Multiple Ovulation and Embryo Transfer with X-sorted semen optimizes response to selection in dairy cattle

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Summary

We used deterministic simulation to investigate the hypothesis that breeding schemes adopting Multiple Ovulation and Embryo Transfer (MOET) with X-sorted semen could realize high response to selection compared to an AI scheme of the same scale. We used a breeding scheme resembling that of dairy cattle in Kenya to investigate this hypothesis. The response to selection in each scheme was computed and compared based on monetary annual genetic gain, returns, costs and profitability per cow per year. The findings confirmed our hypothesis, as the MOET scheme realized higher annual genetic gain, returns, profitability per cow per year of KES 710.82, 2781.23 and 2568.52 compared to corresponding values of 410.68, 2470.20 and 2384.98 in AI scheme. The high response to selection in MOET scheme was attributed to increased reproductive rate in both sexes resulting to higher selection intensity and accuracy of selection. The findings of this study demonstrates that, even though MOET scheme had high costs of production, the returns could cover the costs and result in high profitability than when X-sorted semen is used in an AI scheme.

Key words: *conventional semen; sexed semen; reproductive technologies*

Introduction

Artificial Insemination (AI) has been widely used in dairy production to increase the efficiency of dissemination of genetic materials in commercial dairy production (Omondi et al., 2017). Although, mainly conventional semen (CS) has been used with AI in Kenya, the adoption of X-sorted semen (XS) is on the upward trend (Sørensen et al., 2011; Omondi et al., 2017). The shift from CS to XS has been attributed to scarcity of heifers as replacement stock. The AI increases only reproductive rate of males and therefore their selection intensity. Previous studies, have demonstrated that, increasing reproductive rates of both sexes resulted in higher response to selection (Okeno et al 2014). Currently, few commercial farms in Kenya use multiple ovulation and embryo transfer (MOET). These farms also rely on both CS and XS. We reasoned that utilization of MOET with XS could result in higher response to selection compared to AI with XS. This could be attributed to by three reasons. Firstly, MOET allow us to get more than one offspring per cow per year and therefore the use of XS would result to high number of female candidates to select from leading to high selection intensity on the female lines. Secondly, when selection candidates obtained for MOET are phenotyped for traits in the breeding goal, it would increase the amount of information used to estimate the breeding value of the selected candidates which increases accuracy of selection. It has been demonstrated that accuracy of selection increases with number of information sources (Sørensen et al., 2011). Increased selection intensity and accuracy have direct positive impact on response to selection. The main challenge in adoption of MOET with XS could be their economic worth as these technologies are still expensive in Kenya. We used the Kenyan dairy cattle breeding program as our model example, to test our hypothesis and investigate the economic worth of adopting MOET with XS under Kenyan production and economic conditions. We compared the genetic and economic response to selection for reproductive technologies based on AI and MOET with sexed semen. The dairy cattle breeding goal as developed by Kahi et al. (2004) was adopted.

Materials and methods

Procedure

We used deterministic simulation to predict response to selection realised by breeding schemes utilizing AI and MOET with XS. This was achieved by simulating breeding schemes that resemble those used in dairy cattle breeding program in Kenya.

Breeding Schemes: Two breeding schemes based on the reproductive technology adopted were considered. First scheme was an AI scheme focusing on increasing the reproductive rate of males in the population. The second, was MOET based scheme focusing on production of more than one calf per cow per year. This scheme was combined with AI and therefore targeted increasing the reproductive rates of both sexes.

Population structure and breeding goal: A simulated population of 50,000 cows distributed in two tiers was considered. The top tier (nucleus) consisted of 5% of the highest ranking cows in the population while the remaining 95% constituted the lower tier (commercial population). Truncation selection based on estimated breeding values was used to select top ranking males and females for breeding in the nucleus. The second top ranking males and females were used for breeding in the lower tier. Candidates not selected for breeding culled. In all the schemes the young bull system was adopted to disseminate genetic materials in the population. The breeding goal for dairy cattle as described by Kahi et al. (2004) was adopted in the current investigation. The genetic and economic parameters used were obtained from studies carried out in Kenya (Kahi et al., 2004; Okeno et al., 2014).

