Optimization of dairy herd replacements combining conventional, sexed and beef semen in mating programs

V. Ferrari[1,2], M. Marusi[1], M. Penasa[2], J.B.C.H.M. van Kaam[1], R. Finocchiaro[1] and M. Cassandro[1,2]

[1]Associazione Nazionale Allevatori della Razza Frisona, Bruna e Jersey Italiana (ANAFIBJ), Via Bergamo 292, 26100 Cremona (CR), Italy
[2]Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE), University of Padova, Viale dell'Università 16, 35020 Legnaro (PD), Italy
Corresponding Author: valentinaferrari@anafi.it

Abstract

Farmers have often an abundance of replacement heifers in their herds due to increasing use of sex-sorted semen and genomic tools. Given the current Italian market conditions, rearing more heifers than needed is not a profitable strategy. On the other hand, the higher market value of crossbred dairy calves is an attractive strategy for dairy farmers. The aim of this study was to develop a tool to help Italian dairy farmers identify the annual female replacement needs to optimise economic outcome of the dairy herd. The approach is based on herd performance and combination of different semen types (conventional, sex-sorted, and beef semen), with the ultimate goal of enhancing farm profit. A case study based on a 350-cow Holstein herd was used and 3 levels of herd fertility (high, medium, and low) were simulated to define the required yearly number of dairy female replacements and the number of females yielded under different scenarios of semen utilization. The number of annual dairy replacements was obtained as the number of cows multiplied by the replacement rate, adjusted by the age at first calving, and the number of animals yielded was derived by semen type utilization, calf and heifer mortality, pregnancy losses, and calving interval, and it was used to evaluate the replacement cost per 100 L of milk. The latter was calculated from all costs incurred from birth to first calving of all females yielded minus revenues from selling cull cows, heifers, dairy male calves, and calves from beef when beef semen was used, and dividing the result by income from 100 L of milk sold. Then, four strategies of sexed semen utilization were combined with five strategies of beef semen use. Animals that were not inseminated with sexed or beef semen were bred with conventional semen. Regardless of fertility level, the required number of dairy female replacement heifers were 110. Increasing beef semen use allowed to yield less replacement heifers. Furthermore, as beef semen use increased and the number of replacement heifers decreased, replacement cost per 100 L of milk reduced. Our results suggested that replacement costs increase with increasing number of yielded heifers. Hence, combining beef and sexed semen to reach heifer balance close to zero, decreased the replacement cost. Farmers should choose the strategy that allows them to reach the annual heifer replacement needs, considering the effects of fertility. Once obtained, they should select the scheme that decreases the replacement cost. The tool will be implemented into ANAFIBJ online mating program and used prior to select which heifers or cows to mate with a given bull to enhance herd genetic potential, decrease inbreeding, lower GHG emissions and to provide farmers an approach to identify the best replacement strategy.

Keywords: heifer, management, tool, crossbreeding, sexed semen, mating program. Presented at the ICAR Anual Conference 2024 in Bled at the Session 1a: Decision Support Tools of the Future – Promoting Sustainability Farm Management"

Introduction

When farmers devise their breeding plans, they must weigh numerous factors such as semen type semen destination use (e.g., dairy or beef), and semen price (De Vries *et al.*, 2022). Additionally, integrating sex-sorted semen with genomic tools can accelerate genetic advancements and increase the availability of young females for future herd replacements (Hjortø *et al.*, 2015). As a result, some farmers display surplus replacement heifers and it has been shown that culling cows to leave space to replacement heifers is not necessarily the most profitable strategy for a herd (DeVries, 2020). In the current Italian market, it's generally unprofitable to breed excess heifers for sale to other farmers. However, there's a growing interest among dairy farmers in the higher market value of crossbred dairy calves (Cabrera, 2022).

