SEXED SEMEN – HOW IT IS PRODUCED AND HOW CAN WE USE IT EFFECIENTLY[1]

J. B. Hall and J. B. Glaze, Jr.

Department of Animal and Veterinary Science
University of Idaho

Introduction

Gender selected or sexed semen has been commercially available to the dairy industry for almost a decade. However, sexed semen from beef bulls has only recently become commercially available. The availability of sexed semen from beef bulls along with concerns about success of the technology at the ranch level has limited the use of sexed semen in purebred and commercial beef operations. Recent changes in semen availability combined with current studies with sexed beef semen are providing insights to the uses, limitations, opportunities, and challenges of this technology.

Increased sorting capacity allowed the number of beef bulls with gender selected semen available to increase exponentially over the last five years. For the major US AI studs, the number of beef bulls with gender sorted semen available increased from 0 to 70 from 2008 to 2011 (Hall, 2011). The number of beef bulls with sexed semen available from major studs appears to have stabilized around 60-70 bulls per year. Some major AI studs are no longer offering sexed beef bull semen, while others are offering the service only if the entire collection is purchased (personal communications). Sexing Technologies lists 47 sires with sexed semen in their catalog. In addition to sex sorting operations at all major bull studs in the US and several other countries, Sexing Technologies now has custom semen sexing operations in five locations across the US. However, the number and genetic diversity of beef bulls with sexed semen available is limited compared to the offering of AI beef bulls with conventional semen. While not an overwhelming selection of bulls and genetics, there are now sufficient numbers of beef bulls with sexed semen to begin to meet the needs of the seedstock sector, and address the wanted traits for the commercial producer.

This paper addresses results from studies involving the use of sexed semen in beef herds as well as discussion of possible applications of sexed semen in the beef industry. Many of the papers in these proceedings contain information and recommendations based on years of research with hundreds or thousands of animals at university and field locations. In contrast, the information presented here is based on limited controlled trials. The reader is cautioned not to extrapolate results too greatly and to be cognoscente of the relative risk to reward ratio for this technology. The continuing research into improving success of sexed semen in beef operations makes consideration of sexed semen a reality for some beef producers.

---

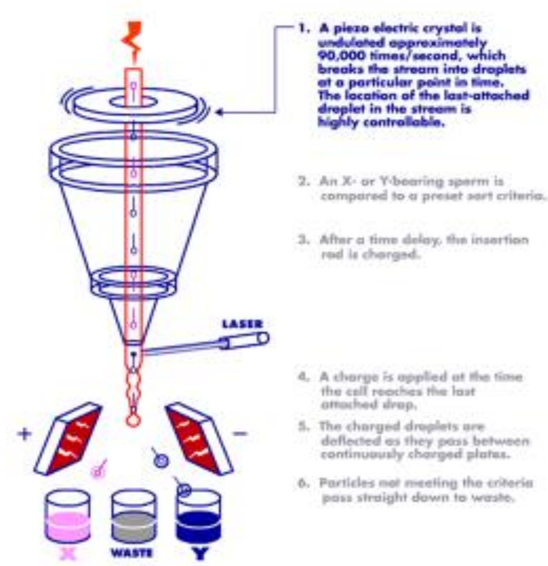
[1] Research conducted by the University of Idaho presented in this manuscript was supported by the Idaho Agricultural Experiment Station, UI Department of Animal and Veterinary Science, and UI Nancy M. Cummings REEC. The authors gratefully acknowledge Pfizer Animal Health (New York, NY) for providing Lutalyse sterile suspension and EAZI BREED CIDR Cattle inserts; Merial (Athens, GA) for providing Cystorelin; Genex and ABS Global for providing semen and AI technicians; The American Simmental Association, AgriBeef Co. and Northwest Simmental breeders for supplying natural service sires.

How is Sexed Semen Produced?

The current status of the technology for sex-sorting bull semen was reviewed recently by Dr. George Seidel, Jr. (2014); therefore, this section will briefly review the technology involved in sexing semen. The only reliable way to sort semen by sex is using flow cytometry or cell sorting. The basis of the current method was established and patented by USDA researchers in the late 1980's and early 1990's (Johnson et al, 1989), and involves sorting each sperm cell individually. The basis for this sorting is that X-bearing sperm contain slightly more DNA that Y-bearing sperm.

After collection, the semen is extended and treated with Hoechst 33342 DNA-binding dye. In the sorting machine, each sperm cell is placed in an individual droplet. The dye will fluoresce when exposed to a laser differentiating X from Y-bearing sperm. Based on the sex determined, a charge is placed on the droplet and the charged deflector sorts the sperm into one of three collection vessels – X, Y, and waste (Figure 1). Sperm that are damaged, oriented incorrectly, or cannot be "read" are discarded. Approximately, 25% of each ejaculate is sorted at X and another 25% is sorted as Y. Sorting accuracy can be adjusted, but most companies sort for 90% accuracy. After sorting, the concentration of sperm in the collection vessels is dilute. Sorted sperm must be concentrated by centrifugation which results in additional loss of sperm numbers (Seidel, 2014).

Figure 1. Semen Sexing Procedure



(Mo-Flo diagram courtesy of XY Inc.)

While sorting speeds are extremely fast at 30,000 sperm/s/nozzle with most machines running two nozzles, time to produce a straw of semen is still very great. Total output of sorted sperm is limited to about 14 straws sorted for each sex per hour when straws are packaged with 2 million cells per straw (Seidel, 2014). At many locations with sex-sorting flow cytometers, the machines run 24/7. Output of straws of sexed semen is about 200 per collection. In some instances, the collection may be split between sexed and conventional semen.

