The Economics of Using Sexed Semen

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Take Home Messages

- Field results with most sexed semen products show that the chance of a heifer calf is 90% and conception rates are 80% of those obtained with conventional semen.
- Sexed semen can be more valuable than conventional semen when heifer calves are more valuable than bull calves, conception rates are high, and the difference in cost between sexed and conventional semen is minor. This is a realistic scenario for some Canadian dairy producers.
- Of all insemination opportunities in a herd, sexed semen has the most value in the first one or two inseminations in heifers. The difference in value between the use of all conventional semen and some inseminations with sexed semen is typically less than $30 per heifer enrolled in the breeding program.
- The use of sexed semen in only those heifers with the highest genetic transmitting ability and the use of conventional semen in heifers with lower transmitting ability adds value to the heifer breeding program. Most herds will have some heifers that should be inseminated with sexed semen.
- Genomics increases the reliability of the transmitting ability of the heifer but its effect on the choice for sexed semen is minor.
- Conventional semen from service sires with a higher transmitting ability is typically more valuable than sexed semen from a service sire with a lower transmitting ability.

Introduction

Sexed semen is semen processed to skew the sex ratio of the spermatozoa in favor of the desired gender. In dairy cattle, the desired gender is a female calf because female calves are considered to be more valuable than male calves.

Most sexed semen is sorted for approximately 90% chance of a female calf. Commercial sales of sexed semen started to take off since early 2006 in the USA and many dairy producers in the USA and elsewhere have used it to obtain more (and genetically better) heifer calves. Most of this use was driven by a large difference between the purchase price of heifers and the cost to raise them. Presently, all major North American A.I. companies sell sexed semen from dairy sires. Because of its higher cost per dose of semen, combined with a reduced conception risk, sexed semen has been primarily used in virgin heifers.

In the USA, demand was greater than the supply of sexed semen until the end of 2008, when the global economic crisis resulted in dramatic decreases of the milk price and sexed semen sales. The widespread use of sexed semen from 2006 until the end of 2008 has resulted in more heifer calves being born and several hundred thousand more heifers are expected to enter herds in the USA in the near future (De Vries and Nebel, 2009). The reduction in milk prices and the concern that an excessive supply of heifers will continue to dampen milk prices have caused dairy producers, A.I. companies and their advisors to rethink the most economical use of sexed semen in heifers and cows. The question is if sexed semen has value to generate enough heifers to replace culled cows, but not necessarily to generate more heifers.

In Canada, sexed semen has been used relatively less than in the USA (ABS Global, personal communication). In Canada, perhaps the opportunities for expansion of the milking herd are limited by the milk quota system. Heifer supplies have been sufficient without the use of sexed semen. Canadian dairy producers may ask if sexed semen has value in herds that do not want to grow while the market value of surplus heifers is low. Thus, the issue of how to best use sexed semen in Canada and the USA is now more similar than a few years ago. This paper provides a brief overview of the technology to sort semen and then summarizes some economic aspects of the use of sexed semen in dairy heifers with a focus on genetic improvement.

■ Technology

Sexed semen is semen which has a modified ratio of X-chromosome (female) bearing sperm to Y-chromosome (male) bearing sperm. This modification is obtained by sorting of normal (conventional) semen that has 50% X-bearing and 50% Y-bearing sperm. Fertilization of an egg with an X-bearing sperm leads to a heifer calf. Thus, sexed semen with relatively more X-bearing sperm has a greater chance to result in a heifer calf.

The only repeatable technique to sort sperm for gender uses a machine called a flow-cytometer to detect varying differences in DNA content over multiple breeds from 3.6 to 4.1% between X and Y-bearing sperm (Garner et al., 1983). Presently, all North American A.I. companies use this same technique. Only 15% of the sperm going into the sorting machine are recovered as viable, sexed semen. Although the 5,000 sperm of each sex sorted per second sounds like a lot, this translates into approximately 1 hour and 7 minutes of sorting to process enough semen for a standard 20 million sperm straw. Thus, due to the slow sorting speed and only 10 to 15% of the sperm entering the sorting machine are recovered as marketable product, commercialization is only possible with very low sperm numbers per straw (approximately 2 million sperm per straw). Additionally, the cost of flow cytometry equipment (approximately $400,000 per machine) and highly skilled labor required to sort sperm dictates that sexed semen be sold at a higher price than the same bull packaged traditionally. Each machine can process approximately 12 units per hour and machine time is approximately 18 hours per day, thus each machine can process approximately 215 units per day. If we assume down time and holidays, every machine has the ability to produce approximately 63,000 units per year. The sorting technology continues to be improved with the most recent gains in sorting speed.

