Decision making for sexed semen and beef semen in dairy production

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Abstract

Breeding strategies using sexed semen on younger and superior animals and beef semen on older and inferior animals are becoming widely used in the dairy industry because it balances the number of replacements produced and required while bringing extra income of selling crossbreed beef calves that are more valuable than dairy calves. The value proposition also implies genetic improvement because of greater breeding selection and shorter intergenerational interval, which can be captured in improved milk productivity. The best semen-type breeding strategy is farm specific and dependent on herd reproductive performance and ever-changing market conditions. Hence, the need to use models and projections to assert the optimal semen-type breeding strategy that optimizes the net return of each farm under specific market conditions. We analyzed the economic value of using alternative breeding strategies using sexed, beef and conventional semen using 2 approaches. A short-term approach contained in a user-friendly decision support tool, the Premium Beef on Dairy Program, assessed the income from calves over semen costs over a breeding cycle whereas a long-term approach, using the Animal Life Cycle submodule of the Ruminant Farm Simulation Model, included additionally breeding, rearing and feed costs, and slaughter, heifer and milk sales revenues. Important in the long-term evaluation was the milk value change as a proxy for genetic improvement. Both approaches consistently pointed out that the advantage of the sexed/beef semen is positively related to herd reproductive performance. The greater the reproductive performance the more the economic opportunity. With medium to high reproductive performance (above ~20% 21-d pregnancy rate), the Premium Beef on Dairy Program found the maximum income from calves over semen cost occurred when sexed semen was used in the first 2 heifer breedings and first and second lactation superior cows, while the rest of the heifer breedings were made with conventional semen and the rest of the cow breedings were made with beef semen. These results were consistent in the long-term analysis, which indicated that even a slightly more aggressive breeding approach using sexed semen in all heifer breedings resulted in the best net return in the long-term when the extra value of increased milk productivity became the most important economic factor. Although the short-term analysis did not include the herd dynamics and milk changes, it still produced the right trend and directionality for decision making. The recommendation is to use the Premium Beef on Dairy user-friendly tool according to a herd's reproductive performance and market conditions, and repeat the analysis constantly as the management and market circumstances change. When a deep and long-term analysis is necessary, the use of the Life Cycle Assessment submodule from the RuFaS is critical. Thus, both approaches are useful and complementary.

Key words: decision making, economics, reproduction

Introduction

The use of female sexed semen together with beef semen has become a popular choice on dairy farms (Ettema et al., 2017), which seems to be profitable (Cabrera, 2022). Improved reproductive performance has caused on-farm replacements oversupply (Overton and Dhuyvetter, 2020). Rearing all of them becomes an economic burden and a management challenge. On the other side, beef semen could be used as a strategy to reduce the production of unwanted replacements. Moreover, increased beef cattle demand and its associated price including beef on dairy crossbred animals remains favorable in the foreseeable future (Cabrera and Li, 2019). Thus, using sexed semen on heifers and/or superior cows while using beef semen on other animals, seems a promising long-term management strategy to boost dairy farm profitability (Cabrera, 2021), and to improve genetic progress by increasing the selection intensity and shortening the generational interval (Hjortø et al., 2015). In this paper, we analyze the economic outcome of alternative breeding strategies that combine sexed, beef and conventional semen. First, we revisit a short-term analysis that reports the income from calves minus the semen cost encapsulated in the Premium Beef on Dairy Program online decision support tool (Cabrera, 2022), and then we present a long-term, more integrated and comprehensive analysis applying the Animal Life Cycle submodule of the Ruminant Farm Simulation Model (RuFaS) (Kebreab et al., 2019; Hansen et al., 2021; Li et al., 2022). Although the analysis did not include genetic progress per se, animal's productivity relative to the herd mates was used to select animals for breedings and to adjust lactation curves.

