Project D-10-00

To assess the potential of the Norwegian (NR) breed as a means of improving the fertility and health status of the Northern Ireland dairy herd

Final Report for AgriSearch

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STRUCTURE OF REPORT

This project was established to examine the performance of Norwegian Red and Holstein-Friesian cows on Northern Ireland dairy farms. The report describes how the project was established, including the sourcing and importation of the Norwegian Red cows into Northern Ireland, the measurements which were recorded during the first five lactations that cows remained on the study, and the overall outcomes of the study.

This report begins with an 'Executive summary' which highlights key aspects of the project. This is followed by two separate chapters: Chapter 1, which represents the main body of this report, describes key aspects of the study, including methodology, results and discussion of the results. A shortened version of this chapter will shortly be submitted to the Journal of Dairy Science for consideration for publication; Chapter 2 includes two abstracts that were published in the proceedings of two separate scientific conferences, and which deal with data not included in Chapter 1, namely type traits and the microbiology of the milk produced by cows of both breeds. The report concludes with a summary of technology transfer articles and events associated with the project.

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EXECUTIVE SUMMARY

While the Holstein-Friesian is the dominant dairy cattle breed within many developed dairying regions of the world, many other breeds are of regional importance, especially within Europe. Interest in some of these ‘alternative breeds’ has increased due to the decline in functional traits observed within many Holstein-Friesian populations during the last two decades. This decline is primarily a consequence of selection programmes which focused almost exclusively on production traits, while ignoring functional traits.

A much broader based multi-trait selection programme has been in place within a number of Scandinavian countries for several decades. For example, within Norway traits such as health and fertility have been incorporated into selection programmes for the Norwegian Red population since the seventies. The current weightings within the Total Merit Index (TMI) for bulls in Norway are milk (28%), mastitis (21%), fertility (18%), udder conformation (15%), growth rate (6%), leg conformation (6%), temperament (2%), diseases other than mastitis (2%), milkability (1%), still birth (0.5%) and calving difficulty (0.5%).

This experiment was established to identify if Norwegian Red cattle have a role in improving the health, fertility and longevity of Northern Ireland (NI) dairy herds. The experiment involved 221 Holstein-Friesian (HF) dairy cows and 221 Norwegian Red (NR) dairy cows. The experiment was established on 19 commercial NI dairy farms in 2000. Farms were selected to represent a range of geographical locations within NI, a range of milk production systems (8 predominantly winter calving herds, 8 predominantly spring calving herds, and 3 mixed winter-spring calving herds), and farms differing in concentrate inputs.

The NR cows were imported from Norway. The HF cows were born on the participating farms, and were selected to be of a similar age as the NR cows. On each farm the HF and NR heifers within each age group were subject to the same rearing regimes until calving. Cows completed five lactations on the experiment, and remained on the experiment until the date of their sixth calving, unless they died or were culled/sold prior to that.

A range of measurements were undertaken, with measurements conducted both by the participating farmers, and by a member of Hillsborough staff. The main findings of the study, and their implications, are discussed below;

Calving difficulty

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. Mean calving difficulty scores for NR cows during lactations 1 and 2 were 2.9 and 2.5, respectively, with these scores being lower than for the HF cows (3.8 and 2.8, respectively). The easier calvings observed with NR cows is likely to reflect the long term inclusion of calving ease within the selection index within Norway. In addition, research at Hillsborough has indicated that NR cows have lighter calves than HF cows. There was no difference between the two breeds in calving difficulty score when calving for the third and fourth times.

Calving temperament

Calving temperament was scored on 1 – 4 scale during the period when the cow was in the calving pen, where 1 = very quiet, 2 = slightly uneasy, 3 = very uneasy, and 4 = aggressive. Norwegian Red cows had a higher calving temperament score than HF cows at their first calving, but not at their second calving.

Still births

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. At first calving the incidence of stillbirths for the NR cows was 4%, compared to 13% for HF cows. While the value recorded for the HF cows may appear to be high, it is in line with values recorded for Holstein populations in some other countries. The lower incidence of still births with NR cows is again likely to reflect the long term inclusion of this trait within the selection index within Norway. There was no significant difference between breeds in the proportion of calves born alive when calving for the second time.

Condition score

Throughout lactations 1 – 3 the NR cattle had a higher condition score than the HF cows. However the changes in condition score with time post calving was similar for each of the two breeds suggesting that differences in tissue mobilisation between breeds were also similar.

Locomotion score

Although the NR cows had higher locomotion scores than the HF cows in each of Lactations 1 and 2, the actual difference in score between breeds was extremely small. Indeed it has been suggested that the higher locomotion scores observed with NR cows may simply reflect the fact that NR cows, as a breed, walk differently compared to HF cows, and as such the higher scores did not reflect poorer claw health. This is supported by the findings of a separate study in which NR cows were found to have lower sole lesion scores and lower white line scores than HF cows, suggesting improved hoof health with the NR cows.

Type traits

During the fourth year of the study (at which point 15 farms remained on the study) 141 NR cattle and 107 HF cattle were assessed for physical traits and linear measures using the Holstein UK Type Classification system. For most of the linear measures assessed, animals of the HF breed had significantly higher scores than animals of the NR breed. Although animals of the HF breed had a higher score for each of the physical characteristics assessed, it is important to note that the scoring system used was developed for the perceived 'ideal' within the HF breed, and as such this system may be inappropriate for animals of the NR breed.

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. While NR cows had a poorer milking temperament than HF cows during the first 48 hours post calving, and at three weeks post calving, there was no difference in milking behaviour score between breeds during lactation 2. Within Norway, temperament (based on milking temperament) is included within the Total Merit index, albeit at a relatively low level (currently 2%). The latter reflects the fact that Norwegian farmers do not perceive the NR breed to have a 'poor' temperament, and indeed it is true that the differences observed between breeds within the current study were relatively minor.

Milk production and composition

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. While differences in milk yield between the two breeds were inconsistent, there was a general trend for HF cows to have higher 305-day milk yields and full lactation milk yields than the NR cows in lactations 1 – 3, but not during lactations 4 and 5. However, as a consequence of the higher milk protein concentrations observed with the NR cows, combined with the trend for the NR cows to produce milk with a higher milk fat concentration, the two breeds did not differ in terms of fat yield, protein yield, or fat plus protein yield in most lactations.

That milk production performance did not differ dramatically between breeds in the current study may be explained by the results of other studies. These studies have indicated that NR and HF cows do not differ in metabolic efficiency or methane production, and have similar intakes. In addition, condition score data from within the current study provided no evidence of the two genotypes either loosing or gaining body condition at different rates.

The data set allowed the response to concentrate feed levels to be examined. In general, the two breeds showed a similar milk yield and fat + protein yield response to concentrate feed level across the range of concentrate feed levels offered.

Somatic cell count and mastitis

There was a trend for SCC to increase with increasing lactation number with both breeds. However, SCC's were approximately 40% lower for the NR cows during each of lactations 1 – 5. While SCC is known to be positively correlated with milk yield, there were only relatively small differences in milk yields between breeds within the current study, suggesting that the lower SCC observed with the NR cows was largely a function of the selection programme in place within Norway.

While detailed information on mastitis incidence was not recorded by farmers within the current study, the proportion of NR cows culled due to mastitis was approximately half of that for the HF population. This agrees with the findings of studies undertaken at Hillsborough in which more HF cows had mastitis than NR cows.

Fertility

All reproductive data were recorded by the participating farmers. There was a clear trend toward higher conception rates to first AI with the NR cows, although actual differences between breeds were only significant during lactations 1 – 3. While there was a trend for NR cows to have a lower calving interval than the HF cows in each of lactations 2 – 5 (significant in lactation 3 only), these data do not take account of the increased culling rates associated with the HF cows. The overall culling data from the experiment highlighted that 28.5% of HF cows and 11.8% of NR cows were culled as infertile prior to lactation 6.

Poorer fertility levels are normally associated with increased levels of negative energy balance, with selection for improved milk production normally negatively correlated with fertility. However within Norway genetic trends for both fertility and milk yield have improved in tandem. Within the current experiment the condition score data collected during lactations 1 – 3 suggest no difference between breeds in the extent of tissue mobilisation. Thus improved fertility within the current study is likely a direct reflection of the long term genetic selection for improved fertility within Norway.

