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Genetic and Economic Aspects of Applying Embryo Transfer in Traditional and Genomic Evaluation in Iranian Holstein Dairy Cattle

Research Article

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ABSTRACT

Embryo transfer (ET) in Holstein dairy cattle became an important commercial enterprise after the introduction of non-surgical recovery technique. Embryo transfer could increase the reproductive rate of genetically superior cows. The objectives of the present study were to evaluate the use of ET in Iranian Holstein dairy cattle to increase selection intensity on the dam side, economically; estimate its impact on genetic improvement with and without using genomic information and compare genetic improvement of ET with its costs. In the present study, the economic value (EV) of two strategies was calculated. In the first strategy, 10% of superior heifers, cows in parity 1 and 2 were assumed to be donor. In the second strategy heifers were not assumed as donors. The results showed that the average loss per individual in population applying ET was US$51.7 and US$46.5, for strategy 1 and 2, respectively. The average genetic superiorities of progenies produced with strategy 1 for net merit (NM$) were US$54.25, US$64.17 and US$71.27 using traditional evaluation, genomic evaluation with 3 k chip and genomic evaluation with 50 k chip and with strategy 2 were US$68.14, US$84.04 and US$87.21, respectively. In conclusion for each strategy using each method of breeding value estimation, genetic gain resulted from ET could justify the economic loss of it.

KEY WORDS economic value, embryo transfer, genetic gain, Holstein dairy cattle.

INTRODUCTION

Embryo transfer (ET) in Holstein dairy cattle began to be an important commercial enterprise in north America after the introduction of non-surgical embryo recovery methods (Hasler, 2006). During the early years of the embryo transfer industry, embryos were almost solely transferred into recipients by means of surgical approach. By the mid-1980 s most transfers were performed by a non-surgical technique; therefore, the number of female calves resulting from embryo transfer that were registered with the American Holstein Association increased from 1 in 1974 to more than 11000 in 1999 (Hasler, 2006). Applying embryo technologies as a tool to enhance reproductive efficiency in dairy herds will come to be more reasonable as these technologies become more efficient and cheaper (Ribeiro *et al.* 2012). Selection intensity can be improved and generation interval decreased by applying reproductive technologies such as ET and sexed semen (Pryce *et al.* 2010). The use of ET programs to test artificial insemination (AI) sires genetically is studied in previous researches (e.g., Smith and Ruane, 1987; Teepker and Keller, 1987). At the present time, about 80% of dairy females must be bred for producing herd replacements to keep herd size constant (Seidel, 2011). Using ET could increase selection intensity among females by increasing reproductive rate of genetically superior females and increase selection intensity on the dam side (Mcdaniel and Cassell, 1981). The conventional genetic evaluation on cows depended on phenotypic and pedigree information (Hayes, 2007). Some studies suggested that genomic selection is possible to make accurate decision for selection of animals by using dense markers as predictors for breeding values. The discovery of a large number of DNA markers as single nucleotide polymorphism (SNP) and dramatic decreasing the cost of genotyping resulted in genomic revolution (Hayes *et al*. 2009). Genomic evaluation was initiated with 5285 progeny-tested bulls in 2008 for US Holsteins (Lourenco *et al*. 2014). Applying genomic evaluation along with ET could be therefore fruitful and helpful for genetic development in dairy cattle. Pedersen *et al*. (2012) evaluated applying sexed semen and ET, in combination with genomic selection in dairy cattle breeding programs. In this research ET was used to bull dams. They concluded that the added genetic gain from using sexed semen is small, compared with ET. Applying ET raised the annual genetic gain by 18.7% when 50% of young bulls were born following ET and by 23.4% when 100% of young bulls were born following ET. The purposes of the present study were to determine the use of ET in Holstein dairy cattle to increase selection intensity on the dam side based on total net present value (TNPV) and estimate its impact on genetic improvement; In addition, the economic comparisons on genetic improvement of ET were made as well.

