An examination of the potential of crossbreeding to improve the profitability of dairying in Northern Ireland

Final Report for AgriSearch

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STRUCTURE OF REPORT

This project was established to examine the performance of Jersey × Holstein crossbred cows and Holstein-Friesian cows on Northern Ireland dairy farms. This report begins with an 'Executive summary' which highlights key aspects of the project. This is followed by the main body of the report, which describes the methodology used, key results and a discussion of the results.

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EXECUTIVE SUMMARY

Historical selection programmes within the Holstein breed focused largely on milk production, while largely ignoring functional traits. The subsequent decline in these functional traits within the Holstein population, especially fertility and health, has now been well documented.

Crossbreeding has been suggested as one option by which some of these problems may be overcome. Benefits which may arise from crossbreeding include the introduction of desirable traits from another breed, the positive effects of hybrid vigour, and a reduction in the negative effects of inbreeding.

To address this issue a number of research programmes were established to compare production, fertility, health and profitability of Holstein-Friesian and Jersey crossbred cows across a range of Northern Ireland milk production systems. Part of this research programme was undertaken on the AFBI-Hillsborough farm, while a second part (described in this report) was undertaken on 11 commercial Northern Ireland dairy farms.

The 11 farms were selected to represent a range of geographical locations within Northern Ireland, and a range of milk production systems (including both spring and autumn calving herds). Concentrate inputs ranged from approximately 0.7 – 2.2 tonnes/cow/year.

On each farm, 10 - 20 pairs of Holstein-Friesian cows were matched for genetic merit, milk yield during the previous lactation and parity. Within pairs, one animal was bred to a Holstein-Friesian sire, while the second was bred to a Jersey sire. This was repeated during a second year on all farms, and during a third year on eight of the eleven farms. The F1 offspring of this breeding programme was used within this experiment.

The experiment involved 192 Holstein-Friesian dairy cows and 189 Jersey crossbred dairy cows. The Holstein-Friesian cows were sired by a total of 64 Holstein-Friesian sires, while the Jersey crossbred cows were sired by a total of 8 Jersey sires. The study finished in 2012 when all cows had completed four lactations on the study.

Data were collected in a number of ways. The participating farmers collected data on calving difficulty, calving temperament, milking behaviour, fertility, concentrate feed levels and reasons for culling. Information on cow condition score was collected by a member of Hillsborough staff during regular visits to the farms. Milk production and milk composition data were obtained through official milk recording schemes.

When calving for the first time the incidence of stillbirths was 8% for Jersey crossbred cows and 12% for Holstein-Friesian cows, although this difference was not significant. When calving for the second time there was no difference between breeds in the proportion of calves born dead.

When calving for the first time Jersey crossbred cows had a marginally poorer temperament at calving than the Holstein-Friesian cows. Milking temperament did not differ between the breeds.

On average across lactations 1 – 4, Holstein cows produced 773 kg more milk than the crossbred cows, while the latter produced milk containing 5.2 g/kg more fat and 1.9 g/kg more protein than the Holstein-Friesian cows. However, the yield of fat plus protein was unaffected by genotype.

Somatic cell counts of the Jersey crossbred cows tended to be slightly higher than for the Holstein-Friesian cows, although these differences were not significant. Heterosis for somatic cell count is normally very low. There was no difference in the proportion of cows of each genotype culled due to mastitis.

Jersey crossbred cows tended to have improved fertility performance for a number of traits compared to the Holstein cows, although differences frequently were not significant. 30.2% of Holstein-Friesian cows and 25.0% of Jersey crossbred cows were culled as infertile prior to lactation 5, although this difference was not significant.

Significantly more Holstein cows than crossbred cows were culled due to ‘legs and feet’ problems.

Crossbred cows had improved longevity, with 48% of crossbred cows and 38% of Holstein-Friesian cows surviving until the end of the fourth lactation. When extrapolated to give lifetime survival, on average Holstein-Friesian cows survived for 3.6 lactations while crossbred cows survived for 4.8 lactations.

An economic analysis of the production data collected from the project indicated that net profit was £39/cow/year (7%) higher with the Jersey crossbred cows.

INTRODUCTION

The problem

The high milk production potential of Holstein cows has resulted in the Holstein breed becoming dominant in many parts of the world. However, historical selection programmes within the Holstein breed focused largely on milk production, and until recently, largely ignored functional traits. The subsequent decline in these traits (especially fertility and health) within the Holstein population is now well documented. As a result, some of the benefits gained with the Holstein breed through increased milk production efficiency have been lost due to poor survivability. While some of these issues may be overcome through improved feeding and management, the potential of 'breeding strategies' must also be considered.

Potential of breeding strategies to overcome the problem

a) Adopt more balanced breeding goals with the Holstein breed: this approach is now being adopted widely. For example, the Profitable Lifetime Index (£PLI) within the United Kingdom incorporates important economic traits such as fertility, health and lifespan, and there is evidence that some of the declines in fitness traits observed previously are now starting to be reversed.

b) Breed substitution: refers to replacing the Holstein breed with an alternative breed which has been selected and bred for traits which are of economic importance. The results of an AgriSearch funded study which compared the Holstein breed with the Norwegian Red breed has now been published (www.agrisearch.org: AgriSearch Booklet Number 22).

c) Cross-breeding: this is a third option, and the one that is examined within this report.

Why consider crossbreeding?

There are a number of reasons why dairy farmers may consider the adoption of crossbreeding within their herds. These include:

1) Introduction of desirable traits from another breed:
Examples of this include the use of Jersey sires within crossbreeding programmes to improve milk composition, and Scandinavian sires to improve functional traits such as fertility and health.

2) To reduce levels of inbreeding:
In general, levels of inbreeding within dairy herds within the UK and Ireland remain relatively low. However, inbreeding levels may be high on individual farms, or individual animals may be heavily inbred due to inappropriate breeding decisions in the past. Crossing with a second breed is one option by which levels of inbreeding can be rapidly reduced.

3) Gaining from hybrid vigour:
Hybrid vigour (or heterosis) describes the additional performance benefits that can be obtained with a crossbred animal, over and above the mean of the two parent breeds. For example, if Breed A has a lactation yield potential of 6000 litres, and breed B has a lactation yield potential of 8000 litres, the offspring of the two breeds might be expected to have a lactation yield potential of approximately 7000 litres (Figure 1). However, in the example given the actual production of the crossbred cow is 7350 litres, with the extra 350 litres of milk over and above that expected due to hybrid vigour. The extent of hybrid vigour varies between traits. For example, for traits such as milk yield, hybrid vigour is normally estimated to be between 3 and 6%. However, for traits such as fertility, health and longevity, hybrid vigour may be between 6 and 15%, depending on the degree of genetic differences between the parent breeds. For some other traits, for example somatic cell count and milk composition, hybrid vigour levels can be very low.

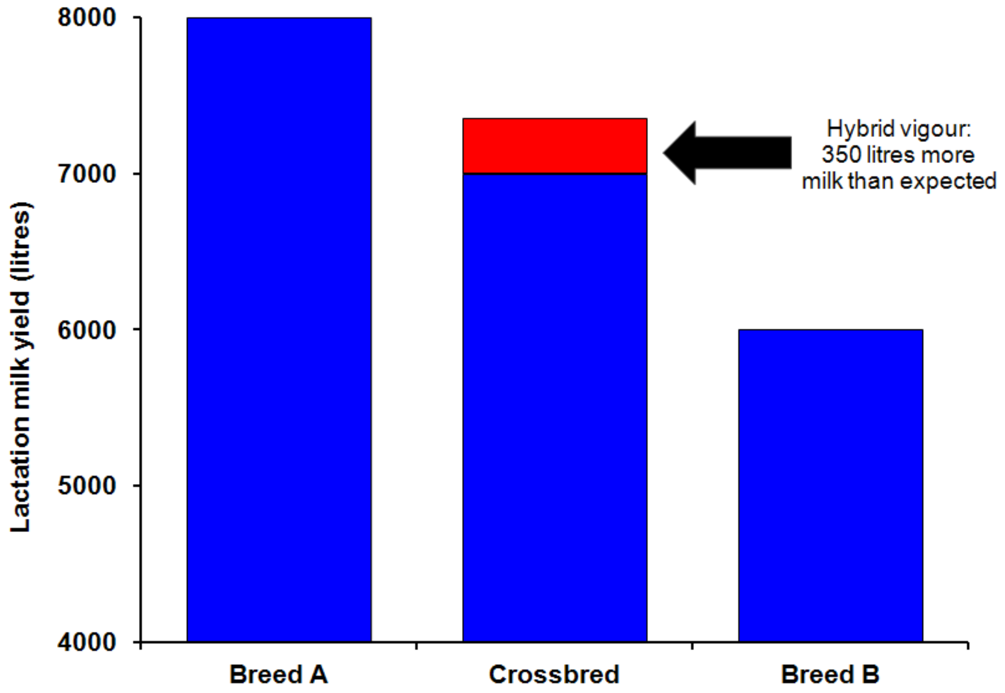

Figure 1 Example of the impact of hybrid vigour on milk production when two breeds are crossed

The benefits of crossbreeding have been clearly established within very low input systems such as New Zealand. However, there is much less information on the role of crossbreeding within moderate input systems, such as those which are common within Northern Ireland. To address this issue, a research programme was established. Part of this research was undertaken at AFBI-Hillsborough, with the aim of providing the underpinning science behind crossbreeding, including the impact on food intake, grazing behaviour, detailed fertility parameters, energy utilisation and blood parameters. However, these experiments involved relatively low numbers of cows, and as such were not designed to provide information on cow longevity, a key factor influencing profitability. To address this issue, the second part of the research programme was established on 11 Northern Ireland dairy farms so as to provide robust information on cow performance, fertility and survival across a range of on-farm management systems. This on-farm component of the research programme is described within this report.

MATERIALS AND METHODS

Overview

An experiment involving 192 Holstein-Friesian dairy cows and 189 Jersey × Holstein crossbred dairy cows was established on 11 commercial Northern Ireland dairy farms in 2000. The 11 farms were selected to represent a range of geographical locations within Northern Ireland, and a range of milk production systems (including both spring and autumn calving herds). Concentrate inputs ranged from approximately 0.7 – 2.2 tonnes/cow/year. The study finished in 2012 when all cows had completed four lactations on the study, although at this stage some cows were in their fifth, sixth and seventh lactations.