Longevity

For all cows culled prior to calving for the sixth time, the culling date and primary reason for culling were recorded by the farmers. A greater percentage of NR cows calved for a sixth time compared to HF cows (27.2 vs 16.3%, respectively), although when longevity was examined using the Kaplan Meier function, there was no statistical difference in longevity between breeds. While the reasons for culling within the study were many and variable, with the exception of cows removed due to farmers leaving the study and for legislative reasons (tuberculosis and brucellosis), the key reasons for culling were infertility, udder structure, mastitis, and feet and legs. While more NR cows were culled due to issues with udder structure than were NR cows, the higher number of HF cows culled as infertile and for mastitis appear to be the key drivers of the increased longevity observed with the NR cows.

CHAPTER 1

A comparison of the performance of Holstein-Friesian and Norwegian Red dairy cattle on commercial dairy farms over five lactations

INTRODUCTION

While the Holstein-Friesian (HF) is the dominant dairy cattle breed within many developed dairying regions of the world, many other breeds are of regional importance, especially within Europe. Nevertheless, there has been an increasing interest in a number of these 'alternative' breeds during the last decade. The reasons for this are several, but are often related to the decline in functional traits, especially fertility and health traits, observed within many Holstein populations until recently. The latter is primarily a consequence of selection programmes which focused almost exclusively on production traits, while ignoring functional traits. While selection programmes for the HF breed are becoming much more balanced in many countries, a much broader based multi-trait selection programme has been in place within a number of Scandinavian countries for several decades. For example, within Norway traits such as health and fertility were first incorporated into selection criteria of the Norwegian Red (NR) population in the seventies (Steine, 2005).

More than 95% of the dairy cows in Norway are NR, and the population consists of approximately 280,000 cows, of which 98% participate in the Norwegian Dairy Herd Recording System. All herds participating in the recording system are active in the breeding program, and the best cows in these herds are elite-cows and potential bull-dams. Each year approximately 330 bull-calves from elite sires and elite dams are selected for performance testing. Around 130 of them are selected as test sires, and are progeny tested based on 250 to 300 daughters each. Of these, 10 to 12 are selected as elite sires based on their total merit index and average relationship with the population. About 90% of calves born are sired by NR AI sires, 40% by test sires, and 60% by elite sires. The current relative weightings within the Total Merit Index (TMI) for bulls in Norway are milk (28%), mastitis (21%), fertility (18%), udder conformation (15%), growth rate (6%), leg conformation (6%), temperament (2%), diseases other than mastitis (2%), milkability (1%), still birth (0.5%) and calving difficulty (0.5%).

In view of this long established selection programme, it might be expected that NR cattle genetics would have the potential to overcome many of the weaknesses which exist within the HF breed. Indeed, evidence from Norway suggests that NR cattle are indeed highly fertile, have a low incidence of mastitis, still-births and calving difficulties, compared to cattle populations in other countries. However, as 95% of dairy cows in Norway belong to the NR breed, there is little comparative data from Norway for these cattle relative to the HF. This is particularly important in view of the very different farm structures and management systems which exist in Norway compared to many other countries.

Nevertheless, a number of studies outside of Norway have examined the performance of NR genetics. For example, Heins *et al*. (2006a, 2006b and 2006c) examined the production, fertility, health and longevity performance of pure bred Holstein and Scandinavian Red x Holstein crossbred cattle within high input systems within the United States (US). The results of this experiment demonstrated that Scandinavian Red x Holstein cattle can produce similar outputs of milk solids as pure bred Holstein cattle, while having improved fertility performance and survivability. In addition, Begley *et al*. (2008) compared the performance of Holstein-Friesian and NR cattle (and their crosses) within predominantly low input grazing systems in the Republic of Ireland in a study conducted across 46 dairy herds. In this study the NR cattle, while having lower milk and milk fat plus protein yields than the HF cattle, also had lower somatic cell counts, a lower incidence of mastitis and improved reproductive performance. However, there appears to be much less information available on the performance of these two cow genotypes within medium concentrate input systems, as are common in many parts of the world, including the UK.

To address this latter issue, and to identify if NR cattle have a role in improving the health, fertility and longevity of cattle on Northern Ireland (NI) dairy farms, a large scale study was established on 19 NI dairy farms so as to provide robust data on these traits, and to examine overall production performance of NR cows in comparison to HF cows.

MATERIALS AND METHODS

Overview

An experiment involving 221 Holstein-Friesian (HF) dairy cows and 221 Norwegian Red (NR) dairy cows was established on 19 commercial Northern Ireland dairy farms in 2000. The NR cows were imported from Norway, while the HF cows were born on the participating farms. Unless culled/sold beforehand, cows completed five lactations on the experiment, and remained on the experiment until the date of their sixth calving.

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.

Nineteen farms were selected to represent a range of geographical locations within Northern Ireland, a range of calving systems (8 predominantly winter calving herds, 8 predominantly spring calving herds, and 3 mixed winter-spring calving herds), and farms differing in concentrate inputs. Three of the participating farms were operated organic milk production systems at the outset of the experiment, while two additional farms converted to organic milk production systems during the experiment. At the outset of the experiment, the average herd size of the 19 farms was 120 cows (70 – 300 cows).

Selection of NR cows

The NR animals were sourced from the areas surrounding three of the main dairying regions in Norway, namely Trondheim, Hamar and Stavanger. Initially, approximately 400 nulliparous animals were identified from a computer database maintained by Geno (The Norwegian cattle breeding organisation in Norway), based on the following specifications:

1) Correct age: four age groups of animals were sourced:
    - *i)* Born between 1 September 1998 and 15 December 1998
    - *ii)* Born between 1 January 1999 and 28 February 1999
    - *iii)* Born between 1 September 1999 and 15 December 1999
    - *iv)* Born between 1 January 2000 and 28 February 2000
2) Pregnancy status: animals within the first age group (i) were pregnant and due to calve between 1 October 2000 and 30 November 2000
3) Daughters of proven bulls (daughters of at least 5 different sires within each age group, and a maximum of 15 daughters per sire)
4) Animals with highest Total Merit Index (TMI), with a 'fertility score' and an 'udder score' of >95 and >100, respectively.

These animals were then inspected and approximately 70 - 75 animals per age group were shortlisted on the following basis:

1) Animals with appropriate live weight according to their age.
2) Polled animals, or animals with horns removed at calving.
3) Suitable overall type appearance.

Animals from farms that were certified as having been free from the following infections for the time periods stated: Brucella abortus (3 years), Bovine Tuberculosis (3 years), Bovine Viral Diarrhoea (3 years), Campylobacter foetus (3 years), Johne's disease (5 years), Mycoplasmal arthritis or mastitis (3 years), Salmonellosis (1 year), Trichomonas foetus (3 years), were then tested for the following: Brucella abortus, Bovine Tuberculosis, Johne's disease, Enzootic Bovine Leucosis (EBL), Bovine Virus Diarrhoea (BVD), Infectious Bovine Rhinotracheitis (IBR) and Neospora Caninum. From those animals with the required 'disease free' status within each age group, approximately 55 were chosen on the basis of highest

TMI. Within each district, animals were brought to a central collection site, and subsequently transported overland to Northern Ireland. The 221 NR cows were sourced from 187 different farms within Norway, and were sired by a total of 26 bulls (average of 8.5 daughters per bull). Pedigree Index Information was provided by Geno.

All animals were transported during April and May 2000. On arrival in Northern Ireland, the average age of the animals within each of the four age groups was 584 (s.d., 28.6), 447 (s.d., 16.4), 200 (s.d., 119) and 119 (s.d., 18.0) days for animals in groups i – iv respectively. On arrival all animals were inspected by a veterinarian, treated with a broad spectrum anthelmintic (Eprinex), and weighted. The mean weight of animals within each of the four age groups (i – iv) was 423 (s.d., 44.5), 316 (s.d., 23.8), 167 (s.d., 29.4) and 101 (s.d., 17.0) kg respectively. Animals were subsequently allocated to each of the 19 farms on the basis of age group. Eight farms with predominantly winter calving herds received animals from each of groups i and iii, while a further 8 farms with animals with predominantly spring calving herds received animals from groups ii and iv. Three farms with both mixed winter-spring calving herds received animals from all four age groups. Within each age group, animals going to each farm were balanced as far as possible for live weight and total merit index (TMI). Animals were delivered to the 19 participating farms after a rest period of approximately 48 hours.

