



# Effect of Sexed Semen on Dairy Heifer Supply from 2006 to 2012<sup>1</sup>

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## Introduction

Commercialization of X-sorted (female) sexed semen started in 2003, but sales did not take off until early 2006. Presently, all major North American artificial insemination (A. I.) companies sell sexed semen from dairy sires. Demand for sexed semen was greater than the supply of sexed semen until the end of 2008 when the sorting capacity was doubled. In addition, low milk prices in 2009 caused a sharp reduction in demand, and consequently many A. I. companies produced less sexed semen in 2009 than in 2008. This fact sheet describes the estimated impact of the use of sexed semen on the national dairy heifer supply.

## Sorting technology

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. The first step in this procedure is to dilute sperm to a very low concentration and stain them with a harmless DNA-specific fluorescent dye. The

sample is then sent through the flow cytometer at 60 mph under 40 psi of pressure. Stained sperm are aligned single file in a fluid stream. Then cells of interest are identified at a particular droplet and sorted if classified as a cell of interest. Droplets holding the cell of interest are deflected into a catch tube. As the cells enter the laser beam profile, they emit light proportional to the amount of DNA. For the sorting to be successful, each sperm head must be precisely oriented so the DNA content can be accurately determined.

Because an X chromosome is larger, it emits slightly more light than a Y-chromosome-bearing sperm cell (male). Detectors measure the amount of fluorescence or light emitted and assign positive or negative charges to each droplet containing a single sperm. Charged deflector plates then split the single stream into three streams: positively charged droplets containing X-bearing sperm go one direction while negatively charged Y-bearing sperm are deflected in the opposite direction. Uncharged droplets containing dead, multiple cells in one drop, or droplets with unidentified, unresolvable sperm pass straight through. This procedure separates sperm of the two sexes with approximately 90% purity (Amann 1999).

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To properly sort, sperm must be precisely oriented as they pass through the laser and fluorescence detectors in the flow cytometer. Due to the flat shape of bull sperm heads, only about 60 to 70% are correctly oriented and half of these are female. Thus, only 15% of the sperm going into the 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 since 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 dictate that sexed semen is sold at a higher price than the same bull sperm 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.

A. I. organization Genex Cooperative, Inc., also offers sexed semen that gives a 75% chance of a heifer calf. The same technology and sorting process is used that produces sexed semen with a 90% chance of a calf. Fertility is expected to be similar to that of 90% sorted semen. Because more sperm can be sorted, the price of the 75% product is less than that of the 90% product, and more elite sires are available.

### **Licensing and production of sexed semen**

In the 1980s, a breakthrough in described sex sorting technology was made by United States Department of Agriculture researchers in Livermore, California, and Beltsville, Maryland, (Garner et al. 1983; Johnson et al. 1989). The patents for this technology were licensed to XY Inc., Fort Collins,

Colorado, which performed a considerable amount of research during the 1990s to optimize efficiency of these sorting procedures (Seidel et al. 1999; Schenk et al. 1999). Commercialization of sexed semen in the United States started in 2003 with a license granted to Sexing Technologies (ST). In February 2003, the first ST sexing laboratory started operations in Navasota, Texas. In February 2006, a second laboratory was established in Plain City, Ohio, at Select Sires Inc. In August 2006, an ST laboratory opened in Madison, Wisconsin and was affiliated with ABS Global, Inc. During mid-2007, an ST sorting laboratory was opened in Ithaca, New York, for Genex Cooperative, Inc. In January of 2008, ST started a sorting laboratory outside of Calgary, Alberta, Canada, for Alta Genetics Inc. In mid-2008, ST opened another sorting laboratory in Fond du Lac, Wisconsin. An ST sorting laboratory started in the fall of 2008 in Baraboo, Wisconsin for Accelerated Genetics. Presently, all major North American A. I. companies have an ST laboratory near a production facility to sort semen with approximately 70 sorting machines. Semen was processed 24 hours per day, seven days per week until the start of 2009 when demand decreased as a result of the sharp declines in milk prices. Several A. I. companies reported less sorting in 2009 and an increased storage of the sorted semen.

