National Heifer Supply and the Effects of Sexed Semen

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Summary

Commercial sales of sexed semen for dairy cattle in the US started to take off in 2006. Use of sexed semen is estimated to have increased from 18,000 units per month in early 2006 to 300,000 units per month in late 2008. Because sexed semen has lower fertility than conventional semen, dairy producers have used sexed semen primarily in virgin heifers. For December 2008, we estimated that 37% of all heifers that got pregnant that month conceived with sexed semen. In that month, 2.5% of all cows that became pregnant conceived with sexed semen. Together, we estimated 12.4% more heifer calves as a result of the use of sexed semen in the cows and heifers that became pregnant that month than if conventional semen had been used. In December 2008, 7% more heifer calves were born than would be born if only conventional semen had been used. The first heifer calves conceived by sexed semen in early 2006 were starting to enter milking herds late 2008. We estimated that less than 1% of all heifers entering milking herds by the end of 2008 were conceived by sexed semen. By the end of 2009, this will be about 2% of all entering heifers and 6% by the end of 2010. The impact of sexed semen on the national heifer supply has been small, but is expected to grow.

Introduction

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. Dairy producers have always been interested in sexed semen because heifer calves are generally much more valuable than bull calves.

Commercialization of X-sorted sexed semen started in 2003 but sales did not take off until early 2006. Presently, all major North American A.I. companies sell sexed semen from dairy sires. Demand has been greater than the supply of sexed semen which has thus far resulted in rapid use in inseminations of all processed sexed semen for the US market. As of December 2008, the use of sexed semen has already resulted in more heifer calves being born and more heifer calves are expected to be born in the near future. In this paper we describe the estimated impact of the use of sexed semen on the national heifer supply. We also briefly describe the technology and current results with sexed semen.

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 pressures of 40 psi. 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. 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).

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% is 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 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 processes 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.

Licensing and production of sexed semen

In the 1980's, a breakthrough in the described sex sorting technology was made by United States Department of Agriculture researchers in Livermore, CA and Beltsville, MD (Garner et al., 1983; Johnson et al., 1989). The patents for this technology were licensed to XY Inc., Fort Collins, CO, which performed a considerable amount of research during the 1990's 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, TX. In February 2006, a second laboratory was established in Plain City, OH at Select Sires Inc. In August 2006, a ST laboratory opened in Madison, WI and was affiliated with ABS Global. During mid-2007 a ST sorting laboratory was opened in Ithaca, NY for Genex Inc. and XY licensee in Canada for Semex 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, WI. The latest ST sorting laboratory started in the fall of 2008 in Baraboo, WI for Accelerated Genetics. Presently (December 2008), all major North American A.I. companies have a ST laboratory near a production facility to sort semen with approximately 70 sorting machines processing semen 24 hours per day seven days per week.

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. Figure 1 shows the estimated monthly amount of sexed semen units produced for the US dairy market from January 2006 to December 2008 based on the capacity of sex sorting laboratories. 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 US dairy market in 2008 is estimated at 2.5 million units.

Total sexed semen production from 2006 to the end of 2008 is probably equal to the projected production in 2009 if all machines are used to maximum capacity. Therefore, for the US dairy market, a total of 3.7 million units of sexed semen are expected to be produced in 2009.

Results with sexed semen

Research has consistently demonstrated that the technology used to sort semen produces about 90% calves with the desired gender (DeJarnette et al., 2008). 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.

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 of 2008, insemination and calving information were retrieved from 198 dairy herds that had used Select Sires' gender SELECTed™ sexed semen from January 2005 to January 2008. The unadjusted conception rate for 41,398 inseminations to gender SELECTed™ semen was 45%.

Across all herds, 74% of gender SELECTed™ semen was used at 1st insemination, 18% at 2nd insemination, and 8% at ≥3 insemination. The conception rate was 47%, 40%, and 34% for insemination numbers 1, 2 and ≥3, respectively. These actual field results revealed that gender

SELECTed™ 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 by increasing biosecurity. Sexed semen will produce more heifer calves that have lower birth weight than bull calves, and will reduce 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). 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. Data from the April, 2008 national genetic evaluation by USDA-Animal Improvements Laboratory (USDA-AIPL) revealed that from 2006 to April 2008, 9.2% of Holstein heifers had at least one insemination with sexed semen (Hutchison and Norman, 2009). Sexed semen was used in 6.8% of all heifer inseminations (by AI). In that same time period, they reported that 2.4% of all Holstein cows had at least one sexed semen insemination; or 0.9% of all reported cow inseminations. (Our own calculations indicated that sexed semen accounted for only 0.3% of all cow inseminations in that period). Larger herds and herds with higher production levels, and herds in the Northwest, Mideast, and Midwest used sexed semen more frequently than other herds and regions.