Selection of the Holstein-Friesian pair mates

On each of the 19 farms, Holstein-Friesian 'pair mates' were selected from the farmers own stock using the following criterion:

1) Animals of a similar age to the NR animals.
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.
3) Animals which were fit and healthy based on a visual inspection.

Health precautions

The following vaccination programme was established. All NR cows were vaccinated for Blackleg before being placed on the farms, with a booster vaccine given six weeks later. Holstein-Friesian animals were not included within this vaccination programmes as vaccination programmes were already in operation on farms where blackleg was a historical problem. All other parts of the vaccination programme was applied to animals of both breeds. Animals were vaccinated for *Salmonella* within 6 weeks of the NR animals arriving on farm, and vaccinated for IBR prior to housing in the autumn. Animals that were either pregnant or due to be bred shortly after arriving, were vaccinated for BVD and Leptospirosis immediately, while those that were less than 12 months of age were vaccinated for BVD and Leptospirosis prior to breeding the following year. On completion of this vaccination programme it was recommended that all animals should be managed within the normal vaccination programme on each farm. While all animals were subject to the farmers own-farm parasite control measures after delivery, it was recommended that all animals over 12 months of age should be treated with Eprinex in late September. This was deemed to be necessary as these animals may have had a low exposure to stomach and lungworms during their first year at grass in Norway, and as such, may have had a lower level of immunity than Northern Ireland bred stock.

Management and breeding of experimental animals

On each farm the HF and NR heifers within each age group 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 nutritional 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 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 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 often included ‘straights’ of by-product feed ingredients in the ration. For fresh calved cows, concentrate feed levels during the housed period ranged from 6.0 – 14.0 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 agreed to offer cows of both breeds the same level of concentrate feeding (on a daily basis) during each of lactations one and two, while thereafter farmers were free to feed the two 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 a NR bull and the HF heifers to a HF bull. A number of farmers used a stock bull on all nulliparous heifers, while others inseminated each heifer once, while thereafter they were bred using a stock bull. If AI was used with primiparous and second lactation cows, farmers were asked to breed approximately half the animals of each breed with a HF bull and half with a NR bull. During subsequent breeding seasons farmers were free to breed the cows as 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 a HF sire, and NR cows to a NR sire, although on occasions a third breed was also used.

Data collection/measurements

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. This assessment was introduced in view of comments being made by farmers at a point when approximately half of the cows had calved for the first time. 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 cows as the sum of individual test day milk yield 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, locomotion scores and live-weights

The 19 farms were visited by a trained technician once every two - three months until all cows had completed their second lactation, and the condition score (scale 1 – 5) and locomotion score (scale 1 – 5) of the experimental cows assessed visually. Each lactation was subsequently divided into 90-day periods, commencing at calving, and a period populated with a condition score or locomotion score if undertaken within that 90-day period (or the mean of two measurements if more than one was taken). The outbreak of Foot and Mouth disease in the United Kingdom during 2002 resulted in these visits being cancelled for a period of approximately five months.

It was planned to record the live weight of all cows on a single occasion during the experiment, namely at a time when all cows were approximately mid way through their first or second lactation. Live weights of all group i and ii cows were recorded in March/April 2002 (92 HF and 103 NR) using a mobile weighbridge. However, enhanced bio-security restrictions following the foot and mouth outbreak later that year meant that the weighing of group ii and group iv cows on farms using a mobile weighbridge was not possible.

Concentrate feed levels

Concentrate inputs during lactations 1 – 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 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 sixth time, the culling date and primary reason for culling were recorded by the farmers. Culling reasons were subsequently rationalised into 20 'reasons'. 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.

RESULTS

On a proportional basis, approximately 0.1 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, namely bovine tuberculosis and brucellosis (Table 1). The latter was due to a disease outbreak on one farm. A significantly higher proportion of HF than NR cows were removed from the study due to infertility (0.285 vs 0.118: $P<0.001$) and mastitis (0.090 vs 0.041: $P<0.05$), while proportionally 0.009 of HF cows compared to 0.068 of NR cows were removed from the study due to problems related to 'udder structure' ($P<0.01$). There were no differences between the two genotypes in incidences of culling related to any of the other categories examined ($P>0.05$). A significantly higher proportion of NR cows survived to calve for a sixth time, compared to HF cows (0.272 vs 0.163: $P<0.01$).

As cows removed from the study due to 'farmers leaving the study' and due to 'culling for statutory health reasons' were not deemed to be 'breed related', the proportion of cows culled due to the four primary reasons (infertility, mastitis, udder structure and 'feet and legs') were examined with the above cows being excluded. Within this analysis, proportionally 0.425 and 0.249 of HF and NR cows were culled as infertile ($P<0.01$), while the respective values due to 'udder structure' were 0.016 and 0.119 ($P<0.001$). Within this analysis there was no difference in the proportion of cows culled due to mastitis or 'feet and leg' problems ($P>0.05$).

Table 1 Reasons for removing cows from the experiment (proportional basis), with actual number of cows removed presented in brackets

	Holstein-Friesian		Norwegian Red		SEM	Significance
Farmers leaving study[1]	0.090	(20)	0.122	(27)	0.0117	NS
Tuberculosis/Brucellosis[2]	0.099	(22)	0.095	(21)	0.0161	NS
Infertile	0.285	(63)	0.118	(26)	0.0254	***
Udder structure	0.009	(2)	0.068	(15)	0.0094	**
Mastitis	0.090	(20)	0.041	(9)	0.0158	*
Injury	0.054	(12)	0.050	(11)	0.0144	NS
Feet and legs	0.050	(11)	0.045	(10)	0.0138	NS
Abortion	0.032	(7)	0.036	(8)	0.0116	NS
Liver/heart/lungs/kidney	0.027	(6)	0.018	(4)	0.0097	NS
Digestive tract (displacement/twisting)	0.023	(5)	0.023	(5)	0.0098	NS
High somatic cell count	0.018	(4)	0.013	(3)	0.0082	NS
Bacterial diseases	0.014	(3)	0.014	(3)	0.0076	NS
Down cow	0.010	(2)	0.000	(0)	0.0027	NS
Milk fever	0.009	(2)	0.005	(1)	0.0053	NS
Grass Tetany	0.005	(1)	0.014	(3)	0.0060	NS
Low milk yield	0.005	(1)	0.018	(4)	0.0064	NS
Unknown	0.005	(1)	0.014	(3)	0.0059	NS
Uterine/ovarian problems	0.005	(1)	0.005	(1)	0.0045	NS
Ill thrift	0.005	(1)	0.005	(1)	0.0044	NS
Management issues	0.005	(1)	0.027	(6)	0.0074	NS
Cows which calved for a sixth time	0.163	(36)	0.272	(60)	0.0253	**
Of cows removed for reasons other than [1] and [2] above, proportion removed due to:						
Infertility	0.425		0.249		0.0393	**
Mastitis	0.140		0.079		0.0267	NS
Udder	0.016		0.119		0.0183	***
Feet and legs	0.073		0.095		0.0235	NS

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

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	**Norwegian Red**	**SEM**	**Significance**
First calving	0.87	0.96	0.019	0.003
Second calving	0.95	0.96	0.017	NS

When assessed on a scale of 1 – 5 (Table 3), a significantly 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=0.03, respectively), while there was no difference between genotypes in the percentage of cows within each calving difficulty score during the third and fourth calving (P>0.05).

Norwegian Red cows had a significantly higher calving temperament score than HF cows at their first calving (P>0.001), while there was no difference between these two genotypes in calving difficulty score when they calved for the second time (Table 4).