Results of AI with Sexed Semen in Beef Cattle

Several large scale studies with use of sexed semen in dairy heifers indicate that pregnancy rates are 10% to 20% lower with sexed semen compared to conventional semen (Seidel et al., 1999; DeJarnette et al., 2009). Using information from 39,763 inseminations with sexed semen and 53,718 inseminations with conventional semen, DeJarnette and coworkers (2009) reported heifer pregnancy rates of 45% and 56% for sexed and conventional semen, respectively. As typical with lactating dairy cows, pregnancy rates are considerably less in dairy cows than in dairy heifers. This led to the general recommendation that sexed semen should be used preferentially in heifers. Controlled studies comparing sexed beef semen to conventional semen are considerably more limited that experiments in dairy cattle.

Results in heifers

Early work which combined results from dairy and beef heifers indicated that conception rates to sexed semen were 70% to 90% of conception rates to conventional semen (Seidel et al., 1999). Nebraska researchers (Deutscher et al., 2002) reported a 3% to 13% reduction in AI pregnancy rates when using sexed versus conventional semen in yearling beef heifers. Similarly, Rhinehart and co-workers (2011) reported a 4% to 38% reduction in pregnancy rates when using sexed compared to conventional semen in beef heifers. More recently, insemination of synchronized heifers with sexed semen resulted in a 17% decrease in pregnancy rates to AI compared to heifers inseminated with conventional semen (Meyer et al., 2012). In this study, a majority of the heifers were inseminated after detected estrus, whereas heifers not detected in estrus were mass mated by FTAI. In general, technical services personnel from the major AI studs report at 10% to 15% reduction in pregnancy rates to sexed semen compared to conventional semen (A. Simmons, personal communication). Overall, these results are consistent with studies in dairy heifers which indicate a 10% to 20% decrease in conception rates with sexed semen compared to conventional semen (DeJarnette et al., 2009).

Results in postpartum cows

Although use of sexed semen with fixed-time AI has been discouraged (Seidel, 2003), fixed-time AI is increasingly becoming the AI method of choice in postpartum beef cows. Research into the use of FTAI with sexed semen is important to expansion of this technology to the beef industry. In addition, pregnant replacement heifers only represent 10% to 20% of a commercial beef herd compared to heifers being 30% to 40% of the females calving on dairy operations.

The concept that using sexed semen in heifers would be more successful than in cows may not be correct in beef cattle. Over a large number of studies, members of the Beef Reproduction Task Force reported pregnancy rates of 65% using fixed-time AI systems with conventional semen (Lamb, 2010). In contrast, same group (and the industry in general) appears to show lower pregnancy rates and greater variability in pregnancy rates to fixed-time AI systems in heifers (Patterson et al., 2010). The one exception is the 14d CIDR-PG system which resulted in 65% AI pregnancy rates with conventional semen in heifers. One theory is that mature postpartum beef cows in good body condition and at least 50 days postpartum may be as fertile a female as we have on the ranch. One study tested the hypothesis that the fertility of sexed semen was not different between heifers and postpartum cows (Rhinehart et al., 2011). These researchers saw no difference in the performance of sexed semen in heifers vs. cows. However, the AI pregnancy rates to sexed semen were only in the 30 to 35% range.

At the University of Idaho Nancy M. Cummings Center, we bred postpartum lactating beef cows with either sexed (n = 235) or conventional (n = 507) semen over three breeding seasons (Hall et al., 2010; Figure 2). Our pregnancy rates to sexed semen averaged 52% (range 48% to 58%) while pregnancy rates to conventional semen averaged 58% percent (range 52% to 69%). Most of the 235 cows bred with sexed semen were bred using the 5-day CO-Synch + CIDR fixed-time AI protocol except during Year 1. Cows inseminated with sexed semen in Year 1 had been detected in estrus whereas cow bred with conventional semen were bred either after detection of estrus or FTAI. Also, Year 3 was the only year that all bulls in the conventional treatment were also represented in the sexed treatment. In that year, there was a 20% difference in pregnancy rates to sexed compared to conventional semen. These results were encouraging especially when our lowest pregnancy rates with FTAI with sexed semen still approached 50%. However, all animals used in these experiments were mature cows and only a limited number of bulls were represented.