MATERIALS AND METHODS

Economic value (EV) and formula as described by Cabrera (2009) for economic evaluation of reproductive program have been used in the present study.

The EVs of different reproductive programs for heifers and cows were assessed as the difference between the NPV of embryo transfer reproductive programs (X) and the ordinary reproductive program (NX).

$$EV = NPV(X) - NPV(NX)$$

The formula used to calculate the NPV of each reproductive program was as follows:

$$NPV = \left(\sum_{s=1}^{n}(\delta_s)(NPV_s)\right) + (\delta_n)(HC - HR)(1 - PP_n)$$

Where:

δ: discount rate.

HC: received heifer or cow cull value (salvage value)= expected weight of heifer or cow at the time of culling × the culling price per kg of weight.

HR: calculated value of a 20-mo pregnant heifer.

PP: proportion of pregnant heifers or cows after final service.

The NPV after each service is:

$$NPVs = CR'_s(CV) - (1-PP_s)(MC) - (1-PP_{s-1})(RC)$$

Where:

CR': conception rate achieved in service s.

CV: calf value= (bull calf probability×bull calf value) + (female calf probability×female calf value).

MC: non-pregnant heifer or cow maintenance cost.

RC: cost of reproductive program (artificial insemination or embryo transfer).

Conditional probabilities were used to determine the CR achieved (CR') and the proportion of pregnant cows or heifers (PP) in each one service were calculated using the following formula:

$$PP_1 = CR'_1 = CR_1$$

$$PP_s = PP_{s-1} + (1-PP_{s-1})CR_s \text{ for s= 2 to final service}$$

$$CR'_s = PP_s - PP_{s-1} \text{ for s= 2 to final service}$$

The EVs of two strategies that would be explained in the section of genetic progress calculation were estimated for donor and recipient heifers, cows in parity 1 and cows in parity 2. Conception rate (CR) for each insemination service obtained from data of three large commercial Holstein farms Iran (in Qom, Esfahan and Yasuj) during March 2009 to March 2011. Mean CRs for different insemination services are summarized in Table 1.

Mean conception rates following transfer of fresh embryos (non-surgically) into heifers and cows were assumed to be 71% and 46.9%, respectively (Hasler, 2006). Economic parameters used in this study were based on Iran's market. The average prices of 10 large commercial Holstein farms were used. The price of semen was US$19.1 per straw and cost of calving heifer to replace culled heifers or cows was US$3339 per head. Salvage value of non-pregnant heifers was 3.1 US$/kg and of non-pregnant cows was 2.16 US$/kg. The costs to raise heifers were US$2.16 per day.

Maintenance costs per day for non-pregnant heifers and non-pregnant cows in parity1 and parity 2 were US$2.16, US$2.63 and US$2.9, respectively. Annual discount rate was set to 12%. Values for heifer and bull calves were US$835 and US$381, respectively. The costs of one superovulation, artificial insemination and transfer of embryos exclude maintenance costs of donors were US$385.89. These costs of embryo transfer were assumed for donors.

The time to prepare donors for superovulation was two months. Then, the embryos were collected between 6 ½ and 7 ½ days after estrus (Hasler, 2010). Donors had natural reproductive cycle with 15 days delay after superovulation.

Table 1 The mean conception rates of heifers and cows in parity 1 and 2 for each service number

	Service number			
	1	2	3	>=4
Heifer	65.0	64.6	63.3	61.9
Parity 1	45.5	44.0	42.8	42.7
Parity 2	43.5	43.0	41.1	40.6

Records were collected from approximately 8400 heifers, 6950 cows in parity 1 and 550 cows in parity 2 in Iran.

