Crossbreeding: A Dirty Word or an Opportunity?

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Introduction

Historically, genetic improvement programs for dairy cattle focused on within-breed selection strategies due to the strong role of breed associations in developing selection policies and a milk pricing system that rewarded volume rather than cheese yield. As a result, Holsteins became the predominant breed in the US and most other major milk producing nations. However, farmers have become increasingly frustrated with the health, fertility, longevity, and calving performance of Holstein cattle. In addition, milk processors have implemented payment schemes that have increased the incentive to produce milk with high fat and protein content. For these reasons, crossbreeding is rapidly gaining attention among dairy producers, as they seek to reduce production costs, veterinary treatments, and management interventions.

A major hindrance to the implementation of efficient dairy crossbreeding programs is the lack of recent research in this subject area. Two large dairy crossbreeding projects have been carried out in North America, but both are now quite dated. Touchberry (1992) summarized the results of a four-generation crossbreeding project at the Illinois Agricultural Experiment Station from 1949 to 1969 involving the Holstein and Guernsey breeds. Crossbred calves (N=2,015) had a 15.6% greater survival rate to 1 week of age than purebreds, and crossbred heifers (N=778) had a 18.4% greater survival rate to first calving and a 24.5% greater survival rate to second calving. Production of crossbred cows exceeded that of their purebred contemporaries by 8.0%, 8.5%, and 7.5% for milk, fat, and protein, respectively. Income per cow per lactation was 14.9% greater for crossbreds than purebreds, whereas income per cow per year was 11.4% greater for crossbreds. Later, McAllister et al. (1994) reported results of a crossbreeding project at Agriculture Canada from 1972 to 1983 involving the Holstein and Ayrshire breeds. A total of 5,070 Holsteins, Ayrshires, and crossbreds were evaluated for lifetime milk yield, milk components, and net profit. Heterosis estimates ranged from 16.6% for lifetime milk yield to 20.6% for annualized discounted net returns. Additive genetic effects favored the Holstein breed, whereas maternal effects favored the Ayrshire breed. The authors recommended a two-breed rotational crossbreeding system for maximizing additive and nonadditive genetic effects on lifetime profitability.

Much of our current knowledge regarding dairy crossbreeding systems comes from New Zealand. Ahlborn-Breier and Hohenboken (1991) reported estimates of heterosis, the percentage improvement in performance of first-generation crossbreds relative to the average of the two parental breeds, of 6.1% for milk yield and 7.2% for fat yield in first lactation Holstein x Jersey crosses on New Zealand dairy farms. Later, Lopez-Villalobos et al. (2000) evaluated the effects of selection and crossbreeding on the profitability of New Zealand dairy farms. Strategies including purebred selection and two- or three-breed rotational crossbreeding systems based on the Holstein, Jersey, and Ayrshire breeds were considered. Results were highly dependent on future milk prices and production costs but generally favored purebred selection of Holsteins or Jerseys or a two-breed rotation of these breeds. Crossbreeding research in tropical countries has also been widespread due to poor viability of Holsteins and other Bos Taurus breeds in challenging, low-input environments. For example, Madalena et al (1990) evaluated crossbreeding strategies based on the Holstein-Friesian and Guzera breeds in Brazil. In well-managed herds, economic performance was greatest for first-generation crossbreds, followed by pure Holsteins and offspring of a modified rotational cross that used Holstein sires for two generations and Zebu sires in the third generation. In poorly-managed herds, economic performance was also greatest for first-generation crosses, but a two-breed rotation of Holstein and Zebu sires ranked second, followed by the modified two-breed rotation described above.

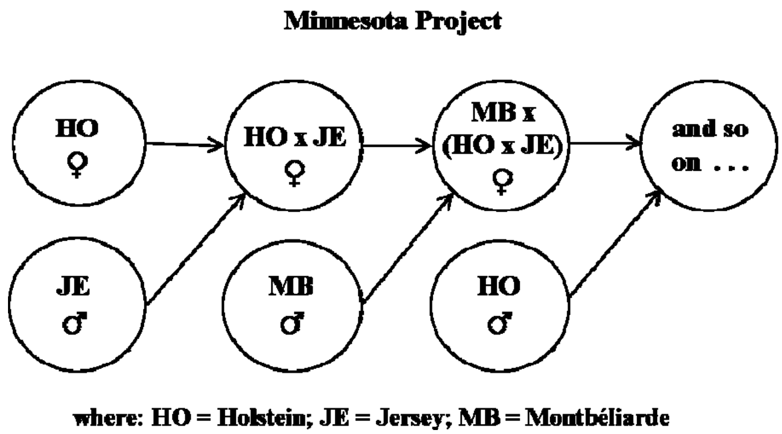
Current Research Efforts in the United States

