Calving traits, milk production, body condition, fertility, and survival of Holstein-Friesian and Norwegian Red dairy cattle on commercial dairy farms over 5 lactations

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ABSTRACT

The objective of this study was to compare calving traits, BCS, milk production, fertility, and survival of Holstein-Friesian (HF) and Norwegian Red (NR) dairy cattle in moderate-concentrate input systems. The experiment was conducted on 19 commercial Northern Ireland dairy farms, and involved 221 HF cows and 221 NR cows. Cows completed 5 lactations during the experiment, unless they died or were culled or sold. Norwegian Red cows had a lower calving difficulty score than HF cows when calving for the first and second time, but not for the third and fourth time. At first calving, the incidence of stillbirths for NR cows was 4%, compared with 13% for HF cows, whereas no difference existed between breeds in the proportion of calves born alive when calving for the second time. When calving for the first time, NR cows had a poorer milking temperament than HF cows, whereas milking temperament was unaffected by breed following the second calving. Holstein-Friesian cows had a higher full-lactation milk yield than NR cows, whereas NR cows produced milk with a higher milk fat and protein content. Full-lactation fat + protein yield was unaffected by genotype. Norwegian Red cows had a lower somatic cell score than HF cows during all lactations. Although NR cattle had a higher BCS than the HF cows during lactations 1 and 2, no evidence existed that the 2 genotypes either lost or gained body condition at different rates. Conception rates to first artificial insemination were higher with the NR cows during lactations 1 to 4 (57.8 vs. 40.9%, respectively), with 28.5% of HF cows and 11.8% of NR cows culled as infertile before lactation 6. A greater percentage of NR cows calved for a sixth time compared with HF cows (27.2 vs. 16.3%, respectively). In general, NR cows outperformed HF cows in traits that have been historically included in the NR breeding program.

Key words: Norwegian Red, Holstein, milk production, fertility, longevity

INTRODUCTION

Until recently, selection programs within the Holstein-Friesian (HF) breed in many countries focused primarily on milk production, with a resultant decline in functional traits, especially fertility and health (Miglior et al., 2005). However, a much broader multitrait selection program has been in place in several Scandinavian countries for several decades. For example, traits such as health and fertility have been included in breeding programs within the Norwegian Red (NR) breed since the 1970s (Steine, 2005). In view of this long-established selection program, it might be expected that the NR breed could help overcome many of the weaknesses that exist within the HF breed. Indeed, evidence from Norway suggests that NR cattle are highly fertile and have a low incidence of mastitis, stillbirths, and calving difficulties (Heringstad et al., 2007; Østerås et al., 2007; Heringstad, 2010). However, as approximately 98% of dairy cows in Norway belong to the NR breed (Steine, 2005), little information exists from within Norway comparing the NR and the HF breeds.

Recent interest in the Scandinavian breeds has resulted in NR genetics being evaluated outside of Norway. For example, Heins et al. (2006a,b,c) examined milk production, fertility, and longevity of purebred Holstein and Scandinavian Red × Holstein crossbred cows in high-input systems in the United States. The results of this experiment demonstrated that Scandinavian Red × Holstein cows can produce similar outputs of milk solids to purebred Holstein cows, while having improved fertility performance and survivability. In addition, Begley et al. (2008) compared HF and NR cows in predominantly low-input grazing systems. In their study, which monitored cow performance over 2 lactations, the NR cows had lower milk yields, fat + protein yields, and SCC than the HF cows as well as having a lower incidence of mastitis and improved reproductive performance. However, much less information appears to be available on the comparative performance of pure-

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bred cows of these 2 genotypes in moderate-concentrate input systems, as are common in many parts of the world.

To address this issue, and to identify if the NR breed can have a beneficial role in more intensive dairy systems, a large-scale study was established on 19 commercial dairy farms to examine calving parameters, milk production, BCS, fertility, and survival of NR cows and HF cows across first to fifth lactations in moderate-concentrate input systems.

MATERIALS AND METHODS

Overview

An experiment involving 221 HF dairy cows and 221 NR dairy cows was established on 19 commercial dairy farms in Northern Ireland (NI) in 2000. The NR cows were imported from Norway, whereas the HF cows were born on the participating farms. Unless they died, or were culled or sold, cows completed 5 lactations during the experiment, and remained in the experiment until the time of their sixth calving.

Selection of Participating Farms and HF Cattle

The 19 participating farms were selected to represent a range of geographical locations within NI, a range of calving systems (winter and spring calving systems), and a range of concentrate inputs. Farms selected met the following criteria: (1) predominantly HF herds with more than 60 cows, (2) involved in an official milk recording scheme, (3) rearing their own replacements, (4) pedigree registered or with ancestry available for the past 2 generations. At the start of the experiment, the average herd size on the 19 farms was 120 cows (70 to 300 cows).

On each of the 19 farms, experimental HF cows were selected from the farmers' own home-bred stocks using the following criteria: (1) animals of similar ages to those being imported from Norway (born between September 1998 and February 1999, or born between September 1999 and February 2000); (2) animals with as high a pedigree index as possible, or in the case of non-pedigree herds, sired by bulls with as high a pedigree index as possible; and (3) animals that were fit and healthy, based on a visual inspection.

