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Genomic testing interacts with reproductive surplus in reducing genetic lag and increasing economic net return

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ABSTRACT

Until now, genomic information has mainly been used to improve the accuracy of genomic breeding values for breeding animals at a population level. However, we hypothesize that the use of information from genotyped females also opens up the possibility of reducing genetic lag in a dairy herd, especially if genomic tests are used in combination with sexed semen or a high management level for reproductive performance, because both factors provide the opportunity for generating a reproductive surplus in the herd. In this study, sexed semen is used in combination with beef semen to produce high-value crossbred beef calves. Thus, on average there is no surplus of and selection among replacement heifers whether to go into the herd or to be sold. In this situation, the selection opportunities arise when deciding which cows to inseminate with sexed semen, conventional semen, or beef semen. We tested the hypothesis by combining the results of 2 stochastic simulation programs, SimHerd and ADAM. SimHerd estimates the economic effect of different strategies for use of sexed semen and beef semen at 3 levels of reproductive performance in a dairy herd. Besides simulating the operational return, SimHerd also simulates the parity distribution of the dams of heifer calves. The ADAM program estimates genetic merit per year in a herd under different strategies for use of sexed semen and genomic tests. The annual net return per slot was calculated as the sum of operational return and value of genetic lag minus costs of genomic tests divided by the total number of slots. Our results showed that the use of genomic tests for decision making decreases genetic lag by as much as 0.14 genetic standard deviation units of the breeding goal and that genetic lag decreases even more (up to 0.30 genetic standard deviation units) when genomic tests are used in combination with strategies for increasing and using a reproductive surplus. Thus, our hypothesis was supported. We also observed that genomic tests are used most efficiently to decrease genetic lag when the genomic information is used more than once in the lifetime of an animal and when as many selection decisions as possible are based on genomic information. However, all breakeven prices were lower than or equal to €50, which is the current price of low-density chip genotyping in Denmark, Finland, and Sweden, so in the vast majority of cases, it is not profitable to genotype routinely for management purposes under the present price assumptions.

Key words: dairy herd management, genomic selection, modeling, sexed semen

INTRODUCTION

Sexed semen has the potential to generate a surplus of reproduction capacity in dairy herds, because fewer pregnancies are required to produce the same number of replacement heifers. Any improvement in pregnancy rate can also result in a surplus of reproduction capacity, because more pregnancies are produced per year, and fewer replacement heifers are required, because fewer cows are culled for reproductive failure. A reproductive surplus generates opportunities for deciding which cows to breed the replacements from, so it is possible to increase the selection intensity. Hence, in combination with selection, use of sexed semen results in reduced genetic lag relative to the sire population (Ettema et al., 2011; Sørensen et al., 2011).

A reproductive surplus can be used to cull low-merit newborn heifers, to sell low-merit pregnant heifers, or to select low-merit cows for production of high-value crossbred calves sired by a beef-breed bull. In this study we assume the last strategy, in which, on average, there is no selection among replacement heifers whether to go into the herd or be sold. In this situation, the selection opportunities arise when deciding which cows to inseminate with sexed semen, conventional semen, or beef semen. The effect of inseminating with sexed

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semen, conventional semen, or beef semen on reducing genetic lag depends on the accuracy with which the animals are selected.

A genomic test involves typing a large number of genetic markers and calculating a genomically enhanced breeding value (**GEBV**). The accuracy of GEBV differs between breeds. But, it is always higher than the accuracy of breeding values based on parent average, so a heifer with a genomic test will have its genetic merit determined at greater precision than without a genomic test (Lund et al., 2011; Thomasen et al., 2012). Hence, a better decision whether to inseminate the heifer with sexed or conventional semen can be made.

We expect that combining the use of sexed semen and genomic tests will increase both selection intensity (i) and accuracy on selection (r_{AI}) and, therefore, decrease genetic lag between the populations of AI bulls and cows to breed cows. However, we also expect that the effect on genetic lag of using genomic tests will be larger at high selection intensities, because the selection intensity and the accuracy interact multiplicatively in the breeder's equation: $I = i \times r_{AI} \times \sigma_H$, where I is the genetic superiority of the selected animals and σ_H is the standard deviation of the breeding goal.

We, therefore, hypothesize that the use of genomic tests for decision making decreases genetic lag within the herd and mostly so in combination with use of sexed semen or high management levels for reproductive performance. Furthermore, we estimated the breakeven price of genomic tests in different scenarios of sexed semen use and management levels for reproductive performance.

MATERIALS AND METHODS

General Design of the Study

To test the hypothesis, we examined and compared the effect of varying the management level, strategies for use of sexed semen and use of genomic tests in a simulated herd with 214 slots.

Outline of Experimental Design

In this study, the management level was only characterized by the reproductive performance of the cows and the replacement rate. The number of cows inseminated with beef semen depended on the pregnancy rate and the replacement rate. Both rates are important for the age distribution of the herd and the possibility of generating a reproductive surplus. For that reason, 3 management levels with poor, average, or good reproductive performance were considered.

Table 1. Strategies for use of sexed semen

Strategy	Proportion (%) inseminated with sexed semen: Heifers	First-parity cows
H0C0	0	0
H40C0	40	0
H60C0	60	0
H80C0	80	0
H40C20	40	20
H40C40	40	40
H60C20	60	20
H60C40	60	40

Use of sexed semen may also contribute to a reproductive surplus in the herd. For that reason, 8 different strategies with varying proportions of heifers and first-parity cows being inseminated with sexed semen were compared within each management level (Table 1).

In addition, 5 different strategies for use of genomic tests were compared within each management level and in combination with the 8 strategies for use of sexed semen. The 5 strategies for use of genomic tests were

- **GT0**: no use of genomic tests,
- **GT25c**: 25% of the heifers centered on the truncation point for use of sexed semen or on the middle, if sexed semen was not used, were genotyped,
- **GT50c**: 50% of the heifers centered on the truncation point for use of sexed semen or on the middle, if sexed semen was not used, were genotyped,
- **GT50b**: top 50% of the heifers were genotyped, and
- **GT100**: all heifers were genotyped.

To sum up, 8 strategies for use of sexed semen times 5 strategies for use of genomic tests were simulated for 3 different management levels.

The general assumptions made in this study were representative of Danish prices and production conditions. However, we believe that the assumptions hold true for many dairy herds in the developed countries. An average Danish dairy farm with regard to production system, production level, and management level formed the basis of the simulations.

General Framework of the Simulation Models

SimHerd IV (software from Aarhus University, Tjele, Denmark) is a mechanistic, dynamic, and stochastic dairy herd model that simulates the production and state changes of dairy cows and young stock in a herd (Østergaard et al., 2005). The state of an animal is