When assessed on a scale of 1 – 4, milking temperament score was significantly higher for NR cows, compared to the HF cows, when assessed within 48 hours of calving (P<0.001), and within three weeks of calving (P=0.004) during lactation 1 (Table 5). However, there was no difference in milking behaviour score between breeds during lactation 2 when assessed on these same two occasions (P>0.05).

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

	Breed	Calving difficulty score					P
		1	2	3	4	5	
Calving 1 (n=401)	Holstein-Friesian	42.1	27.4	27.4	1.5	1.5	0.001
	Norwegian Red	70.1	17.2	11.3	0.5	1.0	
Calving 2 (n=318)	Holstein-Friesian	68.0	23.8	6.1	2.0	0	0.03
	Norwegian Red	81.9	12.9	4.7	0.6	0	
Calving 3 (n=210)	Holstein-Friesian	79.0	8.9	11.0	0	0	0.257
	Norwegian Red	82.4	12.6	5.0	0	0	
Calving 4 (n=109)	Holstein-Friesian	78.6	7.1	11.9	2.4	0	0.266
	Norwegian Red	89.6	6.0	4.5	0	0	

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

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

	Breed	Calving temperament score				P
		1	2	3	4	
Calving 1 (n=198)	Holstein-Friesian	77.1	22.9	0	0	0.001
	Norwegian Red	54.9	33.3	8.8	3	
Calving 2 (n=297)	Holstein-Friesian	89.2	10.1	0.7	0	0.241
	Norwegian Red	82.9	13.3	2.5	1.3	

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

Table 5 Effect of dairy cow genotype on the percentage of cows with each milking temperament score

	Breed	Milking temperament score 1	2	3	4	P
Lactation 1						
Within 48 hours of calving (n = 396)	Holstein-Friesian	37.1	52.1	8.8	2.1	0.001
	Norwegian Red	30.7	39.1	22.3	7.9	
Within 3 weeks of calving (n=396)	Holstein-Friesian	90.6	8.9	0.5	0	0.004
	Norwegian Red	80.2	12.9	4.5	2.5	
Lactation 2						
Within 48 hours of calving (n=283)	Holstein-Friesian	81.5	17.7	0.7	0	0.284
	Norwegian Red	75.2	20.9	2.61	1.3	
Within 3 weeks of calving (n=268)	Holstein-Friesian	96.8	2.4	0.8	0	0.447
	Norwegian Red	93.8	5.5	0.7	0	

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

During lactations 1 and 3, HF cows had a significantly higher 305-day milk yield than NR cows (P=0.032 and 0.018, respectively), while there were no differences in 305-day milk yields between breeds in any other lactation (Table 6). With the exception of lactation 3, when HF cows had a significantly greater number of days in milk than NR cows (P=0.012), there was no difference in days in milk between breeds in any other lactation. Similarly, full lactation milk yields were higher with HF cows during lactation 3 (P=0.006), but did not differ between breeds during any other lactation. NR cows produced milk with a significantly higher milk protein content than HF cows during each of lactations 1 – 5 (P≤0.05), while there was no difference (P>0.05) in milk fat content between breeds during any lactation. With the exception of lactation 3, when protein yield was significantly higher with the HF cows (P=0.049), there was no difference in either full lactation fat yield, protein yield, or fat + protein yield between breeds (P>0.05). Somatic cell counts were numerically lower with the NR cows during each of lactations 1 – 5 (by approximately 40%), while somatic cell scores (log^{10} basis) were significantly lower with NR cows in all lactations (P≤0.05). While total lactation concentrate intakes were significantly higher with the NR cows during lactation 1 (P=0.041), concentrate intakes did not differ between genotypes during any of lactations 2 – 5.

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

	Holstein-Friesian	**Norwegian Red**	**SED**	**Probability**
Lactation 1				
305-day milk yield (kg)	5818	5601	100.8	0.032
Total days in milk	315	321	5.9	0.275
Full lactation milk yield (kg)	6203	6004	142.6	0.164
Fat (g/kg)	38.5	39.1	0.35	0.084
Protein (g/kg)	32.3	33.0	0.18	0.001
Fat yield (kg)	238	233	5.6	0.351
Protein yield (kg)	200	198	4.5	0.552
Fat + protein yield (kg)	439	431	9.95	0.425
Somatic cell count (000/ml)	151	93		
Somatic cell score (000/ml log)	1.93	1.77	0.039	0.001
Concentrate intake (kg/day)	1438	1515	37.6	0.041
Lactation 2				
305-day milk yield (kg)	6479	6269	121.6	0.086
Total days in milk	304	303	5.5	0.787
Full lactation milk yield (kg)	6763	6497	151.1	0.079
Fat (g/kg)	37.1	37.8	0.44	0.115
Protein (g/kg)	32.7	33.3	0.24	0.015
Fat yield (kg)	249	244	5.5	0.407
Protein yield (kg)	220	216	4.9	0.397
Fat + protein yield (kg)	469	461	10.08	0.387
Somatic cell count (000/ml)	183	125		
Somatic cell score (000/ml log)	2.01	1.88	0.048	0.006
Concentrate intake (kg/day)	1445	1410	45.6	0.449

Table 6 (continued)

Lactation 3				
305-day milk yield (kg)	7131	6787	144.8	0.018
Total days in milk	325	305	8.1	0.012
Full lactation milk yield (kg)	7662	7076	213.2	0.006
Fat (g/kg)	37.2	38.2	0.53	0.057
Protein (g/kg)	32.8	33.4	0.25	0.017
Fat yield (kg)	284	270	8.7	0.089
Protein yield (kg)	251	236	7.3	0.049
Fat + protein yield (kg)	535	506	15.63	0.063
Somatic cell count (000/ml)	293	130		
Somatic cell score (000/ml log)	2.21	1.95	0.053	0.001
Concentrate intake (kg/day)	1494	1469	54.6	0.654
Lactation 4				
305-day milk yield (kg)	7323	7108	198.6	0.281
Total days in milk	323	319	8.7	0.677
Full lactation milk yield (kg)	7914	7501	267.1	0.124
Fat (g/kg)	38.5	39.2	0.68	0.371
Protein (g/kg)	32.6	33.5	0.30	0.002
Fat yield (kg)	304	292	10.4	0.264
Protein yield (kg)	258	251	8.6	0.421
Fat + protein yield (kg)	561	543	18.53	0.319
Somatic cell count (000/ml)	323	272		
Somatic cell score (000/ml log)	2.28	2.13	0.072	0.043
Concentrate intake (kg/day)	1553	1480	63.8	0.256
Lactation 5				
305-day milk yield (kg)	7089	7248	243.9	0.516
Total days in milk	303	310	10.4	0.479
Full lactation milk yield (kg)	7348	7534	290.9	0.524
Fat (g/kg)	37.5	39.1	0.86	0.068
Protein (g/kg)	32.3	33.5	0.33	0.001
Fat yield (kg)	274	293	12.8	0.143
Protein yield (kg)	235	252	9.6	0.083
Fat + protein yield (kg)	509	545	21.76	0.107
Somatic cell count (000/ml)	405	202		
Somatic cell score (000/ml log)	2.33	2.12	0.089	0.017
Concentrate intake (kg/day)	1467	1608	80.9	0.084

Parameters of the Wilmink curve (*a*, *b* and *c*) which describe lactation profiles for daily milk yield and daily fat plus protein yield for the HF and NR cows are presented in Table 7, while the actual curves are plotted in Figures 1a, 1b, and 1c for lactations 1, 3 and 5, respectively. Genotype had a significant effect on the *a* parameter for daily milk yield in lactations 1 - 3 (P<0.001) and lactation 4 (P<0.01), and for daily fat + protein yield during lactations 1 (P<0.05) and 2 (P<0.01). The *b* parameters of the curve did not differ between breeds for either milk yield or fat + protein yield (P>0.05), with the exception of lactation 4, where the *b* parameter was significantly lower for the NR cows (P<0.05). The *c* parameter differed between breeds for milk yield during lactations 1 and 3 (P<0.001 and P<0.05, respectively), and between breeds for fat + protein yield during lactations 1 (P<0.001) and 2 (P<0.01). HF cows had a significantly higher peak milk yield and peak fat + protein yield in lactation 1 (P<0.001), and a significantly earlier peak milk yield (P<0.01) and peak fat + protein yield (P<0.05). Peak milk yield was later with the HF cows during lactation 2 (P<0.05). There were no differences between genotype in either peak milk yield or peak fat + protein yield, or in days to peak yield, during any other lactation.