For cows that were not pedigree registered, their genetic potential was calculated using sire and maternal grandsire genetic information (December 2012 proof run) using the following formula:

$$\begin{aligned} \text{Genetic index} &= (0.5 \times \text{sire genetic index}) \\ &+ (0.25 \times \text{maternal grandsire genetic index}). \end{aligned}$$

The genetic index of 6 HF cows could not be determined due to insufficient information on their parentage. The remaining Holstein-Friesian cows had a mean PTA for milk yield (kg) of -67.2 kg, and a mean profitable lifetime index of $-\pounds 12$ (December 2012 proof run). Whereas this group of cows was within the top 25% of Holstein cows in the United Kingdom at the time of their birth, they currently rank within the bottom 25% of the United Kingdom Holstein population.

Selection of NR Cattle

Two-hundred twenty-one nulliparous NR cows were sourced from 187 different farms in Norway (from the areas surrounding Trondheim, Hamar, and Stavanger). Animals were identified from a computer database maintained by Geno (Hamar, Norway; the Norwegian cattle breeding organization), based on the following criteria: (1) an appropriate age (1 of 2 age groups); namely, born between September 1998 and February 1999, with approximately half of these animals (September to December born) confirmed pregnant, or born between September 1999 and February 2000; (2) daughters of at least 5 different proven sires within each age group, and a maximum of 30 daughters per sire; (3) animals within the top 10% of the NR cattle population in terms of total merit index (TMI); and (4) animals with a fertility score and an udder score of >95 and >100 , respectively.

Following a visual inspection (to ensure suitable overall type appearance), animals were tested to ensure that they were free from *Brucella abortus*, bovine tuberculosis, Johne's disease, enzootic bovine leucosis, bovine virus diarrhea, infectious bovine rhinotracheitis, and *Neospora caninum*. The 221 animals selected were sired by a total of 26 NR sires and had an average TMI of -10.5 , and an average fertility and mastitis index of 86.5 and 87.6, respectively (2013 basis; values calculated by Geno, May 2013). With regard to TMI, although this group of cows would have been within the top 10% of the NR population at the time of their birth, they are currently within the bottom 25% of the NR population.

All animals were transported overland to NI, and on arrival were inspected by a veterinarian, and weighed. Animals were subsequently allocated to each of the 19 farms, with each farm receiving either 5 or 6 NR cows from each of the 2 age groups described above. Animals within each age group were matched as closely as possible to the ages of the home-bred Holstein animals on each farm. In addition, NR animals allocated to each of the 19 farms were, as far as possible, balanced for TMI. Animals were delivered to the 19 participating farms after a rest period of approximately 48 h. On average,

NR cows were on the experimental farms for 422 d before calving for the first time (range: 110–846 d).

Management and Breeding of Experimental Cattle

On each farm, the HF and NR heifers within each age group were subject to the same rearing regimens until calving. Although all farms operated grassland-based milk-production systems, considerable variation existed between farms in feeding and management regimens. For example, the duration of the grazing period was normally between 6 and 9 mo, varying between farms and between years, a reflection of geographical location, year-to-year variation in climatic conditions, and the importance of grazing within individual management systems. In general, cows were housed between late September and late November, and offered diets in which the main forage component was grass silage. Alternative forages, including maize silage, cereal silage, and red clover silage were 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. Across the farms, the concentrate component of the diet was offered in several ways: namely via in-parlor feeders, electronic out-of-parlor 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 on some farms with mixer wagons a home-mixed concentrate was offered. For fresh-calved cows, concentrate feed levels during the housed period ranged from 6.0 to 14.0 kg/cow per day, whereas during the grazing period, concentrate feed levels ranged from 0 to 6.0 kg/cow per day. If concentrates were offered during the grazing period, they were normally offered in the parlor. Farmers agreed to offer cows of both genotypes the same level of concentrate feeding (on a daily basis) during each of lactations 1 and 2, whereas thereafter, farmers were free to feed the 2 breeds as they believed to be appropriate.

Fifty-nine of the heifers imported from Norway were pregnant. If AI was used with the remaining nulliparous heifers, farmers were encouraged to breed the NR heifers to an NR sire and the HF heifers to an HF sire. Several farmers used a stock bull on all nulliparous heifers, whereas others inseminated each heifer once and thereafter used a stock bull. During subsequent breeding seasons, farmers were free to breed the cows to the sire they believed to be most appropriate. A range of breeding policies was adopted, with most farmers using a combination of AI and stock bulls. For farmers using AI, most continued to breed HF cows to an HF sire, and NR cows to an NR sire, although on occasions,

crossbreeding involving 1 of these 2 breeds, or a third breed, was also used.

Measurements

Calving Data. Calving date, calving difficulty score (first to fourth calving), and calving temperament scores (first and second calving) were recorded by the participating farmers. Calving difficulty was scored on a 1 to 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 to 4 scale, where 1 = very quiet, 2 = slightly uneasy, 3 = very uneasy, and 4 = aggressive. At first calving, approximately half of the cows had calved before the assessment of calving temperament commenced. At first and second calvings farmers recorded if the calf was born dead (or died within 24 h or birth) or alive.

Milking Temperament. Milking temperament was assessed by farmers on 2 occasions during each of lactations 1 and 2: approximately 48 h postcalving and approximately 3 wk postcalving. Milking temperament was scored on a 1 to 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 to 3, whereas thereafter, several herds moved to alternate-month milk recording. Data provided by the recording agencies included individual cow test-day milk yields, milk fat content, milk protein content, and SCC ($\times 1,000/\text{mL}$). In addition, recording agencies subsequently provided information on full lactation milk yields and average milk fat and protein content for the full lactation. Mean SCC for the full lactation were determined for each individual cow as the sum of individual test-day milk yield multiplied by individual test-day SCC, divided by the sum of all test-day milk yields during that lactation. Mean SCS for each lactation was subsequently determined as the natural logarithm ($\log_e$) of SCC.

