The Impact of Sexed Semen on Breeding, Management and Profitability of the Dairy Herd

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Introduction

The decades of research in the area of gender sorting bovine semen came to the stage of broad commercial application within the past few years. Today, all major North American A.I. organizations offer sexed semen produced by selected sires, both progeny proven and young sires, to Canadian dairy producers. For some early adopters, the decision to use sexed semen in their herd seemed easy, almost automatic, but other dairy producers remain unsure with several questions unanswered. The focus of this paper is to examine the value of sexed semen from various perspectives including genetic improvement, herd management and overall herd profitability.

Sexed Semen Technology and Commercially Available Products

A method referred to as "flow cytometry" is now commonly used to sort sperm that have the X chromosome (that produces a female) from those that have the Y chromosome (that produces a male). Since the X and Y chromosomes are not the same size and weight, the technology separates semen based on the DNA content of each sperm cell. Essentially all A.I organizations in North America that offer sexed semen use the same technology patented by XY, Inc., Colorado, USA, either through contractual agreements for the semen processing or through the purchase and ownership of their own semen sorting equipment and trained personnel. With current laboratory technology and techniques, a single semen sorting machine produces 5-6 doses of semen per hour, which translates to an average of 120 to 150 doses per 24-hour day. For this reasons, most semen sorting facilities operate multiple machines, which increases the capital investment of such organizations. Table 1 provides a summary of the sexed semen products offered in Canada by major global A.I. organizations.

Table 1: Summary of Sexed Semen Products Offered by Major A.I. Organizations

Organization	Sexed Semen Product Label/Name	Stated % Females
ABS	ABS Sexation™	90
Accelerated Genetics	ACC-SS® (ACCESS Sexed Semen)	90
Alta Genetics	Alta511	90
Genex /CRI	GenChoice 90™ GenChoice 75™	90 75
Select Sires	*gender* SELECTed™	90
Semex Alliance	Semexx™	90

Expected Outcomes from Use of Sexed Versus Traditional Semen

The main argument in favour of using sexed semen is the expected shift in the sex ratio of live calves from the standard 50:50 to an average of 90% females and 10% males, or the 75:25 ratio expected with GenChoice 75™ semen offered by Genex/CRI (Table 1). Recent analysis at Canadian Dairy Network (CDN), based on sexed semen breedings with the standard 90:10 product for which a subsequent calving ease record was available, confirms the claimed sex ratio of resulting calves with

93% females born based on nearly 969 Holstein calvings. Key outcomes of this shift in sex ratio towards more females instead of males include:

- Fewer problems at calving and associated reductions in costs for labour, medical treatment and death loss, since females are born on average easier than males. This result provides the option of maintaining normal sire selection strategies and benefiting from fewer calving problems and more alive calves or the option of considering an expanded list of proven sires for virgin heifers that have a genetic evaluation for Calving Ability (CA) that is up to 4 points below average (i.e.: 96 to 99) and achieve the same or better dystocia rates as with an average sire (i.e.: CA=100).
- For herds stable in size (i.e.: closed herds), selection of the best virgin heifers for breeding with sexed semen increases the likelihood of replacement heifers of superior genetic merit, hence faster genetic progress in the herd, and the opportunity to export excess heifers or sell them locally.
- For herds under expansion, heifer calves born from 90% of all virgin heifer calvings reduces the need to purchase additional replacements from outside the herd.
- For any herd, the use of sexed semen to ensure that the required number of replacement heifers needed each year are produced from within the herd has the significant advantage from a biosecurity perspective to control the presence and spread of various diseases.

