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BRIEF REPORT

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A tool to optimise dairy herd replacements combining conventional, sexed, and beef semen

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ABSTRACT
A tool to help Italian dairy farmers choosing the most suitable replacement strategy has been developed. The approach aimed to identify yearly female replacement needs based on herd performance level and combination of different semen type (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 three levels of herd fertility (high, medium, and low) were simulated to define the yearly number of dairy female replacements needed and the number of females yielded under different semen utilisation scenario. 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. Number of animals yielded was used to evaluate the replacement cost per 100 L of milk. Then, four strategies of sexed semen utilisation 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 number of dairy female replacement heifers that the farm needs are 110. Increasing beef semen use allows farmer to yield less replacement heifers. Furthermore, as beef semen use increases and the number of replacement heifers decreases, replacement cost per 100 L of milk reduces. Therefore, our results highlighted 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.

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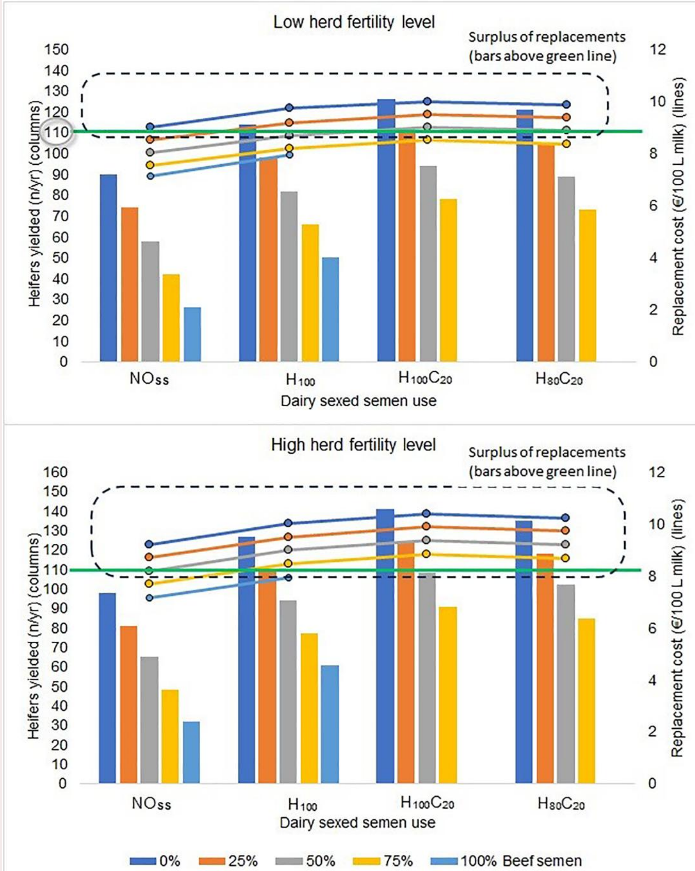
GRAPHICAL ABSTRACT



NOss: 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.

HIGHLIGHTS

- Yielding more heifers than needed is not the most profitable strategy for farmers.
- Combining sexed-sorted semen with beef semen allow farmers to breed less heifers.
- The developed tool will be implemented into a mating program.

Introduction

Farmers have to consider a plethora of factors when defining their mating strategies such as semen type, semen destination use (e.g. dairy or beef), and semen price (De Vries et al. 2022). Furthermore, combining sex-sorted semen with genomic tools can further accelerate the genetic progress of the traits and make more young females available as future replacements in the herd as a result (Borchersen and Peacock 2009; Sørensen et al. 2011; Hjortø et al. 2015). As a consequence, several farmers have an abundance of 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 (De Vries 2020).