The choice to breed high-genetic-merit animals with sexed semen to meet replacement needs, while using beef semen for the rest, presents an opportunity to simultaneously enhance herd genetics and profitability. Various studies have explored different breeding strategies to optimize herd performance, highlighting the advantages of using sex-sorted semen, particularly on genetically superior and fertile animals (Ettema *et al.*, 2017; Holden and Butler, 2018; Clasen *et al.*, 2021). Despite its lower conception rate compared to conventional semen, sexed semen is preferred for virgin heifers and first-lactation cows due to their better fertility performance. Moreover, it's been observed a risk reduction of dystocia and stillbirth with the use of sex-sorted semen, as female calves are typically smaller and easier to deliver (Holden and Butler, 2018; Pahmeyer and Britz, 2020).

Determining the optimal number of replacement heifers to keep and selecting the best strategy are crucial aspects of herd management. Currently, there's a lack of a specific tool for Italian dairy farmers to aid in selecting the most suitable replacement strategy based on their herd's productivity and reproductive data. Therefore, the aim of this study was to develop a replacement tool to help Italian dairy farmers identify the annual female replacement needs by varying use of sexed and beef semen on herd costs and stability under Italian conditions.

Material and methods

The method is based on the approach proposed by Genex Cooperative (Ontario, CA) and adjusted to the Italian herd and market conditions. A practical tool, housed in an Excel spreadsheet, has been devised to allow users to customize it according to their own situations. To illustrate its functionality, a hypothetical scenario was constructed around a 350-cow Holstein herd (250 cows and 100 heifers entering per year) located in the Po Valley (Northern Italy), targeting 40% replacement rate, 7% stillbirth rate, 5% calves and heifers rearing loss, and 8% pregnancy loss, which represents averages extrapolated by the Italian Holstein, Brown Swiss and Jersey Association (Cremona, Italy). Additionally, to account for unexpected issues or to allow for more "voluntary" culling, an additional 10% of heifers has been considered.

The tool simulates different fertility scenarios: high (HFL), medium (MFL), and low fertility (LFL). Age at first calving was set at 24 mo (regardless of the fertility level of the herd), conception rate (CR) at 50%, 43%, and 32% for HFL, MFL, and LFL, respectively, and calving interval at 13, 14, and 14.5 mo for HFL, MFL, and LFL, respectively. It assumes equal fertility rates for conventional beef and dairy semen, with reduced fertility for sexed dairy semen. Percentage of female calves from conventional and beef semen was set at 47%, and from sexed semen at 90%. Farmers can adjust input data to match their specific herd characteristics and objectives. Input variables are displayed in Table 1.

The tool initially calculates the number of dairy female replacements needed annually, assuming all inseminations are done with conventional semen and herd size remaining stable. The number of annual dairy replacements was obtained as the number of cows multiplied by the replacement rate and adjusted by the age at first calving, in order to account only for heifers that are going to calve during the considered year. It then explores various combinations of sexed and beef semen utilization.

The sexed semen scenarios were:

1. No use of sexed semen (NOSS).

2. 100% of heifers inseminated with sexed semen (H100).

3. 100% of heifers and 20% of top cows inseminated with sexed semen (H100C20), and 4) 80% of heifers and 20% of top cows inseminated with sexed semen (H80C20).

Beef semen utilization was allocated to cows that were not inseminated with sexed semen, according to farm management decisions, at the following percentages: 1) 0%, 2) 25%, 3) 50%, 4) 75%, and 5) 100%. All remaining eligible animals that were

Table 1. Input variables of the heifer management tool. All input data can be changed by the farmer or technician according to specific herd situation.

Variable	Input value
Cows (lactating and dry) (n)	250
Breeding heifers entering the herd (n/yr)	100
Annual replacement rate (%)	40
Annual herd growth rate target (%)	0
Heifers' safety percentage (%)	10
Sex ratio (females/males) by semen type (%)	47/53 (conventional and beef) 90/10 (sexed)
Calving interval according to the fertility level[1] (mo)	13 (high), 14 (medium), 14.5 (low)
Animals not inseminated (%)	2
Pregnancy loss (%)	8
Stillbirth rate (%)	7
Mortality from weaning to first calving (%)	5
Age at first calving (mo)	24
Average heifer rearing cost (€/d)	4.29
Average heifer market value (€)	1800
Average cost for disposal of dead-on-farm cow (€)	300
Average cull cow market value (€)	800
Average purebred male dairy calf market value (€)	51.60
Average crossbred calf market value (€)	245
Milk production (L/d)	31
Total milk sold per year (L)	2,828,750

