ABSTRACT

The objective of this study was to implement an in vitro produced embryo transfer (IVP-ET) system in an existing stochastic dynamic dairy simulation model with multitrait genetics to evaluate the genetic, technical, and financial performance of a dairy herd implementing an exclusive IVP-ET or artificial insemination (AI) system. In the AI system, sexed semen was used on the genetically best heifers only. In the IVP-ET system, all of the animals in the herd were impregnated with female sexed embryos created through in vitro fertilization of oocytes collected from animals of superior genetics for different traits of interest. Each donor was assumed to yield on average 4.25 transferable embryos per collection. The remaining animals in the herd were used as recipients and received either a fresh embryo or a frozen embryo when fresh embryos were not available. Selection of donors was random or based on the greatest estimated breeding value (EBV) of lifetime net merit (NM$), milk yield, or daughter pregnancy rate. For both the IVP-ET and AI systems, culling of surplus heifer calves not needed to replace culled cows was based on the lowest EBV for the same traits. A herd of 1,000 milking cows was simulated 15 yr over time after the start of the IVP-ET system. The default cost to produce and transfer 1 embryo was set at $165. Prices of fresh embryos at which an exclusive IVP-ET system financially breaks even with the comparable AI system in yr 15 and for an investment period of 15 yr were also estimated. More surplus heifer calves were sold from the IVP-ET systems than from the comparable AI systems. The surplus calves from the IVP-ET systems were also genetically superior to the surplus calves from the comparable AI systems, which might be reflected in their market value as a premium price. The most profitable scenario among the 4 IVP-ET scenarios in yr 15 was the one in which NM$ was maximized in the herd. This scenario had an additional profit of $8/cow compared with a similar AI scenario that maximized NM$, provided that surplus heifer calves could be sold at a premium price based on the superiority of the EBV of NM$. For the IVP-ET system to be at least as profitable as the comparable AI system during a 15-yr investment period, the surplus calves from the IVP-ET system needed to be sold at the premium prices. The break-even price of fresh embryos was estimated to be $84 for the exclusive IVP-ET system. This resulted in the same profit as the AI system, which maximized NM$ for a 15-yr investment period and in which heifer calves were sold at a premium price. Key words: stochastic modeling, embryo transfer, genetics, profitability

INTRODUCTION

In vitro produced embryo transfer (IVP-ET) systems allow for the production of embryos from genetically superior donors at a young age that can be transferred into recipients in the same or other herds. Genetic progress in the herd can be accelerated because use of an IVP-ET system can increase the intensity of selection, reduce the generation interval, and increase the accuracy of selection (Ruane, 1991; Kruip et al., 1994; Hansen and Block, 2004). The use of an IVP-ET system in a herd to improve the genetics of the herd is growing in popularity (Haag and Dorshorst, 2013; Sjostrom, 2016).

The IVP-ET system increases selection intensity because of the increased number of offspring that can be produced from superior females. In Holsteins, an average of approximately 4 transferable embryos can be produced per collection (Wilson et al., 2006; Bouquet et al., 2015). Oocyte collection can be performed every 2 wk or more frequently as well as into the third month of gestation in pregnant animals (Qi et al., 2013). Even in a conservative IVP-ET system, where oocytes are collected only 7 times/yr from the same female and the calving rate of recipients is 25% (Pontes et al., 2010),...
it is possible to produce 7 calves/yr per donor compared with only 1 calf from AI. With such a production capacity and the use of sexed semen to produce 90% females (DeJarnette et al., 2008), it is feasible to use IVP-ET to produce all pregnancies from the best 2% of the females (heifers and cows) in the herd. In such a system, the use of sexed semen further increases the selection intensity by enabling culling of up to 50% of the heifer calves born every year (Pryce et al., 2010).