Moreover, given the current Italian market conditions, it is not profitable to breed more-than-needed heifers and sell them to other farmers (ISMEA 2023). On the other hand, the higher market value of crossbred dairy calves is an attractive strategy for dairy farmers (Cabrera 2022). The strategy to breed highest genetic merit animals with sexed semen in order to meet herd replacement needs and the remaining cows with beef semen provides an opportunity to farmers to improve both the genetic level of their herds and their profit. Several studies have evaluated different breeding strategies to maximise herd performances (Ettema et al. 2017; Holden and Butler 2018; Clasen et al. 2021). The advantage of sex-sorted semen is maximum when used on high genetic and fertile animals to obtain the number of female calves needed. As conception rate with sex-sorted semen is lower than with conventional semen (Holden and Butler 2018) (~80% that of conventional semen, DeJarnette et al., 2009), it is preferably used on virgin heifers and first-lactation cows, given that fertility performances are better for those animals. Furthermore, it has been shown that sexed-sorted semen lowers the incidence of dystocia and stillbirth, as female calves are usually smaller and easy to calve (Holden and Butler 2018; Pahmeyer and Britz 2020). The determination of the number of animals to keep as replacements heifers and the choice of the best strategy are key aspects in herd management (De Vries 2020). Currently, a specific tool to help Italian dairy farmers choosing the most suitable replacement strategy, based on their productive and reproductive data, is not available. Therefore, the objective of the present study was to test the ability of the replacement tool to investigate the effects of fertility by varying use of sexed and beef semen on herd costs and stability under Italian conditions.

Materials and methods

The method is based on the approach proposed by Genex Cooperative (Ontario, CA) and adjusted to the Italian herd and market conditions. Italian dairy farmers are rearing more heifers than needed and based on current market conditions the sale of surplus heifers is not cost-effective. Moreover, surplus heifers lead to increasing i) voluntary cow culling to allow heifers to enter the milking herd, ii) rearing costs, and iii) GHG emissions (Holden and Butler 2018; Pahmeyer and Britz 2020). A tool has been developed and reported into an Excel spreadsheet to let users adapting it to their situations.

A case study was simulated assuming 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). To account for unexpected issues or to allow for more “voluntary” culling, an additional 10% of heifers has been considered. To explore different scenarios, three levels of herd fertility were simulated: 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. Values of CR were retrieved from the literature (DeJarnette et al. 2009; Mur-Novales and Cabrera 2017; Li and Cabrera 2019) and then adapted to the Italian average situation. Fertility rate for inseminations with conventional beef and dairy semen was assumed to be the same, whereas for inseminations with sexed dairy semen, it was assumed to be 80% that of conventional semen. Percentage of female calves from conventional and beef semen was set at 47%, and from sexed semen at 90%. The method has been developed to enable farmers to adjust all input data described above based on the specific herd conditions and goals. Input variables required by the tool to define the number of dairy female replacements needed in a year, and the number of females yielded under different semen utilisation is reported in Table 1. All these inputs can be adapted by farmers or technicians to the specific situation of a given herd and current market conditions. First, the tool was run assuming that all inseminations were performed with conventional semen under a defined fertility level as previously described (HFL, MFL, LFL) and considering that the herd size remained stable to determine the number of dairy replacement calves needed on a yearly basis. 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. Then, four strategies of sexed semen utilisation were combined with five strategies of beef semen use. The sexed semen scenarios were: 1) no use of sexed semen (**NO_{SS}**), 2) 100% of heifers inseminated with sexed semen (**H_{100}**), 3) 100% of heifers and 20% of top cows inseminated with sexed semen (**$H_{100}C_{20}$**), and 4) 80% of heifers and 20% of top cows inseminated with sexed semen (**$H_{80}C_{20}$**). Beef semen utilisation 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%. Top cows were identified by farmers based on genetic and/or genomic breeding values, and/or phenotypic performances. Selection criteria of top cows differ among farms given that they depend on specific herd objectives and conditions. All remaining eligible animals that were not inseminated with sexed or beef semen were bred with conventional semen. Under the three fertility levels, from each sexed semen scenario combined with beef semen use, the total number of heifers yielded per year was derived. Then, heifer balance was calculated as the difference 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 by alternative

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).

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 three fertility levels[1], assuming 100% use of conventional semen.