[1]high = high herd fertility level (50% conception rate and 13 mo calving interval); medium = medium herd fertility level (43% conception rate and 14 mo calving interval); low = low herd fertility level (32% conception rate and 14.5 mo calving interval).

not inseminated with sexed or beef semen were bred with conventional semen. The method calculates heifer balance between the number of heifers yielded and the annual dairy replacement needs. The number of animals yielded was used to evaluate the replacement cost per 100 L of milk. This information helps evaluate the cost-effectiveness of different semen utilization protocols, taking into account feed costs and market values. Replacement cost (RC) is the cost to maintain a herd at the same size per 100 L of milk sold and is generally used to compare different breeding strategies. It depends on some economic factors such as annual replacement rate, heifer rearing cost, and revenue from selling milk (Bethard and Nunes 2011).

Results and discussion

The method presented in the paper is a valuable instrument to help farmers identify the correct number of dairy heifers to be inseminated to maintain constant the herd size (or to set an annual growth rate) and to minimize rearing costs. Table 2 reported the annual number of heifers and cows eligible to be mated, the number of services per conception needed to maintain a constant adult herd size, the conception rate under the 3 fertility levels (HFL, MFL, and LFL), the number of the annual dairy female replacement cows, and the number of heifers yielded. The number of dairy female replacement heifers that the farm needs is 110, for HFL, MFL, and LFL.

Table 3 summarizes the possible pairwise solutions of the tool (replacement costs per 100 L of milk, and heifer balance) that result from the different strategies of beef and sexed semen use under the 3 different herd fertility levels. Larger use of beef semen allows farmers to yield less heifers, on a yearly basis; indeed, when heifer balance is negative, farmers are breeding less heifers than needed, whereas positive values means that farmers are breeding more than needed heifers. Accordingly, as beef semen use increases and reared heifers reduces, replacement cost per 100 L of milk decreases regardless of reproductive performance. When heifer balance is below zero, replacement cost is reported, but it should be noted that this is not a replacement strategy that should be pursued by farmers, as it means that, if followed, herd size will decrease, or farmers have to buy heifers to maintain their herd size.

Furthermore, increasing the use of dairy sexed-sorted semen within the four dairy sexed semen utilization strategies (NO_{SS}, H_{100}, $H_{100}C_{20}$, $H_{80}C_{20}$) leads to an increase

Table 2. Number of heifers and cows to breed, number of dairy replacements needed per year, number of dairy heifers yielded, number of services per conception, and average conception rate (%) needed to maintain a constant herd size under 3 fertility levels1, assuming 100% use of conventional semen.

		Services/conception, n			Conception rate, %		
Animals	**Eligible animals, n**	**High**	**Medium**	**Low**	**High**	**Medium**	**Low**
Heifers	100	1.8	2.0	2.5	55	50	40
Cows	250	2.2	2.9	4.3	45	35	23
Annual replacements needed	110						
Number of dairy heifers yielded	90 (low) 94 (medium) 98 (high)						

[1]High = high herd fertility level (50% conception rate and 13 mo calving interval); medium = medium herd fertility level (43% conception rate and 14 mo calving interval); low = low herd fertility level (32% conception rate and 14.5 mo calving interval).

Table 3. Replacement costs per 100 L of milk (€) and heifer balance1 (in parentheses) for different strategies of beef and sexed semen use under different herd fertility levels. Missing values refer to breeding strategies that cannot be pursued.