Selection of participating farms

The participating farmers were identified through farmer information meetings and in response to an article in the local press. The following criteria were used to select the participating farms:

1) A herd size >60 cows
2) Herds that were predominantly Holstein-Friesian
3) Involved in an official milk recording scheme
4) Rearing own replacements
5) Not under any health restriction
6) Willingness to collect necessary data
7) Pedigree registered or with ancestry available for the past two generations.

A map showing the location of the 11 participating farms is presented in Figure 2.

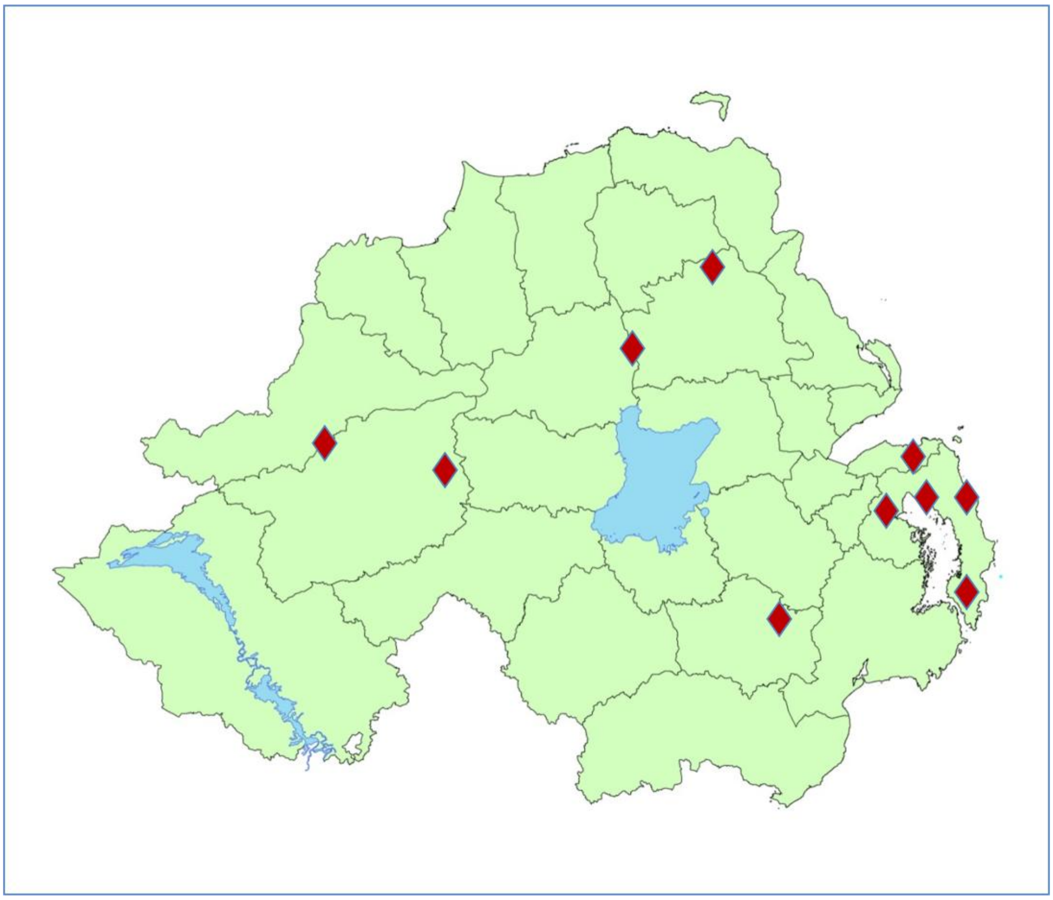

Figure 2 Map showing the location of the eleven farms participating in the project

Breeding programme used to source crossbred cows

On each farm, 10 - 20 pairs of Holstein-Friesian cows were matched for genetic merit, milk yield during the previous lactation, and parity. Within pairs, one animal was bred to a Holstein-Friesian sire, while the second was bred to a Jersey sire. This was repeated during a second year on all farms, and during a third year on eight of the eleven farms. Where possible, cows mated to Holstein-Friesian sires in year 1 were mated to Jersey sires in year 2, and vice versa, with this reversed during year 3. The F_1 offspring of this breeding programme was used within this experiment.

The experiment involved 192 Holstein-Friesian dairy cows and 189 Jersey × Holstein-Friesian dairy cows (mean of 17 animals per farm). The choice of Holstein sire used within the breeding programme remained with the farmer, with the Holstein-Friesian cows sired by a total of 64 Holstein-Friesian sires. Jersey sires used within the programme were chosen by AFBI, with Jersey × Holstein cows sired by a total of 8 Jersey sires.

On each farm the Holstein-Friesian and Jersey × Holstein heifers within each year were subject to the same rearing regimes until calving. Although all farms operated grassland-based milk production systems, there was considerable variation between farms in nutrition and management regimes. For example, the duration of the grazing period varied between farms and between years, a reflection of geographical location, year to year variation in climatic conditions, and the perceived importance of grazing within individual management systems. In general, cows were housed between mid October and late November, and offered diets in which the main forage component was grass silage. Alternative forages, including maize silage and cereal silage comprised part of the conserved forage component of the diet on some farms during some years. Grazing commenced between early February and late April, with none of the participating farmers operating total confinement systems. The concentrate component of the diet was offered via in-parlour feeders, electronic out-of-parlour feeders, mixed with the forage component of the diet via a mixer wagon, or by a combination of these feeding systems. On most farms a commercial concentrate was offered, although some farms with mixer wagons included 'straights' or by-product feed ingredients in the ration. For fresh calved cows, concentrate feed levels during the housed period ranged from 4.0 - 12.0 kg/cow/day, while during the grazing period concentrate feed levels ranged from 0 - 6.0 kg/cow/day. If concentrates were offered during the grazing period, they were normally offered 'in-parlour'.

Farmers were free to breed the crossbred cows as they believed to be most appropriate. A range of breeding policies was adopted, with all farmers using AI.

Data collection/measurements

Data were collected in a number of ways. The participating farmers collected data on calving difficulty, calving temperament, milking behaviour, fertility, concentrate feed levels and reasons for culling. Information on cow condition score was collected by a member of Hillsborough staff during regular visits to the farms. Milk production and milk composition data were obtained through official milk recording schemes.

Calving data

Calving date, calving difficulty score (first - fourth calvings) and calving temperament score (first and second calvings) was recorded by the farmers. Calving difficulty was scored on a 1 – 5 scale, where 1 = unobserved or unassisted, 2 = assisted without calving aid, 3 = assisted with calving aid, 4 = veterinary assistance, and 5 = calf delivered by caesarean section. Calving temperament was assessed during the period when the cow was in the calving pen, and was scored on a 1 – 4 scale, where 1 = very quiet, 2 = slightly uneasy, 3 = very uneasy, and 4 = aggressive. During the first and second calving, farmers recorded if the calf was born dead (or died within 24 hours or birth), or was born alive.

Milking behaviour

Milking behaviour was assessed by farmers on two occasions during each of lactations 1 and 2: approximately 48 hours post-calving and approximately three weeks post-calving. Milking behaviour was scored on a 1 – 4 scale, where 1 = stands calmly, 2 = slightly agitated – may attempt to kick, 3 = moderately agitated – some kicking, and 4 = extremely agitated – milked with difficulty.

Milk recording

Cows were milk-recorded monthly by milk recording technicians during lactations 1 - 3, while thereafter a number of herds moved to alternative monthly milk recording. Data provided by the recording agencies included individual cow test-day milk yields (kg), milk fat content, milk protein content (g/kg) and somatic cell count (000/ml). In addition, recording agencies subsequently provided information on 305-day milk yields, full lactation milk yields and average milk fat and protein content for the full lactation. Mean somatic cell counts (SCC) for the full lactation were determined for each individual cow as the sum of individual test-day milk yields multiplied by individual test-day SCC's, divided by the sum of all-test day milk yields during that lactation.

Fertility data

All reproductive data were recorded by the farmers, including if a cow was bred using a stock bull, by AI, or by a combination of both. For cows bred using AI, the date of the first service and the AI sire used was recorded. Calving rate to first service was defined as the proportion of cows that conceived and subsequently produced a calf to the first insemination, including cows that had a positive pregnancy diagnosis by a veterinarian prior to removal from the herd (in the event of either sale, death or abortion). Cows that were inseminated twice, and were subsequently removed from the herd prior to calving, were deemed not to have conceived to first insemination.

Condition scores and locomotion scores

The 11 farms were visited by a trained technician once every two - three months until all cows had completed their second lactation, and cow condition score (scale 1 – 5) assessed visually.

Concentrate feed levels

Concentrate inputs during lactations 1 – 4 were recorded/calculated using a range of methods, depending on the feeding system in use on the farm. During lactations 1 and 2, farmers recorded mean daily concentrate inputs for each cow on the study on a weekly basis. Thereafter, mean daily concentrate feed levels were recorded on a monthly basis, although this was often on a mean herd basis, rather than on an individual cow basis. For cows receiving part or all of the concentrate component of the diet in a complete diet mixer wagon, total concentrate input to the wagon was divided by the number of cows being fed at that time, and a mean concentrate intake assumed for all cows in the herd at a given period of time.

Culling

For all cows culled prior to calving for the fifth time, the culling date and primary reason for culling were recorded by the farmers. Culling reasons were subsequently rationalised into 12 ‘reasons’.

RESULTS

Calving difficulty: Within this study calving difficulty was scored on a 1 - 5 scale, where 1 = unobserved or unassisted, and 5 = calf delivered by caesarean section. There were no significant differences (P>0.05) between genotypes in calving difficulty score when cows calved for the first and second time (Table 1).

Table 1 Effect of dairy cow genotype on the percentage of cows with each calving difficulty score when calving for the first and second time

		Calving difficulty score			
	Genotype	1	2	3-4	P value
Calving 1	Holstein-Friesian	87.2	3.6	9.2	0.238
	Jersey crossbreds	91.0	2.7	6.3	
Calving 2	Holstein-Friesian	97.1	1.0	1.9	0.728
	Jersey crossbreds	97.6	0.8	1.6	

1 = unobserved or unassisted
2 = assisted without calving aid
3 = assisted with calving aid
4 = veterinary assistance
5 = calf delivered by caesarean section.

