SUPPLY OF DAIRY BEEF STEERS IN THE FUTURE: STATUS OF CROSSBREEDING AND SEXED SEMEN

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Introduction to Dairy Crossbreeding

Crossbreeding is a popular tool for genetic improvement of pigs, beef cattle, and other livestock species, but its use in US dairy cattle has been limited for several reasons. The primary reason is the advantage of Holstein cows in milk volume, coupled with a milk pricing system that still tends to reward quantity, rather than quality, in many regions of the country (i.e., through volume premiums, hauling subsidies, etc.). In addition, most scientific research regarding dairy crossbreeding is outdated, and studies that have utilized the three main US dairy breeds (Holstein, Jersey, and Brown Swiss) are non-existent. Lastly, the historically strong role played by breed associations has tended to hinder the use of crossbreeding. However, a growing number of producers are experimenting with crossbreeding, and many questions have arisen about the results dairymen can expect when crossing various breeds.

Results of a Survey on Dairy Crossbreeding

We recently surveyed 50 producers who currently had crossbred dairy cattle on their farms. About 20% of these herds practiced rotational grazing, while the remainder utilized conventional herd management (i.e., free-stall housing). Reasons for crossbreeding and choices of breeds varied. Many non-Holstein herds looked to crossbreeding as a means of improving milk yield. However, the majority of herds began with Holsteins, and nearly all looked to crossbreeding as a means of improving calving ease, fertility, or longevity.

These herds had been crossbreeding for nine years, on average, and about 80% used AI sires for crossbred matings. Forty-one herds mated their crossbred cows back to a purebred bull from one of the parental breeds (e.g., Holstein x Jersey cow mated to a Jersey bull), eight used purebred sires of another breed (e.g., Holstein x Jersey cow mated to a Brown Swiss bull), and six used crossbred bulls of the same breed composition (e.g., Holstein x Jersey cow mated to a Holstein x Jersey bull). Respondents were asked to score their purebred and crossbred cattle on a scale of 1 (much poorer than my other cows) to 5 (far superior to my other cows) for fertility, calving performance, production, component percentages, survival, and slaughter value. As shown in Table 1, conception rate scores were highest for Jersey male x (Holstein x Jersey) female, Brown Swiss male x Holstein female, and pure Jersey matings. Conception rate scores were poorest for pure Holstein matings.

Table 1. Average producer scores for production, calving performance, fertility, survival, and carcass value of cows from each breed or breed cross, relative to other cows on their farms (BS = Brown Swiss, HO = Holstein, and JE = Jersey). Breed of sire (or service sire) is listed first in each cross, followed by breed(s) of dam. Scores were on a 1 (poor) to 5 (excellent) scale. Results are shown for each breed or cross that was represented in four or more herds.
(Weigel and Barlass, 2003)

Trait	BS x BS	BS x HO	HO x HO	HO x JExHO	HO x JE	JE x HO	JE x JExHO	JE x JE
Milk	2.4	2.9	3.8	3.0	2.8	2.5		2.0
Components	4.5	3.7	2.3	3.5	3.3	3.9	4.5	4.6
Cow Survival		3.1	2.6			3.6	4.2	3.3
Heifer Pregnancy Rate	2.3	3.6	3.0			3.5		3.3
Cow Pregnancy Rate	2.4	3.5	2.7			3.3	3.7	3.6
Calving Ease	3.6	2.7	2.2	3.0		4.5	4.4	4.5
Calf Survival		3.0	2.9	3.2	3.6	3.2	2.8	2.3
Cull Cow Price		3.4	3.2			2.5		
Bull Calf Price		3.1	3.5	2.2		2.0	2.0	1.5

Based on results of this survey, it appears that crossbred matings involving Holstein dams can achieve conception rates comparable to those found in pure Jersey matings. Calving ease scores were highest (fewest problems) for matings involving Jersey bulls and virgin heifers of any breed and were lowest (most problems) for matings involving Holstein heifers and either Holstein or Brown Swiss bulls. Interestingly, Holstein service sires caused more calving problems in pure Holstein heifers than in (smaller) Holstein x Jersey crossbred heifers. Calf survival scores were highest for matings of Holstein males x Jersey females and were lowest for pure Jersey matings. In all cases, survival of crossbred calves was superior to that of pure Holstein or Jersey calves.

