

**A Literature Review on Crossbreeding in Dairy Cattle**

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## **ABSTRACT**

The objective of the literature review was to determine whether or not crossbreeding is a profitable and a viable option for the dairymen of today by reviewing the literature and experiments that have been conducted throughout the world by today's dairy professionals and leaders. The Dairy market today is increasingly competitive and more and more dairymen are considering crossbreeding to decrease health costs and increase profitability. Price premiums from cheese plants are given to milk producers for high components like protein and fat. In recent studies done by universities and research facilities around the world, results have found promising numbers from different kind of crossbred dairy breeds. In this literature review different studies were compared from the universities of Wisconsin, Virginia Tech, Minnesota, Penn State, Kentucky, and a research facility in Canada (Weigel, 2006). Each study reviewed included different types of two-way and three-way crosses made up of different breeds from the United States and Europe. The table results presented are from separate studies done by specialists in the field of genetics and include comparisons between crosses and purebred Holsteins for productions, net profit, calf mortality, calving ease, body condition scoring, etc. The research and results done by various experts in the dairy industry revealed milk yield does not drop off as much as expected but is never superior to Holsteins. (Cassel et. al., 2009). In various studies, both two way and three way crossbreeding programs revealed decreased health costs and maintained production. In conclusion, research done on crossbreeding experiments is still in its early stages, yet is proving again and again as a viable option to improve overall production, reproductive efficiency, and increase profitability.

# INTRODUCTION

Interest in the crossbreeding of dairy pure breeds has been widely considered over recent years due to a shift in interest in overall gross production to overall net profit of Dairy. The Dairy breeds present in the United States were created by breeding less specialized cattle to a purebred bull with desirable traits. Today, more and more dairymen are considering shifting from the breeding strictly for purebred cattle, to crossbreeding purebred cows in order to combine the more desirable traits of different breeds. The primary genetic question asked in crossbreeding is whether the resulting crossbred animals with genes from different parent breeds will perform better over multiple generations than that of the average of their parent's breeds? The term used to measure crossbred performance compared to the parental average is hybrid vigor, also known as heterosis. Crossbreeding has gained interest from producers as processing plants have put into place payment schemes that are beneficial to milk components such as fat and protein (Weigel, 2006). Along with breeding for better milk components, dairymen are looking to combine the better reproductive traits of European breeds and other American breeds in order lower costs and offset the Holstein's breeds poor reproductive traits such as; calving difficulty, preweaning and postweaning mortality, and conception rates. The rise of inbreeding rates due to increased homozygosity has also contributed to the growing interest in crossbreeding across the world. The literature review conducted will look into the research done on crossbreeding and whether or not it proves worthwhile. Studies conducted are widespread in universities around the United States. The majority of research done on crossbreeding looks at overall production and efficiency of crossbreeds compared to the most popular breed in the United States; Holsteins. Nutrition, calf mortality, calving ease, body condition scoring, and a number of other measures used to evaluate a dairy's herds overall efficiency are observed in

experiments done across the country by leading universities and companies in the dairy industry. The literature and experiments done by these professionals will help in determining whether or not crossbreeding is a feasible option for improving efficiency and profit.

# LITERATURE REVIEW

## *Overview*

***The Meaning of F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> generations.*** The terms F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> generations are repeatedly used in crossbreeding. All three refer to the generations following the first crossbreeding insemination. In crossbreeding the best results are usually seen in the F<sub>1</sub> generation, but unfortunately there is no way to continue to maintain the hybrid vigor experienced in the F<sub>1</sub> generation. When using a two breed or three breed crossbreeding program it is important to understand what F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> generations are. The F<sub>1</sub> generation is a result of crossbreeding two selected purebred cattle, and the result is a cow which is 50% of the dam, and 50% of the selected sire. Depending on what type of crossbreeding program is in place, the F<sub>2</sub> generation can be a result of breeding the F<sub>1</sub> crossbred animal to the either of the original two breeds or a new breed. The F<sub>3</sub> generation is the result of breeding the crossbred F<sub>2</sub> cow to one of the original purebred breeds, whether it is a two-way or three-way cross breeding program. An example of a two breed rotation would be when a F<sub>1</sub> ½ Holstein X ½ Jersey cross is bred back to either one of its purebred parents resulting in either a ¼ Holstein X ¾ Jersey or ¾ Holstein X ¼ Jersey F<sub>2</sub> generation cow. (It is important to understand the first breed listed in the combination of Holstein X Jersey cross terminology is the dam, and the Jersey breed is the sire that is bred to the Holstein dam or vice versa, the same can be said in all cross combinations throughout the literature review). In a three way cross program, a F<sub>1</sub> ½ Holstein X ½ Jersey cow would be introduced to a new breed, and be bred to a third breed, possibly to a third European or American purebred sire. The difference between a two way and three way cross is the hybrid vigor maintained that results from the breeding a F<sub>1</sub> cow to either a new breed or once again to one of its original parental breeds. Picking a two breed, three breed, or even four breed crossbreeding

program can be decided by hybrid vigor from F<sub>1</sub>, F<sub>2</sub>, and F<sub>3</sub> generations. Three way crossbreeding programs are said to have more of an upside than a two breed rotational system, but there have been few trials done to distinguish a large difference in hybrid vigor between two breed and three breed rotational systems (Murray, 2002).

