WHAT TYPE OF SEMEN SHOULD I USE?

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TAKE HOME MESSAGES

- Semen selection strategies are strongly influenced by market conditions.
- High-reproductive performance farms are more sensitive to calf prices, whereas low-reproductive performance farms are more sensitive to semen prices.
- Farms with low-reproductive performance could increase their profits by using inexpensive beef semen and buying replacements.
- Farms with high reproductive performance could increase their profit by using sex-sorted semen to produce and sell replacements.
- Current use of sex-sorted semen is more limited by its price than by the technology.

INTRODUCTION

Consequences of producing and using sex-sorted semen in the dairy industry have long-time been discussed (Kiddy and Hafs, 1971; Weigel, 2004; de Vries et al., 2008). Extensive research has been conducted to mitigate the main technological disadvantages of sex-sorted semen such as reduced sexing accuracy and reduced conception rate. As a result, sexing accuracies of up to 90% (Seidel and Schenk, 2008) and improved sex-sorted semen conception rates to the range of 70 to 85% of those achieved with conventional semen (Seidel, 2014) currently are achieved. These technological advances together with a sex-sorted price reduction have led to the widespread use of sex-sorted in commercial dairy farms.

With the use of sex-sorted, farms need to inseminate fewer cows with the objective of cover replacement requirements. To take advantage of this fact, some strategies like using sex-sorted semen in genetically superior animals to produce better-quality replacements (Seidel, 2003) or combine sex-sorted semen utilization with crossbreeding to maximize income from non-replacement calves (Hohenboken, 1999) have been suggested. Furthermore, de Vries et al. (2008) hypothesized that the widespread use of sex-sorted semen would lead some farms to specialize in replacement production, while other farms would buy replacements and specialize in produce crossbreed calves for the beef industry. Farms today have a wide combination of semen selection strategies available.

The profitability of the different semen selection strategies is influenced principally by three factors: 1) market environment; 2) management level; and 3) technological efficiency of sex-sorted semen (McCullock et al., 2013). Because of the complexity of the interaction between these three factors, some decision-support tools like the Premium Beef on Dairy tool from the University of Wisconsin-Madison Dairy Management website (DairyMGT.info: Tools; Lopes and Cabrera, 2014) have been developed to help producers and consultants. The above referenced tool calculates semen cost, number of replacements produced, and income from calves for the different semen selection strategies according to market conditions, reproductive management performance, and technological efficiency of sex-sorted semen. Within this context, the aim of this study was to evaluate comprehensively different dairy cattle semen selection strategies under different market, management, and technological conditions.

MATERIALS AND METHODS

Overview of the Model

A model was developed to evaluate income from calves over semen cost (**ICOSC**) when different combinations of conventional, sexed, and beef semen are used in a Holstein herd under different market, management, and technological conditions. It was assumed that farms have a stable number of adult cows and therefore female calves were bought if females born in the farm did not cover the replacement needs. Similarly, female calves were sold if there were produced in excess. Thus, the ICOSC was calculated with the following formula:

$$ICOSC = \left(HF_{born} - HF_{req}\right) x\ PHF + HM_{born} x\ PHM + B_{born}\ x\ PB - Cow_S\ x\ PSS - Cow_C\ x\ PCS - Cow_B\ x\ PBS$$

where HF_{born}= Holstein female calves born in the farm, HF_{req}= Holstein females calves required to cover the replacement needs, HM_{born} = Holstein males born in the farm, B_{born}= beef crossbreed calves born in the farm, Cow_S= cows inseminated with female sex-sorted semen, Cow_C= cows inseminated with conventional semen, Cow_B= cows inseminated with beef semen and PHF, PHM, PB, PSS, PCS, PBS are the sale prices of a Holstein female calf, a Holstein male calf, a beef crossbreed calf, a dose of sex-sorted semen, a dose of conventional semen, and a dose of beef semen, respectively. In some cases the prices of Holstein females coming from sexed and conventional semen were different to reflect different levels of genetic improvement. All values, except prices in the above equation, were determined using the Premium Beef on Dairy tool from the University of Wisconsin-Madison Dairy Management website (DairyMGT.info: Tools; Lopes and Cabrera, 2014).

Simulated Farm

A farm containing 100 adult Holstein cows was simulated during a year under three different reproductive performance levels (low, medium, and high; Table 1). The structure of the simulated herd was 36% primiparous cows, 24% second-parity cows, and 40% greater than second-parity cows. The number of heifers required in each simulation depended on the adult herd turnover ratio and the combination of conception rate of the first four services in heifers. For instance, if the adult herd turnover ratio was set at 30%, it meant that 30 heifers had to successfully complete their pregnancies within a year. Therefore, with greater conception rates of heifers, fewer heifers were required to get 30 fresh primiparous cows.