Still births: When calving for the first time the incidence of stillbirths was 12% for Holstein-Friesian cows and 8% for the Jersey crossbred cows, although this difference was not statistically significant (P>0.05; Table 2). The incidence of still births was much lower at the second calving, and was again unaffected by cow genotype.

Table 2 Effect of dairy cow genotype on the proportion of calves born alive when cows calved for the first and second time

	Holstein-Friesian	Jersey crossbreds	SEM	Significance
First calving	0.88	0.92	0.020	NS
Second calving	0.97	0.98	0.012	NS

Calving temperament and milking temperament: Calving temperament was scored on 1 - 4 scale during the period when the cow was in the calving pen, where 1 = very quiet and 4 = aggressive. Jersey crossbred cows had a poorer temperament at first calving than Holstein-Friesian cows (P=0.051), while there was no difference in calving temperament between genotypes at second calving (Table 3: P>0.05).

Table 3 Effect of dairy cow genotype on the percentage of cows with each calving temperament score

		Calving temperament score				
	Genotype	1	2	3	4	P value
Calving 1	Holstein-Friesian	78.7	20.5	0.8	0	0.051
	Jersey crossbreds	71.3	27.4	1.3	0	
Calving 2	Holstein-Friesian	96.4	3.4	0.2	0	0.747
	Jersey crossbreds	95.8	3.9	0.3	0	

1 = very quiet
2 = slightly uneasy
3 = very uneasy
4 = aggressive.

Milking temperament was scored on a 1 - 4 scale (within 48 hours of calving and at three weeks post calving), where 1 = stands calmly and 4 = milked with difficulty. The Holstein-Friesian and Jersey crossbred cows did not differ in milking temperament during any of the measurement occasions (P>0.05: Table 4).

Table 4 Effect of dairy cow genotype on the percentage of cows with each milking temperament score

	Genotype	Milking temperament score 1	2	3	4	P value
Lactation 1						
Within 48 hours of calving	Holstein-Friesian	39.7	51.6	6.3	2.4	0.678
	Jersey crossbreds	38.5	52.4	6.5	2.4	
Within 3 weeks of calving	Holstein-Friesian	88.0	10.0	2.0	0	0.284
	Jersey crossbreds	84.4	12.8	2.8	0	
Lactation 2						
Within 48 hours of calving	Holstein-Friesian	87.4	11.0	1.6	0	0.494
	Jersey crossbreds	88.8	9.8	1.4		
Within 3 weeks of calving	Holstein-Friesian	94.6	4.4	1.0	0	0.319
	Jersey crossbreds	96.4	2.9	0.7	0	

1 = stands calmly
2 = slightly agitated – may attempt to kick
3 = moderately agitated – some kicking
4 = extremely agitated – milked with difficulty

Condition score: The crossbred cows had a higher condition score than the Holstein cows throughout lactation 1, and during the first 100 days of lactation 2. However, changes in condition score during each lactation followed a similar trend for cows of both genotypes, thus suggesting that both breeds mobilised and laid down similar amounts of body condition (Figure 3).

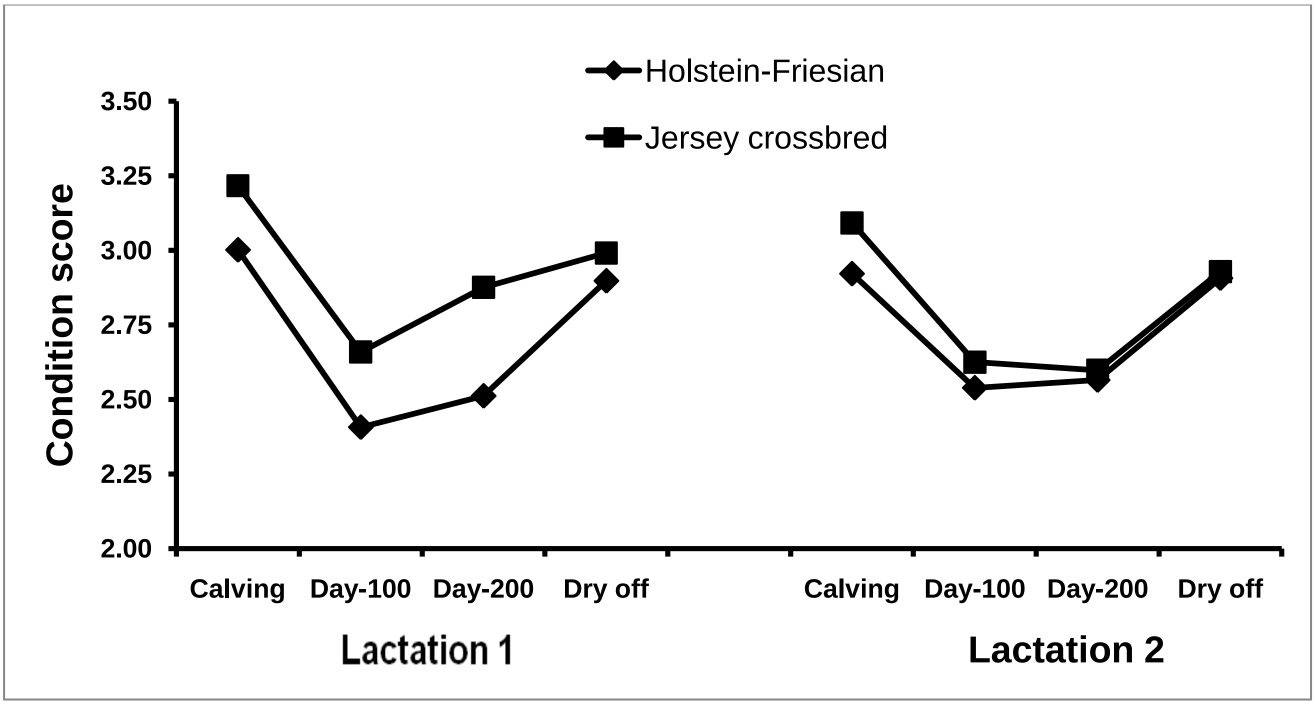

Figure 3 Effect of breed on cow condition score during lactations 1 and 2

Milk production and composition: Milk production (305-day and full lactation) data during each of lactations 1 – 6 are presented in Table 5, with the significance of year, farm and genotype highlighted. Data for lactations 5 and 6 related to approximately 60 and 25 cows of each genotype, and as such should be treated with caution. There was a highly significant effect of farm in each of lactations 1 – 4 for all parameters measured (P<0.001), reflecting the different systems in place across the 11 farms where the experiment was undertaken. Holstein cows had greater 305-day milk yields and full lactation milk yields than the Jersey crossbred cows during each of lactations 1 - 6, with these differences highly significant (P<0.001) in all but lactation 6. Similarly, crossbred cows produced milk with a higher fat and protein content than Holstein cows in each of lactations 1 – 6 (P<0.001). The overall effect was that fat plus protein yield did not differ between breeds in lactations 1, 2, 4 and 6, while being lower with the crossbred cows during lactations 3 and 5. However, in each of lactations 1 – 6 crossbred cows tended to milk for fewer days than the Holstein cows, with this effect being significant during lactations 1, 3 and 5. Actual somatic cell counts during each of lactations 1 – 4 are presented in Figure 4, and tended to be numerically higher with the crossbred cows in each lactation. However, genotype had no effect on somatic cell score in each of lactations 1 – 6 (P>0.05).

Table 5 Effect of dairy cow genotype on milk production during lactations 1-6

	Holstein-Friesian	Jersey ×	SEM	Significance Year	Farm	Geno-type
Lactation 1 n =	186	181				
305-day performance						
Days in milk	294	293	1.40	***	***	NS
Milk yield (litres)	5635	5185	60.1	NS	***	***
Milk fat (%)	4.12	4.57	0.032	NS	***	***
Milk protein (%)	3.34	3.48	0.014	*	***	***
Fat + protein yield (kg)	418	417	4.5	NS	***	NS
SCC (000/ml)	118	133				
SCS (000/ml, log10)	1.87	1.91	0.029	*	***	NS
Full lactation performance						
Days in milk	324	317	4.6	***	***	***
Concentrate intake (kg)	1195	1190	10.4	***	***	NS
Milk yield (litres)	6084	5486	97.5	NS	***	***
Milk fat (%)	4.14	4.59	0.032	NS	***	***
Milk protein (%)	3.35	3.50	0.014	NS	***	***
Fat yield (kg)	250	252	4.4	*	***	NS
Protein yield (kg)	203	192	3.3	NS	***	*
Fat + protein yield (kg)	453	444	7.5	*	***	NS
Energy corrected milk (litres)	6261	6027	102.4	*	***	NS
Milk energy content (MJ/kg)	3.21	3.40	0.014	*	***	***
Milk energy output (GJ)	19.41	18.69	0.317	*	***	NS
SCC (000/ml)	119	135				
SCS (000/ml, log10)	1.88	1.93	0.028	NS	***	NS
Dry period length (days)	78	73	2.5	*	***	NS
Lactation 2 n =	155	165				
305-day performance						
Days in milk	287	288	1.76	NS	***	NS
Milk yield (litres)	6415	5847	85.2	NS	***	***
Milk fat (%)	4.20	4.65	0.040	**	***	***
Milk protein (%)	3.41	3.60	0.018	NS	***	***
Fat + protein yield (kg)	486	480	6.5	NS	***	NS
SCC (000/ml)	132	145				
SCS (000/ml, log10)	1.88	1.93	0.031	NS	***	NS
Full lactation performance						
Days in milk	314	308	4.4	**	***	NS
Concentrate intake (kg)	1186	1168	6.6	***	***	NS
Milk yield (litres)	6783	6152	113.6	NS	***	***
Milk fat (%)	4.22	4.67	0.040	**	***	***
Milk protein (%)	3.43	3.61	0.019	NS	***	***
Fat yield (kg)	286	286	5.4	NS	***	NS
Protein yield (kg)	232	222	3.9	NS	***	NS
Fat + protein yield (kg)	518	508	9.1	NS	***	NS
Energy corrected milk (litres)	7103	6850	122.85	NS	***	NS
Milk energy content (MJ/kg)	3.25	3.46	0.017	*	***	***
Milk energy output (GJ)	22.03	21.23	0.381	NS	***	NS
SCC (000/ml)	136	148				
SCS (000/ml, log10)	1.89	1.93	0.031	NS	***	NS
Dry period length (days)	80	76	2.5	*	***	NS