***Hybrid Vigor (or Heterosis).*** Crossbreeding can be evaluated by hybrid vigor, or heterosis. Hybrid Vigor measures the ability of crossbred offspring to outperform the expected abilities transmitted by their parents. Since the goal of crossbreeding is to combine two, three, or four different breeds in order to achieve some desirable trait from each different breed, researchers measure crossbreeding's success by measuring hybrid vigor to get a feeling of what benefit there could possibly be by crossbreeding a herd. Maintaining hybrid vigor is ideal when running a successful crossbreeding system. Hybrid vigor is most importantly addressed in the second and later generations where hybrid vigor tends to drop in percentages. Dairymen will usually choose purebred sires for crossbreeding their already crossbred cow to maintain hybrid vigor. Another way in maintaining hybrid vigor is by using more than a combination of two breeds. Choosing between a two breed and three breed crossbreeding program can be evaluated by observing the amount of heterosis maintained from generation to generation. In a two breed crossbreeding program heterosis can drop off to 50% in the second generation cross and continue to stay between 50 and 70 percent all the way into later generations and finally leveling off at 67%. A system of 4 breed's results in a high heterosis on average, but the amount of breeds will eventually cause the cross to be diluted of desirable traits achieved from each breed (Pro Cross, 2009). According to Creative Genetics, of California, a three way cross is optimal when deciding on how many breeds to use when crossbreeding. The combination of three breeds provides for maintained heterosis in the second generation, and continuing to stabilize at around

85% (Pro Cross, 2009). A three way crossbreeding could prove to be the best option if heterosis does not drop off as much as expected, and the result of less dilution of breed traits when compared to a four breed crossbreeding program. Along with breed combinations, choosing the best bulls is the key to a successful crossbreeding program. Selecting bulls for their feet and legs, udders, or other traits that are lacking in the dam that will be bred are ideal for maintaining hybrid vigor. A crossbreed program capitalizes on traits that can be improved through heterosis by selecting proven breeds and targeting their strengths in order to improve a herd's profitability.

***Two Breed European Rotational crosses.*** Purebred Holsteins will generally always have significantly higher production numbers than any other breed or cross. The benefits of crossbreeding do not lie within total production but within new component premiums required for cheese and cost benefit when compared to overall feed and health costs. Many herds across the United States have looked into two-way crosses and the benefits they have to offer. When establishing any kind of crossbreeding study, it is vital to establish a strict Artificial Insemination program without the use of bulls and a management process that keeps track of cows and the correct new or old breed to inseminate back to. There are many different European breeds that have been selected to cross with Holsteins because of the resulting crossbred cow that achieves better reproduction traits, resulting in a Holstein X Montbeliarde, Scandinavian Red, and Normande cross (a Holstein dam bred to a European sire). Breeds such as the Normande offered less calving difficulty and still born calves (Normande Genetics, 2010). Along with less stillborns and better calving difficulty the European breeds have shown to offer better survival rates in the first lactation. Normande, Montbeliarde and Scandinavian Red are three dominant European breeds that have been crossed with the traditional Holstein Breed. The Scandinavian Red breed has often been the best breed to cross with when trying to improve overall health

within a Holstein herd. The ½ Holstein X ½ Scandinavian Red cross offers significantly better calving difficulty and less stillborn and stillbirths. The Normande breed has been crossed with Holsteins, but was shown to be less effective than ½ Holstein X ½ Scandinavian Red crosses, but they proved to be open for fewer days in first lactation (Weigel, 2006). A website dedicated to Normande genetics states “Beyond hybrid vigor, they hope to make up for the lost breeding qualities (especially fertility and strength) for such specialized breeds as Holstein and Jersey. Conventional dairymen and grazers alike, all seek maximum heterosis effect. Studies in France have shown that the F1 crosses tend to be above median average of the two breeds for milk but closer to the Normande for components” (Hansen, 2010). What Normande Genetics states, can be said for the other two European breeds Scandinavian Red and Montbeliarde breeds, but which one offers the better improvements when crossbred with is comparable. When Comparing the ½ Holstein X ½ Normande cross to the ½ Holstein X ½ Montbeliarde cross, the ½ Holstein X ½ Normande cross produces less milk than the ½ Holstein X ½ Montbeliarde cross but with better components. The Normande also offers more of a short and heavier physical appearance than the Montbeliarde. The ½ Holstein X ½ Montbeliarde cross is said to have a higher body condition score which is a reflection of overall production. They are also said to have better survival rates and fewer days open when being compared to the Holstein breed. The Montbeliarde have also out produced the Normande Holstein crosses when comparing overall production (Hansen, 2010). When dealing with overall production with the two-way crosses of Holstein and European breeds the ½ Holstein X ½ Scandinavian Red cross proved to maintain production the most in all three lactations when crossed with a Holstein (Weigel, 2006).

***Two-Breed American Rotational Crosses.*** The two predominant American breeds used in crossbreeding Holsteins are the Brown Swiss and the Jersey. The Brown Swiss breed

number 7 million in number, second only to the Holstein breed (Select Sires, 2010). The ½ Holstein X ½ Brown Swiss cross, Holstein dam bred to a Brown Swiss sire, perform considerably well with regards to milk production and protein and butter fat production. Along with high production traits they have correct feet and legs that allow them to stay in the milking herd for more lactations than the bigger breeds like Holsteins. (Brown Swiss USA, 2010). ½ Holstein X ½ Brown Swiss crosses score low in somatic cell counts. “Ontario Holstein breeder Howard Cornwell of Oxford County has tried some crossbreeding using Brown Swiss sires on Holstein cows. The resulting ½ Holstein x ½ Brown Swiss cross has increased herd life due to better breeding success and improved feet and legs. This is retained in the second generation when the F1s are back-crossed to Holstein. The Brown Swiss has a similar body size and production level to the Holstein, and tends to retain body condition better than Holsteins, even in the F1 and F2 generations. The ability to retain higher body condition scores has been shown to have a genetic link to cow fertility (Murray, 2002).

