## Crossbreeding

### Introduction

In general, crossbreeding of dairy cattle is not widely practiced, particularly in the main dairy producing countries of the world, the exception being New Zealand and Ireland. In these countries, production is seasonal, with cows calved in the spring to match the start of the grass growing season. Fertility of cows in these systems is crucial for longevity, as the breeding season is short, (3 months) and the impact on profitability due to non-pregnant cows at the end of the breeding season is large. In most, if not all of the other main dairy producing countries, calving takes place anywhere between 6 and 12 months of the year, so cows have more opportunities to get pregnant and the impact of reduced fertility is less noticeable.

The Holstein-Friesian breed is the dominant breed in most, if not all of the main dairy producing countries of the world, as the breed is renowned for high levels of milk production. However, with breeding for milk production traits, health and fertility traits have often mostly been ignored, or only given a small weighting in breeding indexes, the result being that fertility has declined, as has the length of productive life. This downward trend is now being addressed in estimated breeding indexes, (at least locally). In the UK, only about one third of the profitable lifetime index of bulls is now given to production traits and the rest to fertility, longevity and health traits. While this is helping to improve non-production traits, it is a slow process, as many of these traits have low heritability, relative to milk production traits. With the high propensity for milk production in Holstein-Friesians has come production diseases, such as milk fever and displaced abomasum's, along with condition score loss in early lactation, as most cows cannot eat enough to maintain milk production levels, without using body reserves. Therefore, (directly or indirectly), fertility has been impacted, as measured by days to resumption of cyclical activity, days to first service, days to conception and empty rates. This, together with shorter productive lifetime in herds has led to increasing interest in alternative dairy breeds, either on their own, or as crossbreds with Holstein-Friesians.

Crossbred offspring often perform better than the average of their parents, depending on the traits measured. This phenomenon is called heterosis or hybrid vigour and in Holstein-Friesian crossbreds is more marked for fertility and lifespan, where the gain can be between 5 and 25% above the average of the parent breeds.

Inbreeding is a (increasing) feature of all pure dairy breeds and can be defined as the matings between related parents. The more closely related the parents are, the higher is the level of inbreeding in the offspring, or in term of genetics, more gene pairs will be identical because of common ancestor(s). By definition, a pure-bred animal is inbred, as this removes variation in the offspring for a trait that is being selected for. However, because of the increase in homozygosity in the genome, there is a greater likelihood of lethal recessive genes becoming dominant. From a farmer perspective, inbreeding reduces milk yield, health and fertility traits and longevity, the higher the percentage of inbreeding the greater the impact.

Crossbreeding can be described as the inverse of inbreeding, as genes in the offspring are more likely to be heterozygosis, (different from each other), the bigger the difference in the parent breeds, the higher the level of heterozygosis in the crossbred offspring.

Several studies have been undertaken comparing Holstein-Friesians with other dairy breeds and/or various combinations of 2 way and 3 way crosses. However, breed comparison studies are expensive and as a consequence, many studies have been short term and/or involved a very limited number of animals. Some studies have concentrated on production traits only and not

presented health and fertility information. Very few studies followed animals through to culling, to obtain economic performance data across the lifetime of the animals. The results from a number of studies from both seasonal calving and intensive production systems are presented below, together with the conclusions from each study.

**An assessment of the production, reproduction, and functional traits of Holstein-Friesian, Jersey × Holstein-Friesian and Norwegian Red × (Jersey × Holstein-Friesian) cows in pasture-based systems (TEAGASC).**

| | Holstein | Jer x Hol | Nor x Jer X Hol | P value |
|---|---|---|---|---|
| Milk yield (l) | 5,720[a] | 5,476[b] | 5,366[b] | <0.001 |
| Solids corrected yield | 5827[a] | 5905[a] | 5681[b] | <0.001 |
| Milk solids kg | 460[ab] | 469[a] | 453[b] | 0.004 |
| Milk solids/kg $BW^{0.75}$ | 4.16[a] | 4.58[b] | 4.30[c] | <0.001 |
| Calving to 1st service (days) | 85[a] | 91[b] | 84[a] | <0.001 |
| 1st service conception | 65.2 | 73.0 | 65.6 | 0.242 |
| 12 week pregnancy rate | 96.8 | 93.1 | 93.1 | 0.966 |
| Ave liveweight (kg) | 530[a] | 479[b] | 499[c] | <0.001 |

Superscripts with same letter are not significantly different from each other

**Conclusion from this study:** Holstein-Friesian herds with poor reproductive performance and low milk fat and protein contents are likely to benefit considerably from crossbreeding with high-EBI Jersey bulls, (Economic Breeding Index), with all herds likely to benefit in terms of production efficiency. However, where herd performance, particularly in relation to reproductive performance, is comparable with the HF in the current study, crossbreeding with Jersey or Norwegian Red is unlikely to lead to significant improvements in overall herd performance. The combination of similar milk solids production, reproductive performance, and health traits made all 3 genotypes suitable for spring-calving, pasture-based milk production systems.