Research has consistently demonstrated that the technology used to sort semen produces about 90% calves with the desired gender (DeJarnette et al., 2009). However, not every 10 inseminations result necessarily in exactly 9 heifer calves. Random chance says that in about 26% of the herds that inseminate 10 animals, ≤80% of the offspring will be heifer calves. Seven percent of the time, ≤70% of the offspring will be heifer calves. These are simple mathematical probabilities of which the dairy producer should be aware. Reality is that the current technology is consistently achieving an average of approximately 90% heifer calves when evaluated across a larger number of calvings.

▪ Biological and Economic Components of the Use of Sexed Semen

There are many biological and economic factors that determine the optimal economical use of sexed semen in a dairy herd. Optimal means that sexed semen may be profitable for use in some cases in some heifers and/or cows but not in others cases. In many cases, sexed semen is not profitable compared to the use of conventional semen. Important biological and economic factors that need to be considered are:

Semen Prices

A dose of sexed semen is on average more expensive than conventional semen. In Canada, sexed semen may cost on average $42 (typical range $30 to $75) and conventional semen $28 (typical range $25 to $75) per dose (ABS Global, personal communication). In the past, the price difference was approximately $30 in the USA, but price differences have decreased since late 2008 when demand of sexed semen started to decrease. Price and availability of sexed semen depends on the demand of the sire's conventional semen.

Sexed Semen Fertility

Research and field evaluations have shown that the fertility of sexed semen is approximately 80% of the fertility of conventional semen (DeJarnette et al., 2009). This holds in both heifers and cows. Thus, if the conception rate with conventional semen is 50%, the conception rate with sexed semen is expected to be 50% * 80% = 40%. However, the service sire can have a large effect on the sexed semen conception rate.

Cost of Raising the Heifer

The reduction in conception rates with sexed semen will result in a longer breeding period and consequently in a greater age of first calving. The cost to raise heifers is approximately $2 per day with a range from $1.31 to $2.93 (Kohlman et al., 2008). Thus, the use of sexed semen generally increases the cost of raising the heifer and a delayed entry into the lactating herd.

Effect of Age of Calving On Performance in the First Lactation

Another consideration is the effect of age of first calving on the performance as a lactating cow. Heifers that calve too young may produce less milk and have reduced fertility in the first lactation and older heifers might experience more dystocia (Ettema and Santos, 2004). However, the effect of age of first calving depends to a great extend on growth rates. Therefore, it is not likely that extended age of first calving necessarily reduces profitability of lactating cows.

Dystocia

Heifers and cows that calve with female calves have lower risks of dystocia and lower expected dystocia related costs. Cady, as reported by Fetrow et al. (2007), reported that calving heifers with bull calves had a 10 percentage point greater risk of dystocia. At $147 per case (Dematawewa and Berger, 1997), this results in a net cost of $14.70 per bull calf compared to a heifer calf. They concluded that the reduction in dystocia should probably not be the principal driver for sexed semen use.

Effect of Insemination Number on Heifer Conception Risks

In a large study by USDA following 537,938 AI services, the average conception risk for Holstein heifers with conventional semen was 56.3% (Kuhn et al., 2006). Approximately 88% of U.S. heifer herds had a 40 to 70% heifer conception risk. Conception risk by insemination number decreased from 53% for first inseminations to 33% for seventh inseminations, or 3.8 percentage points per insemination number. Over 60,000 heifer inseminations between November 2006 and November 2007 showed that average unadjusted (raw) conception risks from first to seventh insemination decreased from 56% to 24% (ABS Global, personal communication, 2008). This is a decrease of 5.75 percentage points per insemination number.