The Jersey Breed numbers 1.2 million in the world and has a fat average of 4.6% and a 3.6% protein average (selectsires.com, 2010). What makes the Jersey breed ideal for crossbreeding is its low calving difficulty scores and low feed costs and ability to maintain gross production and component averages. The Jersey breed offers many other traits that could improve an overall herd’s efficiency when crossbred with Holsteins. “According to Dr. Kent Weigel of the University of Wisconsin, field results from New Zealand have yielded several observations; first, straight Holsteins are "superior" for milk volume, but ½ Holstein X ½ Jersey crosses beat either of their parents when it comes to total butterfat and protein. The second observation from New Zealand is Holstein X Jersey crosses rank No. 1 for net profit. In New Zealand they're followed by Jerseys in second place, with Holsteins third” (Johnson, 2006). In

several studies done across the world, the ½ Holstein X ½ Jersey cross has produced the best numbers for a two way crossbreeding program in order to improve overall net profit when receiving cheese premiums (Cassel et. al., 2009). ½ Holstein x ½ Jersey crosses also offers a great number of proven sires, second only to Holsteins, for maintaining heterosis while crossing a herd. In order to establish a good crossbreeding program a dairyman needs a large pool of proven sires to pick from. The Jersey breed has over 630 bulls sampled a year (selectsires.com 2010). An average Jersey's productive life is around 1026 days compared to 843 of a Holstein (U.S. Jersey Association, 2009). Jerseys are also said to have fewer days' open and shorter calving intervals (U.S. Jersey Association, 2009).

***Three Breed Rotational Crosses.*** The aim of going to a three way cross over the traditional two-way cross was to maximize hybrid vigor in future generations. A three way cross will maintain hybrid vigor in later generations at 86%, while a 2 way cross will level off at 67% and a 4 way at 93% (Hansen, 2006). The decision to pick a three way cross over a four way cross can be explained by the complexity and dilution of individual breeds traits from generation to generation and by the minimal improvement of hybrid vigor at 6% in later generations compared to a three way cross program. Three way crosses offer an increased heterosis along with longevity, protein and fat components, and calving ease (Snowdon, 2010). In a three way cross program the F<sub>1</sub> and F<sub>2</sub> generations are both able to maintain %100 percent hybrid vigor compared to a two way cross program where hybrid vigor drops to %50 percent in the F<sub>2</sub> generation (Pro Cross, 2009).

There are many different combinations of three way crosses, most beginning with the most popular breed in the United States, Holsteins. ½ Holstein X ½ Jersey crosses has been bred the third time around with many different European breeds and American breeds. European

breeds offer increased milk production and lowered calving difficulty when performing a three way cross system. Out of the European breeds, breeding a purebred Holstein dam to a Scandinavian Red or Montbeliarde, and then breeding the F<sub>1</sub> generation to the breed that was not bred to the original parental dam, performed well as a three way breeding rotation.

### ***Production***

***Milk lbs. in Holstein X Jersey Crosses.*** In a recent crossbreeding experiment done by the University of Wisconsin, a Holstein herd was crossbred with F<sub>1</sub> generation ½ Holstein X ½ Jersey sires. In the study, the experiment showed that the resulting ¾ Holstein x ¼ Jersey crossbreed produced significant less amount of milk than the Holstein breed. 77 Holsteins were sampled and showed to have an average of 25,051 lbs (11,363 kg) of milk produced compared to the ¾ Holstein X ¼ Jersey crosses that produced 21,457 lbs (9,733 kg) of milk (Weigel, 2006).

**Table 1. Milk lbs In Jersey x Holstein Cross compared to Holstein purebreds (Weigel, 2006)**

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

The ¾ Holstein X ¼ Jersey crosses were also shown to peak earlier in lactation when compared to Holstein purebreds. The total fat production is over the 305 day lactation was also higher in the Holstein Breed compared to the crosses. Producers today are beginning to look towards net profit instead of gross revenue. The study shown above shows that with the ¾ Holstein X ¼ Jersey cross production does not drop off as far as feared when comparing the two

breeds. This factor is crucial whether or not crossbreeding can prove to be effective. The Holstein breed proves itself again and again as the overall top producing breed in the United States, but the drop off in overall production is expected when crossbreeding Holsteins to ½ Holstein X ½ Jersey bulls, once reproduction costs and health costs are calculated, then a producer can decide whether or not to begin a Holstein dam X ½ Holstein ½ Jersey sire crossbreed program. Rising feed and operational costs will play a factor when deciding whether or not to crossbreed. It should also be considered that the study was conducted on Holstein dams bred to ½ Holstein X ½ Jersey sires which could result in production and reproduction numbers different than that of a crossbreeding program with ½ Holsteins X ½ Jersey cows.