**An evaluation of production efficiencies among lactating Holstein-Friesian, Jersey, and Jersey × Holstein-Friesian cows at pasture (Teagasc)**

| | Holstein-Friesian | Jersey | Hol x Jersey |
|---|---|---|---|
| Milk yield (kg) | 18.3[a] | 13.8[b] | 16.7[c] |
| Milk solids (kg) | 1.33[ab] | 1.28[a] | 1.41[b] |
| SCM (kg) | 16.9[a] | 15.7[b] | 17.5[a] |
| Liveweight (kg) | 498[a] | 369[b] | 448[c] |
| BCS | 2.76[a] | 2.93[b] | 3.00[b] |
| DMI (kg) | 16.9[a] | 14.7[b] | 16.2[a] |
| Milk solids/100 kg of BW (kg) | 0.27[a] | 0.35[b] | 0.32[c] |
| Milk solids/kg DMI | 0.079[a] | 0.088[b] | 0.087[b] |

Superscripts with same letter are not significantly different from each other

**Conclusion from this study:** Dairy systems in which pasture environments are core to production are dependent on cows achieving high DMI per unit of BW, with high milk solids production per unit of intake. The results from this study indicate that differences in animal production performance characteristics—milk yield and milk composition, BW, BCS, and TDMI—exist between the HF and J breeds. The reputed superior intake per unit of BW and gross

production efficiency characteristics of J were also confirmed in this study. The results also indicate that crossing HF with J will result in cows very suited to grazing systems, as evidenced by the high intake capacity at pasture, with the added benefit of improved production and feed efficiency. This is borne out of additive genetic improvement caused by the superiority of the J breed compared with the HF breed in this regard, but is also contributed to by hybrid vigour and the complementarity of the 2 breeds.

**Teagasc Five lactation study with 210 cows**

| | Dutch Holstein-Friesian | Irish Holstein-Friesian | Montbeliarde | Normande |
|---|---|---|---|---|
| Milk yield (kg) | 5994[a] | 5321[b] | 5119[b] | 4560[c] |
| Fat + protein (kg) | 435.7[a] | 377[b] | 373.5[b] | 346.2[c] |
| Liveweight (kg) end of lactation | 562[a] | 589[b] | 604[bc] | 618[c] |
| BCS end of lactation | 2.45[a] | 2.81[b] | 3.11[c] | 3.11[c] |
| SCM/kg DMI* | 1.17 | 1.12 | 1.14 | 1.11 |
| Calving to 1st service (days) | 71.5 | 70.9 | 64.9 | 67.7 |
| Calving to conception (days) | 99 | 87.3 | 82.1 | 82.9 |
| Pregnancy rate (%) | 73.7[c] | 83.9[b] | 91.2[a] | 91.9[a] |
| CR 1st serve | 37.2 | 42.3 | 50.4 | 56.6 |
| Serves per conception | 1.81 | 1.79 | 1.70 | 1.61 |
| Proportion surviving to 2500 days of age | 0.206 | 0.397 | 0.492 | 0.558 |

Superscripts with same letter are not significantly different from each other * solids corrected milk/kg dry matter intake

**Conclusion from this study:** The results of this study suggest that although Dutch Holstein-Friesians produced the highest milk yield, this was at the expense of mobilisation of body reserves in early lactation and lower liveweight gain in the latter part of lactation. The results of the present study indicate that the reproductive performance and survival of Holstein-Friesians with a large proportion of North American genes is low in a seasonal grass-based milk production system.

**Teagasc data, 40 spring calving herds, 10,593 cows and 24,279 lactations over the years 2008 - 2012**

| | | | | Heterosis* | | |
|---|---|---|---|---|---|---|
| | Holstein | Friesian | Jersey | Holstein X Friesian | Holstein X Jersey | Friesian x Jersey |
| Milk yield (kg) | 5219[a] | 4591[b] | 4230[c] | 45.0 | 263.8*** | 81.9 |
| Fat yield (kg) | 218[a] | 193[b] | 226[c] | 5.2 | 14.5*** | 4.1 |
| Protein yield (kg) | 186[a] | 168[b] | 169[b] | 0.6 | 11.1*** | 3.4 |
| Age at 1st calving (days) | 744[a] | 730[b] | 762[c] | -1.3 | -11.7*** | -2.9 |
| Calving to 1st service (days) | 71.4[a] | 68.9[b] | 70.5[ab] | 2.4 | -0.4 | -1.8 |
| Calving interval (days) | 382[a] | 376[b] | 387[c] | -5.5 | -7.6*** | -9.3 |

*Heterosis effect is the difference from the average of the 2 breeds combined, for each parameter. Superscripts with same letter are not significantly different from each other.

**Conclusion from this study:** The findings from the present study corroborate previous conclusions from small-scale controlled experiments and illustrate the superior biological performance of crossbred cows' relative to the average of parental breeds within seasonal-calving, grass-based commercial dairy herds. Moreover, the results indicate that the widespread adoption of crossbreeding offers the Irish dairy industry the opportunity to capitalize on heterosis for traits of economic importance and may result in a considerable improvement in profit. Consequently, to fully exploit crossbreeding and maximize attainable heterosis, high-genetic-merit bulls from complementary pure breeds must be available to dairy farmers.

**AFBI study: Holstein versus Swedish Red x Jersey x Holstein, 1 lactation**

| | Holstein | Swedish Red x Jersey x Holstein | P value |
|---|---|---|---|
| Milk yield (l) | 7310 | 6378 | <0.001 |
| Milk solids (kg) | 546 | 520 | 0.16 |
| ECM yield (kg/kg of live weight $^{0.75}$) | 63.6 | 62.7 | 0.611 |
| Early lactation intake (kg DMI) | 18.9 | 17.6 | 0.115 |
| Late lactation intake (kg DMI) | 18.3 | 17.7 | 0.175 |
| Mean liveweight (kg) | 560 | 530 | <0.001 |
| Mean BCS | 2.16 | 2.42 | <0.001 |
| % 1+ cases mastitis | 26 | 6 | 0.033 |
| % ovarian dysfunction | 61 | 28 | 0.007 |

**Conclusion from this study:** Whereas the 3-breed rotational crossbred cows used in the current study, (SR × J/HOL), had a higher BCS than the HOL cows, they were lighter, tended to lose more BW, had lower DMI, and produced less milk than HOL cows. However, their milk had a higher fat

and protein content, meaning that fat plus protein yield was unaffected by genotype. No genotype × system interaction was observed for any of the milk production parameters, meaning that although the SR × J/HOL cows were able to compete with the HOL cows within both low and medium concentrate input systems (for milk solids yield), they offered no advantages. However, the crossbred cows had fewer incidences of mastitis and ovarian dysfunction than the HOL cows, highlighting their improved functional traits, with this likely to be due in part to heterosis. (No fertility data available).