Milk yield was highest in pure Holsteins and lowest in pure Jerseys, with all other breeds and crosses falling in between. Conversely, pure Jersey, pure Brown Swiss, and Jersey male x (Holstein x Jersey) female crosses had the highest fat and protein percentages, and all breeds and crosses had higher components than pure Holsteins.

Scores for functional survival (ability to resist culling due to illness, injury, or infertility) were highest in cows from Jersey sires x (Jersey x Holstein) dams, followed by cows from Jersey sires x Holstein dams. Longevity scores were poorest for pure Holstein cows.

Slaughter prices of cull cows were highest for pure Holstein cows and cows resulting from crossing Brown Swiss sires x Holstein dams. Prices of bull calves were similar, with pure Holstein and Brown Swiss x Holstein calves bringing the highest prices, and prices decreased as the percentage of Jersey genes increased.

Based on our survey results, it appears that crossbred cattle are likely to show improvements in pregnancy rate, calving ease, component percentages, and survival relative to pure Holsteins. Milk volume will be sacrificed, and producers will receive less revenue from animals that are sold for slaughter. Most producers (87%) indicated that they would continue crossbreeding in the future, but it is unlikely that those who responded were a random sample of all producers with crossbred cattle.

Crossbreeding in Commercial Herds in California

The 305-day milk, fat, and protein production of crossbred cows and their Holstein contemporaries that calved from 2002-2005 in several California dairies was compared by researchers at the University of Minnesota (Heins et al., 2005a,b,c).

Table 2. 305-day production for first lactation crossbred and Holstein cows in California herds (Heins et al., 2005a,b,c)

	Holstein	**Normande-Holstein**	**Montbeliarde-Holstein**	**Scandinavian Red-Holstein**
Number of Cows	380	245	494	328
Milk (lb)	21,511	18,806	20,197	20,461
Fat (lb)	763	703	736	750
Protein (lb)	673	610	646	655
Fat (lb) + Protein (lb)	1,436	1,313	1,382	1,405
% of Holstein		-8.6%	-3.8%	-2.2%

Production of the Scandinavian Red-Holstein crossbreds was not significantly different from that of pure Holsteins, but production of Montbeliarde-Holstein crossbreds and Normande-Holstein crossbreds was significantly lower than that of pure Holsteins. However, it is important to note that production records were not adjusted for differences in days open, even though crossbred cows of all three breed combinations had more days in calf than their pure Holstein contemporaries.

Calving difficulty was measured on the usual 1 to 5 scale, with 1 representing an easy birth and 5 representing extreme difficulty. Scores of 1 to 3 were combined as "not difficult", and scores of 4 and 5 were combined "difficult". Stillbirth status was reported as alive or as dead within 24 hours postpartum. Scores were adjusted for age of dam and sex of calf. As shown below, all crossbred calves tended to be born with less difficulty than pure Holstein calves, and the stillbirth rate was also lower, particularly for calves from Scandinavian Red sires. The same pattern was observed for crossbred dams, which tended to calve more easily than Holstein dams.

Table 3. Calving ease and stillbirth results at first calving from crossbred and Holstein calves (direct effect) and crossbred and Holstein dam (maternal effect) in California herds (Heins et al., 2005a,b,c).