Because of the lack of recent, relevant dairy crossbreeding studies, researchers in dairy cattle genetics identified crossbreeding as a key component of the S-1008 multi-state project: "Genetic Selection and Crossbreeding to Enhance Reproduction and Survival of Dairy Cattle". Crossbreeding programs aimed at estimating breed differences and heterosis (hybrid vigor) associated with calf mortality, growth, fertility, metabolic health, resistance to infectious diseases, longevity, feed efficiency, and milk composition have been initiated at the University of Minnesota (Holstein, Jersey, and Montbéliarde breeds), Virginia Tech (Holstein, Jersey, and Swedish Red breeds), and the University of Kentucky (Holstein, Jersey, and Swedish Red breeds). In addition, the production, health, and fertility of Holsteins, Jerseys, and Holstein x Jersey crosses will be evaluated at North Carolina State in a rotational grazing environment. Our research group at the University of Wisconsin has created a ¼ Jersey x ¾ Holstein backcross population by mating lactating Holstein cows to crossbred Jersey x Holstein sires. In addition to assessing the profitability of these second-generation Jersey x Holstein crosses relative to their Holstein contemporaries, our project seeks to identify specific genes that are responsible for the vast differences in milk yield, milk composition, body size, metabolic health, and female fertility between the Holstein and Jersey breeds. Lastly, researchers at several universities are involved in the analysis of performance data from crossbred cattle and their purebred contemporaries on commercial farms. Specifically, Tennessee will evaluate Norwegian Red x Holstein crosses, Minnesota will evaluate Swedish Red x Holstein crosses, and Penn State will evaluate Brown Swiss x Holstein crosses.

Results of the Minnesota Crossbreeding Experiment

A schematic diagram of the University of Minnesota crossbreeding experiment is shown in Figure 1. Briefly, Holstein cows and heifers were mated to either Holstein or Jersey sires in the first generation, and Montbéliarde sires were introduced in the second generation. Animals were allocated to either a confinement and total mixed ration system or a rotational grazing system.

Figure 1. Design of the University of Minnesota crossbreeding experiment.



Seykora et al. (2004) noted that Holstein cows and heifers (N=180) that carried Jersey-sired calves in this experiment had significantly lower calving difficulty scores (1.36 vs. 1.97), lighter birth weights of calves (35.7 vs. 43.6 kg), and reduced incidence of retained placenta (3.6% vs. 8.2%) than Holstein cows and heifers (N=163) that carried Holstein calves. However, breed of calf did not affect milk yield, days open, or culling rate in the ensuing lactation. Subsequent production and fertility data of these Holsteins and crossbreds, measured in first lactation, is shown in Table 1. Combined fat plus protein yield was 3.5% lower for crossbreds than Holsteins, but crossbreds had an average of 16 fewer days open per lactation.

Table 1. Average production and fertility of first lactation Holstein and Jersey x Holstein cows in the University of Minnesota herd (Hansen, 2006 (personal communication)).

Breed of Cow	N	Milk	Fat	Protein	Days to 1st Service	Days Open
Holstein	72	7,266 kg	259 kg	229 kg	88 d	155 d
½ Jersey x ½ Holstein	77	6,693 kg	258 kg	214 kg	78 d	139 d