Fertility Data. All reproductive data were recorded by farmers during lactations 1 to 4, 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 AI, including cows that had a positive pregnancy diagnosis by a veterinarian before removal from the

herd (in the event of either sale or death). Cows that were inseminated twice and were subsequently removed from the herd before calving were deemed not to have conceived to first AI. Conception to first AI was not recorded during lactation 5 due to the relatively small number of cows remaining in the study at this stage.

BCS. The 19 farms were visited by a single trained technician once every 2 to 3 mo until all cows had completed their second lactation, and the BCS (scale 1 to 5; Edmonson et al., 1989) of the experimental cows was assessed visually. Each of lactations 1 and 2 were subsequently divided into 90-d periods (calving to 90, 91 to 180, 181 to 270, and 270+ d), and each period populated with a BCS (or the mean of 2 BCS if more than 1 was recorded during the period). An outbreak of foot and mouth disease in the United Kingdom during 2002 resulted in these visits being cancelled for a period of approximately 5 mo.

Concentrate Feed Levels. Concentrate inputs during lactations 1 to 5 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 in 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. The culling date and primary reason for culling was recorded by the farmers for all cows culled before calving for a sixth time. Culling reasons were subsequently divided into 20 categories. One farm was depopulated due to an outbreak of brucellosis at a stage when 16 cows had completed lactation 1 and 2 cows had completed lactation 2. Three other farms ceased milk production during the study, one of these at a time when 12 cows had completed lactation 1, and a second at a time when 10 cows had completed lactation 1. The third farm ceased milk production at a time when approximately half the cows had completed lactation 3.

Statistical Analysis

Data were analyzed using GenStat Version 11.1 (VSN International, 2009). Genotype effects on categorical data within each lactation (calving difficulty, calving temperament, and milking behavior) were compared using chi-squared 2-way contingency analysis. For each of these 3 parameters, data from categories with low or zero frequency were pooled. Similarly, genotype effects

on binomial data within each lactation (calving difficulty, reasons for culling, and conception to first AI) were analyzed using logistic regression analysis, with the model including the following terms: farm (1 to 19) + age group (1 or 2) + genotype (HF or NR). Genotype differences were examined using Student's *t*-test. In addition, pooled data for conception to first AI for lactations 1 to 4 were analyzed using general estimating equations, with the model including the following terms: farm (1 to 19) + age group (1 or 2) + genotype (HF or NR) + lactation number (1–4) + breed $\times$ lactation number, with the *P*-value ($P > 0.05$, $P < 0.05$, $P < 0.01$, or $P < 0.001$) identified by an approximate *t*-test of the estimated means.

Continuous data (milk production and calving interval) for each of lactations 1 to 5 were analyzed separately using REML analysis. The mixed model used included the following terms as fixed effects: age group (1 or 2) + genotype (HF or NR), whereas farm (1 to 19) + lactation length (d), and cow within farm were included as random effects. In addition, a combined analysis of milk production data from lactations 1 to 5 was undertaken using REML repeated-measures analysis, with the model including the following terms as fixed effects: farm (1–19) + age group (1 or 2) + lactation length (total days as a variable) + lactation number (1–5 as the repeated-measures time factor) + genotype (HF or NR) + lactation number $\times$ genotype, whereas cow $\times$ lactation number was included as a random effect, with the latter modeled by an order 1 autoregressive function of time. Thus, the combined data set (lactations 1–5) was adjusted to the mean length of all lactations completed during the study. In the analysis of the pooled calving interval data, lactation length was excluded from the model.

Body condition score data during each of lactations 1 and 2 were analyzed separately using REML analysis. The repeated-measures mixed model included the following terms as fixed effects: farm + age group (1 or 2) + stage of lactation (d 1 to 90, 91 to 180, 181 to 270, and 270+) + genotype (HF or NR) + stage of lactation $\times$ genotype, whereas cow + cow $\times$ stage of lactation were included as a random effects.

Data from 167 HF cows and 165 NR cows were included in a survival analysis. Cows excluded from the analysis included those culled before calving for the first time, cows removed for statutory reasons (infection with bovine tuberculosis and *B. abortus*), and cows removed due to farmers ceasing participation in the study. Survival was measured as the number of days from first calving until culling/death, with culling defined as the date on which the animal was removed from the herd. Animals with a sixth calving date were assumed censored because their survival time was

Table 1. Reasons for removing cows from the experiment (percentage removed, with actual number of cows in parentheses) before the sixth calving