Inseminated Cows and Born Calves

The number of heifers inseminated in each simulation depended on their conception rate and the turnover ratio as previously explained. The number of first inseminations in each parity of the adult cows was the same in all simulations, but the subsequent inseminations varied according to the accumulated conception rates. It was assumed that the voluntary waiting period was 60 days and the interval between services was 30 days. As a consequence, cows becoming pregnant after first or second inseminations resulted in one calving during the study period, whereas cows getting pregnant at later inseminations produced less than one calving within a year. All were corrected according to their calving to conception interval to calvings per year. In addition, the number of cows delivering a calf during a year was limited by the turnover ratio. For example, if the turnover ratio of adult cows was set at 30%, it implied that at the most, 70% of the adult cows could deliver and start a new lactation on the farm. In cases in which more than 70 adult cows were supposed to become pregnant and calve within a year, the number of deliveries was limited to 70 because these extra pregnant cows were supposed to be culled for reasons other than reproductive reasons. The number of inseminations performed accordingly was proportionally adjusted. Lastly, a combined abortion, stillbirth, and mortality rate of 8% was applied to all pregnancies.

Table 1. Conception rate at 60 days post insemination of the different simulated reproductive performance levels (low, medium, and high).

Parity	AI, no.	Conception rate % Low	Medium	High
Heifer	1	50	60	75
	2	45	55	70
	3	45	55	70
	4	40	50	65
Primiparous	1	35	55	70
	2	30	45	60
	3	30	45	60
	>3	25	40	55
Second parity	1	30	45	50
	2	26	35	40
	3	26	35	40
	>3	22	30	35
>Second parity	1	30	45	50
	2	26	35	40
	3	26	35	40
	>3	22	30	35

Variables Tested

Variables affecting ICOSC under tested reproductive performances were: sex-sorted semen utilization strategy, percentage of cows inseminated with beef semen, price of the different types of calves and seminal doses, turnover ratio, genetic improvement associated to sex-sorted semen, and the fertility of sex-sorted semen in relation to conventional semen.

Because sex-sorted semen has a lesser fertility than conventional semen and this decreased fertility leads to changes in income from milk over feed cost that was not accounted in this model, six different strategies of sex-sorted semen utilization were fixed: 1) Not to use sex-sorted semen (**NS**); 2) 1st service in heifers (**1H**); 3) 1st and 2nd services in heifers (**2H**); 4) 1st and 2nd services in heifers and 1st service in 20% top adult cows (**TOP**); 5) 1st and 2nd services in heifers and 1st service in primiparous cows (**1C**); and 6) 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (**2C**). Sensitivity analyses were performed on the remaining variables individually under 18 scenarios resulting from the combination of three different farm reproductive performance levels (low, medium, and high) and these six sex-sorted semen utilization strategies.

In all simulations, heifers were only inseminated with sexed or Holstein conventional semen, whereas cows could be inseminated with sexed, conventional, or beef semen. It was assumed that beef and conventional semen had the same fertility and produced female calves (47% of the time). In addition, it was assumed that sex-sorted semen produced female calves (90% of the time). Fertility of sex-sorted semen relative to that of conventional semen was tested in the range of 70% to 100%. Sale prices of beef crossbreed calves and Holstein male calves varied proportionally because their prices are correlated and regulated by the beef market. Sale price of female Holstein calves was independent of the others. Scenarios with up to 30% greater value for Holstein female calves coming from sex-sorted semen were tested to represent the use of sex-sorted semen on genetically superior animals. With exception of scenarios in which sexed and beef semen prices were studied, the prices were set at $15 for conventional and beef semen and at $35 for sex-sorted semen. Finally, the adult herd turnover ratio was explored to vary between 30% and 50%. The default values utilized in the simulations are shown in Table 2.

Table 2. Default values utilized in the simulations when other variables were studied.