***Milk lbs in Holstein X Brown Swiss Crosses.*** In a study conducted by both the University of Penn State and University of Tennessee, information was gathered from producers who had implemented a crossbreeding program by breeding their predominately Holstein or Brown Swiss herds, to sires of the opposite of the two breeds. The ½ Holstein X ½ Brown Swiss crosses or ½ Brown Swiss X ½ Holstein Crosses produced 2 lbs less milk than the pure Holstein, but actually produced more fat and protein than the pure Holsteins with a 12 day reduction in days open in the F<sub>1</sub> generations (Penn State. 2007). “While other crosses appear to fall further behind pure Holsteins in second lactation, the relative advantage for production of the Brown Swiss crosses actually increased as lactation progressed. Hybrid vigor increased from 4.43 percent in first lactation to 13.41 percent in third and higher lactations”

**Table 2. Daily Production, somatic cell score and days open for Holstein X Brown Swiss crosses (Penn State, 2007)**

	Milk lbs	Fat lbs	Protein lbs	Somatic Cell Score
Holstein	73	2.66	2.2	2.73
Brown Swiss	62	2.53	2.05	2.78
½ Brown Swiss X ½ Holstein (F <sub>1</sub> generation)	71	2.79	2.24	2.54
Brown Swiss X Holstein X Brown Swiss (F <sub>2</sub> generation)	65	2.56	2.09	2.59
Hybrid Vigor	5.01	7.3	5.63	7.78

The studies conducted by both Penn State University and the University of Tennessee recorded results from 19 ½ Holstein X ½ Brown Swiss cross herds with relation to production and reproductive statistics. The results only include both F<sub>1</sub> crosses and backcrosses due to the lack of later generations. The F<sub>1</sub> crosses did not produce a lower milk yield than the purebred Holstein cows, and produced a higher amount of protein, but not a significant amount of fat yield. ½ Holstein X ½ Brown Swiss crosses (or ½ Brown Swiss X ½ Holstein crosses) also experienced fewer days open than the purebred Holstein cows. It should be noted, the backcross did not fare as well as the F<sub>1</sub> generations, thus proving the doubts about whether or not hybrid vigor would be maintained in second generations with a two way Holstein and Brown Swiss crossbreeding program (Cassel & McAllister, 2009).

***Two Way European Cross Production.*** In California a group of seven commercial herds took part in a two way crossbreeding program using the semen from the Normande, Montbeliarde breeds, Swedish Red, and Norwegian Red breeds (also known collectively as Scandinavian Reds). The crossbred heifers along with the purebred heifers they were being

compared to calved from a period during 2002 to 2005. In order for it to be a fair comparison in the herd studies, all of the calves resulting from natural-service sires or maternal grandsires were removed. The results showed that the combined fat and protein yield of the ½ Holstein X ½ Scandinavian Red crosses was only 2.2% lower than the Holstein breed. The combination of fat and protein in the ½ Holstein X ½ Montbeliarde cows and ½ Holstein X ½ Normande cows was 3.8% and 8.6% lower than that of Holsteins. Milk production was also shown to be the highest in the ½ Holstein X ½ Scandinavian Red cross out of all crosses when compared to the purebred Holstein breed (Weigel, 2006).

**Table 3. California Study Done on Holstein X European Crosses for Milk and component production (Weigel 2006)**

Breed	# of Cows	Milk	Fat	Protein
Holstein	380	9,757 ± 102 kg	346 ± 4 kg	305 ± 3 kg
½ Holstein X ½ Normande	245	8,530 ± 90 kg	319 ± 3 kg	277 ± 3 kg
½ Holstein X ½ Montbeliarde	494	9,161 ± 77 kg	334 ± 3 kg	293 ± 2 kg
½ Holstein X ½ Scandinavian Red	328	9,281 ± 77 kg	340 ± 3 kg	297 ± 2 kg

***Three Way European Cross Production.*** Maintaining hybrid vigor is the main motive when using a three way cross program. A study conducted by Brad Heins, of the University of Minnesota, found that in all facets of production, the Holstein X Montbeliarde X Scandinavian Red crosses faired the best compared to the other three way Holstein and European Crosses. It produced 9461 kg (20,857 lbs) of milk and a fat-protein combination of 664 kg (1,463.9 lbs) over a 305 day lactation period. The Holstein X Brown Swiss X Montbeliarde

crosses performed fairly well with comparison to the Holstein X Montbeliarde X Scandinavian Red crosses, while the Holstein X Scandinavian Red X Normande crosses lagged in production when compared to the other two three way crosses (Heins, et. al., 2007).

**Table 4. 305 day production amongst 3 way cross combinations (Heins, et al., 2007).**

3 Breed Crosses	Number of Cows	Number of Sires	Milk	Fat	Protein	Fat plus Protein
Holstein X Brown Swiss X Montbeliarde	44	8	9297 kg	349 kg	302 kg	651 kg
Holstein X Montbeliarde X Scandinavian Red	43	9	9461 kg	356 kg	308 kg	664 kg
Holstein X Scandinavian Red X Normande	86	10	8809 kg	331 kg	289 kg	620kg

### ***Net Energy Requirements***

In a study done at Virginia Tech, ½ Holstein X ½ Jersey and ½ Jersey X ½ Holstein crosses were compared to purebred Holstein and Jersey cows. All breeds were placed in the same housing barn and fed the same ration in a common feed bunk. NRC equations were used to estimate the amount of energy consumed by each breed. NRC rations account for growth, maintenance, production, and support in fetal development. “The objectives of the study were to compare first lactation purebred Holsteins, Jerseys, and reciprocal crosses for differences in energy balance and components of energy balance under one similar management system. The question that was trying to be answered for commercial producers was, “Can I make more money per unit of feed consumed by crosses when compared to a purebred” (Cassel 2010). The data was collected from first lactation on 43 Holsteins, 34 Holstein X Jerseys crosses, 41 Jersey X Holsteins crosses, and 22 Jerseys. The results revealed a insignificant difference in energy requirements between both the Holstein X Jersey and Jersey X Holstein crosses. Differences in

energy used between the crosses and purebred Holsteins for production, growth, intake, and maintenance are minimal but all less in the crosses than the purebred Holsteins.