Breed	Number of Births		Calving Difficulty		Stillbirth Rate	
	Direct	Maternal	Direct	Maternal	Direct	Maternal
Holstein	371	1,398	16.0%	9.3%	15.7%	11.8%
Montebeliarde	158	370	12.0%	8.1%	13.2%	7.1%
Brown Swiss	224		11.9%		12.0%	
Normande		269		9.2%		7.8%
Scandinavian Red	1,016	264	5.5%	4.7%	7.9%	4.9%

Female fertility of Holstein and crossbred cows during first lactation was also compared. Reproductive success was measure as days open, and all cows were required to have a subsequent calving and/or to have pregnancy status confirmed by a veterinarian. Cows with more than 250 days open had days open set to a maximum of 250. As shown below, Normande-Holstein crosses had the fewest days open, on average, followed by Montbeliarde-Holstein and Scandinavian Red-Holstein crosses.

Table 4. Fertility of first lacation crossbred and Holstein cows in California herds (Heins et al., 2005a,b,c).

Breed of Cow	Number of cows	Days open	Pregnant by 100 d
Holstein	520	150	38%
Normande-Holstein	375	123	52%
Montbeliarde-Holstein	371	131	43%
Scandinavian Red-Holstein	257	129	44%

Introduction to Sexed Semen

The idea of separating bovine semen into X- and Y-bearing fractions has fascinated scientists for decades. This technology would enhance a dairy producers' ability to obtain inexpensive replacement heifers and would offer great prospects for "biosecure" herd expansions. Furthermore, it would mitigate some of the effects of high involuntary culling rates and poor reproductive efficiency. If used widely, sexed semen would have a significant impact on beef production enterprises as well.

Various approaches for separating X- and Y-bearing sperm have been examined. Immunological sexing (killing the Y-bearing sperm) has been attempted in numerous studies, though no one has yet been able to significantly and consistently alter the sex ratio using such an approach. One can also imagine the creation of transgenic bulls that are able to produce only X-bearing sperm, but the idea of introducing transgenic animals into (any step of) the food chain is very controversial.

The only proven method for separating male- and female-bearing sperm at present is the fluorescence activated cell sorting approach of Johnson et al. (1987a, 1987b). Known as the "Beltsville Sperm Sexing Technology", this method, this method is based on the fact that the bovine X chromosome contains 3.8% more DNA than its Y counterpart. Therefore, sperm can be treated with DNA-specific fluorescent dye and subsequently sorted using high-throughput flow cytometry. However, many sperm are damaged, and a large proportion remain unsorted. This process is remarkably fast by laboratory standards, but it is remarkably slow by commercial standards. Speed of the sorting process has improved nearly 50-fold in the past decade, and roughly 18 million sperm can now be sorted per hour. At this rate, about 215 straws of X-bearing sperm (with 2 million sperm/straw) can be produced per machine in a 24-hour period, but US dairy producers currently use approximately 44,000 units of dairy semen per day.

The impact of sexed semen on herd management will likely be much greater than its impact on genetic progress. For example, using X-bearing sperm to mate virgin dairy heifers would substantially decrease the incidence of calving problems (dystocia), because female calves are smaller than males. In addition, the average lactation length of high-producing dairy cows could be extended to 18, 20, or even 24 mo, because these cows could easily provide their own replacements while averaging fewer than two calves per lifetime. Some authors, such as Hohenboken (1999), have suggested that dairy producers could breed the top 50% of their cows using X-bearing dairy semen to produce replacement heifers. Meanwhile, the bottom 50% of their cows could be mated using Y-bearing beef semen to produce crossbred market steers.

Hohenboken (1999) also discussed the potential benefits of using sexed semen in a beef cattle crossbreeding scheme. In a terminal 3-breed cross, 20% of the population consists of purebred cows to produce purebred females, 24% consists of purebred cows to produce crossbred females, and 56% consists of crossbred cows to produce terminal market steers. With sexed semen these proportions could change to 11%, 13%, and 76%, respectively, thereby increasing the number of market steers produced each year and, in turn, enhancing the profitability of the beef operation.