The time between inseminations is approximately 32 days, which is equivalent to a 65% 21-d estrus detection rate. Dairy producers typically cull heifers if they are not pregnant after five or six inseminations.

Calf and Heifer Prices

The value of sexed semen comes primarily from the difference in value between a heifer calf and a bull calf. Where bull calves may be worth $75 to $100 in Canada, heifer calves may be worth several hundreds of dollars more, depending on purchased heifer prices. When heifer calves are not sold, the value of the heifer calf is primarily the difference between the cost to raise a heifer calf to freshening and the purchase price for a similar freshening heifer. Purchased heifer prices are approximately $1800 in Canada in early 2010 (ABS Global, personal communication, 2010) because heifer prices in the USA are depressed. The purchase price may be similar to the cost of raising a heifer. Purchased heifers have greater biosecurity risks. The value of such risk should be added to the purchase price.

Cow and Heifer Culling

A greater supply of heifers, or a lower cost, as a result of the use of sexed semen might increase optimal voluntary culling of cows and slightly increase the cull rate. A reduction in the price, $500 per purchased heifer, would increase the cull rate by approximately 5 percentage points. Profit per cow per year would be slightly increased.

Genetic Progress

Without sexed semen, genetic progress is primarily made by the selection of a very small fraction of superior AI sires. Little selection is possible on the dam side when all heifer calves from cows are needed to be raised as replacement heifers. With sexed semen, enough heifers to replace culled cows could be obtained from the better dams, which would result in some genetic progress on the dam's side. The calves from the genetically bottom end dams would not be needed for replacements and could be sold.

Van Vleck (1981) estimated that the rate of genetic progress could increase by 15% if sexed semen was widely available. Later, Baker et al. (1990) suggested that the use of sexed semen in elite cows and sires would have a very minor impact on the rate of genetic progress.

The rate of genetic progress depends on the difference between the predicted transmitting abilities (PTA) of a trait of the service sire and the dam. The US-Department of Agriculture Animal Improvement Programs Laboratory (USDA-AIPL, 2010) ranks service sires and cows by the "trait" net merit (NM$), which is the expected lifetime extra profit compared to a base animal. The NM$ is calculated from the genetic merit of milk yield, fat, protein, productive life, somatic cell score, composites of udder, feed and legs, and body, daughter pregnancy rate, and calving ability. The base is recalculated every 5 years. In the January 2010 genetic evaluation, the median Holstein cow had a NM$ of $30 (575,892 cows evaluated). The median Holstein service sire had a NM$ of $197 (696 sires evaluated) while the top 1 percentile sires had a NM$ of $802. The average elite service sire transmits several hundreds of NM$ to his daughter whereas the typical dam transmits almost nothing to her daughter.

In Canada, the major index to rank sires is the lifetime profit index (LPI) which also serves to breed cows that are more profitable. Figure 1 shows the association between the January 2010 PTA for NM$ and LPI for 61 service sires from Semex (http://www.semexusa.com). As expected, a greater LPI is associated with a greater NM$. The correlation is 0.78. Per 100 points LPI, NM$ increases on average by $21.83 per lifetime.