Materials and methods

Short-term analysis with the Premium Beef on Dairy Program decision support tool

The Premium Beef on Dairy Program decision support tool from the University of Wisconsin-Madison Dairy Management (**https://DairyMGT.info**, Tools) was released (Lopes and Cabrera, 2014), updated on several occasions (Mur-Novales and Cabrera, 2017; Li and Cabrera, 2019) and it is fully described in Cabrera (2022). It is a user-friendly, online tool to calculate the income from calves over semen cost (ICOSC) to help dairy farmers' decision-making in a relative short term (a breeding cycle including gestation and parturition). The original goal of the Premium Beef on Dairy Program was to assess the value and the opportunity of using beef semen on dairy cows, a decision that is intrinsically related also to the use of sexed semen. Therefore, the tool also assesses the implementation of different semen type strategies to different groups of animals. Briefly, the Premium on Beef Dairy Program model has 2 components. The first one is a monthly Markov chain based on Cabrera (2012) that is used to determine the female calves required to maintain the herd size stable according to the number of adult cows, culling rates and current reproductive performance. This value is important for contrasting it with the expected produced female calves in the second component. The second component defines group-specific (i.e., top/bottom), service-specific (e.g., first, second) and age-specific (i.e., heifer, lactation number) breeding strategies with sexed, beef or conventional semen to calculate their economic value portrayed in the value of the calves produced and the semen costs summarized in the ICOSC. More details of the Premium on Dairy Beef Program decision support tool can be found in Cabrera (2022) and at **https://dairymgt.info/tools.php**. In this proceeding paper, we revisit a sensitivity analysis of different semen type breeding strategies, reproductive performance, and market conditions using this tool and published in Cabrera (2022).

Long-term comprehensive analysis with the Animal Life Cycle submodule of the RuFaS

The Animal Life Cycle submodule of the RuFaS simulates the long-term individual animal's daily growth, production, disease incidence, culling and reproduction according to breed, reproduction protocols, production curves and culling risks using Monte Carlo stochastic processes (Hansen et al., 2021; Li et al., 2022). The submodule has a pre-running system to reach equilibrium only after a few years of simulation. By aggregating all the animals in a herd, it provides a snapshot of the population dynamics at any point in time. An economic component calculates all the revenue streams (e.g., milk or calves sold) and all the costs (e.g., feed or semen purchases) to calculate the net return according to a management scenario. Further detailed description of the Animal Life Cycle submodule is available in Li et al. (2022); all of the default simulation distributions and parameters are available in Li (2021).

The analysis used a virtual dairy herd of 1,000 adult Holstein cows (milking and dry) and their corresponding youngstock, which were imposed a 5-d CIDR-Synch with 2 PGF and a GnRH starting at 380 d of age as the reproductive program for heifers and a Double-Ovsynch followed by Ovsynch-56 for resynchronization having the first insemination at 72 d post-calving as the reproductive program for cows (DCRC, 2018). Then, we distinguished 2 levels of reproductive performance, high performance with 60% conception rate (CR) at first heifer breeding and 55% at first lactation cow first breeding, and moderate performance with 55% CR at first heifer breeding and 50% at first cow first breeding. Both heifers and cows had 2.6 percentage points lower CR for each subsequent insemination thereafter. Cows in second and later lactations had 5 and 10 percentage points lower CR in the first breeding than in the first lactation first breeding, respectively.

Within these reproductive programs, we set 3 scenarios, for each high and moderate reproductive performance, of using combinations of sexed, beef and conventional semen (Table 1). These scenarios were compared against the control reproductive strategy of using only conventional semen for all inseminations.

We assumed that sexed semen produced 90% female calves (DeJarnette et al., 2009) and conventional semen produced 47% female calves (Silva del Rio et al., 2006). We also assumed that beef semen had the same CR as the conventional semen and sexed semen had 80% of the CR of conventional semen (Ettema et al., 2017). We defined 21-d service rate (SR) and 21-d CR as the average performance of the last 15 21-d periods (315 d) before the 7-yr simulations ended. The 21-d pregnancy rate (PR) was defined as the product of the 21-d SR times the 21-d CR.

An estimated 5% above needed female calves were raised on-farm as replacements. All additional heifer calves produced were sold soon after born and all additional springers not needed as replacements were sold before calving. Each animal was assigned a random draw from N (1.0,0.1) within the range [0.8-1.2] to represent the animal's genetic potential relative to the herd mates, which was used to select animals for breedings and adjust their lactation curves.