	Dairy sexed semen use[3]			
Beef semen use, %	**NO_{SS}**	**H_{100}**	**$H_{100}C_{20}$**	**$H_{80}C_{20}$**
Low fertility level[2]				
0	9.02 (-20)	9.73 (4)	10.00 (16)	9.87 (11)
25	8.52 (-36)	9.18 (-12)	9.50 (0)	9.37 (-5)
50	8.03 (-52)	8.68 (-28)	9.00 (-16)	8.87 (-21)
75	7.53 (-68)	8.18 (-44)	8.51 (-32)	8.37 (-37)
100	7.03 (-84)	7.69 (-60)	- (-)	- (-)
Medium fertility level[2]				
0	9.11 (-16)	9.79 (8)	10.12 (20)	9.98 (16)
25	8.59 (-33)	9.27 (-8)	9.61 (4)	9.47 (-1)
50	8.08 (-50)	8.76 (-25)	9.09 (-13)	8.95 (-18)
75	7.56 (-66)	8.24 (-41)	8.57 (-29)	8.44 (-34)
100	7.05 (-83)	7.73 (-58)	- (-)	- (-)
High fertility level[2]				
0	9.22 (-12)	10.01 (17)	10.4 (31)	10.24 (25)
25	8.70 (-29)	9.50 (0)	9.88 (14)	9.73 (8)
50	8.19 (-45)	8.98 (-16)	9.37 (-2)	9.21 (-8)
75	7.67 (-62)	8.46 (-33)	8.85 (-19)	8.69 (-25)
100	7.15 (-78)	7.94 (-49)	- (-)	- (-)

[1]Heifer balance was calculated as annual dairy replacements needed minus annual dairy heifers yielded.

[2]High = high herd fertility level (50% conception rate and 13 mo calving interval); medium = medium herd fertility level (43% conception rate and 14 mo calving interval); low = low herd fertility level (32% conception rate and 14.5 mo calving interval).

[3]NO_{SS} = no use of sexed semen; H_{100} = 100% of heifers inseminated with sexed semen; $H_{100}C_{20}$ = 100% of heifers and 20% of top cows inseminated with sexed semen; $H_{80}C_{20}$ = 80% of heifers and 20% of top cows inseminated with sexed semen. All remaining eligible animals that were not inseminated with sexed or beef semen were bred with conventional semen.

of replacement cost (and higher number of reared heifers), regardless of beef semen use. Better fertility level leads to higher number of heifers reared, at the same level of beef and sexed semen use. Looking at these results, it is clear the positive relationship between replacement cost and heifer balance as greater replacement costs were obtained with higher number of heifers yielded, which also corresponds to lower use of beef semen.

The highest replacement cost has been obtained with 0% beef semen and $H_{100}C_{20}$ (rearing from 20 to 31 heifers more than needed, for MFL and HFL, respectively), whereas the lowest with 100% use of beef semen and NO_{SS} (but rearing from -84 to -83 heifers than needed, for LFL and MFL, respectively, to maintain constant the herd size). Ideal situations can be reached adjusting beef and sexed semen, to reach heifer balance close to zero (Table 3), indeed, the combination of beef semen and sexed semen, within strategies and reproductive performances, decreased the replacement cost. Within their reproductive performance, farmers should choose the strategy that allow them to reach their annual heifer replacement needs; once obtained, they should select the scheme that decreases the replacement cost.

The tool provides dairy farmers with a method to determine the optimal replacement strategy, taking into account the impact of fertility by varying the use of sexed and beef semen on herd costs and stability. This tool will be integrated into the ANAFIBJ online mating program and used beforehand to decide which heifers or cows to mate with a specific bull, aiming to improve the herd's genetic potential and reduce inbreeding.