Reason for removal	Breed		SEM	P-value
	Holstein-Friesian	Norwegian Red		
Farmers leaving study	9.0 (20)	12.2 (27)	1.17	0.067
Tuberculosis/brucellosis	9.9 (22)	9.5 (21)	1.61	0.84
Infertile	28.5 (63)	11.8 (26)	2.54	0.001
Udder structure	0.9 (2)	6.8 (15)	0.94	0.002
Mastitis	9.0 (20)	4.1 (9)	1.58	0.034
Injury	5.4 (12)	5.0 (11)	1.44	0.82
Feet and legs	5.0 (11)	4.5 (10)	1.38	0.82
Abortion	3.2 (7)	3.6 (8)	1.16	0.78
Liver/heart/lungs/kidney	2.7 (6)	1.8 (4)	0.97	0.52
Digestive tract (displacement/twisting)	2.3 (5)	2.3 (5)	0.98	0.99
High SCC	1.8 (4)	1.3 (3)	0.82	0.70
Bacterial diseases	1.4 (3)	1.4 (3)	0.76	0.99
Down cow	1.0 (2)	0 (0)	0.27	0.92
Milk fever	0.9 (2)	0.5 (1)	0.53	0.56
Grass tetany	0.5 (1)	1.4 (3)	0.60	0.33
Low milk yield	0.5 (1)	1.8 (4)	0.64	0.19
Unknown	0.5 (1)	1.4 (3)	0.59	0.32
Uterine/ovarian problems	0.5 (1)	0.5 (1)	0.45	0.99
Ill thrift	0.5 (1)	0.5 (1)	0.44	0.92
Management issues	0.5 (1)	2.7 (6)	0.74	0.084
Cows that calved for a sixth time	16.3 (36)	27.2 (60)	2.53	0.003

unknown (36 HF cows and 60 NR cows). The effect of breed on cow survival was compared using the Cox proportional hazards model. Kaplan-Meier survival functions were estimated for each breed.

RESULTS

Approximately 10% of cows of both genotypes were removed from the study due to farmers leaving the study, with a similar number removed for statutory animal health reasons associated with bovine tuberculosis and *B. abortus* infections (Table 1). A greater percentage of HF than NR cows were removed from the study due to infertility (28.5 vs. 11.8; $P < 0.001$) and mastitis (9.0 vs. 4.1; $P < 0.05$), whereas 0.9% of HF cows compared with 6.8% of NR cows were removed from the study due to problems related to udder structure ($P < 0.01$). Of animals culled as infertile, the actual number culled at the end of lactations 1 to 5 was 13, 16, 10, 11, and 8, respectively, for HF, and 8, 8, 1, 1, and 5, respectively, for NR. No differences existed between the 2 genotypes in incidences of culling related to any of the other categories examined ($P > 0.05$). A higher

percentage of NR cows survived to calve for a sixth time, compared with HF cows (27.2 vs. 16.3; $P < 0.01$).

At first calving, more calves were born alive to NR cows than to HF cows ($P = 0.003$), whereas no difference existed between breeds in the proportion of calves born alive when calving for the second time ($P > 0.05$) (Table 2).

When assessed on a scale of 1 to 5 (Table 3; categories 3 to 5 pooled), a greater percentage of NR cows had a lower calving difficulty score than HF cows at their first and second calving ($P < 0.001$ and $P = 0.016$, respectively), whereas no difference existed between genotypes in the percentage of cows in each calving difficulty score during the third and fourth calving ($P > 0.05$).

Norwegian Red cows had a higher calving temperament score (Table 4; categories 2 to 4 pooled) than HF cows at their first calving ($P > 0.001$; 8.8% of NR cows had a calving temperament score of 3), whereas no difference existed between these 2 genotypes in calving difficulty score when they calved for the second time.

When assessed on a scale of 1 to 4 (pooled for 1 and >1 in Table 5), milking temperament score was higher for NR cows compared with HF cows when assessed

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

Item	Breed		SEM	P-value
	Holstein-Friesian	Norwegian Red		
First calving (n = 397)	87	96	1.9	0.003
Second calving (n = 295)	95	96	1.7	0.67

Table 3. Effect of dairy cow genotype on the percentage of cows with each calving difficulty score at first to fourth calvings

Item	Genotype	Calving difficulty score ¹ (% of cows with each score)			<i>P</i> -value
		1	2	>2	
First calving (n = 401)	Holstein-Friesian	42.1	27.4	30.5	0.001
	Norwegian Red	70.1	17.2	12.7	
Second calving (n = 318)	Holstein-Friesian	68.0	23.8	8.2	0.016
	Norwegian Red	81.9	12.9	5.2	
Third calving (n = 210)	Holstein-Friesian	79.1	9.9	11.0	0.25
	Norwegian Red	82.4	12.6	5.0	
Fourth calving (n = 109)	Holstein-Friesian	78.6	7.1	11.9	0.12
	Norwegian Red	89.6	6.0	4.5	

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

within 48 h of calving ($P < 0.001$) and within 3 wk of calving ($P = 0.004$) during lactation 1. Prior to pooling, 8.8 and 2.1% of HF cows had a milking temperament score of 3 and 4, respectively, whereas values for the NR cows were 22.3 and 7.9%, respectively. However, no difference existed in milking behavior score between breeds during lactation 2 when assessed on these same 2 occasions ($P > 0.05$).

Full-lactation milk yields (Table 6) were higher with HF cows during lactations 1 ($P = 0.001$) and 2 ($P = 0.036$), and during lactations 1 to 5 (pooled data: $P < 0.001$), but did not differ between breeds during any other lactation. Norwegian Red cows produced milk with a higher milk protein ($P < 0.001$) and milk fat ($P = 0.019$) content than HF cows during lactations 1 to 5 (pooled data). Full-lactation fat + protein yield was higher with the HF cows during lactation 1 ($P = 0.011$), but did not differ between breeds during any other lactation ($P > 0.05$), or across lactations 1 to 5 (pooled data; $P = 0.076$). Mean SCC across lactations 1 to 5 were 282 and 176 ($\times 1,000/\text{mL}$) for HF and NR cows, respectively. Somatic cell scores ($\log_e$ basis) were lower with NR cows in all lactations ($P \leq 0.05$). Total lactation concentrate intakes did not differ between genotypes during any lactation ($P > 0.05$).