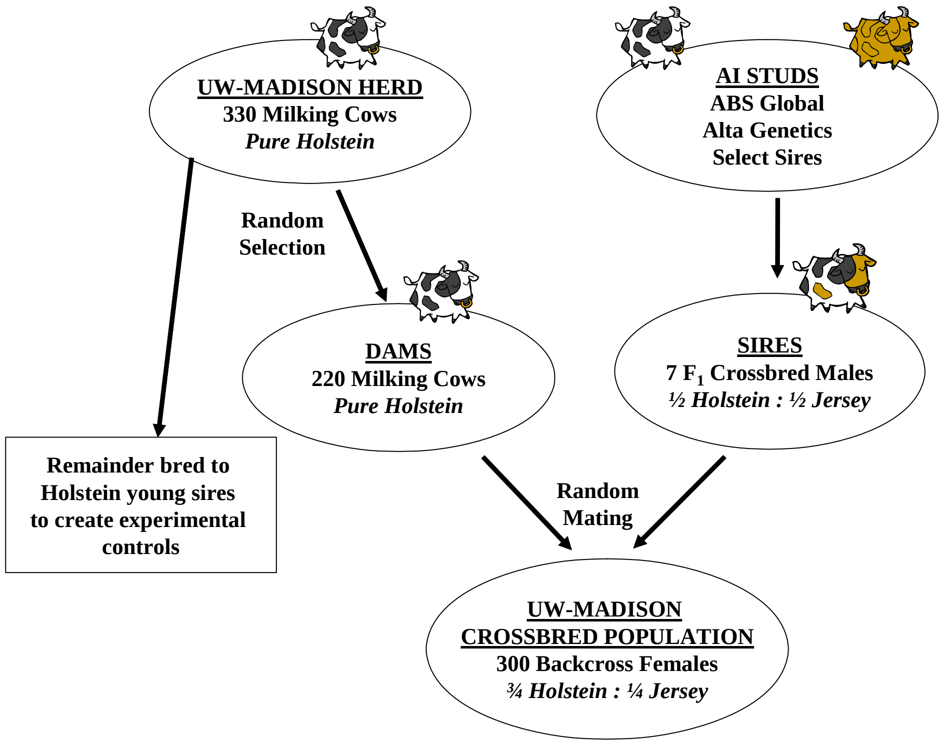
(tests of significance were unavailable)

In a more recent study, no significant differences were observed in feed efficiency between Holsteins and crossbreds in the Minnesota experiment (results not shown). Overall results of the Minnesota trial suggested a modest loss in production, with corresponding gains in calving performance and fertility by crossbreeding Holsteins with Jersey sires.

Results of the University of Wisconsin Crossbreeding Experiment

The design of the University of Wisconsin crossbreeding experiment, in which lactating Holstein cows were bred to either young Holstein sires or young crossbred Jersey x Holstein sires, is shown in Figure 2.

Figure 2. Design of the University of Wisconsin crossbreeding experiment.



Mean conception rates for crossbred service sires did not differ significantly from those of Holstein service sires when both were mated to lactating Holstein cows, and this result seems to contradict the perception among many dairy farmers that crossbred sires are more fertile and should be preferred as mates for cows that are problem breeders. However, our study considered only Jersey x Holstein sires, and it is possible that crossbred sires of other breeds may be more fertile. Results for perinatal mortality, defined as stillborn calves and calves that died within 24 hours, and preweaning mortality, defined as calves that were alive at 24 hours but died before weaning (or before removal from the farm at 1 week of age, in the case of male calves), suggest a significant advantage for crossbred calves, as shown in Table 2.

Table 2. Perinatal mortality (stillborn or dead by 24 hours) and preweaning mortality (alive at 24 hours but dead by weaning (females) or 1 week of age (males)) for Holstein and crossbred Jersey x Holstein calves from multiparous Holstein dams in the University of Wisconsin herd (Maltecca et al., 2006).

Breed	Sex	N	Perinatal Mortality	Preweaning Mortality
Holstein	Male	47	14.9%	10.0%
	Female	67	13.4%	11.9%
¾ Holstein x ¼ Jersey	Male	130	10.8%	2.6%
	Female	105	9.5%	8.4%
Odds ratio: Holstein vs. Crossbred			1.42*	1.23*

*P < 0.05

Mean birth weight of calves from crossbred sires and multiparous Holstein dams (38.7 and 38.1 kg for males and females, respectively) tended to be lower than that of Holstein sires and multiparous Holstein dams (40.1 and 39.2 kg for males and females, respectively). Crossbred calves in this population were also superior to Holstein calves for serum immunoglobulin G and serum protein levels at 24 to 72 hours of age, as shown in Table 3.

Table 3. Least squares means for total serum protein and log (serum IgG) of Holstein and crossbred Jersey x Holstein calves from multiparous Holstein dams in the University of Wisconsin herd (Maltecca et al., 2006).

Breed	Sex	N	Serum Protein	log (Serum IgG)
Holstein	Male	40	4.06 g/dL	6.56
	Female	59	3.95 g/dL	6.87
¾ Holstein x ¼ Jersey	Male	116	4.95 g/dL	6.94
	Female	95	5.10 g/dL	7.02
Contrast: Holstein vs. Crossbred			–1.17 ± 0.25**	–0.26 ± 0.12*

*P < 0.05, **P < 0.01

Crossbred calves also tended to have lower mean fecal consistency scores from birth to 7 days of age than Holstein calves, as well as shorter duration of scours episodes among affected calves (Maltecca et al., 2006). No differences were found in respiratory disease scores from birth to 7 days of age, perhaps due to a very low incidence of respiratory disease in this population.