Variable	Default value
Conventional semen price	$15/dose
Beef semen price	$15/dose
Sex-sorted semen price	$35/dose
Fertility of sex-sorted semen relative to conventional semen	70%
Premium sale price of Holstein females produced by sex-sorted semen	0%
Herd turnover ratio	30%

RESULTS AND DISCUSSION

In all simulated scenarios, the farm with the greatest reproductive performance obtained the greatest ICOSC and the greatest balance of Holstein female calves (Table 3). This occurred because the high-reproductive performance farm always required fewer replacements and fewer inseminations than the other reproductive performance farms (Table 4). The shape of the ICOSC function was defined by the interaction between the sex-sorted semen utilization strategy and reproductive performance. Different levels of beef semen utilization resulted in parallel curves with the same shape. An example of this pattern is shown in Figure 1. This result is a reflection of the fact that changes in reproductive performance and sex-sorted semen utilization strategy caused changes in the number of replacements required, the number of inseminations, and the number of calves obtained, whereas changes in the level of beef semen utilization only caused changes in the cost of semen and price of calves produced.

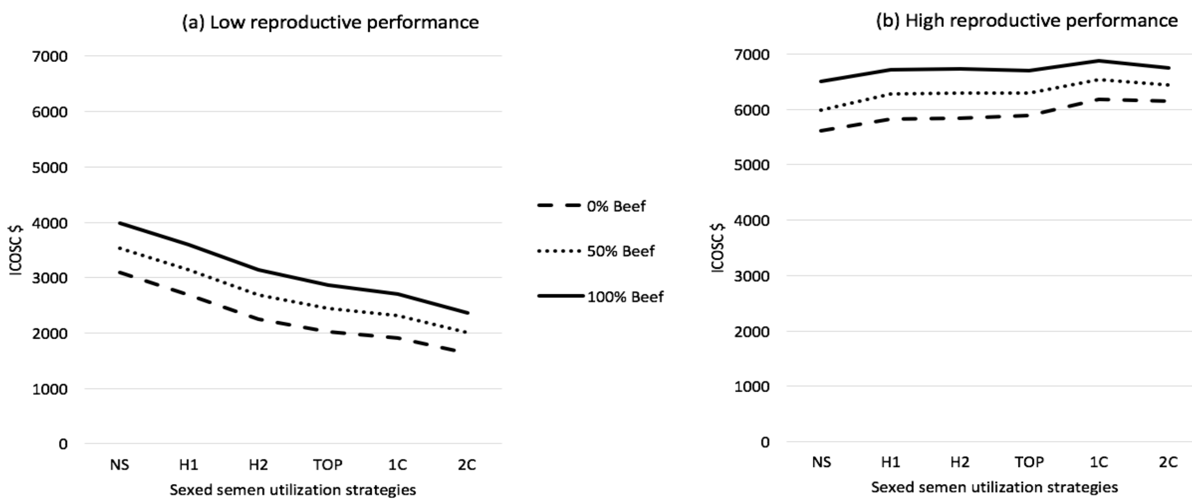

Figure 1. Income from calves over semen cost (ICOSC) for the different sex-sorted semen utilization strategies: no sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C) and low reproductive performance (a) or high reproductive performance (b) under Wisconsin current market prices (Table 3) and different levels of beef semen utilization in the remaining adult cows.

Wisconsin Current Market Conditions

As shown in Table 3 and Figure 2, the best semen selection strategy differed among farms with different reproductive performance under the Wisconsin current market conditions. For farms with low and medium reproductive performance the strategy was to not use sex-sorted semen and inseminate all the adult cows with beef semen, whereas the best option for high reproductive performance farms was to inseminate with sex-sorted semen heifers at 1st and 2nd service and primiparous cows at 1st service and use beef semen in the remaining adult cows. Using these optimal strategies, the low and medium reproductive performance farms needed to buy 20 and 18 replacements, respectively, whereas the high reproductive performance farm would sell 6 Holstein female calves. Thus, farms with low and medium reproductive performance could only optimize their ICOSC if enough Holstein female calves or heifers were available in the market. If replacements were not available in the market or if the risk of Holstein female's price change was to be avoided, farms must seek to optimize their ICOSC only within the semen selection strategies that provide enough replacements. For example, under current Wisconsin market conditions for the medium reproductive performance farm, the greatest ICOSC that provided enough Holstein females was to use the sex-sorted semen strategy (1C) and inseminate the remaining adult cows with beef semen (Figure 3).