Animals	Eligible animals, *n*	Services/conception, *n*			Conception rate, %		
		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).

semen utilisation protocols. Feed costs were retrieved from CLAL (2023), and market value of dairy and crossbred calves from ISMEA (2023). Cows were assumed to produce 31 L/d of milk. 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 information, easily collected by farmers: annual replacement rate, heifer rearing cost, and revenue from selling milk (Bethard and Nunes 2011). The RC was calculated as:

$$RC = \frac{cost\ of\ rearing\ replacements - (cull\ cow\ income + income\ from\ male\ calves\ sold)}{income\ from\ 100\ L\ of\ milk\ sold}$$

where cost of rearing replacements included all costs incurred from birth to first calving calculated for all females yielded; cull cow income included the revenue from selling cull cows and heifers; and income from male calves included the revenue from selling dairy male calves and calves from beef when beef semen is used. The 100 L of milk sold has been identified as an appropriate production unit to compare different herd conditions (e.g. size, location, milk production).

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 minimise rearing costs. 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 three fertility levels (HFL, MFL, and LFL), the number of the annual dairy female replacement cows, and the number of heifers yielded are reported in Table 2. The number of dairy female replacement heifers that the farm needs is 110, for HFL, MFL, and LFL. This number does not reflect differences in reproductive and fertility performances given that the result derived from the number of animals in the herd and the annual turnover rate, adjusted for age at first calving. Indeed, the fertility level does not affect annual replacement needs. Rather, it influences the number of heifers yielded, which increases as fertility improves. Moreover, Overton and Dhuyvetter (2020) demonstrated that yielding more heifers than needed is not economically worth for the farm and hence yielding the right number of heifers would enhance farm profit. As mentioned above, we accounted for additional 10% heifers beyond those needed to satisfy replacement needs of the herd to give farmers the opportunity for voluntary culling or unexpected issues. The percentage can be increased or decreased by farmers based on their own herd objectives. Table 3 summarises 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 three 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. Therefore, herds aiming at maintaining constant their size have to pursue heifer balance of zero or close to zero. 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 utilisation strategies (NO_{SS}, H_{100}, $H_{100}C_{20}$, $H_{80}C_{20}$) leads to an increase of replacement cost (and higher number of reared heifers), regardless of beef semen use. Herd fertility level affects greatly replacement costs and heifer balance. Better fertility level leads to higher number of heifers reared, at the same level of beef and sexed semen use. Within dairy sexed semen strategies, high fertility level showed both greater number of heifers yielded and replacement costs, in accordance with Cabrera (2022), who observed a positive relationship between reproductive performance and replacement balance. 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. Indeed, the use of beef semen in dairy herds has been observed to positively increase herd net present value (Barrientos-Blanco et al. 2018). Also, the combination of beef semen (on inferior genetic merit cows) with sexed semen speeds up the genetic progress of the herd (Ettema et al. 2017). 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). The possible choice of pursuing the lowest replacement cost and then

Table 3. Replacement costs per 100 L of milk (€) and heifer balance[1] (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.

buying extra replacements in the market can be followed, but it is often not feasible and accepted by most farmers. Thus, dairy farmers prefer to produce their own replacements, while using beef semen (Cabrera 2022). Instead, rearing more heifers than needed and then sell them is not economically convenient, as replacement cost per 100 L of milk increases and actual average heifer market value does not cover rearing costs (ISMEA 2023). Thus, 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. As well, decreasing average replacement rate (set at 40% in the present study) will decrease the number of annual replacements and replacement cost per 100 L of milk consequently. The following step will be to select which heifers and cows have to be inseminated with sexed, conventional, and beef semen. Beef semen in dairy herds is usually used on low genetic merit cows or cows with fertility problems (Ettema et al. 2017), and the combined use of beef semen and sexed semen on heifers produces the highest economic return (Clasen et al. 2021). It is worth noting that this study did not include the effect of gestation length and calving ease that have been linked with the use of beef semen on dairy cattle (Fouz et al. 2013). Besides that, the cost of semen has not been considered given that replacement cost as evaluated by our method only considered the cost of rearing replacements without discriminating different types of semen.