Equations describing the full lactation milk yield and full lactation fat + protein yield responses of cows of both genotypes to concentrate supplementation are presented in Table 8 for each of lactations 1 – 5. In each case the responses were tested for linear and quadratic effects, with the former always giving the best fit. Compared to the NR cows, HF cows produced a higher milk output in each of lactations 1 (P<0.001) and 3 (P<0.005), and a significantly greater fat + protein output during lactation 1 (P<0.007). While there was a significant interaction between breed and concentrate feed level for fat + protein yield during lactation 1 (P<0.037), no significant genotype x concentrate feed level interaction was observed for either milk output or fat + protein output during any other lactation (P>0.05).

Body condition score for each of the two cow genotypes during lactations 1 – 3 are presented in Figure 2, with HF cows having a significantly lower body condition score than the NR cows during each lactation (P<0.001). Condition score changed with time during all three lactations (P<0.001), while there was a significant breed x time interaction during lactation 3 (P<0.037).

Figure 1 Daily milk yield and daily fat + protein yield lactation curves for Holstein-Friesian (solid lines) and Norwegian Red cows (dashed lines) during lactations 1 (a), 3 (b) and 5 (c)

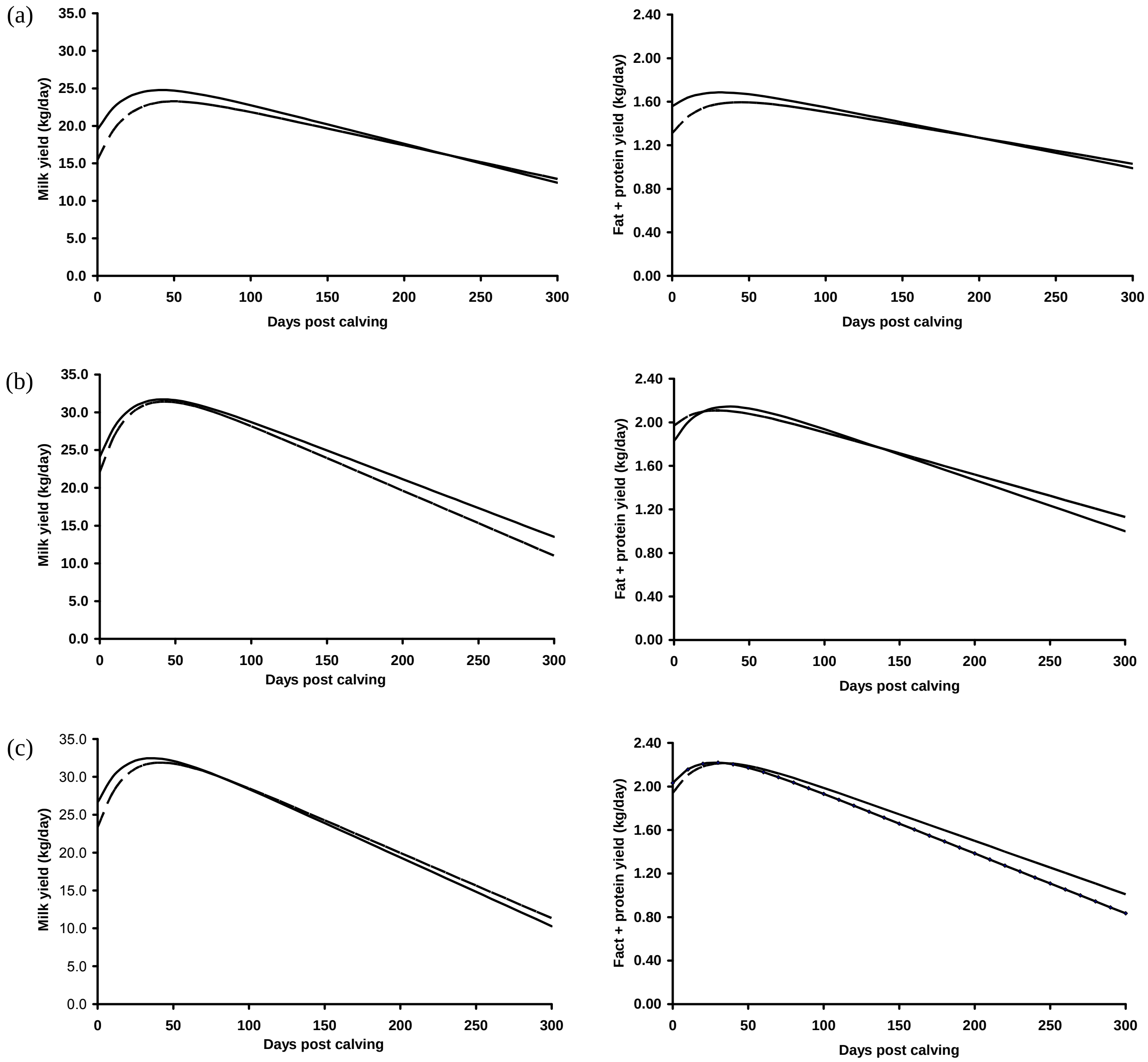


Table 7 Effect of cow genotype on components of the daily milk yield and daily fat plus protein yield lactation curve (Wilmink), and on peak yield and days to peak yield

		Milk yield (kg/day)				Milk fat + protein yield (kg/day)			
		HF	NR	SE	Sig.	HF	NR	SE	Sig.
Lactation 1	a	28.0	26.4	0.30	***	1.83	1.75	0.022	*
	b	-8.46	-10.95	0.969	NS	-0.271	-0.441	0.0717	NS
	c	-0.052	-0.045	0.0016	***	-0.0028	-0.0024	0.00012	***
	Days to peak yield	42.0	50.0	1.6965	**	31.7	44.4	3.77	*
	Peak yield (kg)	24.8	23.2	0.1779	***	1.69	1.60	0.013	***
Lactation 2	a	32.5	32.3	0.26	***	2.07	2.10	0.019	**
	b	-8.41	-9.51	0.851	NS	-0.227	-0.327	0.0624	NS
	c	-0.066	-0.071	0.0014	NS	-0.0034	-0.0038	0.00010	*
	Days to peak yield	36.9	38.1	1.68	NS	24.0	29.2	4.32	NS
	Peak yield (kg)	28.7	28.2	0.15	*	1.92	1.91	0.013	NS
Lactation 3	a	36.4	36.9	0.51	***	2.30	2.41	0.049	NS
	b	-12.33	-14.76	1.675	NS	-0.330	-0.580	0.1595	NS
	c	-0.076	-0.086	0.0027	*	-0.0039	-0.0047	0.00026	NS
	Days to peak yield	41.8	42.9	2.13	NS	29.1	36.3	6.87	NS
	Peak yield (kg)	31.7	31.4	0.30	NS	2.11	2.14	0.030	NS