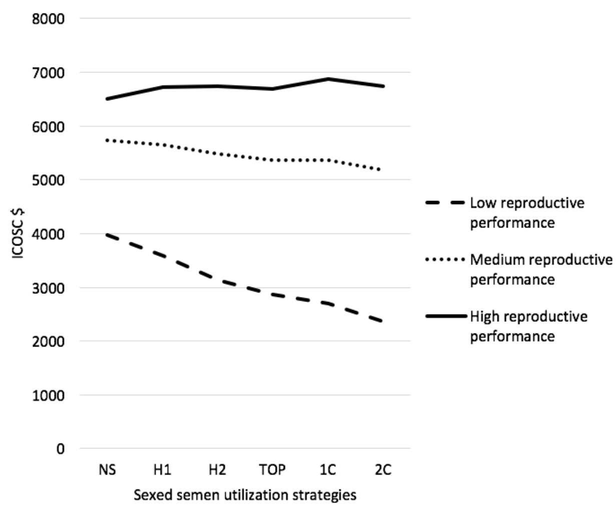

Figure 2. Income from calves over semen cost (ICOSC) for the different sex-sorted semen utilization strategies: Not to use sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C) and inseminating all the remaining adult cows with beef semen under Wisconsin current market prices (Table 3) and different reproductive performances.

Increasing the Price of Holstein Female Calves

As expected, the larger the increase of Holstein female calf price the more profitable becomes the use of conventional and sexed semen. After changing the semen selection strategy to optimize the ICOSC under the new market conditions, the low, medium and high reproductive performance farms arrived to a positive Holstein female balance (Table 3). Because in this scenario all farms had a surplus of replacements, it is not likely that these market conditions would last long, except if the dairy industry is growing greatly.

When only the price of Holstein females coming from sex-sorted semen was increased, the utilization of sex-sorted semen increased, whereas the use of beef semen remained stable. In these scenarios, the low fertility farm had a shortage of replacements, but the medium and high fertility farms had a surplus of replacements (Table 3). These results indicate that in situations when farms are trying to improve their genetics, use of sex-sorted semen could be increased and a market in which high reproductive performance farms sell high genetic animals to farms with low reproductive performance could be established.

Increasing the Price of Holstein Beef Crossbred Calves

When the value of beef and Holstein male calves were increased, use of sex-sorted semen was consequently reduced to increase the number of beef and Holstein males calves obtained to optimize the ICOSC. In these scenarios, optimization of ICOSC led to all farms lacking replacements (Table 3). Under these market prices, farms should use semen selection strategies that optimize the ICOSC, but also provide enough or close to enough replacements because replacements in the market would become extremely expensive or inexistent.

Table 3. Best sex-sorted semen utilization strategy (Best SS): no sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C). Best percentage of beef semen utilization in the remaining adult cows (% Beef) and difference between Holstein females born in the farm and Holstein females required to cover the replacement needs (HF Balance) for the greatest income from calves over semen cost (ICOSC) under different simulation scenarios and reproductive performances.

				Reproductive performance											
	Calf prices			Low				Medium				High			
Case	PHF[1] ($/Calf)	PHM[2] ($/Calf)	PB[3] ($/Calf)	Best SS	% Beef	ICOSC ($)	HF Balance	Best SS	% Beef	ICOSC ($)	HF Balance	Best SS	% Beef	ICOSC ($)	HF Balance
Wisconsin current market prices[4]	262	100	190	NS	100	3980	-20	NS	100	5727	-18	1C	100	6871	6
Increasing PHF $50	312	100	190	NS	0	3585	10	2C	0	5509	28	2C	0	7389	33
Increasing PHF $100	362	100	190	NS	0	4082	10	2C	0	7373	28	2C	0	9441	33
Increasing PHF $150	412	100	190	2C	0	4837	21	2C	0	8790	28	2C	0	11086	33
15% Premium price for HF from SS	262 CS[7] 301 SS[8]	100	190	NS	100	3980	-20	2C	100	6553	7	2C	100	8346	13
20% Premium price for HF from SS	262 CS 314 SS	100	190	1H	100	4111	-17	2C	100	7011	7	2C	100	8882	13
25% Premium price for HF from SS	262CS 327 SS	100	190	1C	100	4258	-8	2C	100	7469	7	2C	100	9417	13
30% Premium price for HF from SS	262CS 340 SS	100	190	2C	100	4634	-3	2C	100	8019	7	2C	100	10060	13
Increasing PB $25	262	110	215	NS	100	5736	-20	NS	100	7418	-18	1H	100	8410	-11
Increasing PB $75	262	130	265	NS	100	9056	-20	NS	100	10803	-18	1H	100	11603	-11
Increasing PB $125	262	150	315	NS	100	9348	-20	NS	100	11096	-18	NS	100	11874	-17
Reducing PSS[5] to $25	262	100	190	NS	100	3980	-20	2C	100	6290	7	2C	100	7794	13
Reducing PSS to $20	262	100	190	2C	100	4154	-3	2C	100	6845	7	2C	100	8321	13
Reducing PBS[6] to $10	262	100	190	NS	100	5121	-20	NS	100	6540	-18	1C	100	7475	6
Reducing PBS to $5	262	100	190	NS	100	6283	-20	NS	100	7352	-18	2H	100	8106	-9
Reducing PBS to $5 and Increasing PHF $100	362	100	190	NS	100	4231	-20	2C	0	7373	28	2C	0	9441	33
Increasing relative fertility of SS to 80%	262	100	190	NS	100	3980	-20	1C	100	5917	3	1C	100	7388	9
Increasing relative fertility of SS to 85%	262	100	190	1H	100	3991	-15	1C	100	6178	4	2C	100	7665	19
Increasing relative fertility of SS to 90%	262	100	190	2H	100	4117	-12	2C	100	6445	14	2C	100	7953	21
Increasing relative fertility of SS to 100%	262	100	190	2H	100	4528	-12	2C	100	701	17	2C	100	8502	25
Increasing turnover ratio to 40%	262	100	190	NS	100	622	-27	NS	100	2622	-24	1C	100	3975	3
Increasing turnover ratio to 50%	262	100	190	NS	100	-2736	-34	NS	100	-482	-1	1C	100	1079	0