Conclusions

The tool provides an approach to dairy farmers to identify the best replacement strategy to follow considering the effects of fertility by varying use of sexed and beef semen on herd costs and stability. This 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 and decrease inbreeding.

Ethical approval

This study did not involve animals and thus prior ethical approval was deemed not required.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

None of the data were deposited in an official repository. The data that support the findings presented in this study are available from the corresponding author upon reasonable request.

References

Barrientos-Blanco JA, Thompson NMO, Widmar NJ, Wolf CA, Snyder LU. 2018. Expected value of crossbred dairy cattle artificial insemination breeding strategies in virgin heifers and lactating cows. Livest. Sci. 211:66–74. doi: 10.1016/j.livsci.2018.03.005.

Bethard G, Nunes AL. 2011. Are you efficiently replacing your herd? Proceeding of the Western Dairy Management Conference, Reno (NV), 9–11 March.

Borchersen S, Peacock M. 2009. Danish A.I. Field data with sexed semen. Theriogenology. 71(1):59–63. doi: 10.1016/j.theriogenology.2008.09.026.

Cabrera VE. 2022. Economics of using beef semen on dairy herds. JDS Commun. 3(2):147–151. doi: 10.3168/jdsc.2021-0155.

CLAL. 2023. [accessed 2023 March 17]. https://www.clal.it/?section=razioni-lombardia-demo.

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(7):8062–8075. doi: 10.3168/jds.2020-20028.

De Vries A. 2020. Symposium review: why revisit dairy cattle productive lifespan? J Dairy Sci. 103(4):3838–3845. doi: 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. 1, p. 2879–2882. doi: 10.3920/978-90-8686-940-4.

DeJarnette JM, Nebel RL, Marshall CE. 2009. Evaluating the success of sex-sorted semen in US dairy herds from on farm records. Theriogenology. 71(1):49–58. doi: 10.1016/j.theriogenology.2008.09.042.

Ettema JF, Thomasen JR, Hjortø L, Kargo M, Østergaard S, Sørensen AC. 2017. Economic opportunities for using sexed semen and semen of beef bulls in dairy herds. J Dairy Sci. 100(5):4161–4171. doi: 10.3168/jds.2016-11333.

Fouz R, Gandoy F, Sanjuán ML, Yus E, Diéguez FJ. 2013. The use of crossbreeding with beef bulls in dairy herds: effects on calving difficulty and gestation length. Animal. 7(2): 211–215. doi: 10.1017/S1751731112001656.

Hjortø L, Ettema JF, Kargo M, Sørensen AC. 2015. Genomic testing interacts with reproductive surplus in reducing genetic lag and increasing economic net return. J Dairy Sci. 98(1):646–658. doi: 10.3168/jds.2014-8401.

Holden SA, Butler ST. 2018. Review: applications and benefits of sexed semen in dairy and beef herds. Animal. 12(s1): s97–s103. doi: 10.1017/S1751731118000721.

ISMEA. 2023. [accessed 2023 March 17] https://www.ismea-mercati.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/723.

Li W, Cabrera VE. 2019. Economics of using beef semen. Proceeding of the Western Dairy Management Conference. Reno (NV 25–28 February).

Mur-Novales RM, Cabrera VE. 2017. What type of semen should I use?. Proceedings of the Dairy Cattle Reproduction Council Annual Convention, Reno (NV), pp. 7–9. November.

Overton MW, Dhuyvetter KC. 2020. Symposium review: an abundance of replacement heifers: what is the economic impact of raising more than are needed? J Dairy Sci. 103(4):3828–3837. doi: 10.3168/jds.2019-17143.

Pahmeyer C, Britz W. 2020. Economic opportunities of using crossbreeding and sexing in Holstein dairy herds. J Dairy Sci. 103(9):8218–8230. doi: 10.3168/jds.2019-17354.

Sørensen MK, Voergaard J, Pedersen LD, Berg P, Sørensen AC. 2011. Genetic gain in dairy cattle populations is increased using sexed semen in commercial herds. J Anim Breed Genet. 128(4):267–275. doi: 10.1111/j.1439-0388.2011.00924.x.