Throughout the rearing period, crossbred heifers in the Wisconsin project have been consistently smaller than their Holstein counterparts, as indicated by significant differences in body weight, body length, hip height, and heart girth (Hoffman et al., 2006). This may translate into reduced feed costs, because fewer resources are required for maintenance, and we plan to assess feed intake and feed efficiency in both growing heifers and lactating cows within the next year. In addition, the smaller frame size of crossbreds may be appealing to an increasing number of dairy producers who are dissatisfied with the large size of mature Holstein cows and their inability to fit into stalls and milking parlors comfortably (especially on farms with older facilities).

The majority of economically important traits in dairy cattle can be measured only in lactating cows. The first crossbred animal in our study calved in October 2005, and a total of 45 crossbreds and 23 controls have initiated first lactation thus far. Among the crossbreds and controls that have calved to date, body weight at calving differed by roughly 35 kg, though body condition scores were very similar, as shown in Table 4.

Table 4. Preliminary means for body weight and body condition score at first calving for Holstein and crossbred Jersey x Holstein cows in the University of Wisconsin herd.

Breed	N	Body Weight	Body Condition Score
Holstein	45	598 ± 14 kg	3.46 ± 0.08
¾ Holstein x ¼ Jersey	23	564 ± 11 kg	3.44 ± 0.06

(tests of significance were unavailable)

Preliminary means for linear classification scores of first lactation crossbred and Holstein cows, which were evaluated between 50 and 200 days postpartum using the Holstein Association's scoring system, indicate significant differences in stature, strength, dairy form, rump angle, rump width, and front teat placement, as shown in Table 5.

Table 5. Preliminary means for type classification scores of first lactation Holstein and crossbred Jersey x Holstein cows in the University of Wisconsin herd.

Trait	Holstein (N=13)	¾ Holstein x ¼ Jersey (N=36)	Difference
Stature	31.4 ± 4.3	20.3 ± 2.4	11.1 ± 3.9**
Strength	24.7 ± 4.2	31.3 ± 2.3	-6.6 ± 3.8†
Body Depth	28.7 ± 3.4	26.0 ± 1.9	2.7 ± 3.1
Dairy Form	32.8 ± 3.4	26.2 ± 1.9	6.6 ± 3.1*
Rump Angle	22.2 ± 3.7	32.9 ± 2.0	-10.6 ± 3.3**
Rump Width	33.3 ± 2.0	22.3 ± 1.1	11.0 ± 1.9**
Rear Legs Side View	27.2 ± 3.5	26.3 ± 1.9	0.9 ± 3.2
Foot Angle	21.5 ± 2.9	25.4 ± 1.6	-3.9 ± 2.7
Fore Udder Attachment	19.1 ± 3.7	21.4 ± 2.0	-2.2 ± 3.3
Rear Udder Height	36.4 ± 4.2	35.8 ± 2.3	0.7 ± 3.8
Rear Udder Width	28.6 ± 3.5	27.6 ± 1.9	1.1 ± 3.2
Udder Cleft	24.0 ± 5.2	26.5 ± 2.9	-2.5 ± 4.8
Udder Depth	30.3 ± 4.4	27.4 ± 2.4	2.8 ± 4.0
Front Teat Placement	16.6 ± 3.4	22.7 ± 1.9	-6.1 ± 3.1†
Teat Length	18.4 ± 3.0	22.8 ± 1.7	-4.4 ± 2.8
Rear Legs Rear View	27.7 ± 3.8	33.3 ± 2.1	-5.6 ± 3.5
Udder Tilt	23.4 ± 4.5	25.0 ± 2.5	-1.6 ± 4.1

** $P < 0.01$, * $P < 0.05$, † $P < 0.10$

Preliminary results regarding milk yield and milk composition of first lactation crossbreds and controls that were at least 50 days postpartum at the time of analysis seem to favor Holsteins, because losses in milk volume in animals that have calved to date have not been offset by gains in fat or protein content, as shown in Table 6.

Table 6. Preliminary means for production traits of first lactation Holstein and crossbred Jersey x Holstein cows in the University of Wisconsin herd.