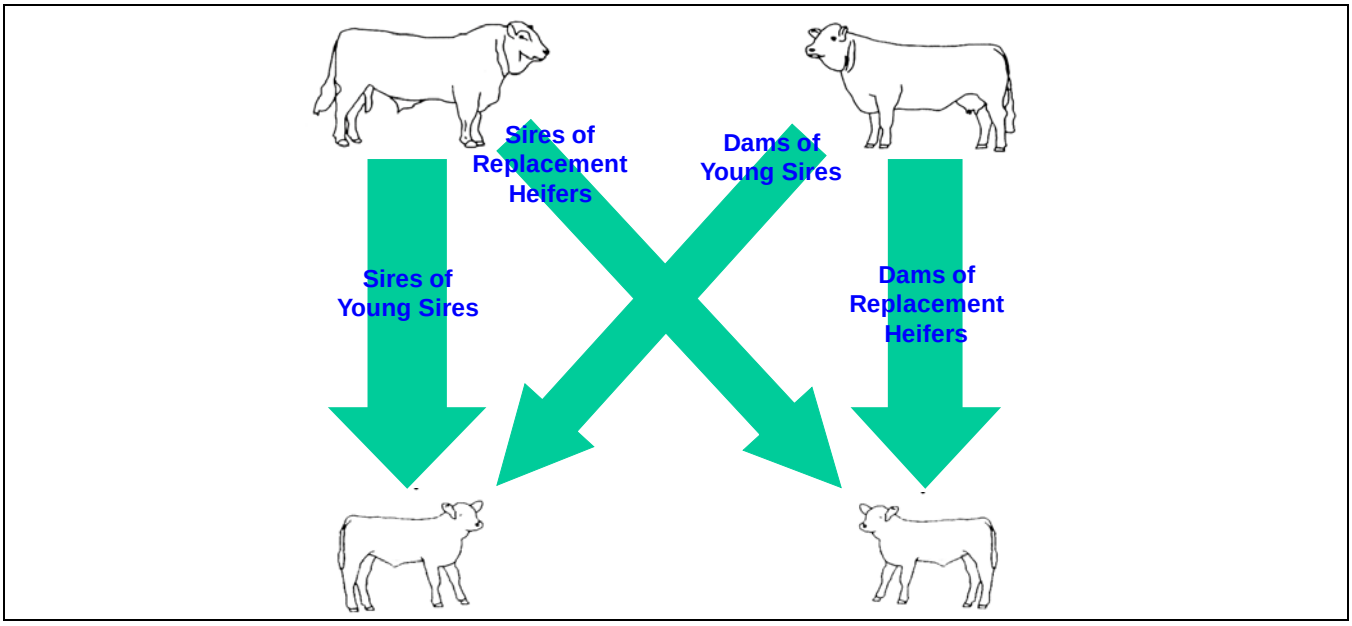
The use of sexed versus traditional semen also involves some key disadvantages, which include:

- Reduced conception rates, normally claimed to be 80% to 85% of those for traditional semen, which translates to additional costs due to extended rearing costs for breeding virgin heifers (recommended) or extended days open if used to breed lactating cows (not recommended).
- Lack of availability of sexed semen for all potential mating sires of interest, both progeny proven and young sires. In general, the high demand for traditional semen from the most elite progeny proven sires is prohibitive due to the significant reduction in doses produced per ejaculate for sexed semen. From any given semen collection, the average ejaculate is able to produce only a fraction of the number of doses of sexed semen compared to the number that would otherwise be produced for conventional semen.

Impact of Sexed Semen Use on Rates of Genetic Gain in the Herd

Genetic progress per year in a breed, population or even at the herd level is a function of four main variables. These include the genetic variation that exists in the population of animals available for selection, the accuracy of selection, the intensity of selection and the interval between generations measured by the average age of parents when progeny are born. In addition, this formula for annual genetic gain can be evaluated within four distinct pathways of selection (Figure 1), namely the selection of sires to produce the next generation of young bulls entering A.I., the selection of dams to produce that same group of young bulls, the selection of sires used to produce replacement heifers in the herd (or population) and the selection of dams used to produce the future replacement heifers in the herd (or population). In general, the first two selection pathways (i.e.: sires and dams of future A.I. young bulls) is the responsibility of the A.I. organizations in a given population or country while each specific dairy producer and/or herd owner is responsible for the latter two selection pathways (i.e.: sires and dams of future replacement heifers for the herd).

Figure 1: Schematic Diagram of the Four Pathways of Genetic Selection and Progress



To evaluate the impact of sexed semen on the rate of genetic gain in the herd, the following assumptions were made:

- Only the two pathways associated with the selection of sires and dams of replacement heifers in the herd are affected by using sexed semen so the contributions to genetic gain from the other two pathways remained fixed.
- The use of sexed semen has no impact on the genetic variation in the population and all sires with semen available have genomic information included in their published genetic evaluation, which increases the average accuracy of selection for sires. Genomic evaluations for cows and heifers in the herd were not assumed in this analysis although this would significantly improve the accuracy of selection of superior virgin heifers for breeding with sexed semen.
- The selection pathway of sires to breed replacement heifers is affected given that sexed semen is currently offered for second tier progeny proven sires with genomic evaluations and elite genomically tested young bulls. This leads to some reduction in the accuracy of selection due to the shift towards using more genomically tested young bulls and also a reduced intensity of selection for the portion of progeny proven sires available for sexed semen usage.
- For the selection pathway of dams to breed replacement heifers, the use of sexed semen on virgin heifers affects three components of annual genetic gain. Assuming a stable herd size whereby the superior half of the virgin heifers would be bred with sexed semen, therefore increasing the total proportion of heifers born each yield from virgin heifers relative to cows, the accuracy of selection is reduced since heifers only have a Parent Average and no performance data available but the intensity of selection is increased and the average generation interval is significantly shortened by .8 years.

Annual genetic gain was estimated for three scenarios. The first is based on the use of conventional semen to breed all breeding age heifers and cows based on the selection of top genomically tested proven sires for 65% of the breedings and elite genomically tested young bulls for the other 35% of the matings. Commonly accepted parameters were used as values for genetic variation, accuracy of selection, selection intensity rates and generation intervals, and the trait of interest was Lifetime Profit Index (LPI) since it is the main selection goal in Canada.

The second scenario included the use of sexed semen to breed the superior half of the virgin heifers and conventional unsexed semen to breed the remaining virgin heifers and cows in the herd. This use

of sexed semen on virgin heifers yields a higher portion of future replacement heifers from this group of dams. In turn, this reduces the average generation interval for dams of daughters but also decreases the accuracy of selection given that heifers have a Parent Average reliability near 35% while cows have EBV reliabilities averaging 50%, both assuming no genotyping of females in the herd. Given that sexed semen is not currently offered for most elite progeny proven sires but it is for the high end genomically tested young bulls, the portion of breedings to proven versus young sires was shifted to 55:45 instead of 65:35 as in scenario 1. In terms of genetic gain, this second scenario shortens the generation interval of sires to breed replacement heifers but also reduces the intensity of selection for proven sire matings. It also reduces the overall accuracy of selection since the average LPI reliability for genomically tested young bulls is 60% compared to 90% for progeny proven sires with genomic evaluations.

To forecast into the future, a third scenario was also evaluated for potential genetic gains. This scenario was identical to the second one except that it was assumed that there were no more technology and cost limitations associated with the production of sexed semen such that it was available for all progeny proven sires and young sires. In other words, there was no sacrifice required in terms of the intensity and accuracy of selection within the pathway of sires to breed replacement heifers, as assumed in the second scenario.

The end result of this analysis yielded a 4.4% increase in the rate of genetic gain achieved for LPI each year for use of sexed semen to breed only virgin heifers as outlined in scenario 2 compared to the use of only conventional unsexed semen in the first scenario. Under scenario 3, as sexed semen becomes increasingly available for all progeny proven sires, including elite LPI sires, the use of sexed semen to breed only virgin heifers in the herd is expected to increase the rate of genetic gain for LPI to 7% per year.

Economic Analysis of Sexed Semen Usage for Virgin Heifers

To conduct an economic analysis of the use of sexed semen in dairy herds in Canada, a Sexed Semen Cost Analysis Module developed by Paul Meyer at Westgen, Milner, British Columbia, was applied. The required input parameters are listed in Table 2 with realistic example values provided. Users of the Excel spreadsheet can input different values to best suit the herd in question. In this example, the herd has a group of 50 breeding age heifers each year of which the top 50% are to be bred with sexed semen. This 50% selection intensity is estimated to yield an average increase of $80 in terms of the genetic value of the heifers produced, and the module varies this added genetic value as the selection intensity changes. The module also allows the user to input their preferred value to override the automatic estimate provided, if desired. Since sexed semen is not recommended to breed older animals, all cows are assumed to be bred with conventional unsexed semen. Based on a survey of the major A.I. organizations offering sexed semen in Canada, conducted by the author, an average $20 increment in the cost of sexed semen versus unsexed semen was assumed with average semen prices set at $25 (unsexed) and $45 (sexed). To account for the known decrease in conception rates with the use of sexed versus unsexed semen, the example assumes a conservative conception rate of 50% for virgin heifers using unsexed semen (acceptable range is 50% to 60%) and a conception rate of 40% for unsexed semen based on a reasonable reduction to 80% of that for sexed semen (i.e.: 50% CR for unsexed semen x 0.8 for CR reduction = 40% CR sexed semen).