**Effects of Breed and Feeding System on Milk Production, Body Weight, Body Condition Score, Reproductive Performance, and Postpartum Ovarian Function (Teagasc)**

| | Holstein | Montbeliarde | Normande | Norwegian Red | Montbeliarde x Holstein | Normande x Holstein |
|---|---|---|---|---|---|---|
| Milk yield (kg) | 5925[a] | 5604[b] | 5464[b] | 5788[a] | 5789[a] | 5795 |
| SCM yield (kg/cow) | 5467[a] | 5125[b] | 5044[b] | 5278[c] | 5332[ac] | 5382[ac] |
| Fat + protein (kg) | 428 | 400 | 392 | 414 | 417 | 420 |
| Liveweight (kg) | 570[b] | 568[b] | 587[a] | 537 | 572[b] | 575[a] |
| BCS | 2.77 | 3.15[a] | 3.16[a] | 3.06[b] | 3.00[b] | 3.00[b] |
| Days to 1st serve | 73.3[a] | 71.8[ac] | 68.9[bc] | 70.1[bc] | 68.2[bd] | 71.3[acd] |
| Days to conception | 89.9[ab] | 95.3[b] | 83.6[a] | 85.4[a] | 86.7[a] | 87.9[a] |
| Serves/ conception | 1.98 | 2.05 | 1.89 | 1.82 | 1.97 | 1.83 |
| Survival days post calving (median) | 695[b] | 1023[b] | 1068[b] | 1416[a] | 1385[a] | 1171[a] |

**Conclusion from this study:** This study confirmed differences in milk production potential between the breeds. The Holstein-Friesian selected for milk production had lower BCS and greater bodyweight compared to the Norwegian Red selected for functional traits concurrently with milk production. The MB and NM, selected simultaneously for milk and beef production, had greater BCS compared with all breeds over the complete lactation. Some differences between the breeds in their capacity to establish and maintain pregnancy were observed despite similarities in their endocrine and metabolic hormone profiles. The HF was less likely to be pregnant at the end of the breeding season; thus, their ability to survive in a seasonal production system may be compromised. Feeding system did not influence reproductive performance of the different breeds.

**AFBI Three year study of Holstein versus Holstein x Jersey crosses**

| | Holstein | Holstein x Jersey | P value |
|---|---|---|---|
| Milk yield lactation 1-3 (L) | 6252 | 5627 | <0.001 |
| Milk solids (kg) | 467 | 471 | NS |
| Mean SCC | 218 | 173 | - |
| Ave liveweight (kg) | 513 | 469 | <0.001 |
| Mean CS | 2.33 | 2.50 | <0.001 |
| Conception to 1st service | 35 | 58 | <0.001 |
| % pregnant at end of breeding | 73 | 89 | <0.05 |
| 1+ cases of mastitis (%) | 29 | 16 | <0.05 |
| 1+ cases of lameness (%) | 19 | 11 | NS |

**Conclusion from this study:** While Holsteins produced more milk, milk solid yield was unaffected by breed type. Within breed type there were similar losses in both liveweight and condition score across lactations. Fertility performance was superior for the crossbred animals.

**Production and reproduction of Fleckvieh, Brown Swiss, and 2 strains of Holstein-Friesian cows in a pasture-based, seasonal-calving dairy system (Switzerland)**

| | NZ Holstein-Friesian | Swiss Holstein-Friesian | Flechvieh | Brown Swiss |
|---|---|---|---|---|
| Milk yield (kg) | $5321^{b}$ | $5921^{c}$ | $5291^{ab}$ | $4927^{a}$ |
| Fat + Protein (kg) | $411^{b}$ | $427^{b}$ | $397^{b}$ | $350^{a}$ |
| ECM efficiency ($kg/kg^{0.75}$) | $23.2^{b}$ | $22.8^{ab}$ | $20.9^{a}$ | $20.9^{a}$ |
| BCS at calving | $3.25^{b}$ | $3.05^{a}$ | $3.52^{c}$ | $3.38^{bc}$ |
| BCS at nadir | $2.69^{b}$ | $2.39^{a}$ | $2.86^{c}$ | $2.74^{bc}$ |
| Calving to conception (days) | 87.3 | 91.0 | 77.2 | 80.2 |
| CR 1st service (%) | 62.0 | 45.5 | 67.4 | 58.9 |
| 12 week pregnancy rate | 91.5 | 80.7 | 94.5 | 93.0 |

Relatively small study, hence no significant differences in fertility parameters between breeds.

**Conclusion from this study:** The results of this analysis indicate large variation between breeds regarding milk production, reproductive performance, and health. Despite their high milk-production efficiency, Swiss Holstein-Friesian are unsuited to seasonal calving production systems due to their poor reproductive ability. On the contrary, Flechvieh achieved compact calving and merit further consideration within pasture-based milk production systems, despite their lower milk production per lactation. These results also indicate that genetic selection for higher BCS postpartum should help to improve overall reproductive performance irrespective of breed.