The cost of raising youngstock was calculated at $5.5/d from born to weaning (60 d of age), $2.2/d thereafter before pregnancy, and $3.19/d when pregnant (Tranel, 2019). Cows received a diet with an average price of $0.175/kg DM and incurred on additional $2.5/d costs due to farm operation and management (Giordano et al., 2012). Other reproductive costs were setup according to Galvao et al. (2013): GnRH at $2.4/dose; PGF at $2.65/dose; $8.0/CIDR; labor at $0.25 per hormone injection, at $5 per insemination, and at $3 per pregnancy check. Semen cost was set at $35/sexed and $15/conventional or beef. Calf price was set at $45/female Holstein, $57.5/male Holstein, and $225/crossbred beef x Holstein (male or female) (Li and Cabrera, 2019). Springer value was set at $1,310/heifer and salvage value of culled animals was set at $1.39/kg liveweight. All other costs and prices were the same as the ones used in Li (2021). All economic outcomes were averaged from 100 iterations of the last 365 d of the 7-yr simulation.

As seen, the main differences between the Premium Beef on Dairy Program decision support online tool and the Animal Life Cycle submodule reside in the calculations detail and the time of evaluation. The tool follows the herd for a breeding cycle to parturition. The submodule follows each individual animal from birth to culling to replacement and therefore accounts for all the consequences of a management strategy in the long-term, until the herd reaches equilibrium. The tool only considers the difference of the value of the calves minus the semen costs, whereas the submodule has a comprehensive economic component that tracks the most important economic factors beyond the value of calves and semen costs such as milk revenue, feed costs, or culling costs. The submodule considers all factors heavily integrated in which productive, reproductive, health, and other factors depend on and influence each other.

Results and discussion

Short-term analysis with the Premium Beef on Dairy Program decision support tool

Cabrera (2022) highlighted the fact that the use of beef semen is valuable when reproductive performance is better than average, crossbreed beef calves are more valuable than dairy calves, and when it is used in combination with dairy sexed semen. The value is even greater if there is an opportunity and willingness to buy replacements from the market. More specifically, results for a ~20% 21-d PR herd showed the optimal strategy, when the farm requires to produce all replacements from within, occurred when using sexed semen in the first 2 breedings of heifers and first and second lactation cows' first breedings, which maximized ICOSC to $2,001 (Figure 1; surplus of replacements), a situation in which the herd would require to sell 2 extra replacements produced each month. The decision would be different and of greater economic value if the farm would buy replacements from outside, when the best strategy would be to use exclusively conventional semen on heifers and beef semen on cows, which could have an ICOSC of as much as $7,150 (Figure 1; deficit of replacements), a situation in which the herd would require buy 16 replacements each month.

Table 1: Studied scenarios of conventional, sexed and beef semen use.

Reproductive performance[1]	Beef/sexed semen use scenario[2]	Female sexed semen		Conventional semen	
		1st lactation	2nd lactation	1st lactation	2nd lactation
High	Intense	Top 45%	Top 10%	None	None
	Medium	Top 25%	None	Top 25-50%	Top 35%
	Low	Top 25% first 3 inseminations	None	Top 25-50% first 3 inseminations, top 50% following inseminations	
	Top 35%				
Moderate	Intense	Top 45%	Top 15%	None	None
	Medium	Top 25%	None	Top 25-55%	Top 40%
	Low	Top 25% first 3 inseminations	None	Top 25-55% first 3 inseminations, top 55% following inseminations	Top 40%

1 High: 60% conception rate (CR) at first heifer breeding and 55% CR at first lactation cow breeding; Moderate: 55% CR at first heifer breeding and 50% CR at first lactation cow breeding.

2 All heifers bred with sexed semen. All 1st and 2nd lactation cows not bred to sexed or conventional semen and all third and later lactation cows bred with beef semen.