Given the 63,000 units per year that can be produced with one machine, the 70 machines running at maximum capacity could produce approximately 4.4 million units per year. However, some of the production will be beef and maybe as much as 10% of production will be sexed semen for the international dairy market. In early 2006, approximately 18,000 units were produced monthly. By the end of 2008, this number had increased to approximately 300,000 units. Total sexed-semen production for the U.S. dairy market in 2008 was estimated at 2.5 million units.

For 2009, total sexed-semen production is more difficult to measure because demand was much less than the sorting capacity. Reports are that some A. I. companies produced less than 50% of the 2008 production. Estimates for 2009 are 1 to 1.4 million units of sexed semen produced.

## Results with sexed semen

Research has consistently demonstrated that the technology used to sort semen produces about 90% of calves with the desired gender (DeJarnette et al. 2008; 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,  $\leq 80\%$  of the offspring will be heifer calves. Seven percent of the time,  $\leq 70\%$  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 (excluding the 75% sexed product from Genex Cooperative, Inc.).

Sexed semen has always been recommended for use in heifers because of the known compromise in conception rates largely due to the reduced sperm number per unit. Initial reports published from a limited number of inseminations warned of approximately a 30% reduction in conception rates in virgin heifers (Olynk and Wolf 2006). In January 2008, insemination and calving information were retrieved from 198 dairy herds that had used Select Sires' sexed semen from January 2005 to January 2008. The unadjusted conception rate for 41,398 inseminations using sexed semen was 45%. Across all herds, 74% of sexed semen was used at 1st insemination, 18% at 2nd insemination, and 8% at  $\geq 3$ rd insemination. The conception rate was 47%, 40%, and 34% for insemination numbers 1st, 2nd and  $\geq 3$ rd, respectively. These actual field results revealed that sexed semen was achieving approximately 80% of the conventional semen conception rate (a 20% reduction in conception rates compared to unsorted semen).

## Recommended use of sexed semen

The optimal use of sexed semen depends on many economic and biological factors. The return on investment for the dairy producer depends on a complex interaction between the initial conception rate with conventional semen, the percent reduction in conception rate due to use of sexed semen, the price differential between sexed and conventional

semen, the value differential between bull and heifer calves, and the enterprise that the extra heifers will be used for (herd replacements, to contract, etc.). Most of these factors will change considerably from herd to herd, which affects the value of sexed semen to each respective producer.

There is no reliable rule of thumb that can dictate proper use across the variety of herds, cows, and economic scenarios possible. Dairy producers could use sexed semen to produce more herd replacements, to produce heifers to sell to other dairy producers, or both. Increasing replacements from within reduces the risk of introducing infectious diseases and increases biosafety. Sexed semen will produce more heifer calves that have lower birth weight than bull calves and will reduce the rate and cost of difficulty calvings. Difficult calvings occur in approximate 1 out of every 10 calvings of first lactation heifers. With sexed semen, culling of poor-performing, growing heifers is more feasible, thereby avoiding losses associated with bringing them into the herd only to have them removed early in lactation. In some specialized dairy sectors, such as organic dairies and herds using crossbreeding programs, the value of replacements may remain significantly above the cost of rearing, making sexed semen very valuable.

Economic analyses that have included these 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). Sexed semen could have value in some cows if the reduction in conception rate is modest, heifer calf prices are high compared to bull calves, and the price of sexed semen is reasonable compared to conventional semen.