An often overlooked benefit of sexed semen is biosecurity. Commercial dairy herds are expanding rapidly in many states, as financial pressure leads producers to seek economies of scale. However, rapid expansion from within a closed herd is impossible without sexed semen or embryos. Therefore, most producers purchase cows and heifers from auctions, cattle dealers, or other farmers. When these animals arrive, the farm may be exposed to many new pathogens (e.g., leptospirosis, paratuberculosis, etc.). The availability of sexed semen would allow producers to expand from within a closed herd and avoid many of the aforementioned problems. Likewise, a cow-calf beef operation (on which the frequency of common "dairy" diseases may be low) could derive additional income by "renting" recipients to a neighboring dairy farmer who wishes to expand in a biosecure manner.

Results of Field Trials using Sexed Semen

Numerous field trials with sexed bovine semen have been conducted within the past five years in the US, and most have used virgin heifers as mates due to concerns about conception rate. Results from field trials in New York, California, Texas, and Wisconsin are shown in Table 5 (Seidel and Shenk, 2002). Based on these results, it is clear that conception rates are compromised by semen sorting, at least at present, and strategies for commercial application should focus on approaches that provide cost-effective use of sexed semen without significantly extending average age at first calving.

Table 5. Summary of field trials in Holstein and Jersey heifers by AI technicians and do-it-yourself inseminators in commercial dairy herds (Seidel and Shenk, 2002).

Location	Mates	Semen Type	Conception Rate
New York	Holsteins (N = 797)	Sexed	42%
		Unsexed	62%
California	Jerseys (N = 637)	Sexed	31%
		Unsexed	52%
Wisconsin	Holsteins (N = 813)	Sexed	31%
		Unsexed	58%
California, Texas	Holsteins (N = 513)	Sexed	31%
		Unsexed	42%

In Vitro Embryo Production with Sexed Semen

Because semen availability is a major concern, breeding programs based on *in vitro* production (IVP) of embryos may be commercially applicable before corresponding *in vivo* applications. Wilson et al. (2005) carried out an IVP project with sexed semen on seven commercial dairies in Wisconsin. Each month, farmers identified cull cows from which they desired additional offspring. Ovaries were retrieved at slaughter, and the recovered ova were joined with sexed sperm from young Holstein sires. Fresh embryos were transferred back into recipient cows and heifers on these farms. Results are shown in Table 6.

Table 6. Summary of results of *in vitro* embryo production using sexed semen (Wilson et al. (2005).

Variable	Mean ± SE
No. oocytes collected per donor (N = 104)	33.9 ± 3.3
No. embryos produced per donor (N = 104)	3.6 ± 0.3
No. embryos transferred per donor (N = 104)	2.6 ± 0.3
Conception rate in yearling heifer recipients (N = 76)	34.2%
Conception rate in milking cow recipients (N = 138)	18.8%
Percentage of live calves born that were female (N = 40)	92.5%

Commercialization of Sexed Semen (Weigel, 2004)

Are we finally on the verge of commercial application of sexed semen technology? We've been a bit premature in declaring this technology "commercially ready" in the past. Consider the "news item" reported in the October 1978 issue of Livestock Farming (page 50):

“A company (name withheld) is offering a semen sexing service to cattle breeders, i.e., separation of semen into X and Y bearing fractions. It can be used on fresh or thawed semen. The cost of separation is $15-20 per ampoule, depending on the size of the order.”

Perhaps this time we are actually ready for commercialization. A British company, Cogent (www.cogentuk.com) has been offering sexed semen of dairy sires commercially for several years. Within the US, Select Sires (www.selectsires.com) is now offering sexed semen from a handful of bulls, as is Heifer Quest (www.heiferquest.com). However, the selection of bulls is relatively limited, and few high genetic merit sires are offered. This situation could change in the near future, though, as Monsanto Inc. recently announced that it will throw its hat into the sexed semen ring. Their recent press release (www.getdecisive.com) claims that a new procedure is available in which compromised conception rates and limited semen availability will no longer be significant concerns. If true, sexed semen could be routinely available through partnerships between Monsanto and major AI studs within the next year.