As seen in Figure 1, there is a positive and strong relationship between use of beef semen and ICOSC. The more the use of beef semen in cows, the greater the ICOSC. However, a more realistic situation is when the reproductive strategy produces at least enough replacements from within, which is important for the farmer for biosecurity, supply management, and price risk issues. Therefore, the red circle within Figure 1, surplus of replacements, is likely the optimal zone to operate. Within that zone, the value proposition must be positive (ICOSC > 0) and the greatest possible, which would coincide with the smallest sphere (balance of produced and required replacements closer to zero, but still positive). Inside the circle, there is also a positive relationship of beef semen and sexed semen usage toward maximum ICOSC. However, outside the circle, where no need for replacements produced on-farm is required, the relationship reverses, maximum ICOSC is attained when most beef and no sexed semen is used.

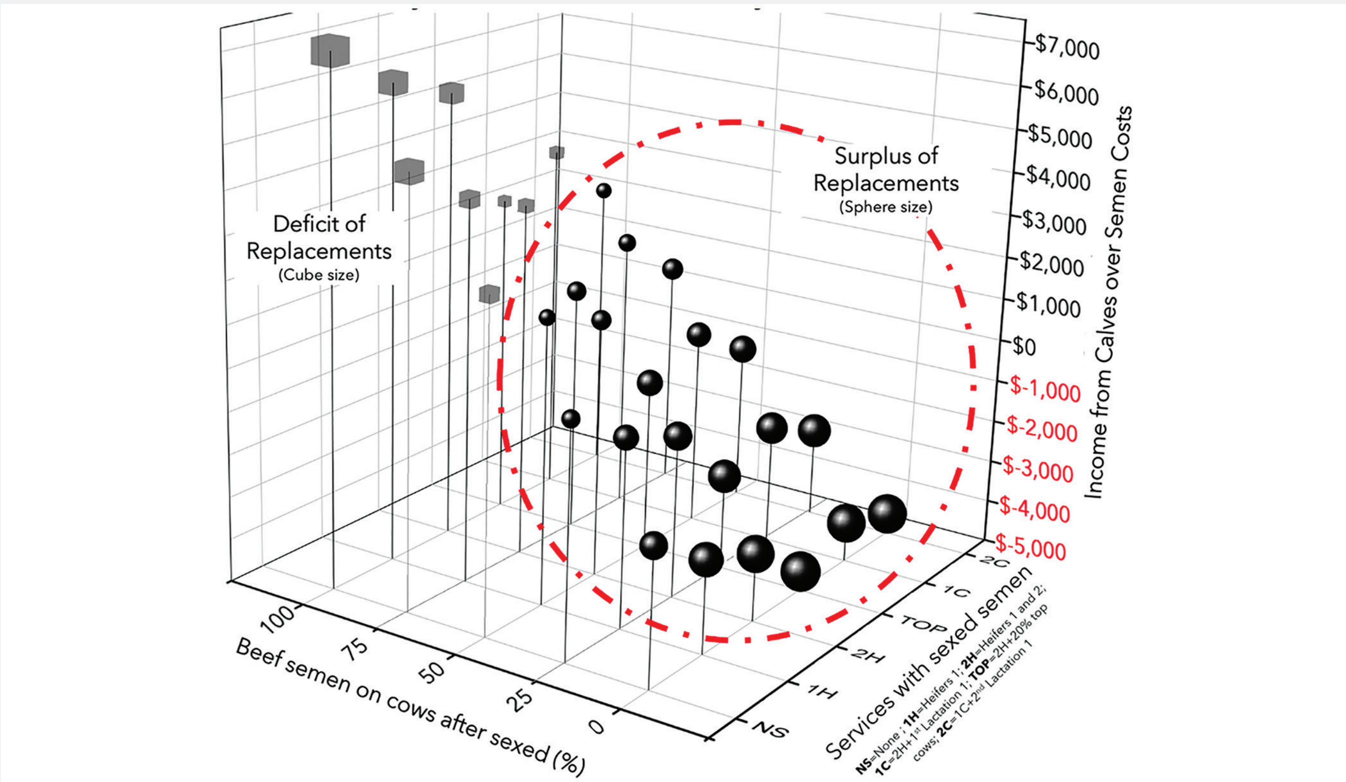
Cabrera (2022) tested three levels of reproductive performance approximated to low (15%), medium (20%) and high (30%) 21-d PR, in which he performed a sensitivity analysis of the most important economic factors. The analysis concluded that the best semen use strategy to have a positive balance of replacements and yet a minimum positive ICOSC with a low reproductive performance would only occur when the average price of sexed and beef semen would be half of their default prices and average calf prices would be about 30% higher than the default. For medium and high reproductive performance, the situation was completely different. The ICOSC was always positive and large despite potential drastic changes in calf and semen prices. Furthermore, the breakeven ICOSC occurred when the crossbred calf price (default price of $225) was as little as $69 for the high and $100 for the medium reproductive performance. This value needed to be as much as $487 for the low reproductive performance. One important conclusion of Cabrera (2022) was that the prospect of sexed and beef semen is heavily attached to the reproductive performance and that farms with a 20% and higher 21-d PR have plenty of opportunities of increasing their net return by using sexed and beef semen according to the historical market conditions of calf prices and semen costs. Under the expectancy of more competitive (relatively lower) prices of sexed semen and a more established crossbred beef calf market, the opportunity of using sexed semen and beef semen is here to stay. At higher 21-d PR of 30% or more, with greater production of calves, the opportunity of using more beef semen is favored against more use of sexed semen. This analysis is critical for year-to-year decision making, which is recommended to rerun as conditions on the farm and/or the market change. However, this analysis does not account for the long-term herd structure changes, nor for all other important factors of the herd performance such as milk production, feed intake, or culling costs, which can be accomplished with the Animal Life Cycle submodule of RuFaS, described next.