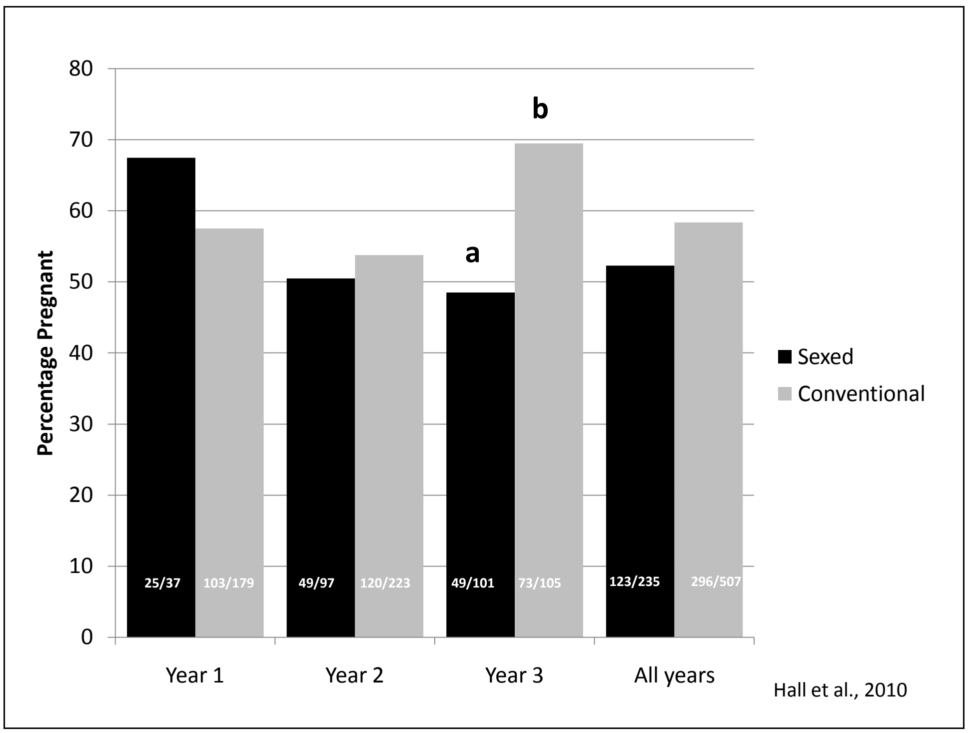


Figure 2. Pregnancy rates to X-sorted or conventional semen in postpartum beef cows. Year 1 cows receiving sexed semen bred 12h after estrus, and conventional cows bred after estrus or fixed time AI. Year 2 & 3 all cows bred by fixed time AI. [a,b] Pregnancy rates differ ($P < 0.05$).

More recently, we inseminated 839 cows with sexed semen in a study investigating the effects of timing of insemination in a FTAI system on pregnancy rates (Hall et al., 2014). Over the three years, we achieved a disappointing 37% pregnancy rate to FTAI. Also, other laboratories report reductions in AI pregnancy rates of 9% to 33% for cows bred by fixed-time AI with sexed semen compared to those inseminated with conventional semen (Rhinehart et al., 2011, Sá Filho et al., 2012, Cooke et al., 2014).

The results of AI with sexed semen in beef heifers and cows indicate that application of sexed semen to the beef industry is feasible. However, there is considerable variation in success with sexed semen. This variation in pregnancy rates and its subsequent impact on production costs, income, and calving distribution must be considered.

Potential Factors Affecting AI Success with Sexed Semen

Current research involving sexed semen in beef cattle is directed towards improving pregnancy rates to either AI after estrus detection or FTAI. Either by design or default these studies are providing insight into factors affecting success with sexed semen. Alternatively, they are also indicating directions for future studies. The primary factors identified in these studies are:

1. Estrus vs no estrus
2. Timing of insemination
3. Bull fertility
4. Follicular size

Cows or heifers that are inseminated based on estrus or exhibit estrus before FTAI have greater pregnancy rates to sexed semen (Hall et al., 2010; Meyer et al., 2012). At our research station, we observed a 10% to 20% decrease in pregnancy rates in postpartum beef cows inseminated with sexed semen without an observed estrus. Meyer and co-workers (2012) reported up to a 43% reduction in pregnancy rate in heifers with no observed estrus that were mass inseminated compared to heifers bred after observed estrus. Combined with data from research on sexed semen in dairy cattle, it seems logical that expression of estrus might be used as a criterion to select animals to be AIed with sexed semen.

Research on the effects of timing of insemination with sexed semen on pregnancy rates is just beginning. Early work with dairy heifers indicated that delaying time of insemination from 12 h to 24 h after observed estrus may slightly improve pregnancy rates. Dr. Seidel has suggested that optimum insemination time would be 18 h after observed estrus. Preliminary data from our research station demonstrated no difference between pregnancy rates to FTAI at 72 h compared to 80 h in the 5-day CO-Synch + CIDR system in postpartum cows (Hall, unpublished data). Similarly, Nebraska researchers found no significant differences in pregnancy rate in heifers inseminated at three different times relative to observed estrus. The optimum time of insemination with sexed semen after estrus or in a fixed time AI program remains to be determined; however, at present a slight delay in timing of insemination may be beneficial.

In contrast, Missouri researchers demonstrated that delaying insemination by 20 hours in cows that did not express estrus by time of FTAI improved pregnancy rates to sexed semen by 13% (Thomas et al., 2013). Cows were synchronized using the 7-day CO-Synch + CIDR protocol, and all cows were given GnRH at 66 h, and cows that had exhibited estrus were inseminated at that time. Cows not exhibiting estrus were inseminated 20 h after GnRH.

Delaying insemination on only the non-estrus cows rather than the entire group makes sense if, as assumed, the lifespan of sorted sperm in the female reproductive tract is shorter than conventional sperm. By delaying insemination of all cows, pregnancy rates may be decreased in cows that express estrus which would account for the many observations of no impact of delaying insemination on pregnancy rate. Inseminating estrus cows at the normal fixed time and delaying insemination of non-estrus cows until after induced ovulation with GnRH may result in a better timing of insemination and ovulation.

Differences in bull fertility may be magnified after sorting. Increasing the dose of sexed semen from 2.1 to as much as 10 million sperm (DeJarnette et al., 2007) does not result in dramatic increases in conception rate indicating that these are non-compensable traits (See Dr. Dalton's paper in these proceedings). Several groups including Univ. of Idaho have observed that there is considerable variation in pregnancy rates from bull to bull with sexed semen (Hall et al., 2010; Meyer et al, 2012; Figure 3).