## Actual use of sexed semen

Actual use of sexed semen follows the results of the economic analyses. That means that most sexed semen has been used in heifers, and then primarily in the first insemination, and little in cows. The USDA-Animal Improvement Programs Laboratory (USDA-AIPL) reports that in Dairy Herd Improvement (DHI) herds, sexed semen was used for 1.4, 9.5, and 17.8% of all reported inseminations in

heifers for 2006, 2007, and 2008, respectively, and for 0.1, 0.2, and 0.4% of all reported inseminations in cows (Norman et al. 2009). For heifers, 82% of all sexed-semen use was in first inseminations. For cows, 61% of sexed semen was for first parity and 43% for first inseminations of the first parity. Larger herds, herds with higher production levels, and herds in the Northwest, Mideast, Midwest, and Southeast used sexed semen more frequently than other herds and regions.

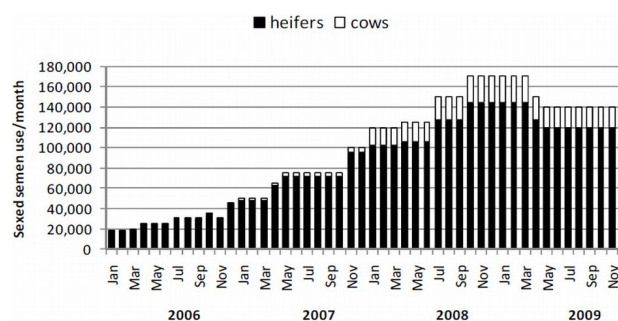
USDA-AIPL calculated that 37% of the 700 active Holstein bulls born in 1994 and later had their sexed semen used in the April 2009 national genetic evaluation (Norman et al. 2009). These 260 bulls were on average slightly better than the average bull-for-milk yield traits (fat, protein, yield), productive life, somatic cell score, daughter pregnancy rate, service-sire calving ease, service-sire stillbirth, sire conception rate, final score, and Net Merit.

Results from a study by Select Sires Inc. of 211 dairy farms suggest that—in heifers—age at first insemination and age at calving was younger when sexed semen was used (DeJarnette et al. 2009). This is a result of the preferential use of sexed semen at first insemination. Cycle lengths were not affected by the use of sexed semen. Sexed semen did not affect stillbirth rates in heifers getting heifer calves, but among heifers getting bull calves (from sexed semen, a 10% chance), the incidence of stillbirths appeared higher. In all calvings resulting from sexed semen, the total incidence of stillbirth was similar as when conventional semen was used. Caution must be used when interpreting results from field data because of the preferential use of sexed semen (only heifers with good standing estrus are inseminated with sexed semen, for example). Heifer calves resulting from sexed semen appear to be completely normal.

## Effect of sexed semen on the national heifer supply

Figure 1 shows the timing and number of sexed semen units used in the domestic dairy market. Until the end of 2008, the produced units have been used in inseminations almost immediately after they have become available. Production in 2009 is reported to

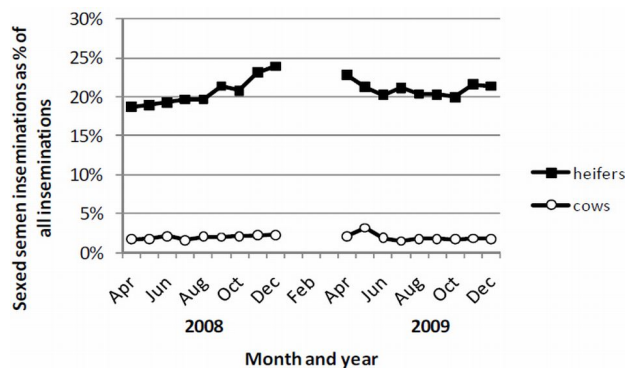
be significantly less, but the fraction of sexed semen used in all inseminations apparently did not change much. Dairy producers probably used up their semen inventories in early 2009 to save on expenses.



**Figure 1.** Estimated amount of used sexed-semen units in the U.S. dairy market from January 2006 to December 2009. Until late 2008, almost all produced units were used in inseminations within a few months. In 2009, less units were produced but apparently a similar number of sexed semen units were used.