Actual use of sexed semen over time has been growing, as was already evident by the increasing number of sorting machines over time. The USDA-AIPL data showed that sexed semen inseminations accounted for 1.5%, 9.6%, and 14.2% of all reported inseminations in 2006, 2007, and

2008. For cows, sexed semen inseminations accounted for 0.1% (2006), 1.3% (2007) and 2.1% (2008) of all reported (AI) inseminations. (Again our estimates are lower: 0.02%, 0.2%, and 1.4%, respectively).

USDA-AIPL also reported that for heifers, 80% of sexed semen was used in the first insemination. In cows, 49% of sexed semen was used in first parity cows including 21% on first insemination. Similarly, the 198 dairy herds that had used Select Sires' gender SELECTed™ sexed semen from January 2005 to January 2008 reported that across all herds, 74% of gender SELECTed™ semen in heifers was used at the 1st insemination, 18% at the 2nd insemination, and 8% at ≥3 inseminations.

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 Net Merit. They were also slightly better for somatic cell score, calving ease, and stillbirth.

Results from Select Sires Inc. of 211 dairy farms suggest that in heifers age of 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 showed the timing and number of sexed semen units produced for the domestic dairy market. The produced units have been used in inseminations almost immediately after they became available. Further, 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 and 2008, these percentages were 96% and 85% respectively. The remainder was used in cows. Thus, more of the sexed semen was used in cows in late 2008 than during the early commercialization in 2006, but the use was still limited. These data are the basis for the following calculations on how the use of sexed semen affects the national heifer supply.

The number of new pregnancies with heifer calves from sexed semen inseminations has increased from 7,200 in January 2006 to 112,000 in December 2008 (Figure 2). 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 further, 90% of the new pregnancies are heifer calves. Because cows have lower conception rates than heifers, cows contributed only 0.6% (January 2006) to 10% (December 2008) of the new pregnancies from sexed semen.

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 60,000 in December 2008. 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 52,000 in December 2008. Summed over the three years (2006 to 2008), the number of extra heifer calf pregnancies due to the use of sexed semen is 630,000. Per unit of sexed semen, we got about 17% more heifer calves.

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 US dairy farms. USDA estimates available on the University of Wisconsin dairy markets website (http://future.aae.wisc.edu) showed the national population of dairy cows at about 9.1 million in 2006 and increasing to 9.2 million in 2008. Commercial dairy cow slaughter and death losses accounted for approximately 3.2 million cows in 2006 and 3.5 million in 2008. Average annual national cull rate (including deaths) is then 36%, 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 277,000 heifers will calve monthly (starting first parities). We also estimated that approximately 459,000 cows will calve monthly (starting second and greater parities).

Of all conceiving heifers, 3% (early 2006) to 37% (late 2008) got pregnant with sexed semen. Of the conceiving cows, 0.01% (early 2006) to 2.4% (late 2008) got pregnant with sexed semen (Figure 3). The remainder of the calving heifers and cows then became pregnant with either conventional AI or by natural service bulls, with 48% of these pregnancies resulting in heifer calves. Nationally, the total number of new pregnancies with heifer calves is approximately 370,000 per month. Sexed semen use has caused 1% (early 2006) to 12% (late 2008) more heifer calves in new pregnancies than if conventional semen has been used (Figure 4).

Figure 4 also shows when the extra heifer calves are 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. For December 2008, we estimated 12.4% more heifer calves as a result of the use of sexed semen in the cows and heifers that became pregnant. During late 2008, 7% more heifer calves were born than would be born if only conventional semen had been used. The first heifer calves conceived with sexed semen in early 2006 were starting to enter milking herds in late 2008. We estimated that less than 1% of all heifers entering milking herds by the end of 2008 were conceived with sexed semen. By the end of 2009, this will be about 2% of all entering heifers and 6% by the end of 2010.

The heifer calves from the cows and heifer that are getting pregnant with sexed semen in December 2008 will enter herds approximately in September 2011. At that time, 10% from all heifers entering milking herds was conceived with sexed semen.