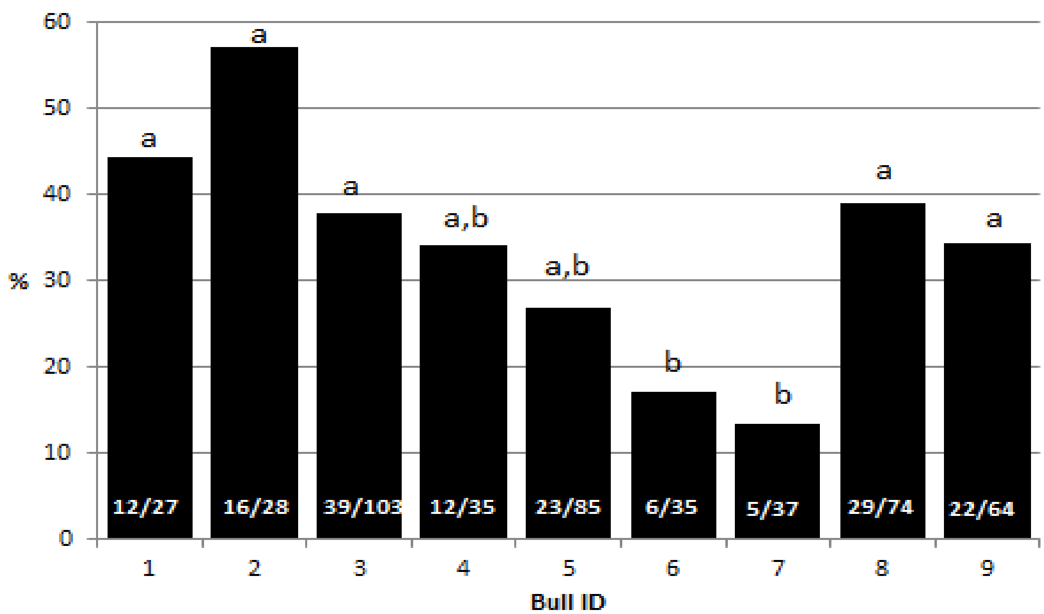


Figure 3. Variation in pregnancy rates to sexed semen from different bulls used at the University of Idaho in 2011 & 2012. Proportion of cows pregnant is indicted on bars. a,b Effect of bull ($P < 0.05$).

In most studies, the number of inseminations per bull limits the power to detect statistically significant differences in sexed semen AI pregnancy rates among bulls. Field studies and reports could be used to identify bulls with sufficient number of inseminations to identify bulls with true differences in fertility. Once identified, these bulls could be used in research to find post-sorting tests to assess fertility in sex sorted semen.

Size of the dominate follicle at the time of FTAI affects pregnancy rate to sexed semen. Suckled *Bos Indicus* cows with follicles ≤ 9mm at the time of FTAI with sexed semen had greater pregnancy compared to cows with > 9mm follicles (Sá Filho et al., 2012). This agrees with reports on the impact of follicle size on pregnancy rates with conventional semen (Perry et al., 2005). In addition, cows with follicles ≤ 9mm at the time of FTAI had similar pregnancy rates regardless of type of semen used (58.9% conventional vs. 56.8% sexed semen; Sá Filho et al., 2012).

Multiple Ovulation Embryo Transfer – MOET

Using sexed semen in superovulated cows to produce embryos also results in decreases in reproductive efficiency. Researchers noted a 20% to 35% reduction in the number of transferable embryos when using sexed semen (Table 1). Most of this reduction is due to an increased number of unfertilized ova. The decrease in transferable embryos may be due in part to sperm number as a dose of 20 million sexed sperm resulted in similar numbers of transferable embryos to 40 million unsorted sperm. A few studies reported delay in development of embryos.

Table 1. Percentage of transferable embryos as affected by sorting and sperm dosage

	% Transferable embryos		Semen dosage (million)		
Experiment	**Sexed**	**Conventional**	**Sexed**	**Conventional**	**Heifers or cows**
Schenk et al., 2006*	18.6/16.5	43.5	10.0/2.0	40	Both
Hayakawa et al., 2009	53.4	68.1	5.0	5.0	Heifers
Peippo et al, 2009 (Expt. 1)	70.3	75.0	6.0 to 8.0	30 to 45	Heifers
Peippo et al, 2009 (Expt. 2)*	53.9	65.5	6.0 to 8.0	30 to 45	Heifers
Larson et al., 2010*	39.5	60.5	8.4	80	Cows

*Effect of semen type on % transferable embryos ($P <0.05$)

Pregnancy rates after transfer are similar among embryos produced with sexed or unsorted semen (Schenk et al., 2006; Hayakawa et al., 2009).

In Vitro Fertilization – IVF

In vitro fertilization drastically reduces the number of sorted sperm needed to fertilize an oocyte. As opposed to millions of sperm for AI or MOET procedures, IVF requires only 600-1500 sorted sperm to fertilize an oocyte (Xu et al., 2009). This greatly increases the potential number of sexed offspring from a sire.

Pregnancy rates from IVF cultured embryos fertilized with sexed semen range from 30% to 50%. While these pregnancy rates may seem low, they are offset by the sheer number of embryos that can be produced. For example, in a large commercial IVF embryo production system using Bos taurus, Bos indicus, and indicus-taurus cross cows, 5,407 embryo pick-up procedures resulted in 16,924 transferable embryos (Pontes et al., 2010). Pregnancy rates were 36%-40% even after some of the embryos had been shipped over 1500 miles during culture. Embryos produced from sexed semen and IVF may have reduced cleavage or blastocyst rates (Zang et al., 2003; Blondin et al., 2009). However, improvements in IVF specifically for sexed semen fertilized embryos are rapidly bringing pregnancy rates of these embryos closer to pregnancy rates of embryos fertilized with conventional semen (Xu et al., 2009). In addition, these studies provide insight into potential solutions for decrease fertility of sexed semen in AI or MOET procedures.