[1]PHF: Price of Holstein female calf.
[2]PHM: Price of Holstein male calf.
[3]PB: Price of Holstein-beef crossbred calf.
[4]Wisconsin current market prices: Stratford Market Report 08/22/17, www.equitycoop.com, scenario used as baseline for the other simulations.
[5]PSS: Price of a dose of sex-sorted semen.
[6]PBS: Price of a dose of beef semen.
[7]Price for calf coming from conventional semen.
[8]Price for calf coming from sex-sorted semen
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Table 4. Number of Holstein females required to cover replacement needs (HF req), number of inseminations carried out with conventional and/or beef semen (No. C/B AI) and number of inseminations carried out with sex-sorted semen (No. SS AI) for farms with low, medium and high reproductive performance using different sex-sorted semen utilization strategies (SS strategy): no sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C).

	Low			Medium			High		
SS strategy	HF req	No. C/B AI	No. SS AI	HF req	No. C/B AI	No. SS AI	HF req	No. C/B AI	No. SS AI
NS	33	293	0	31	214	0	30	178	0
1H	34	270	34	32	193	32	30	157	30
2H	36	254	59	32	179	51	31	147	45
TOP	36	244	79	32	170	67	31	138	65
1C	36	237	95	32	163	87	31	131	81
2C	36	225	119	32	153	111	31	120	105

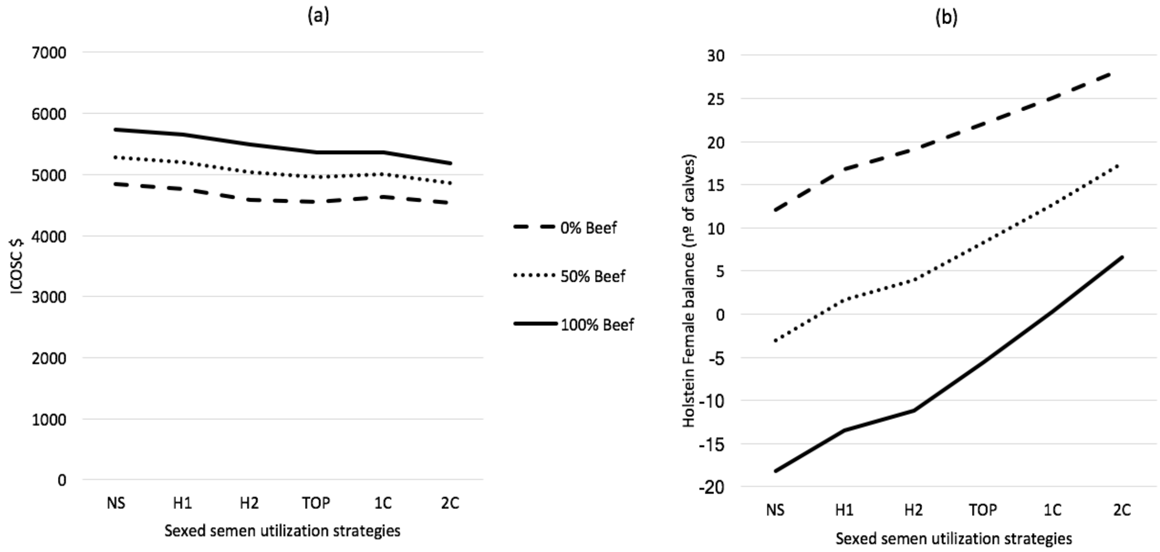

Figure 3. (a) Income from calves over semen cost (ICOSC) and (b) Holstein female balance for the different sex-sorted semen utilization strategies: no use of sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C) and medium reproductive performance under Wisconsin current market prices (Table 3) and different levels of beef semen utilization in the remaining adult cows.