Long-term comprehensive analysis with the Animal Life Cycle submodule of the RuFaS

All studied scenarios with the Animal Life Cycle submodule had a better net return than the base scenario of only using conventional semen (Table 2). Scenarios that used only a combination of sexed and beef semen and no conventional semen (intense) had the best net return regardless of the reproductive performance, $162 and $150 per cow/yr greater net return for the high and moderate reproductive performance, respectively. However, the difference in net return ($/cow/yr) from the intense sexed/beef semen use scenario was small when compared with the medium sexed/beef semen use scenario ($2) and the low sexed/beef use scenario ($3). This difference was more marked for the moderate reproductive performance, in which the intense sexed/beef semen use scenario was $27 and $18 per cow/yr greater than the medium and the low sexed/beef semen use scenario, respectively.

Figure 1: Value proposition of beef and sexed semen combinations on a dairy herd with an approximate 20% 21-d pregnancy rate in a herd of 1,000 adult cows with 35% culling rate, 7% stillbirth rate in which all animals not bred to sexed or beef semen were bred to conventional semen when the crossbred beef calf price was about 4 times greater than the dairy calf price and sexed semen price was about 2.3 times greater than the conventional or beef semen price. Source: Cabrera (2022).

Value proposition of beef and sexed semen combinations on a dairy herd with ~20% 21-day pregnancy rate



Milk and calf selling were the most important income factors improved by using sexed/beef scenarios, which were partially offset by additional rearing and semen costs. The selection of lower productive cows in later breedings, which also would have lower reproductive performance, to beef semen increased the herd's productivity and milk sales income in the long-term. Also, greater prices of crossbreed beef calves compared to Holstein male and female calves had an important differential impact on the herd's income. On the other hand, as expected, greater semen cost was related to the quantity of sexed semen used, which had an important premium. Use of sexed semen that has lower CR also influenced the need for rearing longer youngstock and therefore determined extra costs for rearing replacements. The low sexed/beef semen scenario in both high and moderate reproductive performance had a slightly higher calf income than the medium sexed/beef semen scenario because it produced greater quantity of Holstein calves having an overall greater reproductive performance, even though it did not sell as many crossbred beef calves as the medium scenario. At moderate reproductive performance, the intense sexed/beef semen scenario had a noticeable greater net return than the other scenarios because the investment on greater semen costs were overcompensated by much greater milk income.