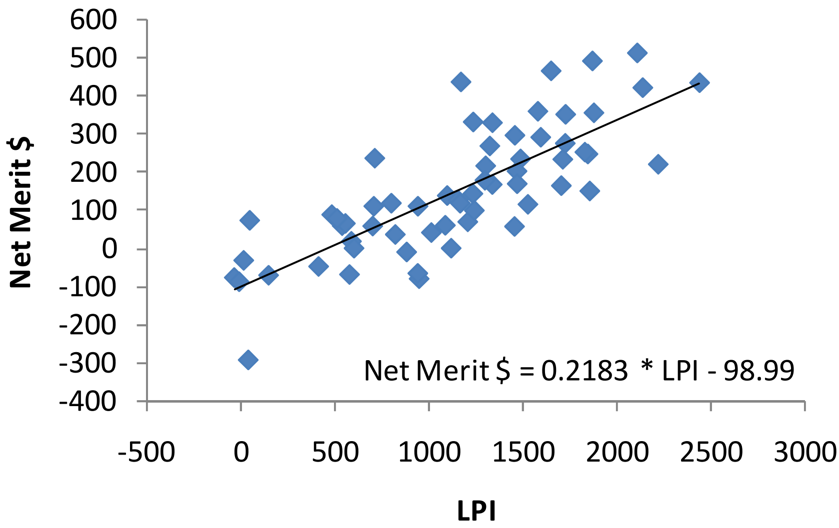

Figure 1. Association between net merit (NM$) and lifetime profit index (LPI) for 61 service sires from Semexusa (http://www.semexusa.com) based on the January 2010 genetic evaluation.

Genetic superiority in additive genetic value is calculated as the accuracy of the evaluation * selection intensity * genetic standard deviation (Van Vleck et al., 1987). The genetic standard deviation for NM$ is $198 (Cole et al., 2009) and is a measure of the genetic variation in NM$ in the population of dairy cattle. Selection intensity refers to the average of the increase in units standard deviation of the top fraction of dams that are selected. If the top 50% of dams for NM$ are selected, then the selection intensity is 0.80, or an increase on average of 0.80 genetic standard deviations. If accuracy is 59% (the square root of a 35% reliability of the parent average (the heifer's PTA) of a typical heifer), then the genetic superiority of these 50% best heifers for NM$ is 0.59 * 0.80 * $198 = $93.46 compared to the average population of heifers. Half of the genetic superiority is transmitted to the calf, so a daughter from the top 50% heifers is expected to be $93.46/2 = $47.73 more profitable in her life than the daughter of an average heifer, assuming equal genetics from their sire.

Van Vleck and Everett (1976) showed how the average transmitting ability for milk of selected cows would increase from 36.3 kg for conventional semen used on the top 90% of cows to produce replacement heifers, to 147.4 kg when sexed semen would result in 90% heifer calves and would be used on the top 50% of cows to produce replacement heifers.

Most dairy producers in the USA do not or cannot rank their heifers for NM$. They either breed all heifers, or a random group of heifers, to sexed semen. The generation interval is reduced, however, if heifers become a major supplier of the next generation of animals.

Genomic information increases the reliability of the genetic evaluation. The reliability of a heifer when no production and/or type information is available is approximately 35%. If an animal has been genomically tested, the reliability may increase to 65%. Given the example above, if the top 50% heifers for NM$ have a reliability of 65%, then the genetic superiority of these top 50% heifers is $127.37 and their daughters would be $63.68 more profitable per lifetime than the daughters of average heifers.

USDA-AIPL calculated that 29% of the 717 active Holstein bulls born after 1994 had their sexed semen used in the April, 2008 national genetic evaluation (Hutchison and Norman, 2009). These 211 bulls were on average slightly better than the average bull for milk yield traits (fat, protein, yield), productive life, daughter pregnancy rate, and NM$. They were also slightly better for somatic cell score, calving ease, and stillbirth. Sexed semen is usually not available from the best sires.

The main biological and economic factors have now described. Economic analyses that have included some (but not all) of the complex interactions suggest that sexed semen is most valuable in virgin heifers, and then primarily in the first insemination, and with diminishing returns in later inseminations (Olynk and Wolf, 2006; Fetrow et al., 2007; De Vries, 2008; Cabrera, 2009). There is no reliable rule of thumb that can dictate proper use across the variety of herds, cows, and economic scenarios possible.

▪ Heifer Results Without Genetic Selection

A spreadsheet was developed to calculate the value of sexed semen in heifers given sets of biological and economic assumptions. Most economic analyses have assumed that the value of a heifer calf is independent of the number of heifer calves born. In the analyses below it is assumed that 40% of the heifers have to generate replacement heifer calves that are to be raised on the farm. In other words, if 100 heifers start the insemination program, the program needs to generate 40 replacement heifer calves. These to be raised heifer calves are valued at $300 plus the added genetic merit. The heifer calves are obtained from the top NM$-ranked heifers. If more heifer calves are produced than the 40% needed, they will be sold for $300 to the market, independent of their genetic merit. Thus, the heifer calves to be raised are more valuable than those sold. This constraint attempts to mimic a situation where the dairy producer does not want to grow the herd size.