Table 5 *(continued)*

	Holstein-Friesian	Jersey x	SEM	Significance: Year	Farm	Geno-type
Lactation 3 n =	125	136				
305-day performance						
Days in milk	283	280	2.3	NS	***	NS
Milk yield (litres)	6933	6029	105.4	*	***	***
Milk fat (%)	4.20	4.75	0.045	***	***	***
Milk protein (%)	3.39	3.61	0.019	***	***	***
Fat + protein yield (kg)	524	502	7.9	NS	***	NS
SCC (000/ml)	171	179				
SCS (000/ml, log10)	1.96	2.02	0.038	NS	***	NS
Full lactation performance						
Days in milk	307	294	4.7	NS	***	*
Concentrate intake (kg)	1211	1183	8.4	***	***	*
Milk yield (litres)	7320	6226	136.2	*	***	***
Milk fat (%)	4.21	4.76	0.045	***	***	***
Milk protein (%)	3.41	3.62	0.019	***	***	***
Fat yield (kg)	308	296	6.4	NS	***	NS
Protein yield (kg)	247	224	4.3	NS	***	NS
Fat + protein yield (kg)	556	520	10.5	NS	***	*
Energy corrected milk (litres)	7643	6999	144.4	NS	***	**
Milk energy content (MJ/kg)	3.24	3.49	0.019	***	***	***
Milk energy output (GJ)	23.69	21.7	0.448	NS	***	**
SCC (000/ml)	176	180				
SCS (000/ml, log10)	1.99	2.03	0.037	NS	***	NS
Dry period length (days)	80	82	2.6	NS	***	NS
Lactation 4 n =	94	113				
305-day performance						
Days in milk	279	280	2.6	*	***	NS
Milk yield (litres)	7145	6450	113.6	NS	***	***
Milk fat (%)	4.17	4.81	0.059	*	***	***
Milk protein (%)	3.37	3.59	0.022	NS	***	***
Fat + protein yield (kg)	369	374	6.5	NS	***	NS
SCC (000/ml)	203	228				
SCS (000/ml, log10)	2.06	2.08	0.043	NS	***	NS
Full lactation performance						
Days in milk	304	294	4.8	**	***	NS
Concentrate intake (kg)	1206	1207	5.2	***	***	NS
Milk yield (litres)	7417	6647	131.0	NS	***	***
Milk fat (%)	4.17	4.81	0.058	*	***	***
Milk protein (%)	3.38	3.60	0.022	NS	***	***
Fat yield (kg)	310	320	6.7	*	***	NS
Protein yield (kg)	249	239	4.5	NS	***	NS
Fat + protein yield (kg)	559	558	10.8	NS	***	NS
Energy corrected milk (litres)	7679	7520	144.3	NS	***	NS
Milk energy content (MJ/kg)	3.23	3.51	0.024	*	***	***
Milk energy output (GJ)	23.89	23.31	0.447	NS	***	NS
SCC (000/ml)	209	226				
SCS (000/ml, log10)	2.08	2.09	0.042	NS	***	NS
Dry period length (days)	92	77	3.7	NS	***	**

Table 5 *(continued)*

	Holstein-Friesian	Jersey x	SEM	Significance: Year	Farm	Geno-type
Lactation 5 n =	58	64				
305-day performance						
Days in milk	283	279	3.8	NS	***	NS
Milk yield (litres)	7147	6296	133.0	NS	***	***
Milk fat (%)	4.12	4.68	0.066	NS	***	***
Milk protein (%)	3.39	3.61	0.030	NS	**	***
Fat + protein yield (kg)	534	520	11.4	NS	***	NS
SCC (000/ml)	237	227				
SCS (000/ml, log10)	2.12	2.09	0.053	NS	***	NS
Full lactation performance						
Days in milk	310	286	6.4	*	***	*
Concentrate intake (kg)	1220	1229	4.8	***	***	NS
Milk yield (litres)	7550	6395	179.6	NS	***	***
Milk fat (%)	4.13	4.68	0.066	NS	***	***
Milk protein (%)	3.40	3.62	0.030	*	**	***
Fat yield (kg)	313	292	9.0	**	***	NS
Protein yield (kg)	258	226	6.4	**	***	***
Fat + protein yield (kg)	570	516	14.9	***	***	**
Energy corrected milk (litres)	7824	7105	199.8	*	***	*
Milk energy content (MJ/kg)	3.21	3.46	0.028	NS	***	***
Milk energy output (GJ)	24.25	22.02	0.619	*	***	*
SCC (000/ml)	240	237				
SCS (000/ml, log10)	2.13	2.11	0.053	NS	***	NS
Dry period length (days)	79	83	5.6	NS	*	NS
Lactation 6 n =	22	26				
305-day performance						
Days in milk	283	279	5.20	NS	*	NS
Milk yield (litres)	7129	6325	210.4	NS	NS	*
Milk fat (%)	4.08	5.00	0.106	NS	***	***
Milk protein (%)	3.36	3.62	0.037	*	NS	***
Fat + protein yield (kg)	530	545	17.5	NS	**	NS
SCC (000/ml)	236	354				
SCS (000/ml, log10)	2.25	2.25	0.072	NS	***	NS
Full lactation performance						
Days in milk	297	289	9.1	NS	*	NS
Concentrate intake (kg)	1380	1379	0.0	***	***	NS
Milk yield (litres)	7389	6478	251.7	NS	NS	*
Milk fat (%)	4.08	5.00	0.104	NS	***	***
Milk protein (%)	3.37	3.63	0.037	*	NS	***
Fat yield (kg)	303	325	13.6	NS	***	NS
Protein yield (kg)	248	235	8.7	NS	NS	NS
Fat + protein yield (kg)	551	560	21.6	NS	**	NS
Energy corrected milk (litres)	7610	7503	288.3	NS	**	NS
Milk energy content (MJ/kg)	3.19	3.59	0.043	NS	***	***
Milk energy output (GJ)	23.59	23.26	0.894	NS	**	NS
SCC (000/ml)	239	359				
SCS (000/ml, log10)	2.26	2.27	0.074	NS	***	NS
Dry period length (days)	69	83	7.0	NS	**	NS

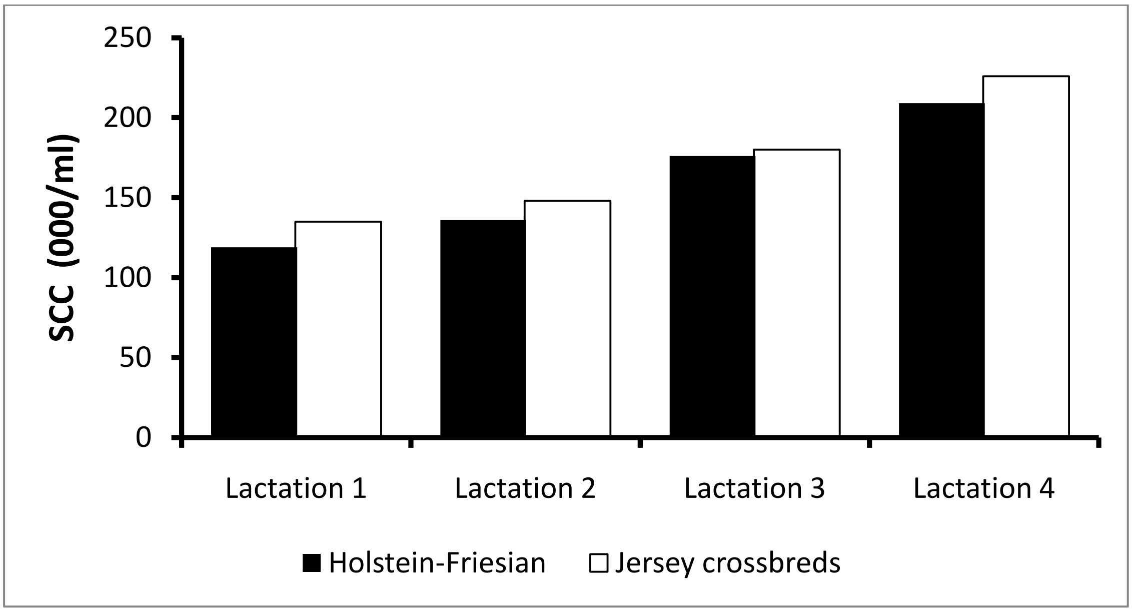

Figure 4 Effect of breed on mean somatic cell count (000/ml) during each of lactations 1-4

<u>*Lactation curves*</u>: Milk yield lactation curves and fat + protein yield lactation curves as described using the Wilmink equation, for each of lactations 1 – 4 (a – d), are presented in Figures 5 and 6, respectively. The effect of genotype on the components of these curves (*a, b* and *c* components), and on days to peak yield and actual peak yield, are presented in Table 6. With regards the milk yield curve, the *a* component of the curve was significantly lower for the crossbred cows in lactations 1 ($P<0.01$) and 4 ($P<0.001$), while the *b* and *c* components of the curves did not differ between genotypes in any lactation. Days to peak yield did not differ between genotype in any lactation, while peak yield was significantly lower with the crossbred cows in each of lactations 1 ($P<0.01$) and 4 ($P<0.001$). With the fat + protein yield curves there was no difference between genotypes in any component of the curves during lactations 1 – 3, while both the *a* component of the curve and peak yield was significantly lower with the crossbred cows ($P<0.05$) during lactation 5.

