recording schemes. The index FI_4, including only this trait, showed that the decrease in profit was only \$0.8/cow/year relative to the optimum index (FI_1). Therefore, in conditions where fertility records are not available, DO can be used efficiently to improve fertility performance. Summation of IFL and DFS is expected to be equal to DO. However, an index including IFL and DFS (FI_3) resulted in a slightly smaller genetic gain than selecting DO (FI_4) (\$3.2 vs. \$3.5) due to the different genetic correlations between these traits and INS. FI_3 showed smaller genetic gain for INS than in FI_4. These results suggest that two cows may have the same DO but different fertility performance either in the re-cycling activity post-calving or the ability to get pregnant. Further, censoring must be taken into account in genetic evaluations to improve predictive ability (González-Recio et al. 2006).

At farm level, it is better to register IFL and DFS instead of DO. It should be acknowledged that DO is affected by management decisions in a stronger manner than other fertility traits. Low genetic correlation (<0.1) was reported previously between INS and DFS (Ghiasi et al. 2011); (González-Recio and Alenda 2005).

Table 1 Additive genetic variance (diagonal), genetic covariance (above diagonal) and phenotypic covariance (below diagonal)

Traits	INS	DFS	IFL	DO
INS	*0.84*	0.25	2.94	3.66
DFS	−4.43	*65.4*	44.48	108.6
IFL	61.5	−142	*132*	196.27
DO	63	960.6	3,083.4	*303*

INS number of inseminations to conception, *DFS* days from calving to first service, *IFL* interval between first and last insemination, *DO* days open

Table 2 Fertility indices and expected genetic gains

Fertility index	Expected genetic gain per generation[a]		
	INS	DFS (days)	Profit (\$)
$FI_1=-0.72\times INS-2.08\times DFS$	−0.39	−7.47	4.3
$FI_2=-54.52\times INS-1.22\times IFL$	−0.377	−2.67	3.2
$FI_3=-1.79\times IFL-1.52\times DFS$	−0.186	−8.97	3.2
$FI_4=-1.69\times DO$	−0.25	−8.6	3.5
$FI_5=-2.3\times DFS$	−0.034	−11.18	2.5
$FI_6=-2.39\times IFL$	−0.256	−4.61	2.8
$FI_7=-77.07\times INS$	−0.40	−0.975	3.0
$FI_8=-30.77\times INS-1.32\times DO$	−0.32	−6.83	3.7

INS number of inseminations to conception, *DFS* days from calving to first service, *IFL* interval between first and last insemination, *DO* days open

[a] Expected genetic gains were calculated assuming selection intensity of one and same generation interval for all traits

Table 3 Fertility indices and observed genetic gains obtained using simulated data

Fertility index[1]	Observed genetic gain per generation[a]				
	INS	DFS (days)	Profit ($)[a]	IFL (days)	DO (days)
$FI_1=-0.72\times INS-2.08\times DFS$	−0.214	−5	2.58	−6	−13.90
$FI_2=-54.52\times INS-1.22\times IFL$	−0.276	−2.21	2.45	−7.40	−12.40
$FI_3=-1.79\times IFL-1.52\times DFS$	−0.137	−6.50	2.33	−7.50	−14.0
$FI_4=-1.69\times DO$	−0.173	−5.50	2.38	−6	−14.0
$FI_5=-2.3\times DFS$	−0.029	−7.18	1.70	−3.5	−10.80
$FI_6=-2.39\times IFL$	−0.168	−3	1.83	−7.5	−11.16
$FI_7=-77.07\times INS$	−0.246	−0.90	1.95	−5	−9.20
$FI_8=-30.77\times INS-1.32\times DO$	−0.230	−5.30	2.75	−6.5	−15.50

INS number of inseminations to conception, *DFS* days from calving to first service, *IFL* Interval between first and last insemination, *DO* days open

[a] Profit was computed by multiplying the economic value of INS and DFS in their observed genetic value

Traits that present stronger genetic correlation with INS and DFS should be used for selection. According to González-Recio and Alenda (2005), the fertility index composed of DFS and pregnancy within 56 days achieved the highest genetic gain for reducing fertility cost in a Spanish Holstein population, reducing days to first service and the number of inseminations per conception. The fertility index proposed for the Dutch Holstein population includes non-return after 56 days and DFS (De Jong 1998). According to Berry et al. (2005), selection for a milk production subindex will cause a reduction in fertility performance. In contrast, selection on a fertility subindex alone is expected to cause a reduction in milk production. Therefore, a balance between the emphasis on milk and fertility should be obtained according to an economic function.

Observed genetic gains

Observed genetic gain for the different fertility indexes are shown in Table 3. Favorable genetic gains were observed in a simulated population as verified in the expected gains, with little differences in the rank of fertility indices. However, the amount of expected genetic gains for INS and DFS were higher than observed genetic gains for all fertility indices. Lowest genetic gains for DFS were observed in FI_7, whereas lowest genetic gains for INS were observed in FI_6. Moderate genetic gains for both INS and DFS were observed in FI_1. Genetic gain observed for INS in FI_2 was higher than those observed in FI_1, probably because of the higher genetic correlation between INS and IFL. As expected in FI_4, in the absence of fertility records, DO is a proper trait for genetic selection of fertility in dairy cows.

Observed genetic gains were also calculated for DO and IFL in the simulation (Table 3). The ranges of observed genetic gains for DO and IFL were between −9.2 to −15.5 days and −3.5 to −7.5 days per generation, respectively. Larger genetic gains for IFL were observed in FI_3 and FI_6. FI_8 showed somewhat greater observed genetic gains for INS, DFS, IFL, and DO than FI_1. Genetic gains for profit show that the amount of genetic gain in INS has higher impact on profit than genetic gain in DFS.

Conclusion

Selection based only on one of the traits included in the aggregate genotype, INS or DFS, cannot improve overall fertility performance. Selection based on both traits accelerate genetic gains for fertility. In a situation in which fertility records (INS and DFS) are not available, selection can be based on DO to improve fertility performance. This study suggests that INS and DFS should be recorded in Iranian Holstein dairy cow recording system in addition to DO, for their inclusion in the genetic evaluations.

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Conflict of interest The authors do not have any conflicts of interest.

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