**Table 5. Cumulative Net Energy (Mcal) Intake and Net Energy Requirements (Cassel, 2010)**

Item (Mcal)	Holsteins	½ Holstein x ½ Jersey	½ Jersey X ½ Holstein	Jersey
Intake	9813	9309	9487	7969
Growth	669	599	496	334
Maintenance	2666	2468	2425	2085
Pregnancy	27	32	33	21
Production	5968	6057	6162	5259

## ***Reproduction***

***Calving Difficulty and Stillbirth rates of Two Way European Crosses.*** Calving difficulty along with stillbirths were recorded in order to track reproduction efficiency. “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 between 1 and 3 were considered a successful and easy calving while scores 4 to 5 were considered difficult calving that most likely required in injury or death to either the calf or mother. Stillbirths were recorded on a binary scale (1 = alive at 24 hours; 2 = stillborn or dead within 24 hours)” (Weigel, 2006). 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 (Heins et. al., 2007). In the following table, the results show resulting F<sub>1</sub> generations (Holstein dams bred to European

breed sires) from the ½ Holstein X ½ Scandinavian Red, ½ Holstein X ½ Montbeliarde, and ½ Holstein X ½ Normande crosses all had stillbirths and calving difficulty reduced significantly. While the ½ Holstein X ½ Montbeliarde crosses and ½ Holstein X ½ Normande crosses did not fare as well.

**Table 6. Calving Difficulty and Stillbirths for Breed group of dam at first calving (Heins, Hansen, & Seykora, 2007)**

Breed of Dam	Number of Births	Calving Difficulty	Stillbirths
Holstein	676	17.7%	14.0%
½ Holstein X ½ Normande	262	11.6%	9.9%
½ Holstein X ½ Montbeliarde	370	7.2%	6.2%
½ Holstein X ½ Scandinavian Red	264	3.7%	5.1%

Averages for days to first breeding and first service conception rate for first lactation cows are shown in Table 6. ½ Holstein X ½ Normande, ½ Holstein X ½ Montbeliarde, and ½ Holstein X ½ Scandinavian Red tended to have fewer days to first service and higher conception rates than pure Holsteins. It should be noted, although minimal, once again ½ Holstein X ½ Scandinavian Red crosses performed better with regards to days to 1<sup>st</sup> breeding and 1<sup>st</sup> service conception rates when compared to both ½ Holstein X ½ Normande crosses and ½ Holstein X ½ Montbeliarde crosses (Heins, 2006).

**Table 7. Least- Breeding and first-service conception rate of first lactation Holsteins and crossbreds in seven commercial herds in California (Heins, 2006)**

Breed	# of cows	Days to 1 <sup>st</sup> Breeding	1 <sup>st</sup> Service Conception Rate
Holstein	536	69 ± 1.2	22 ± 3.0%
½ Holstein X ½ Normande	379	62 ± 1.2	35 ± 3.0%
½ Holstein X ½ Montbeliarde	375	65 ± 1.3	31 ± 3.0%
½ Holstein X ½ Scandinavian Red	261	66 ± 1.4	30 ± 3.0%

Corresponding results from the study done on the 7 California commercial diaries for days open in first lactation are shown in Table 8 where days open data were measured and compared amongst ½ Holstein X ½ Normande crosses, ½ Holstein X ½ Montbeliarde crosses, ½ Holstein X ½ Scandinavian Red crosses, and pure bred Holsteins 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” (Weigel, 2006). The amount of days open was significantly lower for ½ Holstein X ½ Normand, ½ Holstein X ½ Montbeliarde, and ½ Holstein X ½ Scandinavian Red crosses, as compared with Holsteins, with the ½ Holstein X ½ Scandinavian Red crosses accounting for the lowest amount of days open.

**Table 8. Holstein X European crosses compared to Holsteins Measuring Days Open (Weigel, 2006)**

Breed	# of cows	Days Open
Holstein	536	22 ± 3.0%
½ Holstein X ½ Normande	379	35 ± 3.05
½ Holstein X ½ Montbeliarde	375	31 ± 3.0%
½ Holstein X ½ Scandinavian Red	261	30 ± 3.0%

Lastly, survival of Holstein and two way Holstein and European crosses' first lactation cows from 150 days postpartum, to 305 days postpartum was recorded as shown in table 11. There was a 6% increase in survival rates among crosses when compared to Holsteins in the first 150 days postpartum. From 150 days to 305 days postpartum there was at least a 6% increase in survival rates amongst all crosses when compared to purebred Holsteins (Weigel, 2006).