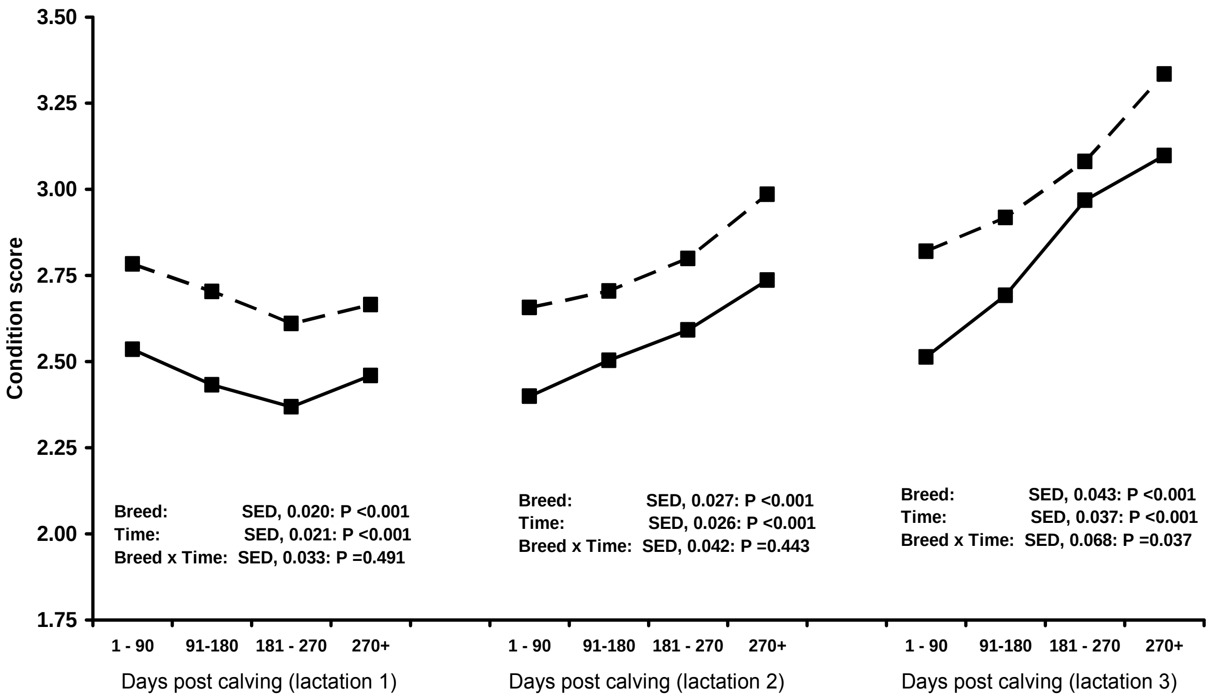
Table 7 (continued)

Lactation 4	a	36.1	36.7	0.58	**	2.40	2.46	0.056	NS
	b	-9.87	-16.51	1.896	*	-0.362	-0.686	0.1837	NS
	c	-0.075	-0.083	0.0031	NS	-0.0044	-0.0048	0.00030	NS
	Days to peak yield	37.7	46.0	2.65	NS	38.4	39.2	7.01	NS
	Peak yield (kg)	31.8	31.2	0.35	NS	2.19	2.18	0.035	NS
Lactation 5	a	37.5	37.2	0.65	NS	2.484	2.479	0.0515	NS
	b	-10.87	-13.86	2.120	NS	-0.451	-0.539	0.1677	NS
	c	-0.091	-0.086	0.0035	NS	-0.0055	-0.0049	0.00027	NS
	Days to peak yield	35.8	41.7	3.05	NS	28.4	34.2	6.21	NS
	Peak yield (kg)	32.5	31.9	0.38	NS	2.22	2.22	0.032	NS

Table 8 Equations describing the full lactation milk yield and full lactation fat plus protein yield response per kilogram additional concentrate offered (x)

	Lactation Number	Breed	Equation	R2	Significance Breed	Significance Conc	Significance Breed x conc (lin)
Lactation milk yield (kg)	1	HF	Y = 2548 + 2.60x	0.36	<0.001	<0.001	0.114
	1	NR	Y = 2634 + 2.27x				
	2	HF	Y = 4001 + 1.94x	0.35	0.106	<0.001	0.08
	2	NR	Y = 4353 + 1.55x				
	3	HF	Y = 4361 + 2.21x	0.44	0.005	<0.001	0.467
	3	NR	Y = 4224 + 1.96x				
	4	HF	Y = 3981 + 2.48x	0.44	0.317	<0.001	0.179
	4	NR	Y = 4677 + 1.85x				
	5	HF	Y = 4502 + 1.83x	0.46	0.914	<0.001	0.359
	5	NR	Y = 3936 + 2.27x				
Lactation fat + protein yield (kg)	1	HF	Y = 179.6 + 0.18x	0.35	0.007	<0.001	0.037
	1	NR	Y = 201.7 + 0.16x				
	2	HF	Y = 290.5 + 0.13x	0.33	0.552	<0.001	0.131
	2	NR	Y = 317.9 + 0.10x				
	3	HF	Y= 291.6 + 0.16x	0.43	0.067	<0.001	0.517
	3	NR	Y = 291.6 + 0.15x				
	4	HF	Y = 265.0 + 0.19x	0.42	0.719	<0.001	0.067
	4	NR	Y = 344.8 + 0.13x				
	5	HF	Y = 321.0 + 0.12x	0.52	0.243	<0.001	0.349
	5	NR	Y = 298.2 + 0.16x				

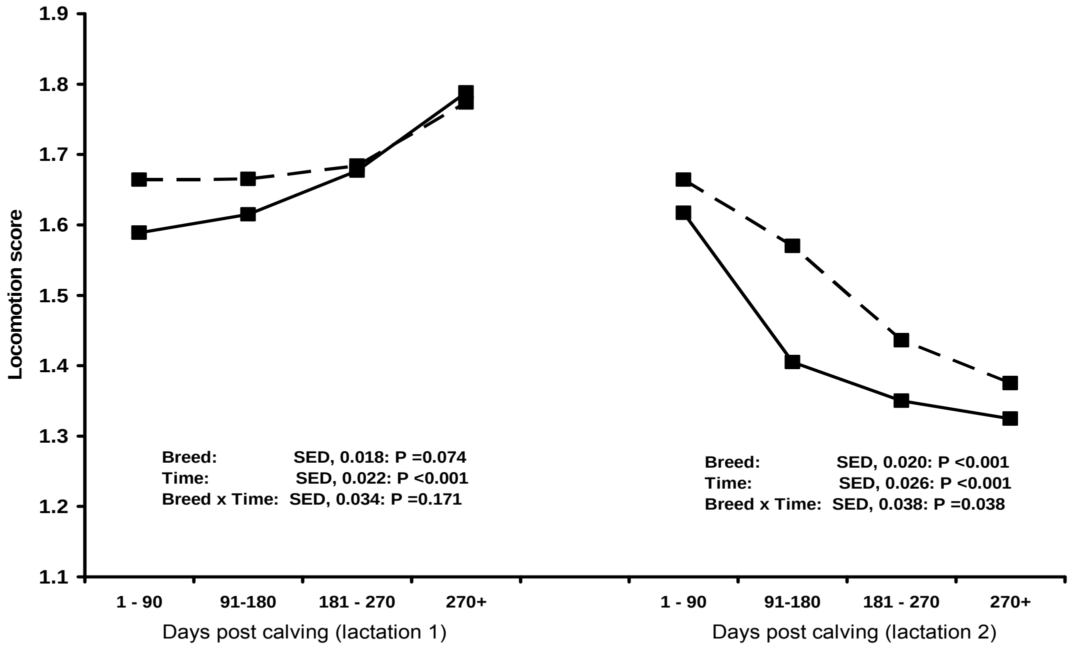
Figure 2 Mean condition scores for Holstein-Friesian (solid lines) and Norwegian red (dashed lines) cows during lactations 1, 2 and 3



Mean locomotion score during each of lactations 1 and 2 are presented in Figure 3, with there being no difference between breeds in locomotion score during lactation 1, while the NR cows had a higher locomotion score during lactation 2 (P<0.001). Locomotion scores increased with stage of lactation during lactation 1, and decrease with stage of lactation during lactation 2 (P<0.001), while a significant breed x time interaction was observed during lactation 2 (P<0.038).

During lactations 1 (P<0.05), 2 (P<0.01) and 3 (P<0.001), a greater proportion of NR cows than HF cows conceived to first AI, while conception rates to first AI of maiden heifers and during lactation 5 did not differ between breeds (Table 9). Calving interval did not differ between genotypes during any of lactations 1, 2, 4 and 5, while being shorter for the NR cows during lactation 3 (P<0.05). Of cows starting the study, a higher proportion of NR cows were removed as infertile during lactations 3 and 4, compared to HF cows (P<0.05), while this difference was not significant during any other lactation.