Prediction of response to selection

All the breeding values were predicted using best linear unbiased prediction (BLUP) by fitting a multivariate animal model to the phenotypes. The model was computed as:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e} \tag{1}$$

where **Y** is the vector of phenotypes, a vector of fixed effects, **a is** a vector of random animal effects, **e***,* a vector of residual errors, and **X** and **Z** the incidence matrices. The breeding values were computed using (co)variance matrix presented below:

$$\begin{pmatrix}\mathbf{a}\\ \mathbf{e}\end{pmatrix} \sim N\left(0;\begin{bmatrix}\mathbf{G}\otimes\mathbf{A} & \mathbf{0}\\ \mathbf{0} & \mathbf{R}\otimes\mathbf{I}\end{bmatrix}\right) \tag{2}$$

where the matrix **A** is the numerator relationship matrix among all animals, and the matrix **G** is the additive genetic (co)variance matrix of traits in the breeding goal. The matrix **R** is the (co)variance matrix for residual effects.

The of rate of genetic gain for each cow was predicted as linear regression of true breeding values for each trait in the breeding goal weighted by its corresponding economic values and expressed per year.

The economic returns were determined based on profitably per cow in each breeding scheme. The profitability per cow was estimated as:

$$\pi = \sum_{t=0}^{T}\left(\frac{R_t - c_t}{(1+r)^t}\right) \tag{3}$$

where T is the evaluation period (25 years), R_t the annual benefits of genetic improvement calculated as realized genetic gain per cow per year, c_t the costs of genetic improvement which includes fixed and variable costs and r the discounting rate. The discounting rate of 5% has been recommended when evaluating animal breeding programs (Bird & Mitchel, 1980).

Data analysis

The deterministic simulation program ZPLAN (William et al., 2008) was used to model and evaluate the alternative breeding schemes. The findings were expressed as economic responses per cow per year.

Results and Discussion

Annual response to selection

The annual genetic gain, returns, costs and profit per cow of the evaluated schemes are presented in Table 1.

Table 1. Returns to selection per cow per year (KES) for breeding schemes using artificial insemination (AI) and Multiple Ovulation and Embryo Transfer (MOET) with sexed semen

	Schemes	
	AI	MOET
Annual genetic gain (KES)	410.68	710.82
Returns per cow (KES)	2470.20	2781.23
Costs per cow (KES)	85.22	212.71
Profit per cow (KES)	2384.98	2568.52

Our hypothesis that utilization of MOET with X-sorted semen would realize higher response to selection and could outperform an AI scheme of the same size was confirmed by our findings.

The additional 42.2, 11.8 and 7.1% annual genetic gain, returns per cow and profitability, respectively, realised in the MOET compared to AI scheme indicates that MOET scheme is superior to AI scheme in response to selection (Table 1). The high returns to selection in MOET scheme could be explained by the fact that, MOET scheme not only increased the reproductive rates of females but also males. This implies that there were more females to select from and therefore the selection intensity of females increased as only few females (5%) were needed for breeding in the nucleus. On the other hand utilization of AI to inseminate the cows in MOET scheme increased reproductive rate of the males. Since recording was in the nucleus, it means that each selection candidate had more sibs with records and therefore could be selected more accurately. This was evident in the accuracy obtained for AI and MOET schemes in this study (results not presented). These findings are in agreement with those obtained by Sørensen et al. (2011) in dairy cattle. In that study it was found that MOET scheme using sexed semen realised more response to selection compared to schemes without sexed semen and MOET.

Although the MOET scheme was 60% more expensive than AI scheme (Table 1), the scheme was able to recover costs and outperformed the AI scheme in profitability. This implies that schemes that adopt utilization of MOET with X-sorted semen would be more profitable and therefore sustainable in dairy cattle production in Kenya. The high profitability in the MOET scheme could be attributed by excess heifers for sale per cow compared to AI scheme where only one heifer could be sold per year.

Conclusion

This study demonstrate that it would be more beneficial to adopt MOET breeding scheme with X-sorted semen in dairy cattle production in Kenya compared to using sexed semen in AI breeding scheme.

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