**Table 9. Least squares means for survival to days postpartum (Weigel, 2006)**

Breed	Survival to 150 Days Postpartum	Survival 305 Days Postpartum
Holstein	91%	86%
½ Holstein X ½ Normande	96%	93%
½ Holstein X ½ Montbeliarde	96%	92%
½ Holstein X ½ Scandinavian Red	96%	93%

***Holstein X Jersey Reproduction Efficiency.*** In the same study conducted by the University of Wisconsin they found that the perinatal mortality (stillborn or dead by 24 hours) of ¾ Holstein x ¼ Jersey crosses was significantly lower than that of the pure breed Holsteins (Weigel 2006).

**Table 10 Perinatal Mortality and Prewearing Mortality (Weigel 2006)**

Breed	Sex	# of cows	Perinatal Mortality	Prewearing Mortality
Holstein	Male	47	14.9%	10.0%
	Female	67	13.%	11.9%
$\frac{3}{4}$ Holstein X $\frac{1}{4}$ Jersey	Male	130	10.8%	8.4%
	Female	105	9.5%	1.23%

When dealing with preweaning mortality which is defined as calves that were alive at 24 hours but died before weaning showed that the crossbreed has a considerable advantage when comparing crossbreeds to Holsteins (Weigel, 2006). Dairyman looking to improve survival rates for calves could consider  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crossbreed cows.

***Reproduction in Holstein X Jersey Crosses.*** In the experiment conducted at the University of Minnesota they found that  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey Crosses (Holstein dam bred to Jersey sires) had significant lower calving difficulty scores (1.36 vs 1.97) when compared with the purebred Holstein cows (Weigel, 2006). The incidence of retained placenta was also considerably lower in  $\frac{1}{2}$  Holstein x  $\frac{1}{2}$  Jersey Cows than that of the Holstein Cows. In overall production the combined fat and protein production is lower than that of the Holsteins. In table 10 below, 77 two way crosses of  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jerseys were sampled and compared to 72 purebred Holsteins, with regards to milk, fat, protein production, days to 1<sup>st</sup> service, and days open. The  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses did not outperform the purebred Holstein production, but could be profitable due to a small drop off when considering days to 1<sup>st</sup> service and days open. The  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  jersey crosses were 10 less in days to 1<sup>st</sup> service, and were 15 fewer days open than purebred Holsteins.

**Table 11 Average production and fertility of first lactation Holstein and Jersey x Holstein cows in the University of Minnesota Herd (Weigel, 2006)**

Breed of Cow	# of cows	Milk	Fat	Protein	Days to 1 <sup>st</sup> Service	Days Open
Holstein	72	7266 kg	259 kg	229 kg	88 d	155 d
½ Holstein X ½ Jersey	77	6693 kg	258 kg	214 kg	78 d	139 d

### ***Lifetime Net Merit in all Crosses***

“Overall, the results from the following 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” (Weigel, 2006). In Weigel’s study of lifetime net profit, he found that Holsteins exceed all other breeds by at least \$305 in net merit and \$186 in cheese Merit. Considering heterosis when crossbreeding, Dr. Weigel found in first generation crosses gains of \$18 in Brown Swiss Net Merit, and a gain of \$44 in ½ Holstein X ½ Jersey crosses. Cheese Merit saw a even bigger boost in Merit, Brown Swiss experience a gain of 79\$ in cheese merit, while ½ Holstein X ½ Jersey crosses saw a gain of \$113 in cheese merit. As a result of crossbreeding, hybrid vigor created gains in net and cheese merit, as shown in table 11. The negative fluid merit amongst both the ½ Holstein X ½ Brown Swiss and ½ Holstein X ½ Jersey crosses begs the question; can crosses compete in a fluid market where dairymen are sending their milk to fluid plants? The ability for crosses to increase net profit as a result of decreased health costs and reproductive costs when correlated with milk production, can only be truly evaluated when a producer is sending his or her milk to a cheese plant. Although

these numbers look promising, it should be noted that the study is only done for first lactation crossbreeds and does not account for later lactation crosses that might see a drop off in overall hybrid vigor.

**Table 12. Expected Net Profit of first generation Holstein X Jersey, Brown Swiss X Holstein, and Scandinavian Red Crosses relative to Holsteins (Weigel 2006)**

Breed	Net Merit	Cheese Merit	Fluid Merit
½ Holstein X ½ Brown Swiss	+\$18	+\$79	-\$241
½ Holstein X ½ Jersey	+\$44	+\$113	-\$269

In a another study done on crossbreeding experiments in New Zealand by the institute of Veterinary, Biomedical and Animal sciences, of Massey University, recorded net income when considering Milk income, beef income, gross income and Production costs. The following table portrays the recorded results. The study found that Hybrid Vigor for survival was a major contributing factor to increase in profitability for the crossbreeds versus Holsteins. Replacement rates for crossbreeds were lower than Holsteins and crossbreeds tended to have a larger proportion of mature cows which led to higher yields for milk, fat, and protein due to longevity (Villalobos at el. (2000)). The Holstein was outperformed by the crosses in only the production category, but saw a small decrease in milk income and beef income. As a result, the ½ Holstein X ½ Jersey and Holstein X Jersey X Aryshire crosses were able to offset gross income with decreased production costs, thus increasing net profit.