Figure 3 Mean locomotion scores for Holstein-Friesian (solid lines) and Norwegian red cows (dashed lines) during lactations 1 and 2

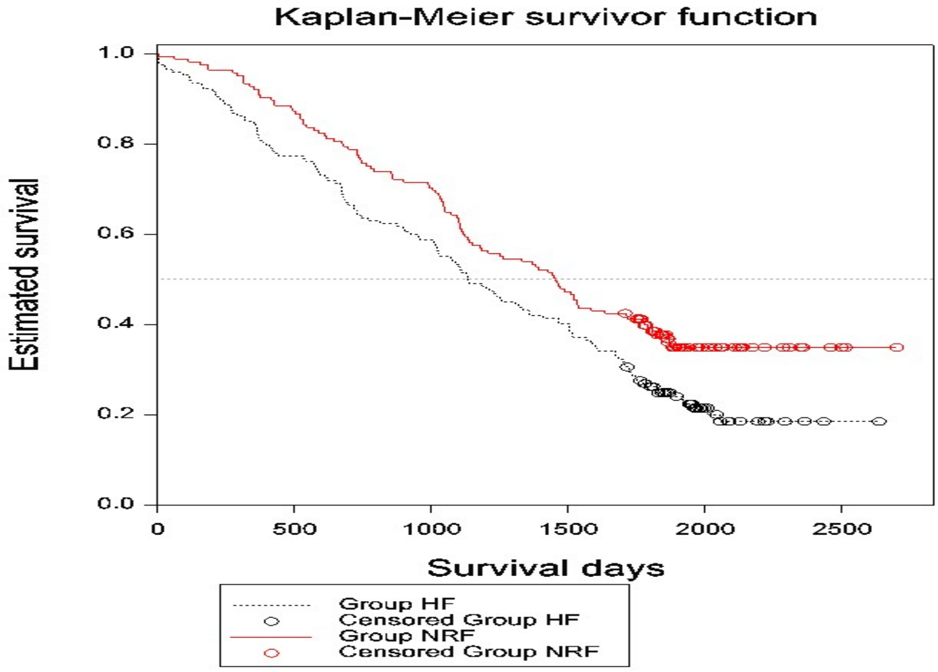


Survival curves for each of the two breeds between the date of first calving until the date of the sixth calving, produced using the Kaplan-Meier survival function, are presented in Figure 4. The estimated time to culling 25, 50 and 75% of HF cows was 575, 1133 (95% Confidence Interval: 1017 and 1355 days) and 1824 days, respectively, while the estimated time to culling 25 and 50% of NR cows was estimated as 777 and 1451 (95% Confidence Interval: 1176 and 1635 days) days, respectively. Differences between breeds were tested and found to be non-significant (P>0.791).

Table 9 Fertility parameters for Holstein-Friesian and Norwegian Red cows

	Holstein-Friesian		Norwegian Red		SEM	Significance
Conception rate to 1st AI (proportion basis)						
Heifers	0.58		0.66		0.065	NS
1st lactation	0.41		0.55		0.040	*
2nd lactation	0.39		0.60		0.047	**
3rd lactation	0.35		0.65		0.058	***
4th lactation	0.52		0.59		0.082	NS
					SED	
Calving interval (days)						
1st lactation	389		399		6.5	NS
2nd lactation	390		379		7.0	NS
3rd lactation	397		376		8.8	*
4th lactation	387		384		10.1	NS
5th lactation	399		386		11.7	NS
Of cows starting study, proportion culled as infertile						
Heifers	0.023	(5)	0.014	(3)	0.0087	NS
1st lactation	0.059	(13)	0.036	(8)	0.0137	NS
2nd lactation	0.072	(16)	0.036	(8)	0.0145	NS
3rd lactation	0.045	(10)	0.005	(1)	0.0088	*
4th lactation	0.050	(11)	0.005	(1)	0.0091	*
5th lactation	0.036	(8)	0.023	(5)	0.0111	NS
Throughout study	0.285	(63)	0.118	(26)	0.0254	***

Figure 4 Survival curves for Holstein-Friesian and Norwegian Red cows following first calving, and until sixth calving



DISCUSSION

The current experiment provides a unique opportunity to compare fertility performance, milk production and longevity of two dairy cow populations which have been selected for very different parameters, when managed across a range of nutritional strategies.

Calving difficulty and stillbirths

Both calving difficulty and still births 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 clearly demonstrate that NR cows had fewer calving difficulties than HF cows when calving for their first and second time. Similarly, Heins *et al*. (2006a) recorded a much reduced incidence of calving difficulty in a study comparing pure bred Holstein cows with Scandinavian Red (which included both Norwegian Red and Swedish Red) x Holstein crossbred cows. At first calving in this latter study, 17.7% of Holstein cows compared to 3.7% of crossbred cows had a difficult calving, while at second calving the values were 3.1% and 1.9%, respectively. Heringstad *et al*. (2007) recently analysed data collected within the Norwegian Dairy Herd Recording System between 1987 and 2004, in which the incidence of 'difficult calvings' within the NR population was recorded on a scale of 1 – 3 (where 1, 2 and 3 represent 'easy calving', 'slight problems' and 'difficult calving', respectively). This analysis indicated that between 1991 and 2001 there was a slight increase in the frequency of 'slight problems' (from 4 to 7% for heifers and from 2 to 3% for cows), while the frequency of 'difficult calvings' increased from approximately 2 to 3% for heifers, while remaining relatively unchanged for cows. Despite these small increases, and although direct comparisons with other breeds are difficult due to different scoring systems adopted within different countries, the overall incidence of difficult calvings in Norway (overall mean frequency of 1.5%; Heringstad *et al*., 2007) is undoubtedly low. For example, within the US between 2003 and 2005, Gevrekci *et al*. (2006) reported dystocia rates of 22.6% and 9.6% for Holstein heifers and cows, respectively, while 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 improved calving ease observed with NR cows is likely to reflect the fact that calving difficulty has been a part of the total merit index used for selection of Norwegian Red sires since 1978 (Geno). In addition, this may also reflect the smaller size of NR calves compared to HF calves, with Ferris *et al*. (2008) in a research Institute-based study recording mean calf birth weights of 42.2 and 39.7 kg for HF and NR cows, respectively. Similarly, Heins *et al*. (2006a) observed a much reduced incidence of calving difficulty when Holstein cows were bred to Scandinavian Red sires (5.5%) compared to Holstein sires (16.4%), with this likely to reflect calves of the latter being larger heavier.

As with calving difficulty, still births has been included within the Total Merit Index used for selection of NR sires since 1978 (Geno). Indeed, the incidence of stillbirths within 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). Within the current study incidence of stillbirths for the NR cows was 4% for each of first and second calving. 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 hours of birth. 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 (13.2%: Meyer *et al*., 2001). Similarly, Heins *et al*. (2006a) in the study involving Scandinavian Red crossbred cows recorded 14% and 3.7% still births for Holstein cows during their first and second calvings, respectively, compared to values of 5.1 and 2.3% for Scandinavian Red x Holstein cows. The evidence from this and other studies would suggest that the long term inclusion of both calving difficulty and still births within the breeding index for NR cattle in Norway has been 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, Mullen *et al*. (2001) subjected both breeds to an open field test and concluded that Holstein cattle showed a ‘greater reactivity’ than Norwegian cows, with the former interacting more with a novel object and vocalising more than the latter. Within 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 hours post calving, and at three weeks post calving, than HF cows.

While Walsh *et al*. (2007) observed no differences in milking characteristics (average milk flow, peak milk flow, average milking duration) between these two genotypes, Wicks *et al*. (2004) observed a slower milk flow rate and peak milk flow rate with NR cows in early lactation. However, in this latter study the impact of habituation to the milking parlour was also examined, with no evidence of an interaction between genotype and habituation identified for number of production parameters. Thus NR cows did not benefit from habituation to a greater extent than HF cows, suggesting that habituation would not overcome the differences in temperament observed in the current study. Nevertheless, within the current study temperament at second calving and milking temperament during lactation 2 did not differ between genotypes, suggesting that these behavioural differences were primarily manifest with primiparous cows. Within Norway, temperament (based on milking temperament) is currently included within the TMI selection index, albeit at a relatively low level (currently 2%). The latter reflects the fact that Norwegian farmers do not perceive the NR breed to have a 'poor' temperament, and indeed it is true that the differences observed between breeds within the current study were relatively minor. Nevertheless, in a recent economic evaluation of breeding goals for Norwegian Red cattle, Steine *et al*. (2008) concluded that an increased weighting on temperament within the breeding index would increase farm profits.