Body condition scores for each of the 2 breeds during lactations 1 and 2 are presented in Figure 1, with

HF cows having a lower BCS than the NR cows during each lactation ($P < 0.001$). Body condition score changed with time during each lactation ($P < 0.001$), whereas no breed $\times$ time interaction existed in either lactation ($P > 0.05$).

During lactations 1 ($P = 0.020$), 2 ($P = 0.002$), and 3 ($P = 0.001$), a greater proportion of NR cows than HF cows conceived to first AI, whereas conception rates of heifers to first AI and of cows during lactation 4 did not differ between breeds (Table 7). Across lactations 1 to 4 (pooled data), NR cows had a higher conception rate to first AI than HF cows ($P < 0.05$). Calving interval did not differ between genotypes during any of lactations 1, 2, 4, and 5 (or across lactations 1 to 5, pooled data), and was shorter for the NR cows during lactation 3 ($P = 0.016$).

Survival curves for each of the 2 breeds between the date of first calving until the date of the sixth calving, produced using the Kaplan-Meier survival function, are presented in Figure 2. The estimated time to culling 25, 50, and 75% of HF cows was 575, 1,133 (95% CI: 1,017–1,355 d), and 1,824 d, respectively, whereas the estimated time to culling 25 and 50% of NR cows was 777 and 1,451 d (95% CI: 1,176–1,635 d), respectively. Differences in survival between breeds, tested using the Cox proportional hazards model, were found to be significant ($P < 0.01$).

Table 4. Effect of dairy cow genotype on the percentage of cows with a calving temperament score of 1 and >1 at first and second calving

Item	Genotype	Calving temperament score ¹ (% of cows with each score)		<i>P</i> -value
		1	>1	
First calving (n = 198)	Holstein-Friesian	77.1	22.9	0.001
	Norwegian Red	54.9	45.1	
Second calving (n = 297)	Holstein-Friesian	89.2	10.8	0.12
	Norwegian Red	82.9	17.1	

¹1 = very quiet; 2 = slightly uneasy; 3 = very uneasy; 4 = aggressive.

Table 5. Effect of dairy cow genotype on the percentage of cows with a milking temperament score of 1 and >1 during first and second lactations

Item	Genotype	Milking temperament score ¹ (% of cows with each score)		P-value
		1	>1	
First lactation				
48 h postcalving (n = 396)	Holstein-Friesian	37.1	62.9	0.001
	Norwegian Red	30.7	69.3	
3 wk postcalving (n = 396)	Holstein-Friesian	90.6	9.4	0.004
	Norwegian Red	80.2	19.8	
Second lactation				
48 h postcalving (n = 283)	Holstein-Friesian	81.5	18.5	0.20
	Norwegian Red	75.2	24.8	
3 wk postcalving (n = 268)	Holstein-Friesian	96.8	3.2	0.26
	Norwegian Red	93.8	6.2	

¹1 = stands calmly; 2 = slightly agitated, may attempt to kick; 3 = moderately agitated, some kicking; 4 = extremely agitated, milked with difficulty.

DISCUSSION

Calving Difficulty and Stillbirths

Both calving difficulty and stillbirths are reproductive traits of economic importance in 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 (Dematawewa and Berger, 1997). The results of the current study clearly demonstrate that NR cows had fewer calving difficulties than HF cows when calving for the first and second time. Similarly, Heins et al. (2006a) recorded a much reduced

Table 6. Effect of cow genotype on full-lactation milk-production performance during first to fifth lactation (all data within each lactation adjusted to a common lactation length)

Item	Breed		SED ¹	P-value
	Holstein-Friesian	Norwegian Red		
First lactation (318 d)				
Full-lactation milk yield (kg)	6,264	5,956	91.8	0.001
Fat + protein yield (kg)	443	427	6.1	0.011
SCS (log _e)	11.36	10.99	0.090	0.001
Concentrate intake (kg/cow)	1,451	1,506	30.1	0.070
Second lactation (304 d)				
Full-lactation milk yield (kg)	6,789	6,550	113.6	0.036
Fat + protein yield (kg)	471	464	7.3	0.35
SCS (log _e)	11.54	11.23	0.112	0.006
Concentrate intake (kg/cow)	1,451	1,422	40.2	0.48
Third lactation (315 d)				
Full-lactation milk yield (kg)	7,415	7,257	137.3	0.25
Fat + protein yield (kg)	516	520	9.02	0.64
SCS (log _e)	11.99	11.41	0.123	0.001
Concentrate intake (kg/cow)	1,448	1,505	45.4	0.22
Fourth lactation (321 d)				
Full-lactation milk yield (kg)	7,826	7,506	188.0	0.090
Fat + protein yield (kg)	555	543	12.2	0.35
SCS (log _e)	12.15	11.81	0.166	0.045
Concentrate intake (kg/cow)	1,535	1,481	51.5	0.29
Fifth lactation (306 d)				
Full-lactation milk yield (kg)	7,397	7,466	225.0	0.76
Fat + protein yield (kg)	514	540	16.7	0.12
SCS (log _e)	12.26	11.78	0.205	0.017
Concentrate intake (kg/d)	1,475	1,584	66.1	0.10
First to fifth lactation (311 d)				
Full-lactation milk yield (kg)	7,193	6,916	88.8	<0.001
Fat (g/kg)	37.6	38.6	0.37	0.019
Protein (g/kg)	32.5	33.4	0.18	<0.001
Fat + protein yield (kg)	503	497	5.9	0.076
SCS (log _e)	11.88	11.51	0.078	<0.001
Concentrate intake (kg/d)	1,542	1,535	26.3	0.68

¹SED = SE of the difference.

