Bio-economic Evaluation Of Twin Births Induced By Sexed Embryo Transfer in Dairy Cows

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Introduction

The economic implications of reproductive management decisions are critical, given the link between dairy herd management and reproductive performance. Reproductive performance on the dairy farm affects profitability directly through the milk production per cow per day, number of replacements available, and voluntary and involuntary culling rates (Britt et al. (1986)). Today, many reproductive technologies are available for use on commercial dairy farms, with the costs and reproductive performance associated with these technologies varying considerably among farms. Reproductive management programs differ because of varying on-farm costs, housing and handling facilities, farm goals and values, and management styles (Olynk and Wolf (2007)).

Use of *in vitro*-produced embryos (IVP) and technology controlling the sex of embryos has the potential to significantly change many aspects of animal production, such as allowing breed of calf to be independent of breed of cow and promoting enhanced rates of genetic gain. The use of sexed embryos also offers an opportunity for the farmer to reduce calving difficulties and thereby improve animal welfare. The majority of the studies on embryo technologies have focused on the aspects of genetic gain within the dairy herd (Colleau (1992); Yates et al. (1996)). Their results have shown that IVP and embryo transfer (ET) technology can be of potential use both for increasing rates of genetic gain within a herd and for enabling a faster dissemination of superior genetics from nucleus breeding herds to commercial milk producers. The objective of this study was the bio-economic evaluation of the use of sexed embryo transfer systems for induction of twin births and comparison with conventional artificial insemination (AI) in the simulated Holstein dairy herds.

Material and methods

Model description. We used Dairy Herd Sim 1.0 simulation model (Honarvar (2009)) written in Visual Basic version 6.0 and made appropriate changes to this model for evaluating the objective of this study. The objective of using a dynamic model for this study was to mimic the biology and management of a herd of individual youngstock and cows over time, with emphasis on reproduction and life time performance. Default input parameters and summary of economic variables used in the model are given in Table 1. The maximum herd size in the model is set by the user. A strategy of using conventional AI or ET using two sex-controlled embryos at different conception rates and herd sizes resulted in a 24 state model. Two sizes of dairy herds were used in the current study: fixed sized herds and expanding herds. Gender of the calf was determined by a U (0, 1) random variable. Bull calves make up 52% of all calves born (Ghavi Hossein-Zadeh et al. (2008)). The remainder is heifer calves. If prior embryo sexing has been carried out, the probability is set to 0.9 for the favored sex (female sex). Incidence of natural twinning is set at 1.10%, 3.20%, 4.22% and 4.50% of all calvings for first, second, third, and fourth and later lactations, respectively (Ghavi Hossein-Zadeh et al. (2009)). The average conception rates investigated were 35%, 40%, 45%, 50%, and 55% for embryos, but the average conception rate of the semen used in AI program was assumed to be as 40%. Parameters for functions for milk production were estimated from the test day records collected from the milk production records of dairy herds collected by Animal Breeding Center of Iran using Proc Nlin in SAS (SAS Inst., Inc., Cary, NC, 2002). Records of milk production were generated by assuming an infinitesimal additive genetic model as $y_i = \mu + a_i + e_i$. Where y_i = phenotypic lactation milk record of the animal i; μ = population mean; a_i = additive genetic effect of the animal i; and e_i = random residual effect. Estrous cycle is one of the time-oriented

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reproductive characteristics for each open cow and heifer. Estrous cycle assumed 18 to 24 d. Synchronization can also reduce the time from the start of calving until mean calving day, provided breeding begins on a fixed date, and may be significant when conception rate is low. Theoretical annual genetic gain in a conventional AI population for milk yield was 150 kg/yr. But, the genetic trend of milk in ET program was assumed to be 225 kg/yr for sexed embryos (Colleau (1992)).