Trait	Holstein (N=11)	¾ Holstein x ¼ Jersey (N=33)	Difference
Peak Milk	35.7 ± 1.5 kg	31.7 ± 0.8 kg	8.7 ± 3.8*
305-Day ME Milk	11,363 ± 455 kg	9,733 ± 236 kg	3,585 ± 1129**
Fat %	3.65 ± 0.26	3.54 ± 0.14	0.12 ± 0.30

Protein %	2.80 ± 0.09	2.82 ± 0.05	-0.02 ± 0.10

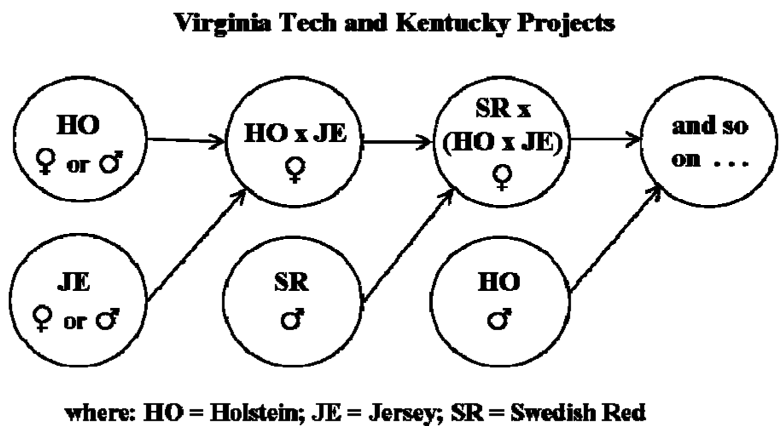
** P < 0.01, * P < 0.05

At this point, preliminary results of the Wisconsin study are in agreement with other recent studies, which indicate losses in milk production among crossbred animals, coupled with gains in calving performance, calf survival, and other health-related traits.

Results of the Virginia Tech and Kentucky Crossbreeding Experiments

Virginia Tech and Kentucky initiated a joint project involving reciprocal crosses of Holstein cows mated to Holstein or Jersey sires and Jersey cows mated to Holstein or Jersey sires. This experimental design, which is shown in Figure 3, will allow estimation of breed effects and heterosis, as well as specific maternal or paternal effects associated with each breed. Swedish Red sires were introduced in the second generation of this project.

Figure 3. Design of the Virginia Tech and University of Kentucky crossbreeding experiments.



Cassell et al. (2005) reported least-squares means for birth weight of 38.5 kg for Holstein calves, 29.4 kg for crossbred calves from Jersey dams, 31.3 kg for crossbred calves from Holstein dams, and 22.5 kg for Jersey calves in this study. Later, Olson et al. (2006) reported significant breed differences and heterosis for body weight and hip height between Holsteins, Jerseys, and crossbreds. Additional results will be forthcoming, including comparisons of age at puberty, feed efficiency, and other traits not routinely recorded in commercial herds.

Analysis of Field Data from California Herds by University of Minnesota Researchers

A group of seven commercial herds in California were among the first to use significant quantities of imported semen from French dairy breeds, Normande and Montbéliarde, and Scandinavian dairy breeds, Swedish Red and Norwegian Red. Although this was not a designed experiment, and despite the fact that these researchers had no control over the choice of sires or pattern of usage these sires, this study has provided vast quantities of data for several breeds that are currently of interest in crossbreeding programs. Crossbred heifers and their Holstein contemporaries calved from 2002 to 2005 in these herds, and all animals resulting from natural-service sires or maternal grandsires were removed from the analysis to ensure fair comparison of crossbreds and their Holstein contemporaries.

Production data of first lactation crossbred and Holstein cows in these herds are shown in Table 7. Combined fat plus protein yield of Scandinavian Red x Holstein cows was 2.2% lower than that of Holsteins, whereas combined fat plus protein yield of Montbéliarde x Holstein cows and Normande x Holstein cows was 3.8% and 8.6% lower than that of Holsteins, respectively.

Table 7. Least-squares means for actual 305-day production of first lactation Holsteins and crossbreds in seven commercial herds in California (Heins et al., 2006a).

Breed	N	Milk	Fat	Protein
Holstein	380	9,757 ± 102 kg	346 ± 4 kg	305 ± 3 kg
Normande x Holstein	245	8,530 ± 90 kg**	319 ± 3 kg**	277 ± 3 kg**
Montbéliarde x Holstein	494	9,161 ± 77 kg**	334 ± 3 kg**	293 ± 2 kg**
Scandinavian Red x Holstein	328	9,281 ± 77 kg**	340 ± 3 kg	297 ± 2 kg*