Table 2: Example Input Parameters Required for Sexed Semen Cost Analysis Module[1]

	Input Values
# Heifers for Breeding	50
% Heifers to Sexed Semen	50%
Unsexed Semen Price	$25
Sexed Semen Price	$45
CR - Unsexed Doses	50%
CR - Sexed Doses	40%
Added Genetic Value per Sexed Calf (Estimate)	$80
Added Genetic Value per Sexed calf (Producer)	$80
Value of Heifer Calf	$400
Value of Bull Calf	$50
Cost per Day for Extra Heifer Rearing*	$3.00

* - Extra Rearing costs for heifers can be replaced by Days Open costs for cows.

Note 1: Module was developed in Excel by Paul Meyer, Westgen, and available on demand.

The remaining parameters required include the current (or expected) market value for week-old bull and heifer calves as well as an estimated cost associated with each extra day that a virgin heifer needs to be reared due to delayed pregnancy and an increase in age at first calving. Since the market value of heifer and bull calves can be quite volatile across time, and perhaps even across herds, reasonable values of $400 for females and $50 for males were used in the example but a sensitivity analysis was also conducted to demonstrate the importance of these parameters on the resulting economic outcome of using sexed semen. A $3.00 cost was assumed for each extra day of heifer rearing, given that Canadian DHI partners use a value of $3.11 in the cow profitability index calculations they provide their clients. Should the user of the module wish to include the option of using sexed semen on cows (and account for the reduction in conception rates accordingly) the parameter of heifer rearing cost per day can be replaced by the cost for each additional day open in lactating cows.

Table 3 provides the results of the economic analysis of using sexed semen based on the example input parameters as described in Table 2. This module automatically applies two scenarios for the use of sexed semen, one where it is only used for first inseminations to breed the desired group of virgin heifers and another whereby sexed semen is also used for second services on the same heifers. The focus of this cost analysis is the evaluation of the impact on the value of all calves produced on the farm. Since most market environments yield higher values for heifer calves relative to males, the end result primarily depends on the extra calf value by producing more heifers compared to the increase cost for semen (due to price differential for sexed semen) as well as the increased number of doses of semen and the extra costs for heifer rearing due to lower conception rates with sexed semen.

The example results in Table 3 are based on very reasonable values for input parameters applied to a herd with 50 breeding age heifers. With the use of all unsexed semen the total value of resulting calves is estimated at $8,138. With the use of sexed semen to breed the top half of those heifers the total value of calves, after considering extra costs for semen and heifer rearing, increases to $8,991 (10.5%) and $9,495 (16.7%), respectively, depending if the sexed semen was used only for first inseminations or the first two inseminations.

Table 3: Output Results for Example Application of Semen Cost Analysis Module[1]

	All Unsexed Semen	Sexed Semen for 1st Services Only	Sexed Semen for 1st & 2nd Services
# Heifer Calves Born	23	27	30
# Bull Calves Born	25	21	18
Total Unsexed Doses	97	77	64
Total Sexed Doses		25	40
Extra Semen Cost per Heifer Calf		**$23**	**$33**
Total Extra Rearing Days		98	154
Extra Rearing Days per Heifer		2.0	3.1
Extra Rearing Cost per Heifer Calf		**$11**	**$15**
Total Extra Semen Cost		**$617**	**$983**
Total Extra Heifer Rearing Cost		**$295**	**$461**
Total Extra Value		**$1,766**	**$2,801**
Total Value of Calves over Extra Costs for Semen & Rearing	**$8,138**	**$8,991**	**$9,495**
Relative (%) Advantage (Loss) with Use of Sexed Semen		**10.5%**	**16.7%**

Total Value of Calves = Heifer Value + Bull Value - Semen Cost - Extra Heifer Rearing Cost

Note 1: Module was developed in Excel by Paul Meyer, Westgen, and available on demand.

In an attempt to show the importance of market value prices for heifer versus bull calves on the economic benefit associated with using sexed semen, a sensitivity analysis using the same module was conducted. While fixing all other parameters identical to those outlined in the example above (Table 1) the value of a heifer calf was incremented at intervals of $100 in the range from $200 to $700. The results, as presented in Table 4, show that heifer calf prices need to be at least $150 more than bull calf prices ($200 row in table - $50 assumed value for bull calves = $150 difference) before sexed semen starts to provide an economic advantage.