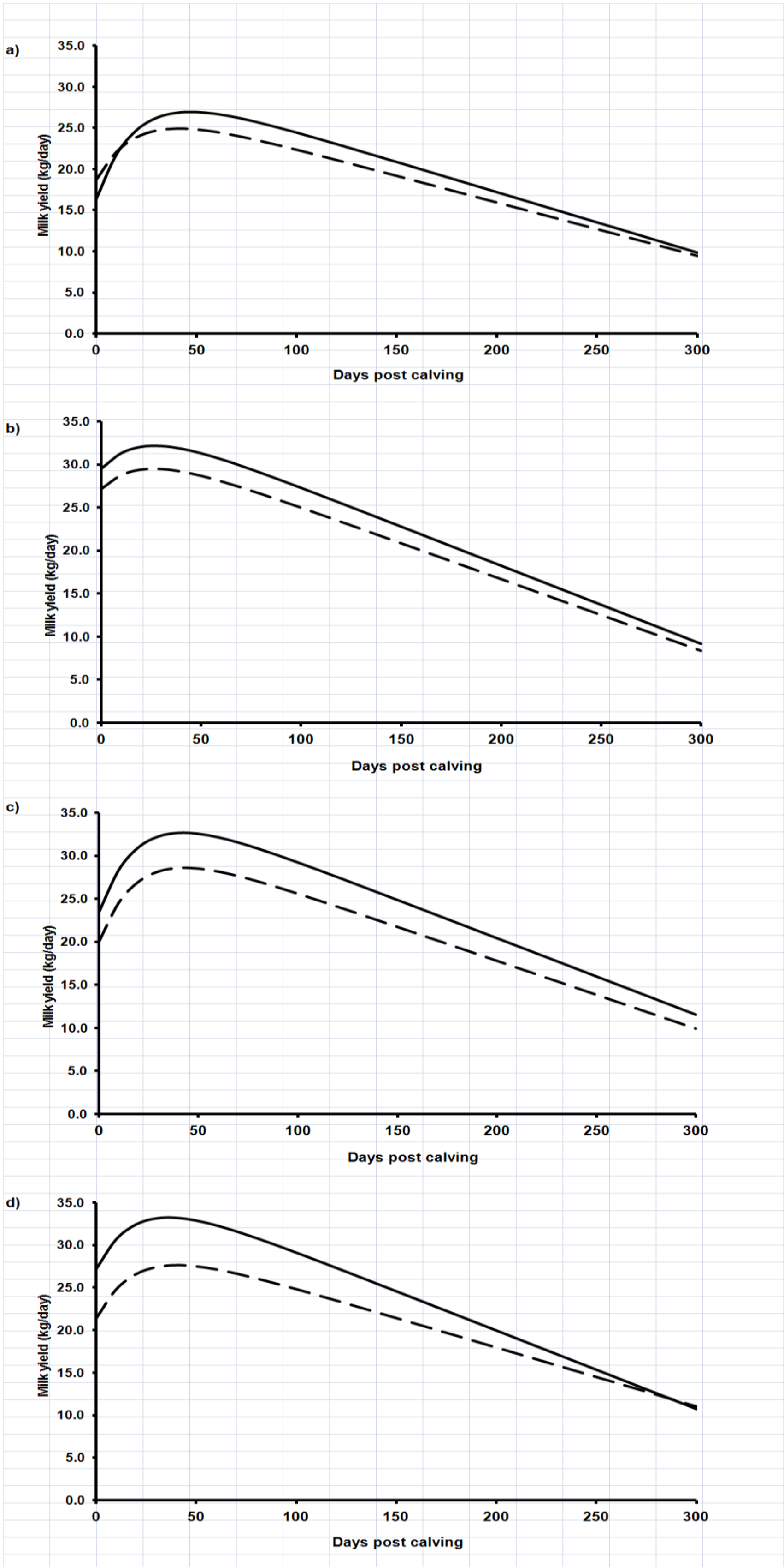

Figure 5 Daily milk yield lactation curves for Holstein-Friesian (solid lines) and Jersey crossbred cows (dashed lines) during lactations 1 (a) – 4 (d)

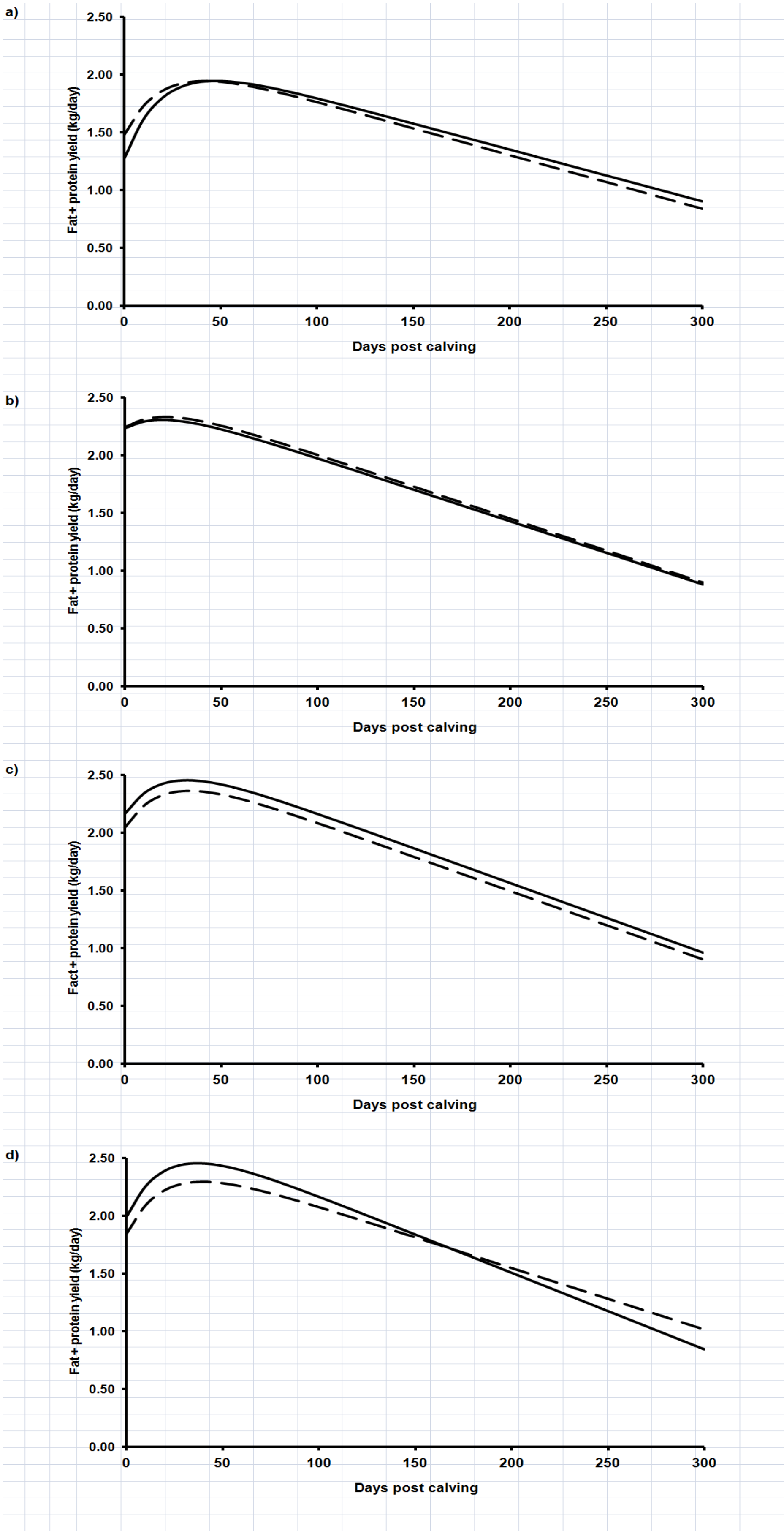

Figure 6 Daily fat + protein yield lactation curves for Holstein-Friesian (solid lines) and Jersey crossbred cows (dashed lines) during lactations 1 (a) – 4 (d)

Table 6 Effect of cow genotype on components of the daily milk yield and daily fat plus protein yield lactation curve (Wilmink), and on peak yield and days to peak yield, during lactations 1 - 4

		Milk yield (kg/day)				Milk fat + protein yield (kg/day)			
		HF	JX	SE	Sig.	HF	JX	SE	Sig.
Lactation 1	a	31.9	28.9	0.84	**	2.25	2.23	0.100	NS
	b	-15.55	-10.20	2.747	NS	-0.975	-0.753	0.3252	NS
	c	-0.073	-0.065	0.0045	NS	-0.0045	-0.0046	0.00052	NS
	Days to peak yield	47.2	41.3	3.78	NS	47.74	41.89	6.4425	NS
	Peak yield (kg)	27.0	24.9	0.50	**	1.95	1.94	0.060	NS
Lactation 2	a	36.4	33.4	2.96	NS	2.56	2.52	0.197	NS
	b	-6.90	-6.20	9.647	NS	-0.316	-0.287	0.6413	NS
	c	-0.091	-0.083	0.0158	NS	-0.0055	-0.0055	0.00105	NS
	Days to peak yield	26.7	26.3	27.74	NS	20.9	19.3	41.455	NS
	Peak yield (kg)	32.2	29.5	1.99	NS	2.33	2.31	0.171	NS
Lactation 3	a	38.2	33.5	3.29	NS	2.77	2.68	0.294	NS
	b	-14.71	-13.48	10.720	NS	-0.605	-0.634	0.9577	NS
	c	-0.089	-0.079	0.0175	NS	-0.0060	-0.0059	0.00156	NS
	Days to peak yield	42.3	43.0	13.04	NS	32.28	33.57	28.275	NS
	Peak yield (kg)	32.7	28.6	1.95	NS	2.46	2.36	0.176	NS
Lactation 4	a	38.4	31.8	1.53	***	2.84	2.62	0.093	*
	b	-11.26	-10.48	4.963	NS	-0.846	-0.772	0.3016	NS
	c	-0.092	-0.069	0.0081	NS	-0.0066	-0.0053	0.00049	NS
	Days to peak yield	36.2	40.4	8.02	NS	37.0	39.6	6.547	NS
	Peak yield (kg)	33.3	27.6	0.90	***	2.46	2.30	0.054	*

Fertility: With the exception of lactation 4 (P<0.05), interval from calving to first service was unaffected by genotype (Table 7). Jersey crossbred cows had higher conception rates to first AI as heifers and during lactation 2 (P<0.05), but not during any other lactation. Crossbred cows tended to have shorter calving intervals than the Holstein-Friesian cows, although these differences were not significant. The duration of pregnancy was unaffected by genotype throughout the experiment (P>0.05), while calving interval was significantly shorter with the crossbred cows in lactation 4 only (P<0.001), while being numerically shorter during the remaining lactations. The proportion of cows culled as infertile was lower with the crossbred cows in each of lactations 1 (P = 0.098), 2 (P <0.05) and 4 (P = 0.92).