Economic implications

The use of sexed semen for gender selection is a reality today. Most dairy producers have used sexed semen to produce more heifers by using it at every first insemination in virgin heifers that are detected in estrus regardless of the genetic merit of the heifer. Because of high market prices for replacement heifers, high milk prices, reproductive inefficiency of dairy herds, and the shortage of heifers for replacements, sexed semen has been used to just get more heifers.
The analysis above has shown that the impact of the use of sexed semen on the availability of springing heifers has thus far been limited. There is some concern that the expected increase in the

number of heifers will promote expansion of the national cow herd, increase the supply of milk, and trigger a drop in milk prices. Future prices depend on many factors beyond the supply of heifers so predictions are quite uncertain.

In 2008, about 8,100 extra heifers will be entering milking herds as a result of the use of sexed semen. In 2009, this number is increased to 63,000 extra heifers. For 2010, our calculations show that 161,000 extra heifers are expected to enter the milking herd.

For comparison, the CWT Herd Retirement Program removed in the five years from 2003 to 2007 respectively 32,724, 50,478, 64,069, 52,783, and 0 cows from the national population. The effect of these removals has been estimated by Dr. Scott Brown from the University of Missouri to increase the milk price by $0.05, $0.17, $0.42, $0.55 and $0.62 per cwt in each of these years (http://www.cwt.coop/pdf/cwt_brochure.pdf). The effect of cow removal lasts several years; for example, the cows removed in 2006 still had an effect on the milk price in 2008 but not as great as in 2007. On average, the CWT Herd Retirement Program effect on milk prices was an increase of $0.25 per cwt per 100,000 cows removed. This effect would continue a few years after the cows were removed. If these relationships continue to hold from 2008 to 2010, the extra heifers entering the national herd would reduce the milk price by $0.02, $0.16 and $0.40 per cwt, respectively.

On the other hand, sexed semen is expected to reduce the cost of milk production. The increase in the supply of heifers likely will decrease the heifer calf price and the purchase price of springing heifers. In the longer term, heifer purchase prices would be reduced to the cost of rearing and a modest profit. This is a cost savings for dairy producers that purchase heifers. For example, a $300 lower heifer price would equal a cost savings of $100 per cow per year in a herd with a 33% cull rate. The $100 savings would offset a decrease in milk price of $0.40 per cwt in a herd with cows producing 25,000 lbs annually.

Lower heifer prices should allow for a small increase in voluntary cull rates as well (De Vries et al., 2008) which also improves farm profitability. If producers are going to cull more heavily, a slightly greater voluntary cull rate will help reduce growth of the national population, thereby reducing the growth of the milk supply and potentially avoiding a reduction in milk prices.

The value of sexed semen in the future will be to source replacement heifers from the best cows in the herd. Who do you really want your replacements from? Sexed semen provides an opportunity to advance the genetic merit of cows in the herd by selecting the best heifers or maybe even cows to be the dams of herd replacements. In conjunction with high genetic merit sires, sexed semen will produce more rapid genetic advancement than obtaining replacements from the whole herd. For this to work, the dairy must be able to rank its dams by genetic merit so sire ID is a must. Genomics testing will be another tool that producers can use to identify the gene profile of dams most eligible for sexed semen. Herds that desire to guarantee a more reliable and better quality of internally grown heifers will use sexed semen to source more heifers and improve biosecurity.

Collectively, the benefits for dairy producers appear to outweigh the possible negative effect of a small increase in the national heifer supply. The cost of milk production will likely be reduced which should benefit consumers as well.

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Figure 1. Estimated amount of produced sexed semen units for the US dairy market from January 2006 to December 2008. Almost all produced units are used in inseminations within a few months.