Summary

This paper provides an update regarding the status of two technologies. One of these, namely crossbreeding, has been widely available for many years but has rarely been used in dairy cattle production. However, trends in milk pricing, coupled with increasing concerns about calving difficulty, fertility, health, and survival, have led to enhanced interest in dairy crossbreeding on commercial farms. The second, namely sexed semen, has been of great interest for many years, but technical difficulties precluded its widespread application. Limited quantities of X-bearing sexed semen are commercially available today, but concerns about reduced conception rates remain. New developments in semen sorting technology may overcome these limitations and, if so, the "floodgates" could open with respect the use of sexed semen on commercial farms.

Widespread commercial use of sexed semen, perhaps in conjunction with crossbreeding, could have a major impact on both dairy and beef production. Longer (and fewer) lactations per dairy cow may become the norm, and concerns about the reproductive performance of high-producing dairy cows in early lactation could be mitigated. The price of replacement heifers would drop substantially, and a large crop of F_1 dairy x beef steers (from low-merit dairy cows) could become available. Such predictions generally take longer than expected to materialize, and for now the most likely scenario is a gradual increase in the use of sexed semen (from a relatively small number of good, but not great, proven sires) for breeding virgin heifers.

If technical difficulties can indeed be overcome in the near future, we'll see a gradual drop in heifer prices, and an accompanying change in the reproductive management of high-producing cows (i.e., less pressure for a 12- or 13-month calving interval). The impact on beef producers will probably come a bit later, as strategies such as crossbreeding selected cows with sexed (Y-bearing) beef semen will likely come after the initial applications in dairy production.

References

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2005a. Crossbreds of Normande-Holstein, Montbeliarde-Holstein, and Scandinavian Red-Holstein compared to pure Holsteins for production during the first 150 days of first lactation. J. Dairy Sci. 88(Suppl. 1):92).

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2005b. Crossbreds of Normande-Holstein, Montbeliarde-Holstein, and Scandinavian Red-Holstein compared to pure Holsteins for dystocia and stillbirths. J. Dairy Sci. 88(Suppl. 1):93).

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2005c. Crossbreds of Normande-Holstein, Mntbeliarde-Holstein, and Scandinavian Red-Holstein compared to pure Holsteins for days to first breeding, first service conception rate, days open, and survival. J. Dairy Sci. 88(Suppl. 1):93).

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

Johnson, L. A., J. P. Flook, and M. V. Look. 1987a. Flow cytometry of X and Y chromosome-bearing sperm for DNA using an improved preparation method and staining with Hoechst 33342. Gamete Res. 17:203-212.

Johnson, L. A., J. P. Flook, M. V. Look, and D. Pinkel. 1987b. Flow sorting of X and Y chromosome-bearing spermatozoa into two populations. Gamete Res. 16:1-9.

Seidel, G. E., Jr., and J. L. Schenk. 2002. Field trials with sexed, frozen bovine semen. Proc. 19th Tech. Conf. on Artificial Insemination and Reproduction, Natl. Assn. of Animal Breeders, Columbia, MO, pp. 64-69.

Weigel, K.A. 2004. Exploring the role of sexed semen in dairy production systems. J. Dairy Sci. 87:(E. Suppl.):E120-E130.

Weigel, K. A., and K. A. Barlass. 2003. Results of a producer survey regarding crossbreeding in US dairy cattle. J. Dairy Sci. 86:4148-4154.

Wilson, R.D., K.A. Weigel, P.M. Fricke, J.J. Rutledge, M.L. Leibfried-Rutledge, D.L. Matthews, and V.R. Schutzkus. 2005. *In vitro* production of Holstein embryos using sex-sorted sperm with ova recovered from selected cull cows on commercial dairy farms. J. Dairy Sci. 88:776-782.