Key assumptions for the heifer calculations are listed in Table 1. Heifers that are not pregnant after the maximum number of inseminations are culled and generate revenue based on their body weight. These heifers were replaced by purchased heifers at the time of calving. Calves from the purchased heifers are expected to have a value of 0 NM$. Calving heifers are sold to the dairy herd for $1800 each, excluding the value of their calf. The estimated breeding value of a heifer to be raised is $200 more ($200 PTA sire + $0 PTA heifer) than a heifer to be sold.

Table 1. Key default assumptions for heifer calculations

- Age at first insemination: 400 days
- 21-day service rate: 65%
- Conception rate conventional semen: 60% first insemination, a reduction of 5.75 percentage points per later insemination
- Conception rate sexed semen: 80% of the conception rate of conventional semen
- Cost to raise heifers: $2 per day
- Maximum number of inseminations: 6
- Number of sexed semen inseminations: first 0 to 6 inseminations, remainder with conventional semen
- Annual discount rate: 8%
- Market value culled open heifers: $980 or less
- Purchase cost calving heifer to replace culled heifer: $1800
- Value calving heifer to the dairy farm (without value of her calf): $1800
- Semen cost: $42 sexed, $28 conventional
- Heifer calves to be raised: 40% of heifers enrolled, remainder are sold
- Value bull calf: $75
- Value of heifer calf to the farm (without genetic progress): $200
- Value of heifer calf sold: $200
- Heifer calves from sexed semen: 90%
- Heifer calves from conventional semen: 48%
- Extra dystocia cost: $14.70 per bull calf compared to heifer calf
- PTA net merit service sire (sexed and conventional): $300
- PTA net merit heifer: $0
- Reliability net merit heifer: 35%
- Genetic standard deviation net merit: $198
- Selection of top net merit heifers: 100% (no heifers selected)

Table 2. Effect of number of sexed semen inseminations on heifer statistics (key assumptions)

Statistic	Number of sexed semen inseminations					
	0	1	2	0	1	2
	60% conception rate[1]			50% conception rate		
Profit	294	302	303	237	234	229
Cull revenue	18	23	28	50	60	69
Value of heifer to dairy	1795	1793	1793	1794	1792	1792
Bull calf sales	39	24	17	39	26	20
Heifer calf sales	24	84	112	24	74	101
Value raised heifer calves, sexed	0	158	158	0	142	158
Value raised heifer calves, conventional	157	0	0	157	16	0
Value raised heifer calves, purchased	0	0	0	0	0	0
Raising cost	1637	1648	1651	1637	1644	1644
Breeding cost	51	72	83	62	83	96
Dystocia losses	8	5	3	8	5	4
Purchased heifer cost	42	55	68	119	143	166
Profit/pregnancy	294	302	303	237	234	229
Profit/insemination	167	152	144	110	98	91
Profit/insemination $	5.96	4.33	3.77	3.94	2.90	2.47
Average age at first calving (days)	701	707	709	706	711	713
Inseminations/heifer enrolled	1.77	1.99	2.11	2.15	2.38	2.50
Inseminations/conception	1.77	1.99	2.11	2.15	2.38	2.50
Insemination cost/pregnancy	51.23	72.42	83.20	62.30	83.50	95.75
%Calving/heifer enrolled	100%	100%	100%	100%	100%	100%
%Heifer calves/heifer enrolled	48%	68%	78%	48%	65%	74%
Average conception risk	55%	49%	46%	43%	39%	36%

[1] First insemination conception rate

Given the default assumptions, Table 2 lists the profit per heifer enrolled for 0 to 2 inseminations with sexed semen. Additional inseminations were with conventional semen. Other statistics are shown as well. Sexed semen increased profit at most by $9 per heifer after 2 sexed semen services when conception rate started at 60%. At a starting conception rate of 50%, sexed semen was not profitable. The use of sexed semen reduced average conception rate, increased the number of heifer calves born, and the average age of first calving.