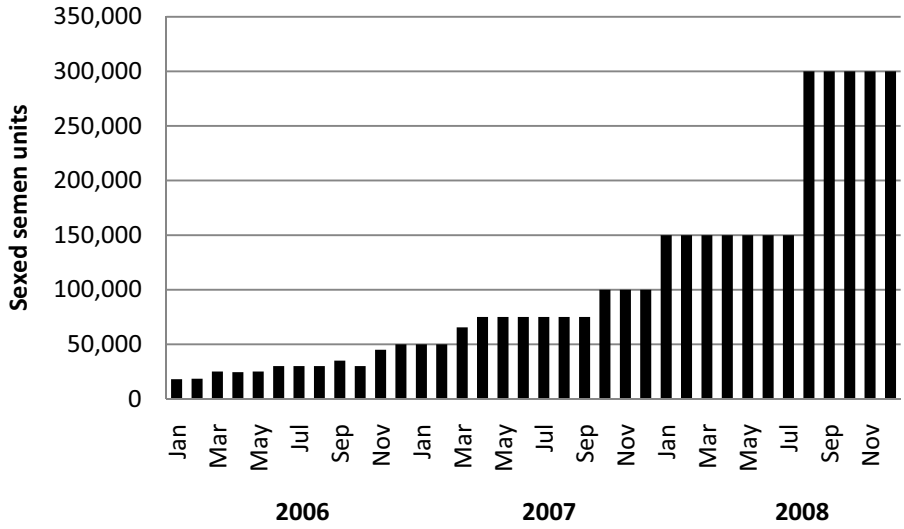

Figure 2. Number of new pregnancies with heifer calves per month in those heifers and cows inseminated with sexed semen from January 2006 to December 2008.

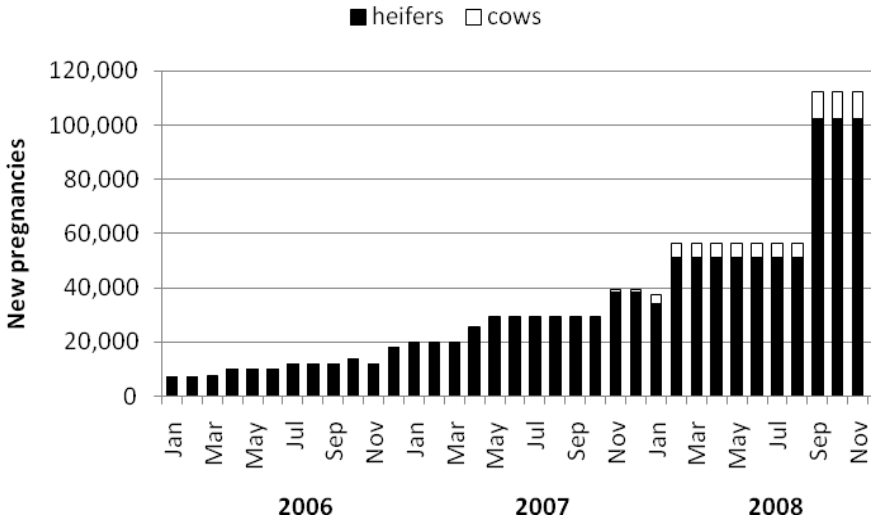

Figure 3. Percentage of new pregnancies with heifer calves in the national population (heifers and cows) that result from inseminations with sexed semen from January 2006 to December 2008.

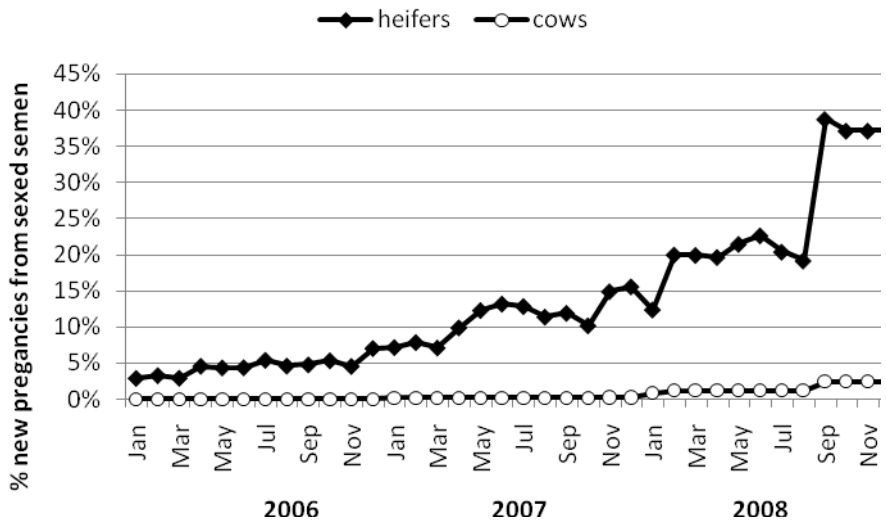

Figure 4. Percentage of extra heifer calves in the national population (heifers and cows) that resulted from inseminations (conceptions) with sexed semen from January 2006 to December 2008. These heifer calves are born (births) 9 months after conception and enter herds 24 months after they are born (entering).