Table 7. Conception rate to first AI and calving interval for Holstein-Friesian and Norwegian Red cows during lactations 1 to 5 (actual numbers of cows contributing to the data in parentheses)

Item	Breed		SEM	P-value
	Holstein-Friesian	Norwegian Red		
Conception rate to first AI (%)				
Heifers	57.7 (46)	65.9 (54)	6.45	0.38
First lactation	41.3 (130)	54.8 (154)	4.00	0.020
Second lactation	38.8 (96)	59.8 (107)	4.78	0.002
Third lactation	34.6 (53)	64.5 (71)	5.73	0.001
Fourth lactation	52.0 (30)	58.6 (45)	8.12	0.59
First to fourth lactation	40.9 (309)	57.8 (377)	2.7	0.050
Calving interval (d)				
First lactation	389 (157)	399 (187)	4.6	0.12
Second lactation	390 (116)	379 (144)	4.9	0.10
Third lactation	397 (87)	376 (112)	6.2	0.016
Fourth lactation	387 (57)	384 (78)	7.1	0.74
Fifth lactation	399 (35)	386 (59)	8.2	0.30
First to fifth lactation	391 (452)	383 (577)	3.1	0.21

incidence of calving difficulty in a study comparing purebred Holstein cows with Scandinavian Red (which included both NR and Swedish Red) $\times$ Holstein crossbred cows. At first calving in this latter study, 17.7% of Holstein cows compared with 3.7% of crossbred cows had a difficult calving, whereas the values were 3.1 and

1.9%, respectively, at the second calving. This is supported by data collected in the Norwegian Dairy Herd Recording System, which has indicated that the overall incidence of difficult calvings in Norway (overall mean frequency of 1.5%) is extremely low (Heringstad et al., 2007). In contrast, in the United States between 2003

Figure 1. Mean condition scores of Holstein-Friesian (solid lines) and Norwegian Red (dashed lines) cows during first and second lactations. SED = SE of the difference.

Figure 2. Survival curves for Holstein-Friesian and Norwegian Red cows from the time of first calving until cows calved for a sixth time.

and 2005, Gevrekçi et al. (2006) reported dystocia rates of 22.6 and 9.6% for Holstein heifers and cows, respectively and Steinbock et al. (2003) recorded incidences of difficult calvings in the Swedish Holstein population of 8.3 and 4.5% at first and second calvings, respectively. The easier calvings observed with NR cows likely reflect the fact that calving difficulty has been a part of the TMI used for selection of NR sires for several decades.

As with calving difficulty, stillbirths have been included in the TMI used for selection of NR sires for several decades. Indeed, the incidence of stillbirths in Norway remained largely unchanged between 1978 and 2004, at 3% at first calving and 1.5% for second and later calvings (Heringstad et al., 2007). In the current study, incidence of stillbirths for the NR cows was 4% for each of first and second calvings. That the value for second-calving animals was higher than presented by Heringstad et al. (2007) may reflect the fact that a proportion of these animals were bred to sires of breeds other than the NR. In contrast, 13% of calves born to primiparous HF cows were either born dead or died within 24 h of birth. In a recent review, Mee et al. (2008) summarized estimates of perinatal calf mortality for Holstein cows across several countries, with values ranging from 4.3% (Iran) to 12.1% (United States), although higher values for Holstein cows have been reported in the United States (13.2%: Meyer et al., 2001). Similarly, Heins et al. (2006a) recorded 14 and 3.7% stillbirths for Holstein cows at their first and second calvings, respectively, compared with values of 5.1 and 2.3% for Scandinavian Red × Holstein cows. The evidence from this and other studies would suggest that the long-term inclusion of both calving difficulty and stillbirths in a breeding index can be highly effective, especially in relation to first-lactation animals.

Calving Temperament and Milking Temperament

Few studies appear to have made direct comparisons between the temperament of HF and NR cows. However, Mullan et al. (2001) subjected both breeds to an open field test and concluded that Holstein cattle showed a greater reactivity than Norwegian cows, the former interacting and vocalizing more when exposed to a novel object than the latter. In the current experiment, NR cows had a poorer temperament than HF cows when calving for the first time. In addition, following their first calving, NR cows had a poorer milking temperament during the first 48 h postcalving, and at 3 wk postcalving, than HF cows.

In the current study, temperament at second calving and milking temperament during lactation 2 did not differ between genotypes, suggesting that these behavioral differences were primarily manifest with primiparous cows. In Norway, temperament (based on milking temperament) is currently included in the TMI selection index, albeit at a relatively low level (currently 2%).