Varying the Price and the Relative Fertility of Sex-Sorted Semen

As shown in Table 3, a reduction of $15 in the sex-sorted semen price drove all farms to use the strategy in which most sex-sorted semen is used (2C) when optimizing ICOSC. In contrast, when the fertility of sex-sorted semen was equalized to the fertility of conventional semen, only the medium and high fertility farm chose the 2C strategy to optimize the ICOSC, whereas the low farm chose to use sex-sorted semen only in heifers (2H). According to these simulations, we conclude that the use of sex-sorted semen is currently more limited by its price than by its reduced fertility.

Reducing the Price of Beef Semen

When reducing the price of beef semen, the low and medium reproductive farms kept their strategy to inseminate all adult cows with beef semen and increased their ICOSC, whereas the high reproductive performance farm reduced its sex-sorted semen use until inseminating all adult cows with beef semen resulted in a lack or replacements (Table 3). An interesting scenario illustrated in Table 3 and Figure 4 occurred when the price of sex-sorted semen was reduced to $5 and the price of Holstein female calf was increased to $362. In this scenario, the low reproductive performance farm optimized its ICOSC using the inexpensive beef semen, whereas the medium and high reproductive performance farms obtained their greatest ICOSC producing as many Holstein female calves as possible using sexed and conventional semen. This scenario indicates that farms with low reproductive performance are more sensitive to semen prices, but farms with high reproductive performance are more sensitive to calf prices. This is explained by the fact that farms with low reproductive performance carry out more inseminations. The reduced ICOSC when sex-sorted semen was used in heifers from low reproductive performance farms was caused not only by performing more inseminations with expensive semen, but also because more Holstein female calves were required to get 30 primiparous cows to calve (Table 4). If these market conditions would last, they would lead to low reproductive farms to increase their profit using inexpensive beef semen, whereas high reproductive performance farms would increase their profit producing Holstein females for low reproductive performance farms.

Varying the Turnover Ratio

Increasing the turnover ratio from 30 to 50% did not modify the semen selection strategies, but reduced the ICOSC in all farms. In addition, it reduced the number of semen selection strategies in which self-supply of replacements could be achieved.

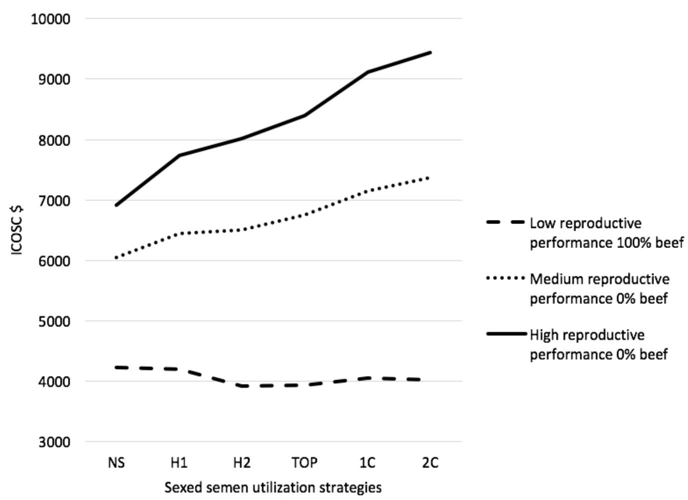

Figure 4. Income from calves over semen cost (ICOSC) for the best semen selection strategies under different sex-sorted semen utilization strategies: Not to use sex-sorted semen (NS); 1st service in heifers (1H); 1st and 2nd services in heifers (2H); 1st and 2nd services in heifers and 1st service in 20% top adult cows (TOP); 1st and 2nd services in heifers and 1st service in primiparous cows (1C); and 1st and 2nd services in heifers and 1st service in primiparous and second-parity cows (2C) when the price of beef semen was $5 and the price of Holstein females was $362.

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