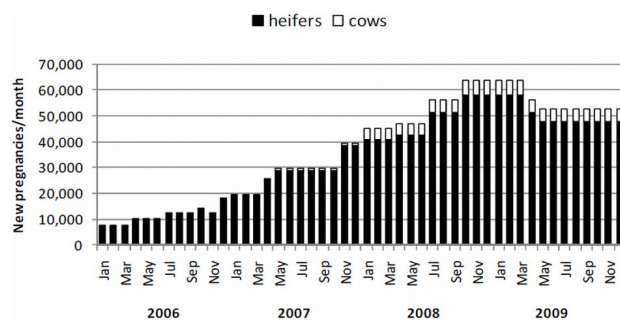
Furthermore, the vast majority of sexed semen has been used in virgin heifers. Our estimates are that in 2006, 99% of the produced sexed semen was used in heifers. In 2007, 2008, and 2009, these percentages were 96%, 85%, and 85%, respectively. The remainder was used in cows. Thus, more of the sexed semen was used in cows in late 2008 and 2009 than during the early commercialization in 2006, but the use was still limited.

Data Records Management Systems (DRMS), in Raleigh, North Carolina, reported that the percentage of sexed semen inseminations of all reported inseminations in heifers was 18.7% in April 2008 and increased to 23.9% in December 2008 (John Clay, DRMS, personal communication) (Figure 2). In April 2009, sexed-semen use in heifers was 22.8% and then varied between 20.2 and 21.6% until December 2009. For cows, sexed semen accounted for 1.7% of all reported inseminations in April 2008 and increased to 2.3% in December 2008. In 2009, the use of sexed semen in cows decreased again to approximately 1.6% in cows. Note that this use in cows is significantly more than the 0.4% reported by USDA-AIPL for 2008. The low milk prices in 2009 apparently did little to the use of sexed semen that year. These usage data and production data prior to 2008 are the basis for the following calculations on how the use of sexed semen affects the national heifer supply.



**Figure 2.** Sexed-semen inseminations as percent of all reported inseminations to DRMS, Raleigh, North Carolina, in heifers and cows in April–December 2008 and April–December 2009 (Source: John Clay, DRMS, personal communication).

The number of new pregnancies with heifer calves from sexed-semen inseminations has increased from 7,200 in January 2006 to 58,000 in December 2008, after which it decreased to 40,000 to 50,000 per month in 2009 (Figure 3). The results for late 2008 are less than predicted in 2009 (De Vries and Nebel 2009). These estimates include 45% and 28% conception rates with sexed semen in heifers and cows, respectively. It also includes a small adjustment for abortions. And furthermore, 90% of the new pregnancies are heifer calves. Because cows have lower conception rates than heifers, cows contributed only 0.6% (2006) to 10% (2008 and 2009) of the new pregnancies from sexed semen.



**Figure 3.** Number of new pregnancies with heifer calves per month in those heifers and cows inseminated with sexed semen from January 2006 to December 2009.

If these same heifers and cows had conceived with conventional semen (48% heifer calves), the number of new pregnancies with heifer calves would have been approximately 3,800 in January 2006 to 31,000 per month in late 2008 and back to about 24,000 per month in 2009. Thus, almost half of the heifers and cows would also be carrying a heifer calf

if they had been inseminated with conventional semen. These heifer calves must be subtracted from the heifer calves from sexed semen to calculate the net gain. The monthly net gain in number of heifer calves ranges from 3,400 in January 2006 to 30,000 per month in late 2008 to 25,000 per month during 2009. Summed over the four years (2006 to 2009), the number of extra heifer calf pregnancies due to the use of sexed semen is 820,000. Per unit of sexed semen, about 17% more heifer calves were obtained.