Milk Production

The mean milk yield of the NR cows in the current study (6,916 L across lactations 1 to 5), was approximately 300 L higher than the mean milk yield of NR cows in Norway in 2005, namely 6,605 L (Østerås et al., 2007). Within individual lactations, differences in milk yield between the 2 genotypes were inconsistent, with HF cows having higher full-lactation milk yields than NR cows in lactations 1 and 2, but not during lactations 3 to 5. However, as a consequence of the higher milk protein concentrations observed with the NR cows, combined with the trend (sometime significant) for the NR cows to produce milk with a higher milk fat concentration, the 2 breeds did not differ in terms of fat + protein yield during lactations 2 to 5. Similarly, Walsh et al. (2008) compared the performance of these 2 genotypes in a 5-yr study involving spring-calving cows (offered either approximately 530 or 1,030 kg concentrate/cow per year), and found no differences between the 2 breeds in terms of milk yield. However, in the latter study, HF cows had a higher SCM yield than the NR cows (5,467 vs. 5,278 kg), with this due to the HF cows producing milk with a significantly higher fat content. In a second Irish study undertaken on 46 commercial dairy farms, HF cows had a significantly higher 305-d milk yield than NR cows in each of lactations 1 (5,358 vs. 5,151 kg) and 2 (6,194 vs. 5,867 kg). As in the study by Walsh et al. (2008), HF cows produced milk with a higher fat content than NR cows, and as such had a higher fat + protein yield in each of

lactations 1 and 2. The differences in milk composition between breeds in the current study, and in the 2 studies conducted in the Republic of Ireland, are likely to reflect differences between the Holstein cows on these studies in their genetic potential for milk components.

That milk production performance did not differ dramatically between breeds in the current study may be attributed to the 2 breeds having a similar efficiency of ME use for milk production (Yan et al., 2006). In addition, BCS data from the current study highlights that although NR cows had a higher BCS than the HF cows during lactations 1 and 2, no evidence existed of the 2 genotypes either losing or gaining BCS at different rates, in agreement with the findings of Walsh et al. (2008). The small differences in performance observed in some lactations may be due to differences in intakes between genotypes, with Prendiville and Buckley (2011) observing NR cows to have lower herbage intakes than HF cows. In addition, the small differences in concentrate intake between genotypes in each of lactations 1 to 5 may also have contributed to the small differences in performance observed.

In contrast to the findings of the current study, Keady and Mayne (2002) compared the performance of primiparous cows of these 2 genotypes in either a low- or high-concentrate input confinement system (mean concentrate inclusion levels, proportionally 0.2 and 0.5 of diet DM), and found 305-d yields to be approximately 1,000 kg higher with HF than NR cows on the high-concentrate input system, whereas milk production was unaffected by genotype in the low-input system. A similar genotype $\times$ nutrition interaction was observed by those authors during wk 1 to 20 of lactation 2. These findings suggest that NR cows may be less suited to very high-concentrate input systems than HF cows, although Walsh et al. (2008) found no evidence of a genotype $\times$ nutrition interaction in their study, which involved low/moderate-concentrate inputs. The different responses observed between studies may be due to the high genetic merit (within the top 1% of United Kingdom genetics at that time) of the Holstein cows in the study by Keady and Mayne (2002), together with the more extreme range of concentrate feed levels adopted in their study. Indeed, recent findings by Vance et al. (2012) have shown that diverse concentrate feed levels are often required before genotype $\times$ nutrition interactions are observed between dairy cows of different genotypes. Body condition score data suggest that the primary reason for the genotype $\times$ nutrition interactions observed by Keady and Mayne (2002) and Vance et al. (2012) was due to the NR and Jersey $\times$ HF cows in their respective studies partitioning an increasing proportion of food nutrients consumed to body tissue reserves at higher-concentrate feed levels, rather than

to milk production. This would suggest that these cows did not have the genetic capacity to continue to utilize additional nutrients for milk when offered high-quality diets. Nevertheless, Heins et al. (2006b) demonstrated that Scandinavian Red $\times$ Holstein crossbred cows were able to produce a similar yield of fat + protein as purebred Holstein cows (637 and 651 kg, respectively) in high-concentrate input systems, suggesting that NR crossbred cows do have a role in these higher-input systems.

Udder Health

Although a trend existed for SCS to increase with increasing lactation number with both breeds, the results of the current study clearly demonstrate that HF cows produced milk with an SCS that was higher than for the NR cows in each of lactations 1 to 5. Similar findings have been recorded in other studies, with Walsh et al. (2007) observing NR cows to have a lower SCS than HF cows in a 5-yr study. Similarly, Begley et al. (2008) observed NR cows to have a significantly lower SCS than Holstein cows during their first lactation in a study conducted on 46 Irish farms and, in a further analysis of data from the same study (30 farms), Begley et al. (2009) found average SCC and peak SCC to be lower with NR cows during their second lactation. Although SCC is known to be positively genetically correlated with milk yield (Mrode and Swanson, 1996), only relatively small differences existed in milk yields between breeds in the current study, suggesting that the lower SCC observed with the NR cows was largely a function of the selection program that has been implemented in Norway.

Although high SCC per se can result in financial penalties for milk producers, a strong genetic correlation exists between SCC and frequency of clinical mastitis (Mrode and Swanson, 1996). Although detailed information on mastitis incidence was not recorded by farmers in the current study, the number of NR cows culled due to mastitis was approximately half of that for the HF population. Indeed, Ferris et al. (2008) recorded a lower incidence of mastitis with NR than HF cows (0.33 and 0.69 cases per lactation, respectively). In the large-scale on-farm study described above (Begley et al., 2008), 14 and 9.5% of HF and NR cows, respectively, had at least 1 case of mastitis during their first lactation and the values during the second lactation were 11.9 and 6.0% for the HF and NR cows, respectively. Indeed, in this latter study, evidence existed of increased culling due to poor udder health with the HF breed, in agreement with the findings of the current study.

Begley et al. (2009) also observed an increased primary antibody-mediated immune response with NR

compared with HF cows, and suggested that this might be indicative of a greater ability to combat initial infection or challenge, especially in relation to extracellular pathogens. However, those authors observed no difference in cell-mediated immune response between breeds, and noted that associations between SCS or mastitis occurrence and immune responses were inconsistent.