The value of sexed semen inseminations for the key assumptions with a 60% starting conception rate is relatively small. The value of sexed semen depends greatly on the heifer price and to a lesser extent on the sexed semen price, and relative decrease in conception risk. When heifer calves are worth $500, excluding genetic merit of raised heifer calves, the first insemination with sexed semen increased profit per heifer from $378 to $426. On the other hand, if heifer calves are worth $100, excluding genetic merit of raised heifer calves, a first insemination with sexed semen reduced profit per heifer from $211 to $178. When sexed semen is profitable in the first insemination, it typically remains profitable in several later inseminations as well, even though the conception rate decreases.

Fetrow et al. (2007) used a similar spreadsheet and found similar results as presented here. The sets of inputs they evaluated were slightly different. In their default situation, losses after 6 inseminations with sexed semen were $35. When only one insemination of sexed semen was used, the loss was $9. The authors concluded that sexed semen in heifers could only be profitable if there were small differentials in the price of sexed semen (< $25), small impacts on conception rate (< 10%), and no consideration for genetic progress.

Olynk and Wolf (2007) studied break-even heifer calf prices and break-even insemination costs for sexed semen strategies in dairy heifers compared to a strategy with only conventional semen. When conception risk for first insemination with conventional semen was 58% and decreasing after first insemination, the profit per heifer enrolled was $208. When conception rates for sexed semen were 75% of those of conventional semen and the first insemination was with sexed semen, the additional profit was $5. Second and later inseminations with sexed semen were not profitable. Under these conditions, break-even heifer calf values were nearly $500. Break-even sexed semen insemination costs were close to $50. Their calculations were quite similar to the ones presented here and spreadsheet by Fetrow et al. (2007) but default assumptions differed in details.

▪ Heifer Results With Genetic Selection

Fetrow et al. (2007) evaluated the value of increased genetic gain from the female side in their economic calculations. If heifers can be ranked for genetic merit, then the value of genetic gain was approximately $32 per heifer entering the breeding pool if the top 30% of heifers were inseminated at least initially with sexed semen and the bottom 70% were inseminated with conventional semen. Without the value of the genetic gain, the use of sexed semen in 30% of the heifers resulted in a loss of $11 per heifer entering the breeding pool (given a large number of reasonable assumptions about prices, fertility etc.). Therefore, considering genetic gain resulted in a $22 (-$11 + $32) net gain of using sexed semen per average heifer. The optimum mix was using sexed semen in 40% of the heifers for approximately a $33 value of genetic gain per average heifer entering the breeding pool. Their results show the potential benefit from accurately ranking heifers for genetic merit, using for example parent averages for heifers.

Using the key assumptions from above, Table 3 shows that profitability per heifer can be increased to $311 when the top 50% of the heifers are inseminated up to 3 times with sexed semen. Compared to the best use of sexed semen in an unselected heifer population ($303 profit per heifer) the gain is only $7. When heifer reliability is increased from 35% to 65%, the profit per heifer is increased to $316.

When the PTA for net merit for conventional semen is $100 greater than for sexed semen ($300 vs. $200), it does not pay anymore to use sexed semen on heifers. Without sexed semen, profit per heifer is $322 and with using sexed semen on the first insemination it is $302.

Table 3. Effect of inseminating top heifer selected for net merit on profit per heifer enrolled.

Sexed semen inseminations	Top heifers selected for NM$[1]				
	100%	75%	50%	25%	0%
0	294	297	296	295	294
1	302	307	306	301	294
2	303	308	309	302	294
3	302	307	311	303	294
4	300	305	310	302	294

[1] Remainder of heifer inseminated with conventional semen.

▪ Outlook

The analyses have shown that the use of sexed semen across all heifers is not necessarily profitable. Sexed semen use in cows is even less likely to be profitable because conception rates are lower (De Vries, 2008). However, exceptions exist for individual cows. By incorporating the genetic merit of the heifer or cow in the insemination decision, a slight improvement in the value of sexed semen is possible if it is used on the “right” heifers and cows. Ultimately, the question of when to use sexed semen in individual heifers and cows depends on the sex and value of the offspring, but also on the age, and predicted performance (and stage of lactation) for the dam.

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