By design, with only slight differences due to the stochastic processes, all the base and studied scenarios had the same adult herd size of about 1,000 cows. As expected, the base scenario not using any sexed or beef semen had the highest 21-d PR of 28.4% for the high reproductive performance and of 24.5% for the moderate reproductive performance (Table 3). Accordingly, the base scenario had also the shortest calving interval and average days in milk. However, average parity and culling rate, which would be expected to be lower in response to lower 21-d PR with the studied scenarios, did not follow that pattern. One possible explanation is the selection of superior animals in the herd using sexed and beef semen in the intense, medium and low scenarios, determining, indirectly, a lower reproductive culling rate, which is tied to productivity (i.e., a threshold of minimum productivity to cull animals that did not become pregnant in a defined time). It is interesting to acknowledge that when studying combinations of sexed, beef and conventional semen, the 21-d PR had not a direct relationship to profitability as it has been documented in many other studies with sole conventional semen (Cabrera, 2014; Overton and Cabrera, 2017). In this analysis, although the differences in 21-d PR were small, for each reproductive performance group, the base scenario that did not use any sexed or beef semen and had the highest 21-d PR, had the lowest net return.

Consistent with the 21-d PR, the base scenarios with the highest 21-d PR had the fewest first lactation cows (more adult herd) than all the studied scenarios, fewest heifer reproduction failure and therefore the need to rearing fewest young animals (Figure 2). Regarding culling, culling distributions because different health reasons and death were relatively similar among all scenarios. However, reproductive culling was different. Scenarios with greater use of sexed semen had greater reproductive culling due to the lower CR of sexed semen. Moreover,

Table 2: Net return of studied scenarios with the Animal Life Cycle submodule of the RuFaS model and important economic components. Combination of semen use scenarios (intense, medium, and low) in each reproductive performance are reported as the difference from the base scenario. All numbers are in $/cow/yr.

Reproductive performance[1]	Beef/sexed semen use scenario[2]	Income				Cost				Net return
		Milk	Slaughter	Heifer	Calf	Feed	Breeding	Semen	Rearing	
High	Base	4673	332	70	36	1353	57	35	890	1863
	Intense	134	2	1	97	-1	5	27	41	162
	Medium	132	3	3	86	-2	4	22	40	160
	Low	134	-1	1	87	1	5	23	34	159
Moderate	Base	4664	337	70	35	1350	61	38	905	1840
	Intense	138	3	3	91	-1	5	30	51	150
	Medium	125	3	2	77	-3	5	24	57	123
	Low	124	1	2	80	0	5	24	46	132

1 High: 60% conception rate (CR) at first breeding for heifers and 55% CR at first breeding for first lactation cows; Moderate: 55% CR at first breeding for heifers and 50% CR at first breeding for first lactation cows.

2 Base: conventional semen for all heifers and cows. All heifers bred to sexed semen in all other scenarios. High Intense: 1st lactation top 45% and 2nd lactation top 10% cows to sexed semen; all other cows to beef semen. High Medium: 1st lactation top 25% cows to sexed semen; 1st lactation top 25 to 50% and 2nd lactation top 35% cows to conventional semen; all other cows to beef semen. High Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 50% of three first inseminations, top 50% following inseminations, and 2nd lactation top 35% to conventional semen; all other cows to beef semen. Moderate Intense: 1st lactation top 45% and 2nd lactation top 15% to sexed semen; all other cows to beef semen. Moderate Medium: 1st lactation top 25% to sexed semen; 1st lactation top 25 to 55% and 2nd lactation top 40% to conventional semen; all other cows to beef semen. Moderate Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 55% of three first inseminations, top 55% following inseminations, and 2nd lactation top 40% to conventional semen; all other cows to beef semen.