Calculation of additional genetic superiority of female calves by using ET

True breeding values (TBVs) and estimated breeding values (EBVs) of a herd with 22000 heifers, 18260 cows in parity 1 and 14425 cows in parity 2 for net merit (NM$) were simulated in Visual basic 6. Two strategies were compared. In the first strategy 10 percent of superior heifers, cows in parity 1 and 2 were assumed to be donor. Embryos produced by heifers were transferred to recipient heifers and embryos produced by cows in parity 1 and 2 were transferred to recipient cows in parity 1 and 2, respectively. In the first strategy 2200 superior heifers, 1826 superior cows in parity 1 and 1443 superior cows in parity 2 were assumed as donor, and 7480 inferior heifers, 9678 inferior cows in parity 1 and 7645 inferior cows in parity 2 were recipient. In the second strategy the number of recipient heifers and cows in parity 1 and 2 were the same as the first strategy but heifers were not donor; 2615 superior cows in parity 1 and 2065 superior cows in parity 2 were assumed as donor.

The number of transferable embryos after superovulation assumed to be 3.4 for heifers and 5.3 for cows (Hasler, 2006). The genetic standard deviation for breeding values (BVs) for NM$ is US$396 and is a measure of the genetic variation in NM$ in the population of dairy cattle (De Vries, 2010). TBVs of the population were taken from a normal distribution with this standard deviation. The average NM$ of heifers was US$52 higher than cows in parity 1 and US$104 higher than cows in parity 2 because genetic trend of BVs for NM$ is US$52 per year (USDA-AIPL, 2010).

The traditional evaluation (TE), genomic evaluation with 50k chip (GE50k) and genomic evaluation with 3k chip (GE3k) methods were considered for genetic evaluation. The reliabilities of EBVs (squared correlation of TBVs and EBVs) for NM$ are 0.35 and 0.59 for TE and GE50k. GE3k has about 0.19 additional reliability for this trait in comparison with TE (VanRaden *et al.* 2010). So the reliabilities of BV estimations in TE, GE3k and GE50k were assumed to be 0.35, 0.54 and 0.59, respectively. The EBVs were simulated with the mentioned reliabilities from TBVs for NM$. To estimate the genetic gain of applying ET, genetic superiority of female calves born in each strategy, over female calves born applying conventional semen (common breeding program in dairy cattle industry) was calculated.

RESULTS AND DISCUSSION

The economic value of using embryo transfer

The economic value of using embryo transfer in recipients and donors for heifers and cows are shown in Table 2. It should be noted that all costs of embryo transfer were assumed for donors. High economic value of using ET in recipients is due to higher conception rate resulted from ET compared to AI.

Table 2 The economic value (EV) of using embryo transfer in recipients and donors (US$) for heifers and cows in parity 1 and 2

	Donors	Recipients
Heifers	-261.66	12.20
Cows in parity 1	-544.70	17.92
Cows in parity 2	-599.76	23.05

The percentages of recipient and donor heifers and cows in population for both strategies are shown in Table 3 and 4.

Table 3 The percentages of recipient and donor heifers and cows of population for strategy 1

	Donor	Recipient	Other
Heifers	4.02	12.43	23.77
Cows in parity 1	3.34	16.08	13.96
Cows in parity 2	2.64	12.70	11.03

Table 4 The percentages of recipient and donor heifers and cows of population for strategy 2

	Donor	Recipient	Other
Heifers	0	12.43	27.79
Cows in parity 1	4.78	16.08	12.52
Cows in parity 2	3.78	12.70	9.89

Average EVs of each individual in population, using embryo transfer according to the first and second strategy using above percentages were US$-46.5 and US$-51.7, respectively. This means that there would be US$46.5-51.7 loss per individual in population when embryo transfer is applied using these strategies.

The genetic superiorities of progenies produced with embryo transfer

The genetic superiorities of progenies produced by these strategies using TE, GE3k and GE50k for selection of superior and inferior individuals, over progenies produced applying conventional semen (common breeding program in dairy cattle industry) are shown in Table 5.

As shown in Table 5, for each strategy using each method of BV estimation, genetic gain resulted from ET would justify its economic loss. Genetic gain of second strategy was lower than the first strategy because heifers in the second strategy were not used as donors and heifers are genetically better than cows.