**Other AFBI studies: On farm study comparing Holstein and Norwegian Red animals**

| | Holstein | Hol x Nor | P value |
|---|---|---|---|
| Lactation 1-5 yield ave (L) | 7193 | 6916 | <0.001 |
| Milk solids (kg) | 503 | 497 | 0.076 |
| Conception rate 1-4 lactations (%) | 40.9 | 57.8 | 0.05 |
| Calving interval (days) | 391 | 383 | 0.21 |
| Reaching 6th lactation (%) | 16.3 | 27.3 | - |

**Conclusion from this study:** The multi-trait selection program, which has been in place in Norway for several decades appears to have been highly effective in developing a breed with improved calving ease, fewer stillbirths, reduced SCC, and improved fertility and longevity. In general, differences in milk-production performance between the 2 breeds were small. Overall cow longevity was longer with the NR cows, with this largely due to improved fertility and a lower incidence of culling for mastitis. Culling for udder structure was an issue with the Norwegian Red cows.

**AFBI Total confinement versus summer grazing for Holstein and Jersey x Holstein cattle over 1 lactation**

| | Total confinement | | Grazing | | Interaction | | |
|---|---|---|---|---|---|---|---|
| | Holstein | Jer x Hol | Holstein | Jer x Hol | Genotype | System | Interaction |
| Milk yield (L) | 9053 | 7048 | 6274 | 5964 | ** | *** | * |
| Fat + Protein (kg) | 697 | 631 | 483 | 493 | NS | *** | NS |
| SCC | 217 | 289 | 79 | 183 | ** | NS | NS |
| 1+ cases mastitis | 0.32 | 0.60 | 0.28 | 0.22 | NS | NS | NS |
| Mean liveweight (kg) | 590 | 578 | 591 | 528 | * | NS | NS |
| Mean BCS | 2.5 | 2.7 | 2.3 | 2.4 | * | *** | NS |
| CR to 1st & 2nd serve | 0.58 | 0.75 | 0.67 | 0.70 | NS | NS | NS |
| 12 week pregnancy rate | 0.74 | 0.85 | 0.72 | 0.75 | NS | NS | NS |

**Conclusion from this study:** The lighter-weight J × HF cows were able to compete in terms of milk production with the larger HF cows within the medium-input grazing system, with the crossbred cows compensating for their smaller size by having a higher intake per kilogram of BW. However, the J × HF cows were unable to exhibit as large a milk production response to high concentrate feed levels as the HF (with a similar trend observed for SCM), the HF cows mobilizing more body tissue in early lactation and partitioning less feed nutrients to body tissue reserves in mid or late lactation. In summary, although well-suited to medium concentrate input grazing systems, J × HF cows would appear less suited than HF cows to high concentrate input systems.

**Danish study Comparison of Danish Holsteins (n=103,307) and Nordic Red x Holsteins (n=14,832) from Danish database, across three levels of production.**

| | High production | | Average production | | Low production | |
|---|---|---|---|---|---|---|
| | Holstein | Holstein x Nordic Red | Holstein | Holstein x Nordic Red | Holstein | Holstein x Nordic Red |
| 305 d fat yield (kg) 1st lact | 360 | +9 | 331 | +7 | 295 | +3 |
| 305 d fat yield 2nd lact | 417 | +3 | 391 | -4 | 354 | -2 |
| 305 d protein yield (kg) 1st lact | 307 | -2 | 280 | 0 | 246 | 0 |
| 305 d protein yield (kg) 2nd lact | 357 | -7 | 332 | -8 | 296 | -5 |
| Days open 1st parity | 74 | -9 | 75 | -10 | 76 | -16 |
| Days open 2nd parity | 74 | -8 | 68 | -10 | 75 | -11 |
| Mastitis relative % 1st parity | - | -15 | - | -15 | - | 0 |
| Mastitis relative % 2nd parity | - | -14 | - | -11 | - | -6 |
| Survival 1st-2nd parity (%) | - | +3.6 | - | +1.2 | - | +5.1 |
| Survival 1st-3nd parity (%) | - | +15 | - | +7.5 | - | +11 |

**Conclusion from this study:** We showed that performance in F1 crossbreds between Nordic Red × Holstein compared with Holstein was independent of production level for most traits. Thus, these results disprove the common opinion among farmers that crossbred animals perform best in herds with a poor management level. Our results are consistent with those of previous studies, showing that F1 crossbreds outperform Holstein cows in traits for fertility, udder health, stillbirth, and survival. Investigations of the economics of crossbreeding at the herd level, as well as more studies on different breeds crossed in different herd levels, may strengthen the general trust of crossbreeding of dairy cattle.

**American studies, mostly high input confined systems**

**Production of Pure Holsteins Versus Crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red in 7 dairies in California.**

| | Holstein | Normande/ Holstein | Montbeliarde/ Holstein | Scandinavian Red/Holstein |
|---|---|---|---|---|
| Milk yield (kg) | 9757** | 8530 | 9161 | 9281 |
| Fat kg | 346* | 319 | 334 | 340* |
| Protein kg | 305* | 277 | 293 | 297 |
| Milk solids (kg) | 651* | 596 | 627 | 637* |

**Conclusion from this study:** Pure Holsteins in this study had significantly higher 305-d milk and protein production than all crossbred groups; however, pure Holsteins were not significantly different from SR/Holstein crossbreds for fat production. The SR/Holstein crossbreds (−2.2%) were not significantly different from the pure Holstein for fat plus protein production; however, the Montbeliarde/Holstein (−3.8%) and the Normande/Holstein (−8.6%) crossbreds were significantly lower ($P < 0.01$) than the pure Holsteins for fat plus protein production. No adjustment was made to production for differences in days open of cows. Cows with fewer days open are penalized for 305-d production. (no health and fertility data)