Applications of Sexed Semen in Beef Production Systems

Potential applications of sexed semen to the beef and dairy industries were previously well discussed by other authors (Hohenboken, 1999; Seidel, 2003). While discussions of current or potential applications are important, the utility and practicality of applications are dynamic as the usefulness depends on price of sexed semen, percentage sorted sex (75% vs. 90%), and current market environment. Since the publication of works of Hohenboken and Seidel availability of sexed beef semen increased, cost per unit decreased, weaned and finished calf value increased, and estrous synchronization programs improved. In light of these changes, a brief discussion of current and potential applications is warranted.

Seedstock sector applications

The most common use of sexed semen in the beef industry is to increase the number of desired sex animals in purebred operations. Generating more bull calves from a popular herd sire to produce bulls for the commercial sector is an important consideration. Similarly, deriving more daughters from a purebred maternal line would also be advantageous to certain purebred breeders. In the purebred industry, costs associated with decreases in fertility to sexed semen maybe offset by the demand for offspring of a particular individual or the ability to effectively market animals from a broader age range.

In certain breeding programs, use of sexed semen in MOET may be of greater use in rapidly producing offspring from desired matings despite a 20% to 30% reduction in transferable embryos. For example, sons of a particular bull-cow mating are desired for their exceptional growth and carcass traits; however, daughters from the same mating are difficult to market as seedstock due to their lack of maternal traits. Using Y-sorted semen with MOET would eliminate a large percentage of the daughters while increasing the number of bulls available by 20% to 30%. As opposed to MOET with conventional semen followed by fetal sexing, this method make more efficient use of recipient cows as they would predominately be carrying the most marketable gender.

Recently, several deleterious traits have been identified in purebred beef cattle, especially the Angus breed. In some cases, a significant percentage of the females in a herd are carriers. Sexed semen coupled with MOET or IVF could help purebred operations rapidly replace carrier females with "clean lines" while maintaining some of the genetic progress of their herd. For example, non-carrier dams from desired lines could either be superovulated or have oocytes collected for IVF. In both cases, fertilization could occur with sexed semen from non-carrier bulls. Carrier females could serve as recipients. If the highest need is to repopulate the breeding herd then X-sorted semen would be used. If the greatest need was to produce high numbers of non-carrier bulls then Y-sorted semen could be used.

Commercial sector applications

Development of maternal lines

The value of crossbred females in the commercial cowherd is well documented (Gregory and Cundiff, 1980; Cundiff and Gregory, 1999). However, crossbreeding continues to decrease in the US cow herd predominately due to complexities of many cross breeding systems, the need for separate herds, use of multiple breeds of bulls, limited cow herd size, and variation in calf crop. Even a simple two breed rotational cross is difficult in small herds or results in excessive variation in calf uniformity. In contrast, competing meat species make considerable use of maternal and terminal lines. Sexed semen provides the opportunity to use as small number of elite cows to generate replacements while mating the remainder of the cows to terminal sires.

Over the past five years, our research station has employed X-sorted semen on 20% of our cows to generate Angus X Hereford heifers. In this paradigm, cows are identified as candidates as "heifer dams" before the breeding season based on performance records, visual appraisal, and, in the near future, custom EPD's. These "elite" cows are bred once by fixed-time AI to X-sorted semen followed by natural mating to a maternal type bull. Cows pregnant to sexed semen consistently produced calves that were 90% to 92% female. Overall, calves from this group of females were 62% to 78% female (Hall et al., 2010; Hall, unpublished data; Table 2). The remaining cows are mated to terminal type Angus and Simmental sires.

Utilizing the sexed semen maternal line strategy to produce replacement females could reduce proportion of the herd dedicated to generating replacements. In a typical, commercial production setting where 15% of the cows are replaced and overall pregnancy rate is 90%, it takes one third of the herd to be mated to maternal sires to generate replacements. If the gender ratio of offspring born to cows dedicated to producing replacement could be shifted to 66:34 female to male by FTAI with sexed semen followed with natural service, then only 25% if the cowherd is needed for replacements. Using sexed semen after detected estrus over three cycles may shift the ratio to 83% female: 17% male. With this ratio, only 20% of the herd is needed to generate replacements and only 9% to 12% of the steers are maternal genetic influenced.

Table 2. Impact of semen type on gender ratios and performance of female calves.

	Year 1		**Year 2**		**Year 3**	
Semen Type	**Sexed**	**Con**	**Sexed**	**Con**	**Sexed**	**Con**
Female to Male Ratio	**78:22**	**47:53**	**68:31**	**50:50**	**62:38**	**56:44**
Growth Performance, kg (lb)*	**259.8 (572.8)**	**258.7 (570.4)**	**277.7 (612.3)**	**273.2 (602.4)**	**277.0 (610.8)**	**271.8 (599.3)**

Sexed = X-sorted, Con = conventional; *205 day adjusted weight

Heifer-Heifer System

The Heifer-Heifer system uses bred replacement heifers to produce the next generation of replacements which allows the mature cows to be bred to terminal type sires. This system is not to be confused with the single-sex bred heifer system proposed by Taylor et al. (1985), and discussed in the next section. In the Heifer-Heifer system replacement heifers move into the mature cowherd and are retained after producing their first calf.