Bio-economic evaluation. At first, the present economic study started with the assumption that cows in the twin group had a naturally occurring twin pregnancy and therefore had no embryo transplantation. Then it is assumed that the embryo transfer has been performed in dairy herd, using sexed embryos. Also, only the effects of twinning were considered; ignored were causes and risk factors and direct influences of twin births on feed consumption and on diseases other than reproductive problems of the dam. The additional income was completely based on the returns from the calves. The value of the calf was based on weight, sex, breed, mortality, and the price per kilogram of body weight. In the present study, the birth weight of twin calves was assumed to be 8 kg lighter than for singles (Ghavi Hossein-Zadeh et al. (2010)). The net return (profit) for the system was calculated as the sum of daily income from the milk, male calves, culled cows, surplus heifers, and other products (total income) minus total costs including feed, embryo, veterinary and health, livestock supplies, equipment repairs, home expenses, trucking and miscellaneous. To test the sensitivity of the model, milk payment, meat and heifer prices, feed and non-feed costs were varied by +/- 20%.

Results and discussion

The net profit of using conventional AI system at different herd size and with or without estrous synchronization is shown in Table 2. Also, the net profits of using sexed embryo transfer for induction of twinning at different herd sizes and with or without estrous synchronization are shown in Figure 1. In general, the net profit of the AI strategies was positive at the end of time horizon. The trend of net profit of using AI strategies with conventional semen over the time horizon was greater when the size of the herds was under expansion ($P<0.01$). This increase was due to the genetic trend of milk yield and increase in the milk production over the years. But the trend of net profit of fixed sized herds were generally negative, however, expanding herds experienced the positive net profits over the years. However, the net profit of the embryo-based strategies was negative at the end of time horizon. The reason for this effect was that the increase in the milk production and its related incomes cannot decrease the costs of sexed embryos and their transfers. There were no restriction on inbreeding in the all of strategies under study, therefore, allowing the best genetic material to be used each month. The net profit of applying sexed embryo transfer for induction of twinning was greater when the conception rates of sexed embryo in the fixed and expanding dairy herds were 35 and 45 to 50%, respectively. The net profit of using sexed embryo transfer in the expanding herds were greater than that of fixed sized herds (in average 47 $/yr).

A key outcome is that most performance parameters, such as number of ET services, number of induced cows and number of surplus dairy heifers are sensitive to conception rate differences between ET and AI. In general, the percentage of cows finally pregnant is lower where the conception rate is poorer. As expected, the total number of mating services or embryo transfers required increased as the conception rate decreased. This was because a greater number of cows required re-serving in subsequent service periods when the conception rate was lower. Synchronized services had minimal effect on final pregnancy rate, in part because submission rate was 90% for all scenarios. However, synchronization improved the mean calving date because the start of breeding coincided with the peak of the first synchrony. In practice, non-pregnant cows are the preferred candidates for culling. The total number of cows culled is constant in herds of fixed size and is determined by the number of cows surplus to the required number of lactating cows. The income obtained from the milk sales and feed costs were the most important revenue and cost variables, respectively, which their variations by 20% have been modified significantly the net profit of AI strategies (not shown as a table). A 20% lower feed costs and 20% larger milk sales income resulted in an increase in the net profit of dairy herds. On the other hand, the income obtained from the milk and heifer sales were the most important revenue variables and feed and embryo costs were the most important cost variables in the embryo-based strategies.

Table 1. Default input parameter values and economic variables used in the model.

Parameter	Value
Number of replications	40
Breeding period, yr	7
Simulation period, yr	15
Size of the herd	5000
Birth weight, kg	42
Mature live weight, kg	600
Heat detection rate, %	50
Synchronization rate, %	90
Female rate (for sexed embryo), %	90
Conception rate (conventional semen), %	40
Conception rate (sexed embryo), %	35, 40, 45, 50, 55
Voluntary waiting period, d	45
Calf mortality, % of calves born	5
Cow death rate from weaning to first calving, %	2
Mean gestation length, d	280
Age at first freshening, mo	24
Genetic variance of milk, kg^2	292852
Residual variance of milk, kg^2	757000
Milk sales, $/kg	0.42
Meat price, $/kg	2.7
Heifer price, $	4000
Carcass weight price, $	1.7
Price of male calf at birth, $	150
Price of female calf at birth, $	900
Veterinary costs, $/cow/yr	163
Synchronization cost, $	5
Conventional semen, $	20
Sexed embryo and implantation costs, $	400

Table 2. Net profit of milk production per cow ($) for breeding cows and heifers with conventional semen at different herd sizes and with or without estrous synchronization.