**P < 0.01, *P < 0.05 for contrast of difference from Holstein cows

Calving difficulty was recorded on a 5-point scale (1 = quick, easy birth with no assistance; 2 = over 2 h in labor, but no assistance; 3 = minimum assistance, but no calving difficulty; 4 = used obstetrical chains; and 5 = extremely difficult birth that required a mechanical puller). Scores of 1 to 3 were combined as an easy calving, whereas scores of 4 and 5 were combined as a difficult calving. Stillbirths were recorded on a binary scale (1 = alive at 24 hours; 2 = stillborn or dead within 24 hours). Unadjusted means for first lactation cows were 10.8% for calving difficulty and 10.9% for stillbirths, whereas unadjusted means for second and later lactation cows were 5.0% for calving difficulty and 5.2% for stillbirths. Results from Holstein cows and heifers mated to service sire of various breeds are shown in Table 8. Both calving difficulty and stillbirths were reduced significantly in crosses involving Scandinavian Red service sires and were improved modestly in crosses involving service sires of the French breeds.

Table 8. Least squares means for dystocia (calving difficulty) and stillbirths by breed of service sire for Holstein cows and heifers in seven commercial herds in California (Heins et al., 2006b).

	1st Lactation Dams			2nd to 5th Lactation Dams		
Breed of Service Sire	N	Dystocia	Stillbirths	N	Dystocia	Stillbirths
Holstein	371	16.4%	15.1%	303	8.4%	12.7%
Normande				326	8.7%	7.3%*
Montbéliarde	158	11.6%	12.7%	2,373	5.4%	5.0%**
Scandinavian Red	855	5.5%**	7.7%**	515	2.1%**	4.7%**

**P < 0.01, *P < 0.05 for contrast of difference from Holstein service sires

Information regarding calving difficulty and stillbirths of crossbred and Holstein dams (when these animals grew up and had calves of their own), when bred to Brown Swiss, Montbéliarde, or Scandinavian Red bulls, is shown in Table 9. Relative rankings of breeds for maternal calving ease were similar to those for direct calving ease, as Scandinavian Red x Holstein cows and heifers calved most easily and had the fewest stillbirths. Calving performance of crosses involving the French breeds was intermediate between that of Scandinavian Red x Holstein crosses and that of pure Holsteins.

Table 9. Least squares means for dystocia (calving difficulty) and stillbirths by breed of dam for Holstein and crossbred cows and heifers in seven commercial herds in California (Heins et al., 2006b).

	1st Lactation Dams			2nd Lactation Dams		
Breed of Dam	N	Dystocia	Stillbirths	N	Dystocia	Stillbirths
Holstein	676	17.7%	14.0%	307	3.1%	3.7%
Normande x Holstein	262	11.6%*	9.9%	190	3.3%	4.7%
Montbéliarde x Holstein	370	7.2%**	6.2%**	75	0.2%	5.9%
Scandinavian Red x Holstein	264	3.7%**	5.1%**	69	1.9%	2.3%

**P < 0.01, *P < 0.05 for contrast of difference from Holstein dams

Averages for days to first breeding and first service conception rate for first lactation cows are shown in Table 10. Normande x Holstein, Montbéliarde x Holstein, and Scandinavian Red x Holstein crosses tended to have fewer days to first service and higher conception rates than pure Holsteins.

Table 10. Least-squares means for days to first breeding and first-service conception rate of first lactation Holsteins and crossbreds in seven commercial herds in California (Heins et al., 2006c).

Breed	N	Days to 1st Breeding	1st Service Conception Rate
Holstein	536	69 ± 1.2	22 ± 3.0%
Normande x Holstein	379	62 ± 1.2**	35 ± 3.0%*
Montbéliarde x Holstein	375	65 ± 1.3*	31 ± 3.0%**
Scandinavian Red x Holstein	261	66 ± 1.4	30 ± 3.0%

**P < 0.01, *P < 0.05 for contrast of difference from Holstein cows

Corresponding results for days open in first lactation are shown in Table 11. Days open data were confirmed by subsequent calving or pregnancy examination by a veterinarian. If no inseminations were recorded, date of conception was inferred by subtracting 280 days from the date of calving. Cows were required to have at least 250 days in milk to be included in the analysis. A lower limit of 35 days open was applied, whereas cows that remained open at 250 days postpartum were assigned a value of 250 days open. Mean days open was significantly lower for Normande x Holstein, Montbéliarde x Holstein, and Scandinavian Red x Holstein crosses, as compared with Holsteins.

Table 11. Least squares means for days open of first lactation Holsteins and crossbreds in seven commercial herds in California (Heins et al., 2006c).