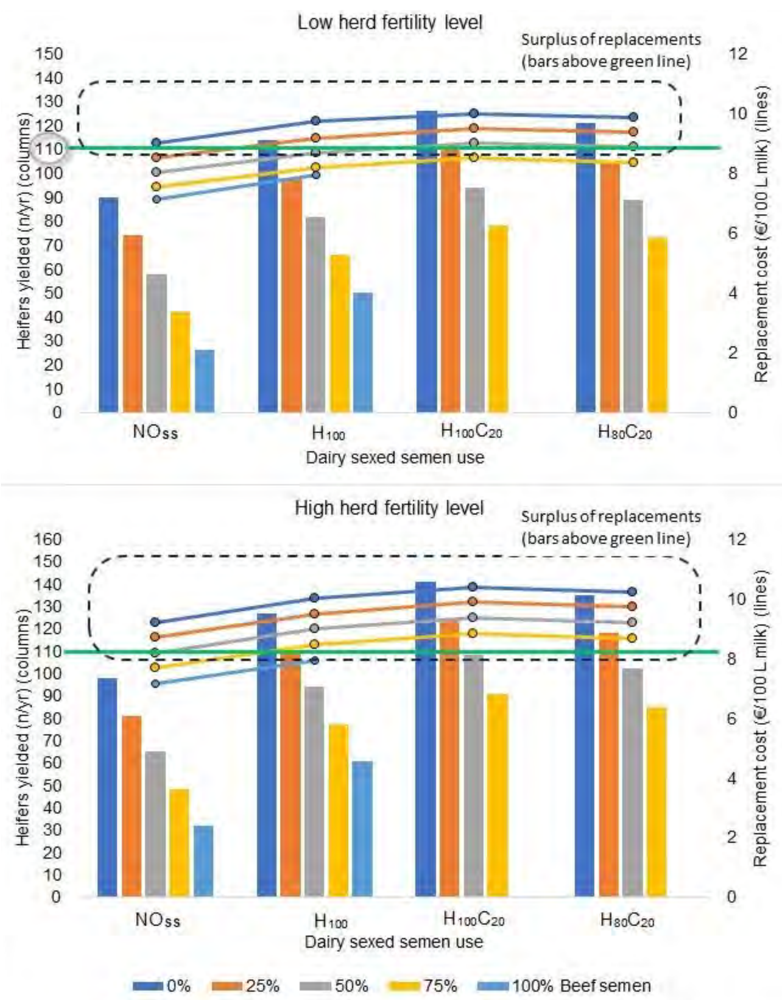

Figure 1. Annual dairy heifers yielded for the different sex semen utilization strategies by different dairy sexed semen use (NOSS = no use of sexed semen; H100 = 100% of heifers inseminated with sexed semen; H100C20 = 100% of heifers and 20% of top cows inseminated with sexed semen; H80C20 = 80% of heifers and 20% of top cows inseminated with sexed semen) (bars) and replacement costs (lines, second axis) at different beef semen use for a) low herd fertility and b) high herd fertility level. Green line represents the number of annual dairy female replacements needed.

Replacement cost:

RC = [cost of rearing replacements – (cull cow income + income from male calves sold)] / income from 100 L of milk sold (1)

List of references

Cabrera VE. 2022. Economics of using beef semen on dairy herds. JDS Commun. 3:147-151. https://doi.org/10.3168/jdsc.2021-0155

Clasen JB, Kargo M, Østergaard S, Fikse WF, Rydhmer L, Strandberg E. 2021. Genetic consequences of terminal crossbreeding, genomic test, sexed semen, and beef semen in dairy herds. J. Dairy Sci. 104:8062–8075. https://doi.org/10.3168/jds.2020-20028

De Vries A. 2020. Symposium review: Why revisit dairy cattle productive lifespan? J. Dairy Sci. 103:3838–3845. https://doi.org/10.3168/jds.2019-17361

De Vries A., Bliznyuk N, Sharma1 P, Han Y, Pinedo P. 2022. Insemination values to support mating decisions under dairy heifer calf herd size constraints. Proceeding of the 12th World Congress on Genetics Applied to Livestock Production. Rotterdam (NL), 3-8 July. https://doi.org/10.3920/978-90-8686-940-4

Ettema J F, Thomasen J.R, Hjortø L, Kargo M, Østergaard S, Sørensen A.C. 2017. Economic opportunities for using sexed semen and semen of beef bulls in dairy herds. J. Dairy Sci. 100:4161–4171. https://doi.org/10.3168/jds.2016-11333

Hjortø L, Ettema J.F, Kargo M, Sørensen A.C. 2015. Genomic testing interacts with reproductive surplus in reducing genetic lag and increasing economic net return. J. Dairy Sci. 98:646-658. https://doi.org/10.3168/jds.2014-8401

Holden SA, Butler ST. 2018. Review: Applications and benefits of sexed semen in dairy and beef her.ds. Animal. 12:s97–s103. https://doi.org/10.1017/S1751731118000721

Pahmeyer C, Britz W. 2020. Economic opportunities of using crossbreeding and sexing in Holstein dairy herds. J. Dairy Sci. 103:8218–8230. https://doi.org/10.3168/jds.2019-17354