Reasons for culling and cow longevity: While cows were culled for many reasons (Table 8), infertility was the primary reason for culling, although there were no differences between genotypes in the proportions of cows culled as infertile (P>0.05). With regards to other culling reasons, there were few differences between breeds. However, more Holstein cows than crossbred cows were culled due to ‘feet and leg’ problems (P<0.05). Crossbred cows had a higher survivability than Holstein cows, with 48% of Jersey crossbred cows surviving until the end of the fourth lactation, compared to 39% of Holstein cows (P = 0.063: Table 8).

Survival curves for each of the two genotypes, from first calving until fifth calving, as produced using the Kaplan-Meier survival function, are presented in Figure 7. The estimated time to culling 25%, 50% and 75% of Holstein-Friesian cows was 706, 1387 (95% Confidence Interval: 1196 and 1600 days) and 1809 days, respectively, while the estimated time to culling 25%, 50% and 75% of crossbred cows was 960 and 1678 (95% Confidence Interval: 1432 and 1847 days) and 1847 days, respectively. Differences between breeds were tested using the Wilcoxon (Breslow) test and found to be significant (P<0.042), with the crossbred cows having the greater survival.

Table 7 Effect of dairy cow genotype on fertility performance

	Holstein-Friesian	Jersey x	SEM	P value
Heifers				
Age at first service (days)	464	462	3.4	0.724
Conception to first service (proportion)	0.61	0.72	0.033	0.022
Conception to first and second service (proportion)	0.92	0.95	0.018	0.210
Age at first calving (days)	754	750	3.7	0.470
Gestation length (days)	280	280	0.4	0.114
Mean number of services	1.5	1.3	0.05	0.028
Lactation 1				
Interval from calving to first service (days)	88	90	2.2	0.415
Interval from calving to conception (days)	117	112	4.2	0.428
Conception to first service (proportion)	0.46	0.54	0.035	0.126
Conception to first and second service (proportion)	0.73	0.77	0.031	0.457
Mean number of services	1.9	1.7	0.08	0.094
Pregnancy length (days)	281	281	1.3	0.167
Calving interval (days)	397	392	4.3	NS
Cows culled as infertile (proportion)	0.060	0.027	0.0143	0.098
Lactation 2				
Interval from calving to first service (days)	80	77	2.1	0.332
Interval from calving to conception (days)	111	104	4.8	0.261
Conception to first service (proportion)	0.44	0.54	0.038	0.047
Conception to first and second service (proportion)	0.68	0.78	0.034	0.051
Mean number of services	2.0	1.8	0.09	0.252
Pregnancy length (days)	282	281	0.5	0.336
Calving interval (days)	394	384	4.6	NS
Cows culled as infertile (proportion)	0.070	0.043	0.0166	0.025
Lactation 3				
Interval from calving to first service (days)	81	78	2.6	0.497
Interval from calving to conception (days)	106	98	4.4	0.181
Conception to first service (proportion)	0.51	0.55	0.043	0.488
Conception to first and second service (proportion)	0.73	0.78	0.038	0.377
Mean number of services	1.9	1.8	0.09	0.345
Pregnancy length (days)	282	282	0.5	0.481
Calving interval (days)	389	380	4.6	NS
Cows culled as infertile (proportion)	0.098	0.064	0.0197	0.202
Lactation 4				
Interval from calving to first service (days)	81	74	2.5	0.027
Interval from calving to conception (days)	118	92	5.8	0.002
Conception to first service (proportion)	0.45	0.52	0.049	0.308
Conception to first and second service (proportion)	0.63	0.74	0.044	0.088
Mean number of services	2.1	1.8	0.12	0.043
Pregnancy length (days)	281	280	0.81	0.493
Calving interval (days)	398	370	6.19	***
Cows culled as infertile (proportion)	0.073	0.122	0.0207	0.092
Lactation 5				
Interval from calving to first service (days)	75	70	2.8	0.274
Interval from calving to conception (days)	101	97	7.3	0.724
Conception to first service (proportion)	0.47	0.56	0.064	0.358
Conception to first and second service (proportion)	0.69	0.74	0.052	0.570
Mean number of services	2.0	1.9	0.17	0.704
Pregnancy length (days)	280	282	0.9	0.230
Calving interval (days)	394	376	8.1	NS
Cows culled as infertile (proportion)	0.044	0.056	0.0158	0.606

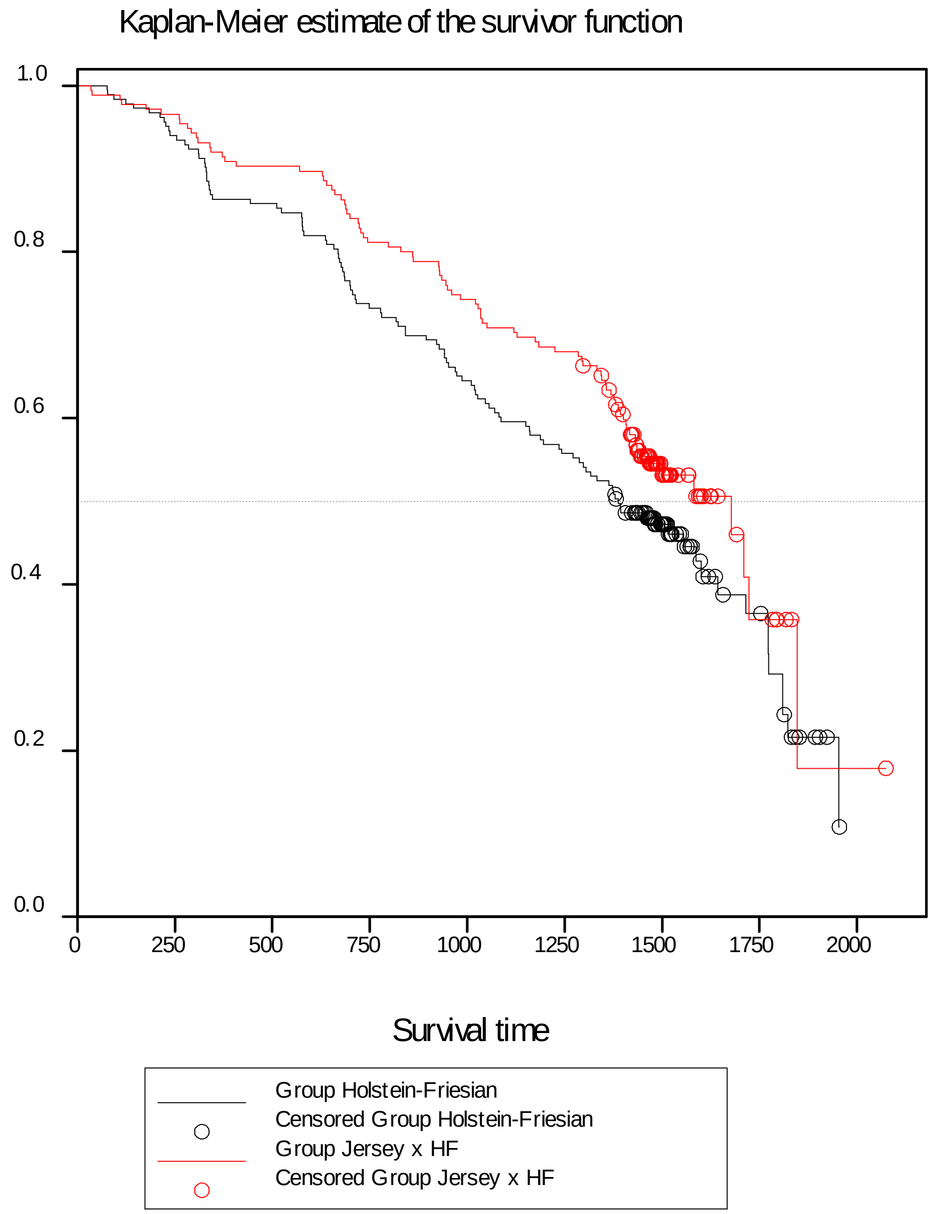

Figure 7 Survival curves for Holstein-Friesian (lower curve) and Jersey crossbred cows (upper curve) from 1st calving until fifth calving

The proportion of cows completing each of lactations 1 – 4 is presented graphically in Figure 8. In addition, a linear relationship has been fitted to the data from each genotype, and these lines extrapolated until they crossed the *x* axis. These lines crossed the *x* axis at 7.25 lactations and 9.75 lactations for the Holstein and crossbred cows respectively. Dividing these two values by two indicates that on average Holstein cows completed 3.63 lactations while crossbred cows completed 4.88 lactations in the herds.