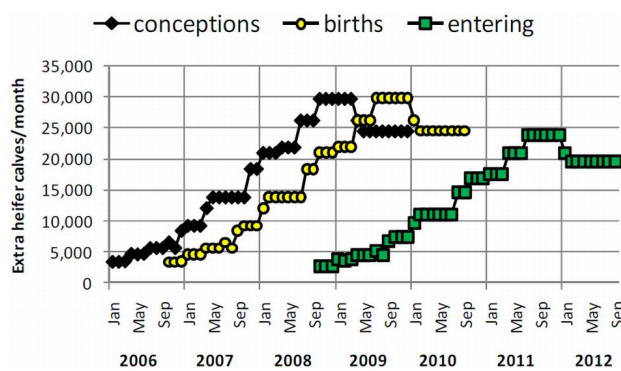
These numbers of new pregnancies with heifer calves from sexed semen need to be compared with the total number of new pregnancies with heifer calves on U.S. dairy farms. USDA estimates available on the University of Wisconsin dairy markets Web site (<http://future.aae.wisc.edu>) showed the national population of dairy cows at about 9.1 million in 2006 and increasing to 9.3 million in late 2008 and 9.1 million in 2009. Commercial dairy cow slaughter and death losses accounted for approximately 3.2 million cows in 2006 and 3.5 million in 2009. Average annual national cull rate (including deaths) is then 35%, which agrees with the 2007 Dairy Report from USDA (2008). Culled and dead cows are replaced by calving heifers because the national cow population is fairly constant. Thus, approximately 275,000 heifers will calve monthly (starting first parities). We also estimated that approximately 440,000 cows will calve monthly (starting second and greater parities).

Of all conceiving heifers, 3% (early 2006) to 23% (late 2008), and decreasing to approximately 20% in 2009, became pregnant with sexed semen. Of the conceiving cows, 0.01% (early 2006) to 1.4% (late 2008) and then decreasing to 1.2% (in 2009) became pregnant with sexed semen. The remainder of the calving heifers and cows then became pregnant with either conventional A. I. or by natural service bulls, with 48% of these pregnancies resulting in heifer calves. Sexed-semen use has caused 1% (early 2006) to 8% (late 2008) to 7% (2009) more heifer calves in new pregnancies than if conventional semen had been used.

Figure 4 shows when the extra heifer calves that are a result of the use of sexed semen are conceived



(conceptions), born (births) and when they are expected to enter the milking herd as heifers themselves (entering). We assumed that 80% of heifer calves enter the milking herd as heifers 24 months after they are born. The first heifer calves conceived with sexed semen in early 2006 were starting to enter milking herds in late 2008. The estimated numbers of extra heifers entering the national milking herd in 2008, 2009, 2010, 2011, and 2012, as a result of the use of sexed semen, are 8,000, 63,000, 156,000, 258,000, and 237,000. Based on the conceptions from sexed semen from 2006 to 2009, a total of 722,000 extra heifers are projected to calve in the five years from 2008 to 2012.



**Figure 4.** Number of extra heifer calves in the national population (heifers and cows) that resulted from inseminations (conceptions) with sexed semen from January 2006 to December 2009. These heifer calves are born (births) 9 months after conception and enter herds 24 months after they are born (entering).

## Summary

Commercial sales of sexed semen for dairy cattle in the U.S. started to take off in 2006. The use of sexed semen is estimated to have increased from 18,000 units per month in early 2006 to approximately 170,000 units per month in late 2008. In 2009, the use decreased to approximately 140,000 units per month. Because sexed semen has lower fertility than conventional semen, dairy producers have used sexed semen primarily in virgin heifers. Approximately 20% of all heifer inseminations were to sexed semen in 2008 and 2009. For cows, approximately 1.2% of all inseminations were to sexed semen in 2008 and 2009. The first heifer calves conceived with sexed semen in early 2006 were starting to enter milking herds in late 2008. The estimated numbers of extra heifers entering the

national milking herd in 2008, 2009, 2010, 2011, and 2012, as a result of the use of sexed semen, are 8,000, 63,000, 156,000, 258,000, and 237,000. Based on the conceptions from sexed semen from 2006 to 2009, a total of 722,000 extra heifers are projected to calve in the five years from 2008 to 2012.

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