Identification of heifers with superior genetics to propagate replacements is more challenging in commercial than purebred herds. However, excellent production records, development of EPDs for commercial cows, and marker assisted selection may enhance the probability of selecting genetically superior heifers. Genetically, use of X-sorted semen in replacement heifers could decrease the generation interval and, potentially, enhance genetic progress.

Physiologically, use of X-sorted semen should reduce dystocia in heifers as there is an increased incidence of dystocia in dams giving birth to male calves. (Bellows et al., 1971). Combing X-sorted semen with selection of bulls with low birth weight EPDs or positive calving ease EPDs could further reduce the incidence of dystocia.

A significant concern of the Heifer-Heifer System is the impact of reduced 1st service conception rate on calving distribution. There is considerable economic and biological advantage to heifers that calve in the first 21 days of their initial calving season (Lesmeister, 1973; Kill et al., 2012). Inseminating only heifers that are detected in estrus with X-sorted semen would maximize pregnancy rates to sexed semen, but additional heifers would have to be retained to compensate for the reduced pregnancy rates. However, open yearling heifers marketed through retained ownership have been profitable in recent years. Alternatively, breeding heifers with X-sorted semen after observed estrus over three estrous cycles may be an option for producers of commercial bred heifers because the variation in expected calving dates of heifers may match calving seasons of diverse customers.

Single-Calf Heifer System (Single Sex Bred Heifer System)

The original single-calf heifer system eliminates the need for maintaining a mature cow herd (Harte, 1975; Brethour, 1986). In this system, yearling heifers are bred and calved. After calving, calves are early weaned (< 90 d of age) and multiparous cows are sent directly to the feedlot and sold as finished heifers. Calves are placed in drylot with steer calves selling at normal weaning time and heifers retained to begin the next rotation. Additional heifers need to be purchased to maintain the number of bred heifers desired by the ranch. In an economic analysis study, the single-calf heifers system was more profitable over a 20 year period compared to the conventional cow-calf system or a cow-calf system with retained ownership (Sell et al., 1988).

It was proposed that the single-calf heifer system could be modified to a single-sex-calf heifer system if sexed semen was available (Taylor et al., 1985). In this system, all heifers are bred to X-sorted semen thereby producing the next generation of heifers and reducing the number of heifers needed to be purchased. Recently, Dr. George Seidel, Jr. has re-proposed this concept and is currently testing it. While this systems holds great promise, it also has considerable challenges including management of early weaned calves, pregnancy rates to sexed semen, rapid finishing of heifers, and cash flow issues at start-up. While very risky the outcomes of this experiment should be interesting.

Shifting Gender Ratios to Enhance Marketing

Steers weigh more at weaning and are worth more per pound than their heifer cohorts (USDA-AMS, 2012). Altering the steer to heifer ratio in favor of steers may increase returns per cow. However, this may be offset by a reduction in calves born early in the calving season which results in decreased average weaning weight.

Increasing the percentage of steers marketed may be of particular advantage to beef producers with less than 200 cows. These producers are often unable to offer single sex tractor-trailer load lots of weaned vaccinated calves which currently command a premium in the market. The increased value of a steer compared to a heifer as well as the $35 to $75 per animal premium for weaned vaccinated cattle may more than compensate for increased semen costs and decreased weaning weights.

For the past three years, we synchronized postpartum cows using the 5-day CO-Synch + CIDR protocol and inseminated by fixed-time AI with Y-sorted semen from one of 9 bulls. Pregnancy rates were a disappointing 38%; however, calving data from two years resulted in a steer to heifer ratio of 65:35. Steers averaged 60 lbs heavier and 5 days older at weaning than heifer calves. In addition, we are gaining more information on the impact of repeated whole herd use of sexed semen on retention of cows in the cow herd. The average calving date of the herd has moved about 5 days later; however, this is confounded by a portion of cows going out to range for two years of the study. At University of Idaho, we consider this an exciting project; however, this application has high risk, and more information is needed from research and field studies.

Economics

Previously, several authors addressed the economics of the use of sexed semen (Hohenboken, 1999; Seidel, 2003). Review of these papers will provide information on assumptions that may need to be included in economic analysis of the feasibility of use of sexed semen for an individual ranch. Calculations on the economics of use of sexed semen in production of bred heifers are probably the most accurate. Management of yearling heifers bred with conventional or sexed semen is similar with only pregnancy rates and semen cost as primary variables. Meyer and co-workers (2012) reported a net increase in cost of $44.00 per pregnant heifer for heifers bred with sexed compared to conventional semen.

At UI NMCREEC, using sexed semen to produce a calf crop that is 65:35 male to female ratio allows us to market 2 tractor trailer loads of steers instead of 1 tractor trailer load of steers and 1 smaller load of heifers (or a split-sex load). For producers with about 120 to 150 cows, there may be a positive economic impact to using sexed semen to produce more steers.

Actual 2013 data from a local ranch selling on Superior Livestock Auction is shown in Table 3. This rancher has 150 cows and sells a split load of steer and heifers. The load sells with heifers priced at $10/cwt below steers. Data from the entire sale indicated that heifers were probably valued at $13/cwt less than steers; therefore, his steers may also have been discounted. The split load line shows what he actually received. The two whole load lines indicate what he would have received for a full load of steers or a full load of steer without the $3/cwt discount.

Table 3. Impact of mixed sex and all steer loads on returns to ranch.