Table 8 Reasons for removing cows from the experiment (proportional basis), with actual number of cows removed in brackets

	Holstein-Friesian		Jersey crossbreds		SEM	P value
Cows remaining at start of lactation 5	0.388	(74)	0.479	(91)	0.0346	0.063
Sold	0.043	(6)	0.074	(12)	0.0159	0.131
Tuberculosis/Brucellosis	0.017	(3)	0.011	(2)	0.1848	0.562
Infertile	0.302	(58)	0.250	(47)	0.0311	0.239
Slipped calving pattern	0.055	(11)	0.041	(8)	0.0146	0.518
Other health issues[†]	0.047	(9)	0.048	(9)	0.0153	0.967
Udder structure	0.008	(2)	0.009	(2)	0.0062	0.873
Mastitis	0.027	(5)	0.027	(5)	0.0116	0.998
Injury	0.036	(7)	0.023	(4)	0.0120	0.446
Feet and legs	0.041	(7)	0.005	(1)	0.0102	0.015
Abortion	0.0	(0)	0.004	(1)	0.0018	0.193
High somatic cell count	0.030	(6)	0.028	(5)	0.0117	0.888
Low milk yield	0.023	(4)	0.011	(2)	0.0094	0.353

[†] Includes pneumonia, digestive problems, metabolic problems, bacterial diseases, unexplained deaths and cows with no reason recorded

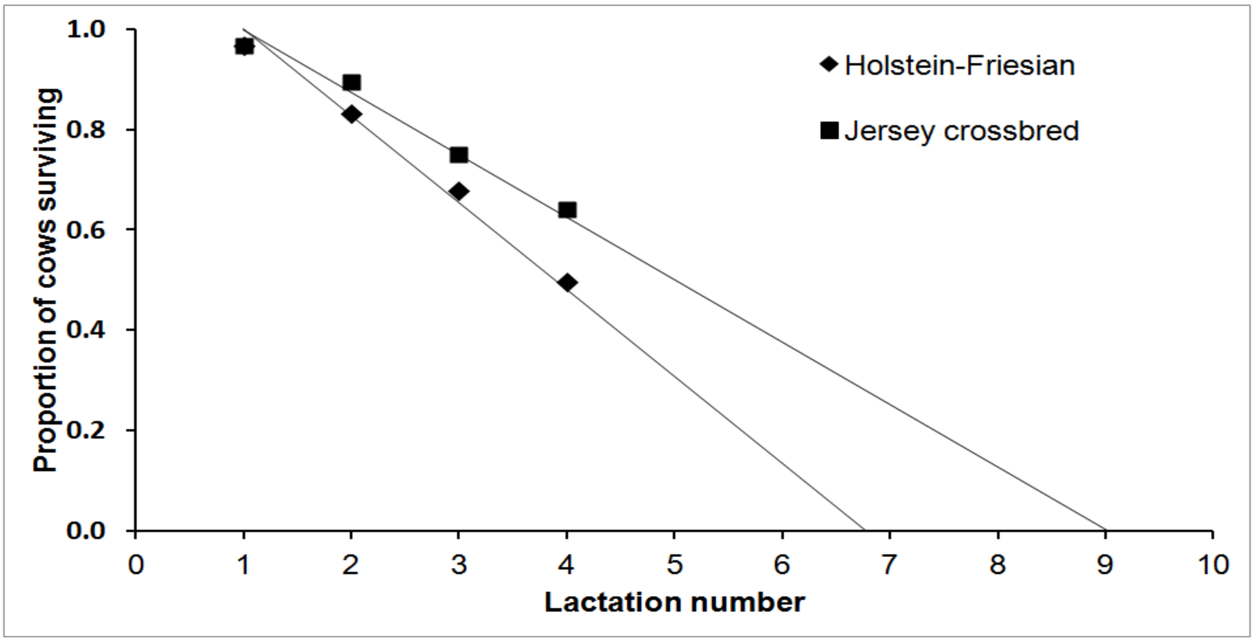

Figure 8 Effect of genotype on the proportion of cows surviving until the end of each of lactations 1 – 4, with lines extrapolated to meet the *x* axis

DISCUSSION

The current experiment provides a unique opportunity to compare calving traits, cow behaviours, milk production, fertility performance and longevity of purebred Holstein-Friesian cows and Jersey × Holstein Friesian cows.

Calving difficulty and stillbirths

Both calving difficulty and stillbirths are reproductive traits of economic importance within dairy cattle. The effects of difficult calvings are several, and include a loss of production, poorer fertility, and increased cow and calf morbidity and mortality. The results of this study provided no evidence of easier calvings with crossbred cows. In contrast, in a smaller scale study at AFBI, Holstein-Friesian cows had a marginally (although significantly) higher calving difficulty score than Jersey crossbred cows, with this attributed in part to the lighter calf birth weights with crossbred cows (43.1 vs 37.0 kg, respectively) (Vance *et al*., 2013).

Although not significant, the incidence of stillbirths was numerically lower with the crossbred cows when calving for the first time, with 12% of calves born to the Holstein cows either born dead or dying within 24 hours of birth, compared to 8% of calves born to the crossbred cows. While the value of 12% for the Holstein breed might appear to be high, it is almost identical to the value of 13% recorded for Holstein cows in the AgriSearch funded on-farm Norwegian cow project (Ferris, 2012), and similar to values published for some cattle populations in other parts of the world. For example, in a recent review Mee *et al*. (2008) summarised estimates of perinatal calf mortality for Holstein cows across a number of countries, with values ranging from 4.3% (Iran) to 12.1% (USA), although higher values for Holstein cows have been reported in the US previously (13.2%: Meyer *et al*., 2001). Similarly, Heins *et al*. (2006) in the study involving Scandinavian Red crossbred cows recorded 14% and 3.7% stillbirths for Holstein cows during their first and second calvings, respectively, compared to values of 5.1 and 2.3% for Scandinavian Red × Holstein cows. The incidence of stillbirths with the two genotypes within the current study was almost identical when calving for the second time.

Calving temperament and milking temperament

Few studies have compared the calving temperament of different dairy cow genotypes. In one exception, Ferris (2012) compared the calving temperament of Holstein and Norwegian dairy cows, and found the latter to have a poorer calving temperament score than the Holstein cows at first, but not second calving. Similarly, within the current study crossbred cows had a poorer calving temperament score than the Holstein cows when calving for the first time, but not the second time. Milking behaviour of the two cow genotypes did not differ either during lactation 1 or 2.

Milk production

Differences between genotypes in terms of milk yield, milk composition and fat + protein yield within the current study are in line with those reported previously within the literature (Auldist *et al.*, 2007; Prendiville *et al.*, 2009; Prendiville *et al.*, 2010b). For example, Holstein-Friesian cows produced 773 kg more milk than Jersey × Holstein-Friesian cows (mean of lactations 1 – 4), while the latter produced milk containing 5.2 g/kg more fat and 1.9 g/kg more protein than the Holstein-Friesian cows. These differences are in close agreement with those reported in an earlier AFBI study involving spring calving cows (Vance *et al*., 2013), namely 625 kg more milk with the Holstein-Friesian cows and 5.8 g/kg more fat and 2.9 g/kg more protein with the crossbred cows. The average concentrate input within the current study (1.2 tonnes/lactation) was similar to the mean concentrate input in the study by Vance *et al*. (2013).

The overall effect of the higher milk volumes and poorer milk composition with the Holstein cows was that fat + protein output was unaffected by genotype. Thus within moderate concentrate input systems, the results of the current study, in line with much of the literature, demonstrates that crossbreeding Holstein-Friesian dairy cows with proven Jersey sires with a high genetic potential for milk production traits will normally result in some loss in milk yield, but no loss in the yield of milk constituents. While the contribution of hybrid vigour to milk production performance cannot be identified within the current study, Lopez-Villalobos (1998) summarised estimates across a number of studies, with mean values of 4.7%, 0.2% and -0.3% for lactation milk yield, milk fat and milk protein content, respectively.

Surprisingly, despite these differences in milk yields, and the visual differences in the lactation curves (Figures 3), few of the parameters describing components of the lactation curves differed significantly. While peak yield was higher with the Holstein cows in lactations 1 and 3, (with this reflected in significantly higher '*a*' values), there were no differences between genotypes in peak yield during lactations 2 and 3, nor in any other components of the milk yield lactation curves during lactations 1 - 4. Similarly, there were few differences between genotypes for parameters describing the fat + protein yield lactation curves. That few of the visible differences in the milk yield lactation curves were significant may simply reflect the large variability that existed between farms, a reflection of the range of concentrate inputs in place. For example, in a study involving fewer animals but a common management regime, Vance *et al*. (2013) observed clear differences between these same two genotypes in the shape of their lactation curves, especially for peak yield and the rates of decline of the curves. This is consistent with the findings of Hickson *et al.* (2006), who reported higher lactation persistency in pure bred Jersey dairy cows compared with Friesian dairy cows.

That milk solids yield and energy corrected milk yield did not differ dramatically between breeds in the current study may be attributed to a number of factors.

Firstly, based on the findings of Heins *et al.* (2008b), Prendiville *et al*. (2009), Vance *et al.* (2012) and Vance *et al.* (2013), it is unlikely that food intakes of the two cow genotypes differed either during the confinement period or while grazing. In each of these experiments, similar food intakes were observed even though the crossbred cows were normally between 30 – 60 kg lighter than the Holstein cows. Prendiville *et al*. (2010a), in a study involving grazing dairy cattle, observed that Jersey crossbred cows had an increased biting rate and a tendency to achieve a higher intake per bite compared with the average of the parent breeds, with these benefits attributed in part to hybrid vigour for intake characteristics.

Secondly, while the trends in body condition score suggest that although crossbred cows had a higher condition score than the Holstein cows, especially during lactation 1, there was no evidence of differences in nutrient partitioning between genotypes, with both genotypes having similar levels of tissue mobilisation in early lactation, and tissue gain in late lactation. The similar trends in tissue mobilisation with the two genotypes in the current study are in agreement with the observations of Olson *et al.* (2010), Prendiville *et al.* (2009) and Vance *et al*. (2013) who reported similar live weight change trends in Holstein-Friesian, Jersey and Jersey × Holstein-Friesian cows. While a number of cows on the current study were managed within higher concentrate input systems (up to 2.5 tonnes concentrate/cow/lactation), the analysis undertaken provides no evidence of a genotype x environment interaction for either milk yield or body tissue change. Nevertheless, within higher input systems Heins *et al.* (2008a) reported that condition score loss in early lactation plateaued earlier with Jersey × Holstein cows, while Vance *et al*. (2012) observed that from approximately week 15 of lactation onwards, Jersey crossbred cows partitioned a greater proportion of their nutrients consumed to body tissue in comparison to Holstein-Friesian cows.

Thirdly, evidence from energy utilisation studies suggest that metabolic efficiencies are similar between the two genotypes. For example, in a study comparing nutrient use efficiency of Holstein and Jersey crossbred cows, Xue *et al*. (2011) found little evidence of differences in metabolic efficiency between Holstein and Jersey × Holstein cows. In that study these two genotypes digested their food, utilised energy consumed and had a similar efficiency of lactation. This agrees with the findings of other experiments comparing contrasting genotypes, for example, Yan *et al*. (2006) observed that when offered low concentrate diets, Norwegian Red and Holstein cows did not differ dramatically either in terms of methane production per kg of energy corrected milk produced or in the efficiency of metabolisable energy use for lactation. While the smaller crossbred cows would have been expected to have a lower maintenance energy requirement (approximately 5.0 MJ/day: Thomas, 2004) than the larger Holstein-Friesian cows (with this having the potential to support the production of an additional 1.0 kg (approximately) of SCM/day), a performance benefit associated with this energy saving was not observed.