	Strategy			
Year	Fixed size	Fixed size and synchronized	Expanding size	Expanding size and synchronized
1	60.28	76.42	3.07	31.40
2	16.22	48.53	5.96	11.77
3	45.54	7.71	-8.53	4.56
4	-12.69	21.72	-3.62	12.10
5	51.98	70.65	6.49	7.82
6	26.78	19.00	-2.94	-1.10
7	27.29	24.86	-4.67	23.17
8	32.37	2.26	5.46	50.25
9	15.05	3.98	35.35	67.00
10	9.54	7.75	13.57	36.37
11	28.14	17.17	17.72	24.57
12	3.16	11.73	42.65	28.81
13	23.68	47.00	39.61	34.42
14	4.91	24.54	42.19	21.95
15	36.18	35.75	27.23	59.06

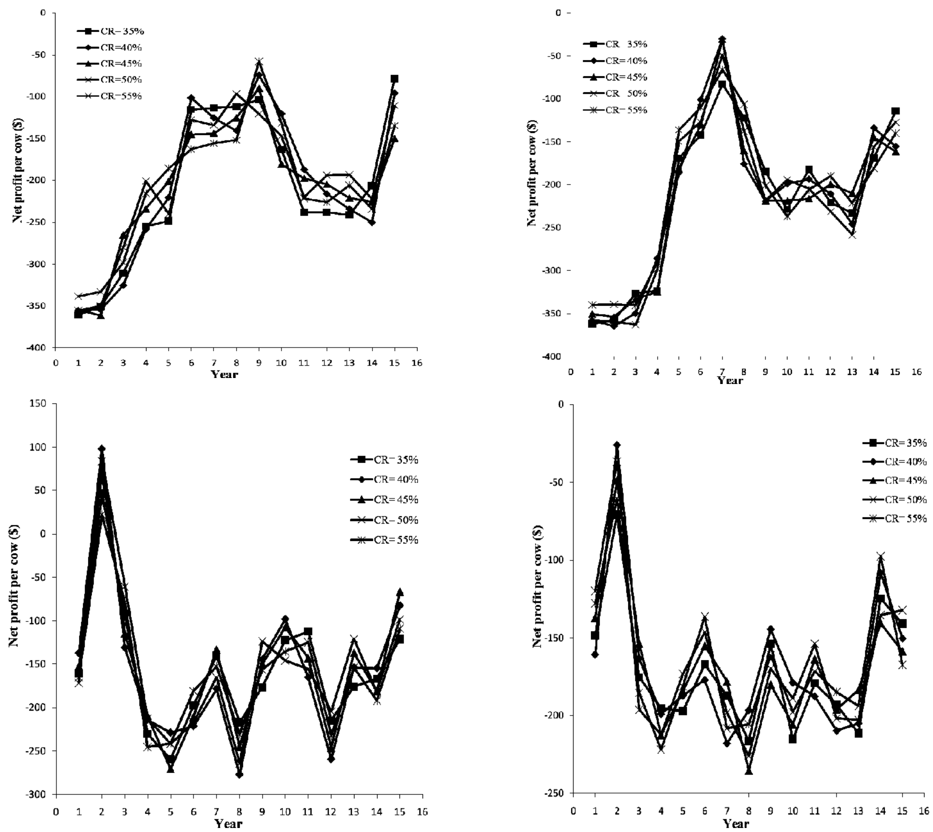

Figure 1: The net profit of milk production per cow ($) for transferring two sexed embryos at different conception rates (CR) in the fixed (above left), synchronized fixed (above right), expanding (below left) and synchronized expanding (below right) herds

Conclusion

The results of sensitivity analyses indicated that significant reductions in cost and increases in performance of ET using sexed embryos would be required for the technology to become profitable. The price of the sexed embryos needs to be considerably lower than at present to make the new embryo-based technologies economic for dairy producers. High conception rates for ET technology and the use of sex-controlled embryo systems, especially for induction of twin births, to produce dairy replacements will be critical elements of the system that produces significant numbers of calves with favor sex in the dairy herds. There will be considerable economic advantage to sexing embryo for dairy cattle production if the technology is efficacious and costs of sexing are minimal. The biological efficiency also improves with sexed embryo, i.e. more milk and meat are produced per unit of feed and other input items.

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