**Table 13. Gross and Net Income Cost Per Cow in a Study Done in New Zealand (Villalobos et al. (2000).**

Payment Received	Holstein	½ Holstein X ½ Jersey	Holstein X Jersey X Ayrshire
Milk Income	\$ 746.84	\$ 746.08	\$742.32
Beef Income	\$ 61.76	\$ 47.38	\$ 47.38
Gross Income	\$ 813.77	\$ 797.98	\$ 794.22
Production Costs	\$ 689.68	\$ 652.82	\$ 652.82
Net Income	\$ 124.10	\$ 145.16	\$ 142.15

***Net Profit on Three Way European Crosses:*** In a study done by Creative Genetics of California, feed costs, replacement costs, operating cost, cull rates, and milk pricing were calculated and compared to Holstein purebreds. The study revealed significant decreases in operational costs and increased milk prices received as a direct result of maintained hybrid vigor from crossbreeding. The study included Holstein X Montbeliarde X Scandinavian Red crosses and Holstein X Scandinavian Red X Montbeliarde Crosses compared to Holsteins. The following table 14 lists includes the increase in lifetime net profit as a result of increased days in herd and decrease in overall production costs amongst crosses (Pro Cross, 2009).

**Table 14. Lifetime Profit of Montbeliarde X Holstein Crosses and Scandinavian Red X Holstein Crosses (Pro Cross, 2009)**

	Holstein	Holstein X Montbeliarde X Scandinavian Red	Holstein X Scandinavian Red X Montbeliarde
Cows	165	369	218
Days in Herd	857	1122	1062
Lifetime Profit	\$3819	\$5194	\$4859
Difference to Holstein		+\$1375	+\$1040
% of Holstein		+36%	+27%

## **DISCUSSION AND SUMMARY**

When crossbreeding on large a commercial dairy, producers must ask themselves do they want to maximize milk production per cow, or do they want to maximize milk components and decrease feed costs? This question is vital in order to achieve success with a crossbreeding program. The value of Crossbreeding can only be truly evaluated when the producer considers sending his or her milk to a cheese plant where the dairyman will receive fat and protein premiums. There are many different approaches to starting a crossbreeding program, unfortunately, at the moment the only leading industry semen company in California that offers an organized crossbreeding program is Creative Genetics, which is limited to European breeds. Holstein X Jersey two way crosses can be profitable when receiving cheese premiums, according to the various studies reviewed. When breeding Holsteins to European breeds, the literature revealed that the Holstein x European crosses experienced a drop off in overall component and milk production, but when considering overall net profit, the results could prove logical for choosing a Montbeliarde, Normande, or Scandinavian Red cross. The Scandinavian Red breed proved to be the best breed to cross with Holsteins when trying to maintain heterosis with overall production.

Overall production in three-way cross programs looks promising for dairy producers. European breeds offer maintained production and hybrid vigor. The best performing three-way cross in terms of production, is the Holstein X Montbeliarde X Scandinavian Red, while the combination of Brown Swiss and Holstein X Montbeliarde Cross also looks promising, as its production saw a minimal amount of drop of in overall production, and it continued to maintain component percentages.

Reproduction problems such as calving difficulty can plague dairyman with herds made up of the large Holstein breed. Crossbreeding Holstein cows, which are notorious for poor calving difficulty scores, with European breeds can prove to be a feasible option when looking at the recorded results. In Dr. Weigel's review of studies done across the United States he found that Scandinavian Red and Swedish Red breeds fared much better than the Montbeliarde and Normande breeds. The Holstein X Scandinavian Red cross scored a 3.7% calving difficulty along with a 5.1% stillbirth rate compared to 17.7% calving difficulty score and 14.0% stillbirth rate in the Holstein breed (Heins et al., 2007). It is clear when crossbreeding for improved calving and production in European breeds, Scandinavian Red proves to be the best option.

Crossing Holsteins with European breeds for improved fertility is also being considered in order to increase efficiency. Results from seven commercial dairies in California showed the ½ Holstein X ½ Normande crosses improved in conception rates the most when compared to the Holstein breed. The ½ Holstein X ½ Normande breed's conception rate was 35% while the Holstein's at the commercial dairies were 22%. Improved survival rates were also experienced in the commercial herds when crossing the Holsteins with European crosses. All crosses increased survival rates by at least 5% 150 days and 305 days postpartum (Heins et al., 2007).

When considering ½ Holstein X ½ Brown Swiss crosses a producer should realize that although maintained production proves to be a valuable trait, reproductive and health traits do not improve as much as the ½ Holstein X ½ Jersey Crosses. Producers should consider that Brown Swiss calves are very difficult to deal with. If a producer is also looking to cross his or her Holsteins herd with Brown Swiss in order to achieve overall smaller cow size they might want to consider another breed because the ½ Holstein X ½ Brown Swiss cross is not much smaller when comparing it to the pure Holstein breed. Also, it should be noted that the ½

Holstein X  $\frac{1}{2}$  Brown Swiss crosses experienced a farther drop of in hybrid vigor in F<sub>2</sub> generations compared to other two way crossbreeding programs (Dechow, et. al., 2007).