Breed	N	Days Open

Holstein	520	150± 4.1
Normande x Holstein	375	123 ± 3.8**
Montbéliarde x Holstein	371	131 ± 4.4**
Scandinavian Red x Holstein	257	129± 4.6**

**P < 0.01 for contrast of difference from Holstein cows

Lastly, survival of first lactation crossbred and Holstein cows to 30 days postpartum, 150 days postpartum, and 305 days postpartum was computed for each breed group, and these results are shown in Table 12. Culling rates for Normande x Holstein, Montbéliarde x Holstein, and Scandinavian Red x Holstein cows were approximately half of those for Holstein cows, regardless of the time period considered.

Table 12. Least squares means for survival to 30, 150, and 305 days postpartum of first lactation Holsteins and crossbreds in seven commercial herds in California (Heins et al., 2006c).

Breed	Survival to 30 Days Postpartum	Survival to 150 Days Postpartum	Survival to 305 Days Postpartum
Holstein	95%	91%	86%
Normande x Holstein	98%*	96%*	93%*
Montbéliarde x Holstein	98%*	96%**	92%**
Scandinavian Red x Holstein	98%*	96%**	93%*

**P < 0.01, *P < 0.05 for contrast of difference from Holstein cows

Overall, results from these commercial dairies in California suggest that crossbreeding will lead to a modest reduction in milk yield, with corresponding gains in calving ease, stillbirth rate, female fertility, and cow survival. It should be noted that preliminary comparisons of milk production of Holsteins and crossbreds from second and third lactation suggest that the superiority of Holsteins may be greater in later lactations than in first lactation (Hansen, personal communication, 2006).

Analysis of DHI Records by the USDA Animal Improvement Programs Laboratory

The number of crossbred and mixed herds of dairy cattle in the national milk-recording program has increased by more than 60% in the past decade (source: http://www.aipl.arsusda.gov). Using data from crossbred cows and mixed herds, scientists at the USDA-ARS Animal Improvement Programs Laboratory estimated breed differences and heterosis for milk, fat, protein, somatic cell score, length of productive life, and mature body size (VanRaden and Sanders, 2003), as shown in Table 13.

Table 13. Breed averages and heterosis for US dairy cows on DHI milk recording programs (VanRaden and Sanders, 2003).

Breed	Milk	Fat	Protein	SCS	PL	Mature Size
Ayrshire	26.3 kg/d	0.99 kg/d	0.81 kg/d	2.86	23.2 mo	550 kg
Brown Swiss	26.8 kg/d	1.04 kg/d	0.87 kg/d	2.96	23.8 mo	680 kg
Guernsey	24.1 kg/d	1.01 kg/d	0.77 kg/d	3.01	18.2 mo	520 kg

Jersey	23.9 kg/d	1.04 kg/d	0.81 kg/d	3.14	25.8 mo	450 kg
Milking Shorthorn	25.6 kg/d	0.92 kg/d	0.78 kg/d	2.98	19.5 mo	590 kg
Holstein	31.5 kg/d	1.12 kg/d	0.94 kg/d	3.10	24.3 mo	680 kg
Heterosis	3.4%	4.4%	4.1%	0.7%	1.2%	3.0%

(tests of significance were unavailable)

These breed averages can easily be combined into economic indices that reflect lifetime net profit per animal, including Net Merit (typical US milk market), Cheese Merit (cheese yield market), and Fluid Merit (fluid milk market). Average lifetime net profit of Holsteins exceeded other breeds by $305 to $892 in Net Merit, $186 to $862 in Cheese Merit, and $728 to $1,117 in Fluid Merit. However, heterosis provided gains of $197, $207, and $163 in Net Merit, Cheese Merit, and Fluid Merit, respectively, in first generation crosses. Using these estimated breed differences and heterosis parameters, the expected genetic merit of first-generation crosses of Holsteins with each of the other breeds can be computed, as shown in Table 14.

Table 14. Expected genetic merit of first-generation crosses of Holsteins with each of the other US dairy breeds for Net Merit, Cheese Merit, and Fluid Merit, relative to pure Holsteins (VanRaden and Sanders, 2003).