	Steers (hd)	**Wt. (lbs)**	**Price ($/cwt)**	**Value**	**Heifers (hd)**	**Wt. (lbs)**	**Price ($/cwt)**	**Value**	**Total load value**	**All Steer Impact**
Split load	55	580	160	$51,040	35	520	150	$27,300	$78,340	
Whole load	90	580	160	$83,520						$5,180
Whole load	90	580	163	$85,086						$6,746

Would using sexed semen to increase the number of steers available for marketing be a positive economic decision for this ranch? If this ranch was already using AI then using sexed semen would increase costs by about $2250 (assuming $15 more per unit for sexed compared to conventional semen). Any loss in weaning weight due to changes in calving distribution would be offset by more steers and use of terminal sires. The potential increase in income to this ranch would be $2,900 to $4,500.

Estimation of economic cost or benefit of using sexed semen in postpartum cows is highly speculative and dependent on a number of factors including production costs, current AI usage, pregnancy rates to sexed semen, long-term impacts, production environment, and marketing advantages/opportunities. Results from a recent trial indicated that increase value by increasing the percentage of steers may be offset by younger age and weight at weaning and decreased weight of heifer progeny (Cooke et al., 2014). This reinforces the need for a marketing advantage to make the use of sexed semen cost effective at present pregnancy rates.

What is really needed to properly discuss economic impacts of sexed semen is additional hard data based on actual field studies. Each individual ranch condition is different, and those differences are going to impact the value of sexed semen on that operation. For that reason rather than speculate on the value of these different applications, producers are encouraged to conduct their own cost/benefit analyses.

One of the best calculators for the cost and returns to using sexed semen can be found on the Genex Cooperative, Inc. website at:
http://documents.crinet.com/Genex-Cooperative-Inc/Beef/GenChoiceBeefQuickMath.pdf
This calculator is rather conservative so it gives a realistic analysis if inputs are listed honestly.

Conclusions

Sexed semen can be a useful part of a breeding program for beef producers. Producers need to enter the project with the understanding that pregnancy rates to sexed semen are 10% to 20% below conventional semen. In some cases, inseminating only females detected in estrus results in pregnancy rates approaching conventional semen.

Sexed semen can be used in postpartum beef cows and heifers. Results with the use of sexed semen in pure fixed-time AI systems are often disappointing. However, estrus synchronization and AI systems that combine estrus detection and FTAI should be more successful. Alternatively, the combination of breeding cows detected in estrus before FTAI with sexed semen, and cows not detected in estrus with conventional semen may yield more acceptable results.

At present, purebred and commercial seedstock producers will receive the most benefit from the use of sexed semen. In addition, use of sexed semen by commercial producers to generate replacement heifers or to breed replacement heifers is a viable option. Sexed semen has the potential to increase per cow beef production and returns by increasing the percentage of terminal-type steers produced; however, improvements in pregnancy rates to sexed semen will be needed.

References

Bellows R. A., R. E. Short, D. C. Anderson, B. W. Knapp, and O. F. Pahnish. 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. J. Anim. Sci. 33:407-415.

Blondin , P., M. Beaulieu, V. Fournier, N. Morin, L. Crawford, P. Madan, W.A. King. 2009. Analysis of bovine sexed sperm for IVF from sorting to the embryo. Theriogenology 71:30-38.

Cooke, R.F., D.W. Bohnert, B.I. Cappellozza, R.S. Marques, T. DelCurto and C.J. Mueller. 2014. Incorporation of sexed semen into reproductive management of cow-calf operations. Livestock Sci. 163:165-171.

Cundiff, L.V., and K.E. Gregory. 1999. What is systematic crossbreeding?. Proc. NCBA Cattleman's College, Charlotte, NC, February 1999.

DeJarnette, J. M., R. L. Nebel, C. E. Marshall, J. F. Moreno, C. R. McCleary, and R. W. Lenz. 2007. Effect of Sex-Sorted Sperm Dosage on Conception Rates in Holstein Heifers and Lactating Cows. J. Dairy Sci. 91:1778-1785.

DeJarnette, J.M., R.L. Nebel, C.E. Marshall. 2009. Evaluating the success of sex-sorted semen in US dairy herds from on farm records. Theriogenology 71:49-58.

Deutscher, G., R. Davis, G. Seidel, Z. Brink, J. Schenk. 2002. Use of sexed (female) sperm is successful in yearling heifers. 2002 Nebraska Beef Report pp 12.

Gregory, K. E. and L. V. Cundiff. 1980. Crossbreeding in Beef Cattle: Evaluation of Systems. Journal of Animal Science, 51:1224.

Hall, J.B., A. Ahmadzadeh, R.H. Stokes, C. Stephenson, and J. K. Ahola**.** 2010. Impact of gender-selected semen on AI pregnancy rates, gender ratios, and calf performance in crossbred postpartum beef cows. Proceedings of the 8th International Ruminant Reproduction Symposium, Anchorage, AK.

Hall, J. B. 2011. Sexed Semen – The newest reproductive technology for the beef industry NCBA Pfizer Cattlemen's College, Denver, CO.

Hayakawa, H., T. Hirai, A. Takimoto, A. Ideta, Y. Aoyagi. 2009. Superovulation and embryo transfer in Holstein cattle using sexed sperm. Theriogenology 71:68-73.

Hohenboken, W. D. 1999. Applications of sexed semen in cattle production. Theriogenology 52:1421-1433.

Hutchison, J. L. and H.D. Norman. 2009. Characterization and usage of sexed semen from US field data. Theriogenology 71:48 (Abstract).

Johnson, L. A., and G. R. Welch. 1999. Sex preselection: High-speed flow cytometric sorting of X and Y sperm for maximum efficiency. Theriogenology 52:1323-1341.