**Comparison of Holstein versus Montbeliarde x Holstein and Montbeliarde x (Jersey x Holstein) over 5 years in 2 systems: total confinement and summer grazing/winter housing, (Michigan).**

| | Holstein | Montbeliarde x Holstein | Montbeliarde x (Jersey x Holstein) | Herd system |
|---|---|---|---|---|
| Milk solids 1-5 lactations (kg/lactation) | 585[a] | 585[a] | 573[a] | Confinement |
| Milk solids 1-5 lactations (kg/lactation) | 486[a] | 504[a] | 497[a] | Pasture herd |
| 1st service CR | 26.9[a] | 45.1[b] | 49.9[b] | Both |
| Days open | 167[a] | 128[b] | 124[b] | Both |
| Pregnancy rate (21day) | 12.1 | 22.9 | 24.9 | Both |
| Mortality rate (%) | 17.7[a] | 5.1[b] | 11.7[ab] | Both |
| Survival to 2nd calving | 68.1[a] | 81.4[a] | 81.2[a] | Both |
| Survival to 3rd calving | 31.4[a] | 58.3[b] | 51.1[b] | Both |
| Survival to 4th calving | 14.2[a] | 42.5[b] | 34.7[b] | Both |
| Survival to 5th calving | 6.4[a] | 26.7[b] | 20.2[b] | Both |
| Mean liveweight | 572[a] | 611[b] | 554[c] | Both |
| Mean BCS | 2.87[a] | 3.36[b] | 3.33[b] | Both |
| Udder clearance (cm) floor to udder base | 51.6[a] | 49.0[b] | 46.9[c] | Both |

**Conclusion from this study:** The MO-sired crossbred cows in this study did not significantly differ from pure HO cows for fat-plus-protein production across herds and lactations. The similar production for the breed groups may have resulted from genetic improvement within the HO and MO breeds, heterosis when breeds are crossed, or a combination of these 2 factors. More importantly, the MO-sired crossbreds were much superior to pure HO cows for fertility, mortality rate, survival to subsequent calving, and longevity. Some of the superiority for fertility and longevity of the MO-sired crossbreds compared with pure HO cows in this study may have resulted from the greater BCS of the MO-sired crossbreds. A breeding objective of the MO breed in France has continuously been to place emphasis on maintaining BCS, which is contrary to the

breeding objective of the HO breed to increase angularity. Results of this study indicated that MO-sired crossbred cows had similar production to pure HO cows, but the MO-sired crossbred cows had advantages over pure HO cows for fertility, survival, and longevity in both a confinement and a seasonal pasture herd. Three-breed rotational crossbreeding using purebred bulls from distinct dairy breeds is the most common approach currently being recommended and used for commercial milk production. The 3 breeds must be complementary to each other, and they must be well suited to specific management systems. The alternative combinations of dairy breeds for crossbreeding have not yet been examined across management systems and warrant further research.

**Fertility, somatic cell score, and production of Normande × Holstein, Montbéliarde × Holstein, and Scandinavian Red × Holstein crossbreds versus pure Holsteins during their first 5 lactations (Minnesota**)

| | Holstein | Normande x Holstein | Montbéliarde × Holstein | Scandinavian Red × Holstein |
|---|---|---|---|---|
| Projected milk yield* (kg, 305 day) | 11417 | 9903** | 10744** | 10627** |
| Projected milk solids* (kg) | 762 | 687** | 738** | 733** |
| SCC | 327 | 325 | 298** | 312** |
| Days to 1st breeding | 70 | 66** | 63** | 66** |
| CR 1st service (%) | 22.6 | 27.9 | 32.6* | 28.8* |
| Days open | 148 | 128** | 122** | 136* |
| Pregnancy rate (%) | 14.7 | 19.2** | 20.0** | 17.5** |
| % reaching 5th lactation | 16.6 | 26.9** | 28.3** | 24.2* |

*Culls included in projections for yield and solids production

**Conclusion from this study:** Crossbreeding of dairy cattle is being explored mostly for its potential to improve the calving ease, fertility, health, and survival of cows. Advantages for these functional traits will compensate substantially for any potential loss of production of crossbreds compared with pure HO cows. Production and functional traits must be assessed collectively to gauge the total economic merit of dairy cows. Increasingly, dairy producers, consultants, extension educators, and industry leaders should measure dairy cow performance in a more comprehensive way instead of by milk production alone.

**Jersey × Holstein crossbreds compared with pure Holsteins for production, mastitis, and body measurements during the first 3 lactations (Minnesota)**

| | 1st lactation | | 2nd lactation | | 3rd lactation | |
|---|---|---|---|---|---|---|
| | Holstein | Jersey x Holstein | Holstein | Jersey x Holstein | Holstein | Jersey x Holstein |
| Milk yield (kg) | 7905 | 7361** | 9421 | 8510** | 9803 | 8530** |
| Fat + protein (kg) | 526 | 518 | 630 | 605* | 660 | 601** |
| SCC? | 291 | 277 | 287 | 263 | 340 | 301 |
| Mastitis % | 27.7 | 24.3 | 59.7 | 44.4 | 71.6 | 48.2* |
| Liveweight (kg) | 523.9 | 468.2 | 582.7 | 515.7 | 619.2 | 537.4 |
| BCS | 2.84 | 2.94** | 2.84 | 2.97** | 2.87 | 2.99** |
| Udder clearance (cm) | 54.8 | 47.8** | 51.4 | 42.2** | 48.9 | 40.4** |
| Days to 1st breeding | 90.0 | 79.4 | 86.1 | 77.7 | 76.7 | 65.4 |
| No. of serves | 2.1 | 2.1 | 2.7 | 2.2 | - | - |
| Pregnancy rate (%) | 12.3 | 20.3 | 13.3 | 24.5 | - | - |
| Days open | 148.1 | 124.3* | 162.7 | 120.9* | 200.2 | 158.3* |
| % Calved by 14 months | - | - | 48.1 | 61.3 | 40.0 | 64.1* |
| % Calved by 17 months | - | - | 57.1 | 68.8 | 56.4 | 70.3 |
| % Calved by 20 months | - | - | 68.8 | 78.8 | 69.1 | 78.1 |

| Lifetime | Holstein | Jersey x Holstein |
|---|---|---|
| Yield (kg) | 21,447 | 19,194 |
| Fat + protein (kg) | 1455 | 1349 |
| SCC | 310 | 294 |
| % calving 2nd time | 71.4 | 80.0 |
| % calving 3rd time | 49.4 | 63.8 |