Udder health

While there was a trend for SCC to increase with increasing lactation number (Figure 4), SCC's did not differ between the two genotypes in any of lactations 1 - 4. Most studies have reported no difference between Holstein-Friesian and Jersey × Holstein-Friesian cows for mean SCS (Heins *et al.*, 2008a; Prendiville *et al.*, 2010b: Vance *et al.*, 2013. This is perhaps not surprising when we consider that purebred Jersey cows often have similar or higher (Washburn *et al.*, 2002; Prendiville *et al.*, 2010b) SCS's than pure bred Holstein cows. In addition, benefits of hybrid vigour on SCC appear to be low, with VanRaden and Sanders (2003) reporting levels of hybrid vigour for SCC in Holstein, Jersey and Guernsey crossbred cows to be low and unfavourable, while Prendiville *et al.* (2010b) observed no evidence of hybrid vigour for SCS in Jersey crossbred cows.

While high SCC *per se* can result in financial penalties for milk producers, a genetic correlation exists between SCC and frequency of clinical mastitis, with Mrode and Swanson (1996), based on values in the literature, suggesting a correlation of approximately 0.7. Although detailed information on mastitis incidence was not recorded by farmers within the current study, the number of cows culled due to mastitis did not differ between breeds (Table 8). In contrast, the proportion of cows with one or more cases of mastitis was approximately 45% higher with the Holstein-Friesian cows in the study by Vance *et al*. (2013), while Heins *et al.* (2011) observed similar trends for Jersey crossbred and Holstein cows in their third lactation. In contrast, Prendiville *et al.* (2010b) reported no difference between Holstein-Friesian and Jersey × Holstein-Friesian cows for the proportion of cows having at least one case of mastitis. Within the current study the proportion of cows culled due to mastitis did not differ between the two genotypes.

Fertility

The overall culling data from the experiment highlighted that 30.2% of Holstein-Friesian cows and 25.0% of Jersey crossbred cows were culled as infertile prior to lactation 5, with this difference not significant. For most of the fertility parameters examined within this experiment, crossbred cows tended to have improved fertility performance compared to the Holstein-Friesian cows, although for most parameters, these differences were not significant. These trends are in general agreement with those within the literature, with Auldist *et al.* (2007), Prendiville *et al.* (2008) and Thackaberry *et al.* (2009) observing higher conception rates to first service (mean: 22 percentage points higher) and Heins *et al.* (2008b) and Auldist *et al.* (2007) observing higher overall conception rates (mean: 10.5 percentage points higher) with Jersey crossbred cows. In addition, they are in agreement with the findings of recent AFBI studies where conception rate to first service, conception rate to first and second service and pregnancy rate at the end of the breeding season were 23, 29 and 16 percentage points higher with the Jersey × Holstein-Friesian cows, compared to the Holstein-Friesian cows. Nevertheless, in a second AFBI study, few significant differences in fertility performance were observed between these two genotypes, although there was also a numerical trend for higher conception rates and 12-week in-calf rate with the Jersey × Holstein-Friesian cows. Improved fertility performance has also been observed in studies involving other crossbred genotypes with Walsh *et al.* (2008) reporting higher overall pregnancy rates with Montbelliarde × Holstein-Friesian and Normande × Holstein-Friesian cows, compared with pure bred Holstein-Friesian cows.

Poorer fertility levels are normally associated with increased levels of negative energy balance in cows, with selection for improved milk production normally negatively correlated with fertility. For example, Pryce *et al.* (2001) suggested that cows which are genetically predisposed to lose more body condition between weeks 1 - 10 of lactation will have increased days to first observed heat, increased days to first service, and longer calving intervals. However, the improved fertility performance with the Jersey × Holstein-Friesian cows within the current study occurred despite similar levels of condition score loss with the two genotypes. While there is some evidence that pure bred Jersey cows tend to have higher levels of fertility performance than pure bred Holstein-Friesian cows (Washburn *et al.*, 2002), hybrid vigour is likely to have been a significant contributor to the improved fertility performance observed with the crossbred cows (Lopez-Villalobos, 1998). Thus, the findings of this experiment suggests that crossbreeding Holstein dairy cows with Jersey sires can provide an immediate opportunity to overcome some of the fertility problems widely reported with the Holstein breed. While the results from this project suggest an overall higher level of fertility with the Jersey crossbred cows, compared to the Holstein cows, these differences were not as great as those recorded within previous Hillsborough studies. This difference may reflect the fact that the Holstein cows in this latter project had a much higher genetic merit for milk yield than those within the current project, and this is likely to have reduced their fertility performance.

Longevity

There is no doubt that cow longevity, combined with annual milk production performance, are both key drivers of economic performance on dairy farms. While the reasons for culling within the study were many and variable, the predominant reasons for culling, as already discussed, was infertility.

While there were few significant differences between genotypes in the reasons for culling, significantly more Holstein cows than crossbred cows were culled due to feet problems. This supports the trends observed by Vance *et al*. (2013) for Holstein cows to have an increased incidence of lameness compared to Jersey × Holstein-Friesian cows. Similarly, Logue *et al.* (1994) reported that Jersey × Holstein cows had a lower incidence and prevalence of lameness than pure bred Holstein cows, as well as having lower sole lesion scores. A number of studies comparing hoof health of pure bred Jersey cows with that of a second breed suggest Jersey cows to have improved hoof health (Alban, 1995; Huang *et al.*, 1995), with this likely due to Jersey cows having harder hooves. For example, in a small scale study Leithbridge and Margerison (2008) reported that the force needed to puncture the hooves of Jersey × Friesian cows was significantly higher than for the hooves of pure bred Friesian cows, and this could make the former more resilient to challenges of the hoof.

With regards many of the other reasons for culling, there was a non significant trend for culling incidence to be lower for the crossbred cows than for Holstein cows, with the overall effect being that 38.8% of Holstein-Friesian cows and 47.9% of crossbred cows survived until the start of the fifth lactation, with this overall difference being significant (P=0.063). The improved survival of the crossbred cows was reflected in the Kaplan-Meier estimate of survival function for each of the two genotypes, from first calving until fifth calving. In this, the estimated time to culling 25%, 50% and

75% of Holstein-Friesian cows was 706, 1387 and 1809 days, respectively, while the estimated time to culling 25%, 50% and 75% of crossbred cows was 960 and 1678 and 1847 days, respectively, reflecting a significantly higher survival with the Holstein cows ($P<0.042$).

While the study did not encompass full lifetime survival, an attempt was made to examine the mean number of lactations that cows of each genotype survived for (Figure 7). Based on an extrapolation of the proportion of cows completing each of lactations 1 – 4, 'maximum' lifetime survival of cows of each of the two genotypes was determined as 7.25 lactations and 9.75 lactations for the Holstein and crossbred cows respectively. By dividing these two values by two, on average Holstein cows survived for 3.63 lactations while crossbred cows survived for 4.88 lactations. Thus, based on this analysis, crossbred cows are likely to have remained in the herd for an additional 1.25 lactations, compared to Holstein cows. These data become critically important when examining the economic performance of each of the two genotypes, and when examining the carbon footprint of the different genotypes.

Financial performance of the two breeds in Experiment 3:

The financial performance of the two genotypes has been compared in Table 9. Milk yield and milk composition were adjusted to take account of the different herd structures arising due to differences in survival between breeds, with milk price adjusted for compositional bonuses. The analysis has been undertaken at a milk price of 26 pence per litre. Differences between breeds in replacement rates, stillbirth rates, calves sold, and cull cows sold have been included within the calculations. The values of Holstein calves sold were assumed as £100 (bull) and £150 (heifer), while the value of Jersey crossbred calves sold were assumed as £50 (bull) and £150 (heifer). Holstein cull cows were assumed to have a value of £600, while crossbred cull cows were assumed to have a value of £470. The value of replacement heifers was assumed to be the same for both breeds. Feed costs were based on annual food intakes obtained from previous Hillsborough studies (involving similar levels of performance), with feed costs assumed to be the same for both breeds. Veterinary/medicine and semen costs were assumed to be 20% lower with the crossbred cows due to their improved health and fertility.

Table 9 Comparison of the economic performance of Holstein-Friesian and Jersey crossbred cows (cow/year basis)

	Holstein-Friesian	**Jersey crossbred**
Milk sold (litres/cow/year)	6372	5973
Fat (%)	4.17	4.74
Protein (%)	3.39	35.9
Outputs (£/cow/year)		
Milk sold	1728	1739
Calves sold	90	71
Cull cows sold	165	96
Less replacement charge	358	266
Total outputs	1626	1640
Variable costs (£/cow/year)	763	739
Gross margin (£/cow/year)	863	902
Overhead costs (£/cow/year)	490	490
Net profit (£/cow/year)	373	412

Milk price, 26 ppl: Value of Holstein bull calf, £100: Value of Holstein heifer calf, £150: Value of crossbred bull calf, £50: Value of crossbred heifer calf, £160: Value of Holstein cull cow, £600: Value of crossbred cull cow, £570: Value of replacement heifer, £1300: Annual feed costs, £618/cow; Sundries, £145/cow/year for Holstein cows and £121 for crossbred cows; Total overhead costs £490/cow/year.

The overall outcome of the economic analysis was that Jersey crossbred cows had a gross margin and net profit which was £39/cow/year higher than for the Holstein Friesian cows. When this analysis was repeated at a milk price of 18 ppl and 34 ppl, the difference in net profit was £70 and £6 in favour of the crossbred cows, respectively. Similarly, at a milk value of 26 ppl, and the value of the crossbred calf valued at either £100 or £0/calf, the difference in net profit was £65 and £11 in favour of the crossbred cows respectively. If vet/medicine and AI costs were assumed to be 40% lower with the crossbred cows than the Holstein cows (compared to the 20% difference adopted in Table 9), net profit was calculated as £62 in favour of the crossbred cows.

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