Kill, L.K., E.M. Mousel, R.A. Cushman, and G.A. Perry. 2012. Effect of heifer calving date on longevity and lifetime productivity. J. Anim. Sci. 90 (Suppl. 2):131.

Lamb, G. C. 2010. Estrus synchronization protocols for cows. Applied Reproductive Strategies Conference Proceedings August 5 & 6 Nashville, TN

Larson, J.E., G.C. Lamb, B.J. Funnell, S. Bird, A. Martins, J.C. Rodgers. 2010. Embryo production in superovulated Angus cows inseminated four times with sexed-sorted or conventional, frozen-thawed semen. Theriogenology 73:698-703.

Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. J. Anim. Sci. 36:1-6.

Meyer, T. L., R. N. Funston, Kelly Ranch, Sexing Technologies, ABS Global, J. M. McGrann. 2012. Evaluating Conventional and Sexed Semen in a Commercial Beef Heifer Program. 2012 Nebraska Beef Cattle Report pp 20-21

Patterson, D. J., D.A. Mallory, J. M. Nash, and M.F. Smith. 2010. Estrus synchronization protocols for heifers. Applied Reproductive Strategies Conference Proceedings August 5 & 6 Nashville, TN.

Peippo, J. K. Vartia, K. Kananen-Anttila, M. Raty, K. Korhonen, T. Hurme, H. Myllymaki, A. Sairanen, and A. Maki-Tanila. 2009. Embryo production from superovulated Holstein-Friesian dairy heifers and cows after insemination with frozen-thawed sex-sorted X spermatozoa or unsorted semen. Anim. Reprod. Sci. 111:80-92.

Perry, G. A., M. F. Smith, A. J. Roberts, M. D. MacNeil, and T. W. Geary. 2007. Relationship between size of the ovulatory follicle and pregnancy success in beef heifers. J. Anim. Sci. 85:684-689.

Pontes, J.H.F., K.C.F. Silva, A.C. Basso, A.G. Rigo, C.R. Ferreira, G.M.G. Santos, B.V. Sanches, J.P.F. Porcionato, P.H.S. Vieira, F.S. Faifer, F.A.M. Sterza, J.L. Schenk, M.M. Seneda. 2010. Large-scale *in vitro* embryo production and pregnancy rates from *Bos taurus*, *Bos indicus*, and *indicus-taurus* dairy cows using sexed sperm. Theriogenology 74:1349-1355.

Rhinehart, J. D., A. M. Arnett, L. H. Anderson, W. D. Whittier, J. E. Larson, W. R. Burris, J. B. Elmore, D. T. Dean, and J. M. DeJarnette. 2011. Conception rates of sex-sorted semen in beef heifers and cows. J. Anim. Sci. 89 (Suppl. 2):

Sá Filho, M.F., H. Ayres, R.M. Ferreira, M. Nichi, M. Fosado, E.P. Campos Filho, P.S. Baruselli. 2010. Strategies to improve pregnancy per insemination using sex-sorted semen in dairy heifers detected in estrus. Theriogenology 74:1636-1642.

Sá Filho, M. F., R. Girotto, E. K. Abe, L. Penteado, E. P. Campos Filho, J. F. Moreno, R. V. Sala, M. Nichi, and P. S. Baruselli. 2012. Optimizing the use of sex-sorted sperm in timed artificial insemination programs for suckled beef cows. J. Anim. Sci. 2012:1816–1823.

Schenk, J.L., T.K. Suh, G.E. Seidel Jr. 2006. Embryo production from superovulated cattle following insemination of sexed sperm. Theriogenology 65:299-307.

Schenk, J.L., D.G. Cran, R.W. Everett, G.E. Seidel Jr. 2009. Pregnancy rates in heifers and cows with cryopreserved sexed sperm: Effects of sperm numbers per inseminate, sorting pressure and sperm storage before sorting. Theriogenology 71:717-728.

Seidel, Jr., G.E., J.L. Schenk, L.S. Herickhoff , S.P. Doyle, Z. Brink, R.D. Green and D.G. Cran. 1999. Insemination of heifers with sexed sperm. Theriogenology 52:1407-1420.

Seidel, Jr. G. E., 2003. Economics of selecting for sex: the most important genetic trait. Theriogenology 59:585-598.

Seidel, G. E., Jr. 2003. Sexing mammalian sperm—intertwining of commerce, technology, and biology. Anim. Reprod. Sci 79:145-156

Seidel, Jr. G. E., 2014. Update on sexed semen technology in cattle. Animal 8:160-164.

Sell, Randall S., D. L. Watt, R. D. Little, and T. A. Petry. 1988. Single-calf heifer system profitability compared to other North Dakota beef production systems. Agricultural Economics Report No. 240, North Dakota State University.

Sharpe, J.C., K.M. Evans. 2009. Advances in flow cytometry for sperm sexing. Theriogenology 71:4-10.

Taylor S. C .S, A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. Anim Prod 40:401-440.

Thomas, J. M., S.L. Lock, S.E. Poock, and D.J. Patterson. 2013. Delayed insemination of non-estrous cows improves pregnancy rates when using sex-sorted semen in timed artificial insemination of suckled beef cows. Proceedings of the National Association of Animal Breeders Symposium. June 12, 2013. Oklahoma City, OK.

Xu, J., S.A. Chaubal, F. Du. 2009. Optimizing IVF with sexed sperm in cattle. Theriogenology 71:39-47.

Zhang, M, K.H. Lua, G.E. Seidel Jr. 2003. Development of bovine embryos after in vitro fertilization of oocytes with flow cytometrically sorted, stained and unsorted sperm from different bulls. Theriogenology 60:1657-1663.