Table 4: Impact of Market Value of Heifer Calves on Economic Advantage of Sexed Semen Instead of Conventional Unsexed Semen

Heifer Calf Value at Market	Total Value of Calves over Extra Costs for Semen & Rearing				
	All Unsexed Semen	Sexed Semen for 1st Services Only		Sexed Semen for 1st & 2nd Services	
		Calf Value	% Increase	Calf Value	% Increase
$200	$3,488	$3,516	0.8%	$3,534	1.3%
$300	$5,813	$6,253	7.6%	$6,515	12.1%
$400	$8,138	$8,991	10.5%	$9,495	16.7%
$500	$10,463	$11,728	12.1%	$12,476	19.2%
$600	$12,788	$14,466	13.1%	$15,456	20.9%
$700	$15,113	$17,203	13.8%	$18,437	22.0%

Note: Assumed $50 market value for healthy newborn male calves.

While the dollar values presented in Table 4 are a function of using an example input value of 50 breeding age heifers for the herd, the percentage increase values are not affected by the actual number of breeding age heifers, whether it be 10 to several hundred. Even within a global environment that may have heifer prices at $400, which is a reasonable current estimate for Ontario, specific herds with superior genetic merit and/or a strong market for their heifer calves, such as elite breeder herds for

example, may still realize heifer calf prices of $700 and therefore gain more by the use of sexed semen to breed their virgin heifers.

An alternative strategy that may be considered by herd owners using sexed semen to minimize the extra heifer rearing costs due to delayed conception is to inseminate virgin heifers with sexed semen one heat cycle earlier than usual for conventional unsexed semen. Reducing that average age at first insemination for these virgin heifers would therefore not delay the average age at first calving, compared to using only conventional unsexed semen.

Use of Sexed Semen Requires Quality Herd Management

While sexed semen use to breed virgin heifers makes economical sense in given market environments with strong heifer calf prices relative to bull calf prices, this technology requires extra attention and quality management to avoid causing major havoc in the reproductive performance and profitability of the herd. Only herds with excellent heifer rearing programs, quality feed rations and general nutrition and effective overall herd management skills should add the complexities associated with the use of sexed semen. Improper use of sexed semen, in terms of storage, handling, thawing and insemination can significantly reduce conception rates to levels much lower than the average loss to 80% of conception rates achieved with conventional semen. In addition, virgin heifers selected for breeding with sexed semen must be healthy, normally cycling with observed heat signs, well-grown with moderate or better body condition and stress free as much as possible. Increased frequency and effort for proper heat detection will contribute to more desired results. Sexed semen is not recommended in conjunction with timed breeding protocols but the use of estrus synchronization programs with observed heat is acceptable. In addition, sexed semen is not recommended for insemination of embryo transfer donor heifers or cows. Since average conception rates in cows when bred with conventional semen is 35-40% and the use of sexed semen is expected to reduce this to a level at or below 30%, it is highly recommended that sexed semen not be used to breed cows or any age.

Summary and Conclusions

Sexed semen has been commercially offered by most global A.I. companies in North America with the standard product yielding a sex ratio of at least 90% heifers accompanied by a reduction in heifer conception rates to a level of 80% of what is achieved with conventional semen (i.e.: 40% versus 50%). Given the significant time and cost associated with the production of sexed semen, in addition to the reduced efficiency in terms of doses per collection, compared to conventional semen, most elite progeny proven sires are not available via sexed semen although an increasing trend exists towards the provision of sexed semen for elite genomically tested young sires. Under these situations, the use of sexed semen is estimated to increase the herd's rate of genetic progress by 4.4% per year, compared to no use of sexed semen, which could gradually increase to 7% per year if sexed semen progressively became available for all elite A.I. sires, both young and progeny proven.

From an economical perspective, the use of sexed semen to breed a portion (or all) of the virgin heifers in a herd, regardless of herd size, yields financial advantages once market prices for week-old heifers exceed that for bull calves by at least $150. The economic benefits increase proportionally as this price difference expands due to higher heifer value prices.

Sexed semen is recommended for breeding only virgin heifers that have been well managed, are healthy with good body condition and are reproductively fit with clear heat signs. Sexed semen should not be used to breed cows or in conjunction with any embryo transfer donor inseminations or timing breeding protocols. Use of sexed semen should be considered by owners of herds with quality heifer rearing, nutritional and general herd management systems in order to capitalize on the potential genetic and economic gains available via this new technology in the early stages of broad adoption across the industry.