**Conclusion from this study:** The results of the present study indicate the JE × HO cows had major advantages over pure HO for fertility and survival, but there were numerous shortcomings of JE × HO cows, especially at medium to high production levels by global standards. The reduced production of fat plus protein during second and third lactations of JE × HO cows compared with HO cows would negatively affect dairying profitability. Furthermore, udders are important for functional milk production and compared with other dairy cattle breeds, JE cows have proportionately larger udders in relation to their body size. The higher frequency of JE × HO cows than HO cows culled for udder conformation in this study would be unwelcome by dairy producers. Therefore, dairy producers must carefully choose a breed, multiple breeds, or crosses among breeds that are optimal for conditions unique to their dairy operations, considering climate, facility design, nutritional regimens, reproductive protocols and low-input versus high-input management.

**Survival, lifetime production, and profitability of Normande × Holstein, Montbéliarde × Holstein, and Scandinavian Red × Holstein crossbreds versus pure Holsteins in 6 commercial herds in California**

| | Holstein | Normande × Holstein | Montbéliarde × Holstein | Scandinavian Red × Holstein |
|---|---|---|---|---|
| Number | 151 | 162 | 360 | 212 |
| Milk yield (kg) | 28,086 | 29,766 | 32,891** | 31,246* |
| Fat + protein (kg) | 1,867 | 2,070 | 2,268** | 2157** |
| % Survival to 2nd lactation | 75.2 | 88.1** | 88.9** | 85.3** |
| % Survival to 3rd lactation | 50.9 | 73.2** | 74.8** | 71.0** |
| % Survival to 4th lactation | 29.1 | 53.0** | 55.0** | 50.5** |
| Days of life | 946 | 1263** | 1358** | 1306** |
| Lifetime profit ($) | 4317 | 5467** | 6473** | 6242** |
| Profit/day ($) | 4.17 | 3.89** | 4.39** | 4.32** |

No figures available for health costs.

**Conclusion from this study:** Dairy producers may improve the survival of cows and the profitability of dairying by crossing pure HO cows with bulls of at least some other breeds of dairy cattle. The NO × HO, MO × HO, and SR × HO cows had more projected lifetime profit per cow than did pure HO cows; however, crossbreds remained in herds much longer to achieve the substantial advantages for projected lifetime profit per cow. Projected profit per cow-day was significantly greater for MO × HO (+$0.22) and SR × HO (+$0.15) than for pure HO cows, but significantly lower for NO × HO (−$0.28) than pure HO cows in these confinement dairies.

**Procross 2 way comparisons with Holsteins (Minnesota) Viking Red and Montbéliard**

| **Procross 2 way cross** | Holstein | VR×HO | MO×HO |
|---|---|---|---|
| Cows (n) | 1180 | 582 | 556 |
| Age at calving (months) | 23.8 | 23.8 | 23.8 |
| 1st lactation 305 day yield (kg) | 11378 | 10959** | 11445 |
| 305-d fat + protein (kg) | 765 | 776 | 788** |
| Cows (n) | 883 | 461 | 443 |
| Age at 2nd calving (months) | 36.5 | -.1 | -.1 |
| 2nd lactation 305 day yield (kg) | 13338 | 12548** | 13335 |
| 305-d fat + protein (kg) | 887 | 882 | 906** |
| Cows (n) | 451 | 281 | 297 |
| Age at 3rd calving (months) | 48.9 | -.4 | -.5 |
| 3rd lactation 305 day yield (kg) | 13932 | 13267** | 13860 |
| 305-d fat + protein (kg) | 927 | 927 | 940 |
| Lifetime fat + protein (kg) | 2201 | 2397 | 2810** |
| Days in herd | 886 | 982 | 1105 |
| Daily fat + protein (kg) | 2.51 | 2.49** | 2.57** |
| Lifetime profit ($) | 2842 | 3340 | 4480** |
| Daily profit ($) | 3.74 | 3.96** | 4.44** |
| 1st lactation | | | |
| 1st service CR | 37% | 45%** | 43%** |
| Overall CR | 37% | 41%* | 45%** |
| Times bred | 2.4 | 2.2* | 2.1** |
| Days open | 127 | 120 | 115** |
| Pregnancy rate | 27% | 30% | 32%** |
| 2nd lactation | | | |
| 1st service CR | 29% | 36%** | 40%** |
| Overall CR | 31% | 35%* | 40%** |
| Times bred | 2.6 | 2.3** | 2.2** |
| Days open | 139 | 128* | 117** |
| Pregnancy rate | 24% | 27%* | 31%** |
| 3rd lactation | | | |
| 1st service CR | 30% | 31% | 41%** |
| Overall CR | 31% | 32% | 40%** |
| Times bred | 2.5 | 2.5 | 2.2* |
| Days open | 143 | 139 | 120** |
| Pregnancy rate | 23% | 24% | 30%** |
| | Holstein | VR×HO | MO×HO |
| Surviving to 1st calving | 86.7% | 89.7 | 86.9% |
| Survival to 2nd calving | 80% | 84% | 84% |
| Survival to 3rd calving | 51% | 57%* | 62%** |
| Survival to 4th calving | 28% | 33% | 44%** |
| Lived to at least 45 months (after 1st calving) | 18.0% | 24.7%** | 33.3%** |