Crossing Holsteins and Jerseys for cutting feed cost and health costs could be a promising option in today's dairy market. Beginning a two way crossbreeding program with Holstein's and Jersey's may result in a drop off in hybrid vigor in later generations, but lack of information has yet to prove otherwise. A  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey or  $\frac{3}{4}$  Holstein X  $\frac{1}{2}$  Jersey cross program reduces complexity when compared to a three way crossbreeding program and is most beneficial when the producers milk is receiving cheese component premiums. In the study performed by experts at the University of Wisconsin, a total of 77 cows were sampled resulting in results for 305-Day Mature Equivalent Milk for Holsteins and  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses. The results showed  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses produced far less than Holsteins (Table 1) and small drop off in overall Fat production. In table 8, a study done by the University of Minnesota showed when measuring protein,  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses also experienced a small drop off in overall Protein production. The studies conducted at both Minnesota and Virginia Tech with  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses offer intriguing results, the drop off in overall production was expected when comparing  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses to pure bred Holsteins, but the amount of drop off will be able to distinguish whether or not crossbreeding is profitable. The Virginia Tech study also found through NRC equations, the results showed that there was not a huge drop off in intake from Holsteins to the crosses, but when dealing with energy required supporting production, the study found significant hybrid vigor of 8.8 percent for total net energy for production. While purebred Jerseys are more efficient than that of Holsteins, the  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey and  $\frac{1}{2}$  Jersey X  $\frac{1}{2}$  Holstein crosses did not differ in efficiency when compared to purebred Holsteins. The results showed that crossbreeds cows consume less energy than Holsteins,

required less energy for maintenance than Holsteins, required the same or less energy for growth than Holsteins, but ultimately gave the same amount of net energy in it's milk (Cassel 2010).

The NRC measurements from Virginia Tech's experiment provide hope for a two way crossbreeding programs success. The ability of a  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey cross to produce a significant amount of milk without consuming as much energy as the purebred Holstein, could prove to be profitable in a crossbreeding program.

Improving reproduction traits in  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey or  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses is a huge reason why dairymen are considering the two breeds. The University of Wisconsin's study on Perinatal Morality and Prewaning morality (Table 7) showed a significant improvement for  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses versus purebred Holsteins. The study done by the University of Minnesota recorded days to first service and days open in Holstein and  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses, finding  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey crosses averaged ten days less to first service and 14 days less open. As the Holstein breed has evolved into a larger and larger cow over years of breeding for production and body condition scores, calving difficulty has increased. Dairymen are forced to pay the price for increased calving difficulty scores across all lactations. The  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey or  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses offer relieved stress on health costs and improves profitably in the long run.

Creative Genetics three way crossbreeding program yielded results positive results with Holstein, Montbeliarde, and Scandinavian Red breeds. Whether the original Holstein dam was bred first to a Montbeliarde or Scandinavian Red sire, the F<sub>2</sub> generation outperformed the purebred Holstein. The F<sub>2</sub> generation cross had an increase in net profit compared to Holsteins, whether it was bred the third time by the Scandinavian Red or Montbeliarde sire. Both combinations of three-way European cross exceeded Holsteins by at least \$1000 in overall net

profit. The three way crosses achieved longer days in herd, thus producing more milk and overall profit (Weigel, 2006).

A study conducted by the University of Minnesota, the ½ Holstein X ½ Jersey crosses prove to achieve the largest gains in profit when compared to purebred Holsteins and 1/2 Holstein X ½ Brown Swiss crosses. ½ Holstein X ½ Jersey crosses also experienced a \$44 dollar increase in net merit when compared to Holsteins as a result of hybrid vigor gains. The most significant improvement among merit improvement in crosses is the ½ Holstein X ½ Jersey's cross' \$113 increase in cheese merit. As expected, both the ½ Holstein X ½ Jersey cross and ½ Holstein X ½ Brown Swiss cross lagged in fluid merit by at least \$240 a cow (Weigel, 2006). A separate study conducted by Massey University of New Zealand, produced similar findings to the University of Minnesota's numbers. The Animal Science department discovered increased numbers in crossbreeds in later lactations, compared to Holsteins. Due to an increase in mature cows, the ½ Holstein X ½ Jersey and ½ Jersey X ½ Holstein crossbreeds outperformed purebred Holsteins in net income (Villalobos et al., 2000). Both Universities' studies point to crossbreeding success in cheese markets, but before producers decide whether or not a crossbreeding program is right for them, they should consider feed costs and other production variables that can greatly affect profit and the overall outcome of a crossbreeding program.

## CONCLUSION

In conclusion, the  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey cross will have reduced calving difficulty when born with Holstein dams and can perform well in cheese markets. Out of all the two way crosses the  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey or  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses have an advantage with fertility rates and reproductive traits.  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Brown Swiss crosses experienced a slight drop off in overall production when compared to purebred Holsteins. The  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Brown Swiss crosses experienced fewer days open. Out of the European breeds, Scandinavian Red is the most ideal breed when aiming for maintained production and increased reproductive performance. Due to increased longevity, increased reproduction traits, maintained production traits, and milk markets paying premiums to fat and protein components in milk, the  $\frac{1}{2}$  Holstein X  $\frac{1}{2}$  Jersey or  $\frac{3}{4}$  Holstein X  $\frac{1}{4}$  Jersey crosses could be a practical option to increasing profitability in today's competitive dairy market. A three-way crossbreeding program is the best option when trying to achieve hybrid vigor. The Holstein X Scandinavian Red X Montbeliarde cross proves to be the best combination of breeds in all aspects of dairy traits. A producer must consider all variables before deciding whether or not a crossbreeding program will prove to be effective. Feed resources, management capability, labor costs, and milk component premiums must all be considered.

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