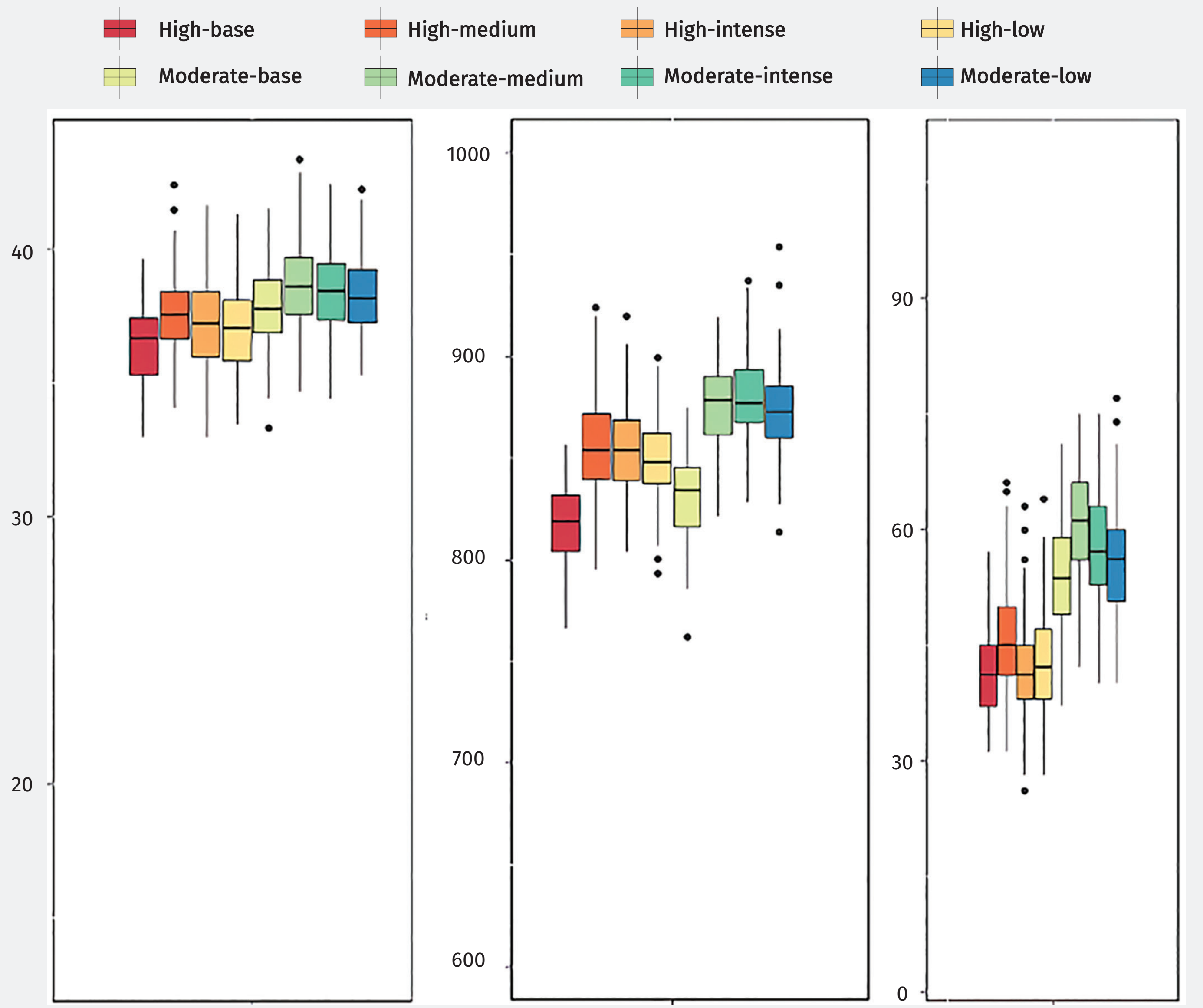
Table 3: Resulting herd demographics with the Animal Life Cycle submodule of the RuFaS model.

Reproductive performance[1]	Beef/Sexed semen use scenario[2]	21-d pregnancy rate	Average parity	Average calving interval	Average days in milk	Average culling rate
		%	#	d	d	%
High	Base	28.4	2.36	397.1	172.5	38.4
	Intense	26.4	2.34	399.7	175.0	38.5
	Medium	27.4	2.35	398.4	173.7	38.6
	Low	27.5	2.36	398.8	173.7	38.1
Moderate	Base	24.5	2.30	402.2	177.3	38.7
	Intense	22.5	2.28	405.5	180.4	39.0
	Medium	23.6	2.29	403.8	178.1	39.1
	Low	23.7	2.30	403.7	178.0	38.8

1 High: 60% conception rate (CR) at first breeding for heifers and 55% CR at first breeding for first lactation cows; Moderate: 55% CR at first breeding for heifers and 50% CR at first breeding for first lactation cows.