One of the striking findings of the current study was the fact that 6.8% of NR cows were culled due to poor udder structure, in contrast to 0.9% of HF cows. Although udder structure encompassed a wide range of problems, including poor teat placement and spacing, the most widespread problem appeared to have arisen from a weakness in the medial suspensory ligament of the udder, which resulted in low-hanging udders and splayed teats. This problem tended to be more common in later lactations, and especially on farms where feed inputs and milk outputs were high. That udder type did not appear to have been identified as a particular problem in Norway may reflect the smaller herd sizes in Norway, which would allow farmers to be more patient when dealing with poorly shaped udders, compared with farmers working with much larger herd sizes. In addition, no doubt exists that what is perceived to be an acceptable udder for a milking cow will vary greatly between farmers, and that farmers with a particular interest in type traits in Holstein cows may cull more ruthlessly on udder type than farmers used to more commercial type animals.

Fertility

Fertility in the NR population in Norway is high, with a review of fertility data collected between 1985 and 2005 indicating that 60-d nonreturn rates after a single insemination increased from 68.1 to 72.7% during this period, whereas the number of services per inseminated animals decreased from 1.8 to 1.6 (Refsdal, 2007). In a more recent analysis of data from a smaller population in Norway ($n = 829$ animals), Garmo et al. (2008) recorded 6-d nonreturn rates for heifers, first-lactation, second-lactation, and greater-than-second-lactation cows of 76.9, 67.1, 69.9, and 76.2%, respectively, and overall pregnancy incidence after first AI of 70.0, 58.2, 61.6, and 64.9%, respectively. Although fertility has been included in the selection index in Norway for almost 4 decades, it is also possible that small herd sizes in Norway help contribute to these high levels of fertility performance. In the current study, clear evidence existed of improved fertility with the NR breed, compared with the HF breed. For example, across lactations 1 to 4, NR cows had higher conception rates to first AI than HF cows. This was reflected in the overall culling data from the experiment, which demonstrated that 28.5%

of HF cows and 11.8% of NR cows were culled as infertile before lactation 6. Although a trend existed for NR cows to have a lower calving interval than the HF cows in each of lactations 2 to 5 (significant in lactation 3 only), these data did not take account of the increased culling rates associated with the HF cows.

Walsh et al. (2008) also observed improved fertility performance with NR cows. In this study, the HF cows had a lower submission rate ($P = 0.014$), lower pregnancy rate to first service ($P = 0.064$), lower 6-wk in-calf rate ($P = 0.074$), and lower overall pregnancy rate ($P = 0.011$) than NR cows. In a separate study, Ferris et al. (2008) recorded a reduced interval to first observed heat, an increased conception rate to first service, and an increased pregnancy rate at the end of the breeding season with NR cows, compared with HF cows. In contrast, during the first lactation in an on-farm study involving 46 dairy herds, Begley et al. (2008) observed that the interval from calving to first service, the pregnancy rate to first service, and the final in-calf rate was unaffected by breed, although the 6-wk in-calf rate was higher with NR than HF cows. However, during the second lactation in Begley et al. (2008), NR cows had a lower interval from calving to first service, a higher pregnancy rate to first service, a higher 6-wk in-calf rate, and a lower interval from calving to conception than HF cows, although the overall in-calf rate did not differ between breed. In another on-farm study involving Scandinavian Red $\times$ Holstein crossbred cows, the crossbred cows had fewer days open as first-calf heifers than purebred Holstein cows, although conception to first service did not differ between genotypes (Heins et al., 2006c).

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. However, in Norway, genetic trends for both fertility and milk yield have improved in tandem. In the current experiment, the BCS data collected during lactations 1 to 3 suggest no difference between breeds in the extent of tissue mobilization. Thus, improved fertility in the current study is likely a direct reflection of the long-term genetic selection for improved fertility in Norway. In addition, this is also likely in part to reflect the low incidence of fertility-related diseases and reproductive disorders in the NR population, with mean frequencies of 3.1, 0.9, 0.5, and 1.5% for silent heat, cystic ovaries, metritis, and retained placenta, respectively (Heringstad, 2010).

Longevity

Cow longevity, combined with annual milk production performance, are both key drivers of economic per-

formance on dairy farms. In the current study, a greater percentage of NR cows calved for a sixth time compared with HF cows (27.2 vs. 16.3, respectively). Although the reasons for culling in the study were many and variable, when cows removed due to farmers leaving the study and for legislative reasons (tuberculosis and brucellosis) are excluded, the key reasons for culling were infertility, udder structure, mastitis, injury, and feet and leg problems. Although more NR cows were culled due to issues with udder structure than were NR cows, the much higher incidence of HF cows culled as infertile and for mastitis appear to be the key drivers of the increased longevity observed with the NR cows. Similarly, over a 5-yr period Walsh et al. (2008) also observed NR cows to have a greater survivability than HF cows, with the former remaining in the herd for an average of 3.9 lactations, compared with 1.9 lactations for the HF. In addition, within a single lactation, Heins et al. (2006c) recorded improved survival of Scandinavian Red × Holstein crossbreds at 30, 150, and 305 d of lactation (98, 96, and 93% respectively), compared with purebred Holstein cows (95, 91, and 86%, respectively). Each of these experiments demonstrate the potential of a much broader selection index, such as the TMI adopted in Norway, to improve cow longevity.

CONCLUSIONS

The multitrait 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.

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