**Procross 3 way comparisons with Holsteins (Minnesota) Viking Red and Montbéliard**

| **Procross 3 way cross** | Holstein | VR×MO/HO | MO×VR/HO |
|---|---|---|---|
| Cows (n) | 1073 | 505 | 462 |
| Age at calving (months) | 23.2 | -.5** | -.3* |
| 1st lactation 305 day yield (kg) | 11803 | 10601 | 10871 |
| 305-d fat + protein (kg) | 795 | 757** | 773** |
| Cows (n) | 582 | 309 | 291 |
| Age at calving (months) | 35.9 | -.9** | -.6** |
| 2nd lactation 305 day yield (kg) | 13551 | 12225** | 12701** |
| 305-d fat + protein (kg) | 906 | 862** | 890 |
| Cows (n) | 228 | 143 | 134 |
| Age at calving (months) | 48.5 | -1.7** | -1.6** |
| 3rd lactation 305 day yield (kg) | 14295 | 12829** | 13208** |
| 305-d fat + protein (kg) | 953 | 897** | 926* |
| Lifetime fat + protein (kg) | 2132 | 2517 | 2439 |
| Days in herd | 850 | 1026* | 967 |
| Daily fat + protein (kg) | 2.55 | 2.49** | 2.58** |
| Lifetime profit ($) | 2823 | 3725* | 3761* |
| Daily profit ($) | 3.95 | 4.12** | 4.46** |
| 1st lactation | Holstein | VR×MO/HO | MO×VR/HO |
| 1st service CR | 43% | 52%** | 51%** |
| Overall CR | 41% | 48%** | 50%** |
| Times bred | 2.2 | 1.9** | 2.0** |
| Days open | 126 | 111** | 110** |
| Pregnancy rate | 28% | 34%** | 35%** |
| 2nd lactation | Holstein | VR×MO/HO | MO×VR/HO |
| 1st service CR | 35% | 42% | 47%** |
| Overall CR | 36% | 42%* | 44%** |
| Times bred | 2.4 | 2.2* | 2.1** |
| Days open | 124 | 104** | 107** |
| Pregnancy rate | 25% | 33%** | 31%** |
| 3rd lactation | Holstein | VR×MO/HO | MO×VR/HO |
| 1st service CR | 35% | 42% | 48%* |
| Overall CR | 33% | 44%** | 48%** |
| Times bred | 2.4 | 1.9** | 1.9** |
| Days open | 135 | 120 | 110** |
| Pregnancy rate | 25% | 30% | 36%** |
| | Holstein | VR×MO/HO | MO×VR/HO |
| Surviving to 1st calving | 85.7% | 89.6%* | 88.8% |
| Survival to 2nd calving | 79% | 84%* | 78% |
| Survival to 3rd calving | 51% | 65%** | 59%* |
| Survival to 4th calving | 22% | 46%** | 39%** |
| Lived to at least 45 months (after 1st calving) | 17.4% | 31.3%** | 26.3%** |

**Conclusion from these studies:** Unlike previous research on crossbreeding of dairy cattle, this 10-year study had controlled and balanced enrolment of foundation cows, had a clear design, used high-ranking proven A.I. bulls for all breeds (Holstein, Viking Red, and Montbeliarde) and had dedicated recording of data by the high-performance participating herds. Daily fat + protein production for lifetimes of cows was +1% higher for 2-breed crossbreds (Viking Red×Holstein and Montbeliarde×Holstein) and was –1% lower for 3-breed crossbreds than their Holstein herdmates. All generations of the crossbred cows had lower stillbirth rates, and the 3-breed crossbred calves born to 2-breed crossbred dams had one-half the number of stillborn calves at 1st calving than their Holstein herdmates. The 2-breed crossbreds had 12 fewer days open and the 3-breed crossbreds had 17 fewer days open than their Holstein herdmates. Health treatment cost was –23% lower for the 2-breed crossbreds and –17% lower for 3-breed crossbreds than their Holstein herdmates. Lifetime death loss was –4% lower for both the 2-breed crossbreds and the 3-breed crossbreds than their Holstein herdmates. The combined 2-breed and 3-breed crossbreds had +153 more days in the herd than their Holstein herdmates. Therefore, replacement cost was substantially lower for both the 2-breed and 3-breed crossbreds than their Holstein herdmates. Daily profit was +13% higher for the 2-breed crossbreds and +9% higher for the 3-breed crossbreds than their Holstein herdmates. The average inbreeding coefficient of U.S. Holstein females born in 2019 surpassed 8%, and the annual rate of increase in average inbreeding is approaching +0.4%, which seems to be an unsustainable increase into the future. Heterosis (hybrid vigour) from crossbreeding is most influential for traits related to fertility, health, and survival, and it comes on top of genetic improvement within breeds.