2 Base: conventional semen for all heifers and cows. All heifers bred to sexed semen in all other scenarios. High Intense: 1st lactation top 45% and 2nd lactation top 10% cows to sexed semen; all other cows to beef semen. High Medium: 1st lactation top 25% cows to sexed semen; 1st lactation top 25 to 50% and 2nd lactation top 35% cows to conventional semen; all other cows to beef semen. High Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 50% of three first inseminations, top 50% following inseminations, and 2nd lactation top 35% to conventional semen; all other cows to beef semen. Moderate Intense: 1st lactation top 45% and 2nd lactation top 15% to sexed semen; all other cows to beef semen. Moderate Medium: 1st lactation top 25% to sexed semen; 1st lactation top 25 to 55% and 2nd lactation top 40% to conventional semen; all other cows to beef semen. Moderate Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 55% of three first inseminations, top 55% following inseminations, and 2nd lactation top 40% to conventional semen; all other cows to beef semen.

Figure 2: Box-and-whisker plot (median, first and third percentiles, range) of key herd demographics of resulting herd under different semen-type breeding strategies during the last year of a 7-yr simulation with 100 iterations for each scenario. High reproductive performance: 60% conception rate (CR) at first breeding for heifers and 55% CR at first breeding for first lactation cows; Moderate reproductive performance: 55% CR at first breeding for heifers and 50% CR at first breeding for first lactation cows.



reproductive culling signaled a larger variation not only between high and moderate reproductive performance, but among all the scenarios analyzed (Figure 2).

Base: conventional semen for all heifers and cows. All heifers bred to sexed semen in all other scenarios. High Intense: 1st lactation top 45% and 2nd lactation top 10% cows to sexed semen; all other cows to beef semen. High Medium: 1st lactation top 25% cows to sexed semen; 1st lactation top 25 to 50% and 2nd lactation top 35% cows to conventional semen; all other cows to beef semen. High Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 50% of three first inseminations, top 50% following inseminations, and 2nd lactation top 35% to conventional semen; all other cows to beef semen. Moderate Intense: 1st lactation top 45% and 2nd lactation top 15% to sexed semen; all other cows to beef semen. Moderate Medium: 1st lactation top 25% to sexed semen; 1st lactation top 25 to 55% and 2nd lactation top 40% to conventional semen; all other cows to beef semen. Moderate Low: 1st lactation top 25% of three first inseminations to sexed semen; 1st lactation top 25 to 55% of three first inseminations, top 55% following inseminations, and 2nd lactation top 40% to conventional semen; all other cows to beef semen.

Conclusions and take-home messages

Whether the evaluation is operational (short-term, within a year) or strategic (long-term, more than 5 years), breeding management strategies using combinations of sexed and beef semen (with or without conventional semen) are economically superior to strategies using simply conventional semen given that the reproductive performance of the herd is at least moderate (20% 21-d PR or above). In the short-term, the extra value of crossbred beef calves is much larger than the extra costs of costly sexed semen. In the long-term, furthermore, increased milk productivity results in substantial additional milk revenue that makes the proposition even more attractive. Milk production increases because selective breeding of sexed semen to superior cows and beef semen to inferior cows determines a herd composed of more productive cows over time. Although the short-term analysis is a partial budgeting without considering the herd dynamics, still yields the right trend and directionality for decision making, which is confirmed with the full long-term analysis. The recommendation is to use the Premium Beef on Dairy user-friendly decision support tool according to herd's reproductive performance and market conditions and repeat the analysis constantly as the management and market circumstances change. The optimal combination of semen types for different groups of eligible animals is farm specific. Best semen type breeding strategies obtained with the decision support tool are likely to generally match the ones with the long-term strategies. However, when there is a need to quantify the absolute and detailed value of different semen type breeding strategies, validate the continuous evaluations with the tool, or simply assess semen type combined value with other technologies (e.g., genomic testing and selection), the use of the Life Cycle Assessment submodule from the RuFaS is critical. Both approaches are useful.

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