	Lifetime Net Profit of First-Generation Crosses Relative to Holsteins		
Breed	Net Merit	Cheese Merit	Fluid Merit
Ayrshire x Holstein	-$58	−$27	−$201
Brown Swiss x Holstein	+$18	+$79	−$241
Guernsey x Holstein	−$184	−$138	−$395
Jersey x Holstein	+$44	+$113	−$269
Milking Shorthorn x Holstein	−$249	−$223	−$373

As expected, the value of crossbreeding varies considerably according to the type of milk market and the breeds that are utilized. VanRaden and Tooker (2006) revised these estimates to reflect new economic weights in Lifetime Net Merit, including additional traits such as calving ease and daughter pregnancy rate, and to reflect breed differences estimated from a multi-breed genetic evaluation model. Mean percentages of difficult births for each breed were: 7.9% for Holsteins, 7.8% for Milking Shorthorns, 4.7% for Brown Swiss, 4.4% for Ayrshires, 3.3% for Guernseys, and 0.8% for Jerseys. In addition, breed differences (relative to Holsteins) for daughter pregnancy rate were +1.8%, +0.1%, +2.0%, +4.6%, and +4.3% for Ayrshires, Brown Swiss, Guernseys, Jerseys, and Milking Shorthorns, respectively. Estimated heterosis for daughter pregnancy rate was +1.8%, or roughly 10% of the average of the parental breeds. Estimated lifetime net profit of Jersey x Holstein and Brown Swiss x Holstein crosses, relative to pure Holsteins, changed minimally from the previous estimates of VanRaden and Sanders (2003). First-generation Jersey x Holstein crosses exceeded pure Holsteins by $22 for Net Merit and $123 for Cheese Merit, whereas first-generation Brown Swiss x Holstein crosses exceeded pure Holsteins by $32 for Net Merit and $102 for Cheese Merit. However, estimates for Ayrshire x Holstein, Guernsey x Holstein, and Milking Shorthorn x Holstein crosses changed significantly from the previous estimates of VanRaden and Sanders (2003), with new estimates of $261 to

$364 inferiority per cow for Ayrshire x Holstein crosses, $405 to $503 inferiority per cow for Guernsey x Holstein crosses, and $405 to $503 inferiority per cow for Milking Shorthorn x Holstein crosses, depending on the milk pricing system. Preliminary data from second-generation crosses suggest that Holstein backcrosses will be superior for Net Merit, whereas some three-breed crosses may equal pure Holsteins for Cheese Merit. Lastly, it is important to note that the Swedish Red, Norwegian Red, and Finnish Ayrshire breeds are evaluated relative to the US Ayrshire base, rather than the US Holstein base, and that there is no corresponding genetic base on which the Normande and Montbéliarde breeds can be evaluated at the present time.

Researchers at the USDA-ARS Animal Improvement Programs Laboratory recently developed a multi-breed genetic evaluation system that will allow simultaneous analysis of data from all purebred and crossbred cows and all single- and mixed-breed herds (VanRaden et al., 2006). At this point, we anticipate that the predicted transmitting abilities of sires and cows obtained from the multi-breed evaluation system will be converted back to their respective within-breed genetic bases for publication and distribution to the public (this will make results more consistent with the current evaluation system). However, estimates of breed differences and heterosis will be routinely available for all economically important traits, such that combined purebred/crossbred sire rankings can easily be created for farmers, consultants, extension agents, and AI stud personnel who have an interest in crossbreeding.

Take-Home Messages

• Crossbreeding research is lacking at present, but projects that will assess breed differences and heterosis for traits of economic importance are underway at seven land-grant universities. It will take five to ten years to accumulate enough knowledge to predict the outcomes of all possible crossbreeding systems and breed combinations with certainty.

• Producers who utilize crossbreeding are making a conscious decision to sacrifice milk production in order to achieve gains in calving performance, health, fertility, and longevity. There is no “magic cross” that will improve income and reduce expenses.

• In milk markets with adequate premiums for fat and protein content, first generation crosses of Holsteins with three or four leading North American and European dairy breeds will exceed pure Holsteins for lifetime net profit.

• Comparisons of the merit of various breeds and crosses must consider all traits that have economic value, from birth until death or culling. Particular attention should be paid to cumulate changes in inventory resulting from small differences in stillbirth rate, pre-weaning mortality, attrition during the rearing period, losses due to calving complications, death or culling during the early postpartum period, and removal of nonpregnant animals.

• The underlying factors that have led to increased interest in crossbreeding among US dairy producers, namely frustration with the calving performance, fertility, and longevity of Holsteins, have also led to significant changes in within-breed selection programs. More attention is given to “functional traits” in economic indices of US dairy breeds today than at any point in history.

• Implementation of a crossbreeding program is a serious, long-term commitment, and neither this decision nor the selection of the specific breeds and type of crossbreeding system should be taken lightly. Vast differences exist between farms in milk prices, volume premiums, feed resources, labor availability, management ability, facilities, and goals, and these should be considered carefully when developing a long-term breeding strategy.

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