**Milk, Fat, Protein, Somatic Cell Score, and Days Open Among Holstein, Brown Swiss, and their Crosses: 3473 cows with 6534 lactations in 19 herds with Brown Swiss and Holstein crossbred cows in USA**

| | Holstein | Brown Swiss | Holstein x Brown Swiss | Brown Swiss backcross | Heterosis %* | Recombination % |
|---|---|---|---|---|---|---|
| Daily milk yield (kg) | 11105$^{a}$ | 9746$^{b}$ | 10910$^{a}$ | 10019$^{b}$ | 5.01$^{***}$ | -3.49 |
| Fat yld (kg) | 393$^{a}$ | 376$^{b}$ | 402$^{a}$ | 382$^{ab}$ | 4.43$^{*}$ | -1.78 |
| Protein yld (kg) | 326$^{a}$ | 314$^{b}$ | 340$^{c}$ | 319$^{ab}$ | 6.49$^{***}$ | -2.54 |
| Days open | 156.0$^{a}$ | 156.3$^{a}$ | 143.7$^{b}$ | 153.4$^{ab}$ | 7.99$^{***}$ | -2.24 |
| SCS | 2.73$^{ab}$ | 2.78$^{a}$ | 2.54$^{b}$ | 2.66$^{ab}$ | 7.78$^{*}$ | -0.16 |
| AFC (months) | 25.85$^{a}$ | 26.58$^{b}$ | 25.68$^{a}$ | 26.58$^{b}$ | 2.06$^{*}$ | -1.71 |

SCS = log of SCC? AFC = age at first calving. Within rows different superscripts are significantly different.

**Conclusion from this study:** Crossbreeding will allow dairy producers to match the genotype of dairy herds to farm management conditions and Brown Swiss is a viable choice for crossbreeding systems. Brown Swiss-sired cows from HO dams had higher fat and protein production than pure HO with fewer DO and lower SCS. Although F1 crosses performed favourably, performance of future generations was depressed by the effects of recombination. Recombination effects were generally not severe and producers who want to capitalize on favourable heterosis for fitness traits should be able to do so with marginal losses of fat and protein yield. However, further exploration of future generations is warranted to define recombination effects more fully.

**South Africa: The production performance of Holstein and Fleckvieh x Holstein cows in an intensive feeding system (S Africa) Masters Degree**

| | Holstein | Flechvieh x Holstein | P value |
|---|---|---|---|
| Milk yield | 6330 | 6108 | NS |
| Fat % | 3.98 | 4.13 | <0.001 |
| Protein % | 3.20 | 3.30 | <0.001 |
| Fat + protein (kg) | 454 | 451 | NS |
| Calving to 1st service (days) | 104.7 | 86.2 | <0.01 |
| Calving to conception (days) | 153.1 | 135.3 | NS |
| Serves per conception | 2.24 | 2.30 | NS |
| % pregnant | 78 | 82 | NS |

**Conclusion from this study:** No differences in production between the two genotypes. Crossbreds had shorter interval to 1st service and consequently shorter time to get pregnant, although overall pregnancy was not significantly different from the Holsteins.

**Methane/carbon emissions**

None on the studies highlighted above considered methane emissions from crossbred cows, compared to purebred cows. From an environmental perspective this could be considered an important omission. However, while no figures can be directly attributed to any potential differences between pure breeds and crossbreeds, there are a number of variables that are likely to result in lower methane emissions in the crossbreds, namely: lower numbers of replacements required due to increased longevity of crossbreds, (replacement heifers are a major source of methane/carbon emissions in dairy systems), better health, leading to more days with marketable milk in the tank, improved feed efficiency, (from ProCross study, similar output for less input).

**Summary/comments**

From the data presented and the conclusions made, it is evident that crossbreeding has a role to play in modern dairy production systems, from seasonal production systems to fully housed intensive systems. Pure bred alternative breeds, while usually being more fertile than Holstein-Friesians, cannot compete with them for milk production litres or solids yield and hence, are unlikely to be considered a substitute breed for them.

The impact of crossbreeding is most evident in health, fertility parameters and longevity such as shorter time to 1st service, higher conception rates, lower empty rates and longer productive life, compared to pure bred Holstein-Friesians. There was also evidence that Holstein-Friesian crossbred cows have lower levels of calving difficulty, lower mortality rates and less calving related issues, compared to purebred Holstein-Friesians, (data not presented).

The choice of alternative breed(s) needs to be considered very carefully, as not all dairy breeds may be complimentary with each other. The choice of alternative breed sire will to some extent depend on the production system. Jersey crosses seem to be well suited to seasonal calving systems, as they produce similar amounts of milk solids compared to their Holstein-Friesian counterparts and usually have better fertility, but they generally have more pendulous udders and milk somatic cell counts tends to be higher. The Nordic breeds have been selected for udder

health and fertility and as a consequence, exhibit good fertility, low somatic cell counts and good udder health. The Viking Red, a composite breed comprising Finnish Ayrshire, Swedish Red and Danish Red, compared very favourably with purebred Holstein-Friesians in the Procross 2 way and 3 way cross trial.

Dual purpose breeds such as Normande and Montbéliard and their crosses have been compared to Holstein-Friesian cows for production and fertility in several studies. Some studies showed lower milk solids yield for the dual-purpose crosses compared to purebred Holstein-Friesians, but better fertility, whilst others showed similar or better solids yield, better fertility and in the Californian study, much greater lifetime profit per cow.

Crossbreeding is not a magic bullet to overcome current herd deficiencies. The potential benefits of crossbreeding very much depend on the genetics of the purebred bulls selected for the mating program and only the top bulls within any breed should be considered for a crossbreeding program.

With much more emphasis being placed on health and longevity of Holstein-Friesians, the case for crossbreeding needs to be carefully weighed up, as it is profit that determines the success of a dairy enterprise, not milk yield, not milk solids production, not value of calves and culls or fertility indexes. Farmers may decide to go down this route for many reasons, such as presumed easier management/better health of crossbreds. What to do with the first-generation cross animals is a big issue to address: backcross, use another pure dairy breed, put to beef sire?

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