Table 5 The genetic superiorities of progenies produced with both strategies using TE, GE3k and GE50k for NM$

	Method of genetic evaluation		
	TE	GE3k	GE50k
Strategy 1	54.25	64.17	71.27
Strategy 2	68.14	84.04	87.21

The BV estimation method influenced the results strongly. Using GE3k and GE50k resulted in about 23% and 28% additional genetic gain compared to TE in the first strategy and 18% and 31% in the second strategy, respectively. By artificial insemination (AI), the genetic improvement mostly comes from the male side whereas ET could increase the number of progenies of genetically superior females. Therefore, genetic gain from the female side could be increased applying ET. Mcdaniel and Cassell (1981) stated that embryo transfer could decrease generation interval as bull dams could produce several sons early in their lives by using this technology. Petersen and Hansen (1977) explained that ET could increase genetic gain by increasing the number of sons obtained per elite cow if selection of dams of bulls is efficient. The results of the current study showed that the costs associated to using ET were lower than the genetic gain resulted from this technology.

Costs of genomic testing versus gain

The cost of genetic testing was not considered in economic evaluations in the current research. The results showed that genetic gain for net merit would increase by US$9.92 and US$17.02 applying GE50k and GE3k, compared to TE in the first strategy and US$15.9, US$19.07 in the second strategy; it is obvious that the cost of genomic testing is not justified only by using embryo transfer. Boustan *et al.* (2014) studied economic and genetic aspects of applying sexed semen in traditional and genomic evaluation. They did not consider the cost of genetic testing in economic evaluation. They showed that the cost of genomic testing could not be economically reasonable only by applying sexed semen. In their study applying GE50k increased genetic gain by US$8.41, compared to TE. The results of the present study showed that if genetic evaluations (genomic or traditional) are available, applying embryo transfer according to strategies of the current study could be profitable. Currently, embryo transfer in cattle is an important industry in the world, with more than 500000 embryos being transferred per year (Mapletoft and Hasler, 2005). This technique produces very small number of calves, given the total number of calves born in the world annually. Its impact is however large because the quality of offspring being produced by this technology is high (Mapletoft and Hasler, 2005). Nowadays, embryo transfer is commonly used to produce artificial insemination (AI) sires from genetically superior cows and the most highly proven bulls (Mapletoft, 2006).

In the current research, it is concluded that using embryo transfer could be reasonable to increase genetic gain on the dam side and the genetic gain generated by ET could justify the costs associated to applying this technology.

A potential concern of using ET could be the increase of the rate of inbreeding as ET would reduce the number of dams. In a research, ET was applied to bull dams, when all young bulls were born following ET, the rate of inbreeding was increased about 20.3% when conventional semen was applied but when Y-semen was used, the application of ET did not increase the rate of inbreeding greatly because the number of young bull candidates were increased (Pedersen *et al.* 2012).

Bouquet *et al.* (2015) concluded that applying ET program would increase genetic gain without influencing the rate of inbreeding when the number of donors and the number of sires in this program are large enough.

Another potential benefit of using genomic selection approaches, in combination with ET could be the selection of high genetic merit embryos at early stage before transferring them into recipients. Currently, determining genetic merit at birth using genomic breeding values is an important issue in dairy cattle industry (Shojaei Saadi *et al.* 2014).

Shojaei Saadi *et al.* (2014) concluded that it is possible to provide high quality DNA from an early embryo biopsy to perform genomic evaluations for pre-transfer embryos. By predicting genomic breeding values of early embryos accurately, before they are transferred into recipients, it is possible to achieve further increase in genetic gain and decrease in generation interval.

CONCLUSION

In dairy cattle breeding program, using embryo transfer in cow dams would increase the genetic gain. Applying genomic evaluation in combination with embryo transfer would improve the genetic gain further, compared with traditional evaluation; but the added genetic gain from applying genomic evaluation would not justify the costs of this evaluation. Genetic and economic aspects of applying genomic evaluation for embryos at early stage before transferring them into recipients are important issues for future researches.

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