Genomic testing allows the top and bottom of the herd to be identified with greater reliability than traditional EBV based on parent averages (Meuwissen et al., 2001). The EBV are estimates of true breeding values (TBV), which in practice are unknown. Greater reliabilities increase the accuracy of these estimates. Previous modeling studies have found that using genomic EBV to make early selection decisions of sires can increase genetic gains by 30 to 217% over genetic gain in dairy herds based on parent average selection (Schaaf- fer, 2006; König et al., 2009). Additional benefits of an IVP-ET system compared with AI systems may include added value of heifer calves not used as replacements, optimization of herd turnover rates, reduced dystocia, and improved biosecurity if open herds could be closed (De Vries et al., 2008; Heikkilä and Peippo, 2012).

One major disadvantage of IVP-ET is the greater cost per breeding and pregnancy compared with AI. For example, Ribeiro et al. (2012) calculated a difference in the cost of a female pregnancy to be $329 higher for IVP-ET than for AI using sexed semen. That study did not include genetic and additional benefits from IVP-ET, however. The increased cost includes the expense of the IVP-ET procedures but also higher probabilities of abortion and neonatal death loss (Taverne et al., 2002; Bonilla et al., 2014). Given the genetic benefits but greater costs, it is not clear how exclusive IVP-ET systems compare with exclusive AI systems regarding genetic, technical, and financial performance. Of interest is how much the genetic changes made through an IVP-ET system affect the technical and financial performance of the IVP-ET system and the break-even cost per transfer to make the IVP-ET system financially competitive with AI. In some related work, Pryce et al. (2010) used a deterministic model and estimated that IVP-ET in the cow–dam selection pathway could result in a yearly genetic gain of 0.59 SD of the genetic trait under selection compared with 0.47 SD when selection occurred without IVP-ET.

Bouquet et al. (2015), working with stochastic simulation and the Viking Red breeding scheme, showed that multiple ovolation and embryo transfer increased genetic gain without increasing inbreeding rates provided that the multiple ovolation and embryo transfer nucleus size and number of sires were large enough. Increasing the number of flushings per heifer had a greater effect on genetic gain with simultaneous reduction in inbreeding rates compared with increasing the number of flushed heifers. Moreover, genetic gain and reduction in inbreeding rates was greater when more heifers in the population were genotyped to select the heifers that were flushed.

None of these 3 studies (Pryce et al., 2010; Ribeiro et al., 2012; Bouquet et al., 2015) estimated the financial benefits that result from using embryo transfer in combination with genetic selection strategies. Thomassen et al. (2016) reported that the greatest increase in economic value of genetic gain for a 2-trait selection goal was obtained when juvenile IVP-ET was used along with genomic selection in the bull-dam part of the Danish dairy population. This was compared with a scenario without genomic selection and no IVP-ET. Combining IVP-ET with genomic testing was profitable in almost all evaluated scenarios when the cost of producing a calf by IVP-ET ranged from $500 to $1,500. They did not study the cost of IVP-ET to improve the female performance in a closed herd. We did not find studies that reported the genetic, technical, and financial herd performance from using IVP-ET on just the cow-dam side in a herd.

Earlier we developed a stochastic dynamic model in which the 12 traits included in the lifetime net merit (NM$) index (VanRaden and Cole, 2014) were modeled simultaneously to study genetic, technical, and financial performance of AI systems over time (Kaniyamattam et al., 2016). In that study we showed that inclusion of multitrait genetic variation and correlations in a model for evaluating reproduction and replacement strategies changed the genetic, technical, and financial results considerably. Further, we showed that the selection focus of surplus heifer calves (e.g., based only on milk yield or NM$) had significant effects on herd results over time. The model included only AI systems but could be expanded to include IVP-ET systems as well.

The current study had 3 objectives. The first objective was to describe the incorporation of an IVP-ET system into an existing stochastic dynamic model. The second objective was to compare the genetic, technical, and financial performance of exclusive IVP-ET systems with that of exclusive AI systems given realistic prices for embryos and surplus calves. Selection of donors and surplus heifers was either random or based on the EBV of milk yield, daughter pregnancy rate (DPR), or NM$ in a closed dairy farm. The third objective was to estimate the break-even prices of IVP embryo transfers to obtain the same financial herd performance as an exclusive AI system, depending on how surplus calves were priced.
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