Milk production

The mean milk yield of the NR cows in the current study (approximately 6900 litres across lactations 1 – 5), was approximately 300 litres higher than the mean milk yield of NR cows in Norway in 2005, namely 6605 litres (Østerås *et al*., 2007). While differences in milk yield between the two genotypes were inconsistent, there was a general trend for HF cows to have higher 305-day milk yields and full lactation milk yields ($P<0.10$) than NR cows in lactations 1 – 3, but not during lactations 4 and 5. However, as a consequence of the higher milk protein concentrations observed with the NR cows, combined with the trend for the NR cows to produce milk with a higher milk fat concentration, the two breeds did not differ in terms of fat yield, protein yield, or fat plus protein yield in most lactations. Similarly, Walsh *et al*. (2008) compared the performance of these two genotypes in a five year study involving spring calving cows (offered either approximately 530 or 1030 kg concentrate/cow/year), and found no differences between the two breeds in terms of milk yield. However in the latter study HF cows had a higher solids corrected milk yield than the NR cows (5467 vs 5278 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-day milk yield than NR cows in each of lactations 1 (5358 vs 5151 kg) and 2 (6194 vs 5867 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 within the current study, and in the two 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 composition.

That milk production performance did not differ dramatically between breeds in the current study may be attributed to a number of factors. Firstly, 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. In addition, Yan *et al*. (2006) observed that energy intakes of Holstein and Norwegian cows did not differ when managed on a low concentrate input system, a reflection of similar cow live weights within this study. In contrast, Walsh *et al*. (2008) found NR cows to be 33 kg lighter than HF cows, while Prendiville and Buckley (2011), in a study involving a subset of animals from this study, observed lower herbage intakes with Norwegian Red cows compared to HF cows. In addition, these latter authors observed subtle differences in grazing behaviour between the two breeds, with Norwegian cows having an increased biting rate per minute and an increased number of grazing mastications/day, but fewer total bites per day compared to Holstein cows. However, neither grazing time per 100 kg bodyweight or per kg grass DM intake differed between breeds. When offered confinement diets O'Driscoll *et al*. (2009) also observed Norwegian cows to have significantly more mastications/day than Holstein cows, but significantly fewer bites per minute. In addition, condition score data from the current study highlights that while NR cows had a higher condition score than the HF cows during the lactations when CS was measured (1, 2 and 3), there was no evidence of the two genotypes either loosing or gaining body condition at different rates. Similarly, Walsh *et al*. (2008) observed HF cows to have a significantly lower mean lactation CS than NR cows (2.71 vs 3.06), while both breeds lost a similar amount of body condition during weeks 2 – 8 of lactation (-0.19 and -0.15 condition score units respectively).

In contrast to the findings of the current study, Keady and Mayne (2002) compared the performance of primiparous cows of these two genotypes within 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-day yields to be approximately 1000 kg higher with HF than NR cows on the high concentrate input system, while milk production was unaffected by genotype within the low input system. A similar genotype x nutrition interaction was observed by these authors during weeks 1 - 20 of lactation 2. While these findings suggest that NR cows may be less suited to higher concentrate input systems than HF cows, the results of the current study provided no evidence of a genotype x nutrition interaction during any of lactations 1 – 5 for either milk yield or milk fat + protein yield. Similarly, Walsh *et al*. (2008) found no evidence of a genotype x nutrition interaction in their study. The different responses observed between studies may be due to the high genetic merit (within the top 1% of UK 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 within their study. Indeed, recent findings by Vance *et al*. (2011a and 2011b) have shown that diverse concentrate feed levels are often required before genotype x nutrition interactions are observed between dairy cows of different genotypes. Body condition score data suggest that the primary reason for the genotype x nutrition interactions observed by Keady and Mayne (2002) and Vance *et al*. (2011b) was due to the Norwegian Red and Jersey x Holstein Friesian 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 utilise additional nutrients for milk when offered high quality diets. Nevertheless, Heins *et al*. (2006b) demonstrated that Scandinavian Red x Holstein crossbred cows were able to produce a similar yield of fat + protein as pure bred Holstein cows (637 and 651 kg, respectively) within high concentrate input systems, suggesting that NR crossbred cows do have a role within these higher input systems.

Udder health

While there was a trend for SCC to increase with increasing lactation number with both breeds, the results of the current study clearly demonstrate that HF cows produced milk with a SCC that was numerically 70% higher than for the NR cows, while the latter had a significantly lower SCS than HF cows in each of lactations 1 – 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 five year study. Similarly, Begley *et al*. (2008) observed NR cows to have a significantly lower SCS than Holstein cows during their first lactation (actual SCC, 131, 000 and 188, 000, respectively) in a study conducted on 46 Irish farms, while 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 NRC cows during their second lactation. While SCC is known to be positively genetically correlated with milk yield (Mrode and Swanson, 1996), there were only relatively small differences in milk yields between breeds within the current study, suggesting that the lower SCC observed with the NR cows was largely a function of the selection programme which has been implemented within Norway.

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. While detailed information on mastitis incidence was not recorded by farmers within the current study, the proportion 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), while 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 one case of mastitis during their first lactation, while the values during the second lactation were 11.9 and 6.0% for the HF and NR cows, respectively. Indeed, in this latter study there was evidence of increased culling due to poor udder health with the HF breed, in agreement with the findings of the current study. Within Norway the incidence of clinical mastitis increased from 0.15 cows treated per cow-year in 1975 to 0.44 in 1994, and then decreased to 0.23 in 2002 (Østerås *et al*., 2007), with these values lower than for many other cow populations.

Begley *et al*. (2009) also observed an increased primary antibody-mediated immune response with NR compared to 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 these 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 this study was the fact that proportionally 0.068 of NR cows were culled due to 'Udder structure', with a value of 0.009 for HF cows. In general, this appeared to have been related to a weakness in the medial suspensory ligament of the udder, and 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 within Norway may reflect the smaller herd sizes in Norway, which would allow farmers to be more patient when dealing with poorly shaped udders, compared to farmers working with much larger herd sizes. In addition, there is no doubt 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 within Holstein cows may cull more ruthlessly on udder type than farmers used to more commercial type animals. Nevertheless, in recognition of the importance of udder characteristics within International semen markets, the weighting on udder type within Norway has increased during the last decade from a relatively low value to 15% at present.

Fertility

Fertility within the NR population in Norway is high, with a review of fertility data collected between 1985 and 2005 indicating that sixty-day non-return rates after a single insemination increased from 68.1 to 72.7% during this period, while 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 within Norway (n = 829 animals), Garmo *et al*. (2008) recorded sixty-day non-return rates for heifers, first-lactation, second-lactation and >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. While fertility has been included within the selection index within Norway for almost four decades, it is also possible that small herd sizes within Norway help contribute to these high levels of fertility performance. Nevertheless, within the current study there was clear evidence of improved fertility with the NR cows, compared to the HF cows. For example, there was a clear trend toward higher conception rates to first AI with the NR cows, although actual differences between breeds were only significant during lactations 1 – 3. Nevertheless, these individual trends were reflected in the overall culling data from the experiment which demonstrated that proportionally 0.285 of HF cows and 0.118 of NR cows were culled as infertile prior to lactation 6. While there was a trend for NR cows to have a lower calving interval than the HF cows in each of lactations 2 – 5 (significant in lactation 3 only), these data do 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 six-week 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 to first service and an increased pregnancy rate at the end of the breeding season with NR cows, compared to 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 six-week in-calf rate was higher with NR than HF cows. However, during the second lactation in this study NR cows had a lower interval from calving to first service, a higher pregnancy rate to first service, a higher 6-week 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 x Holstein crossbred cows, the crossbred cows had a lower 'days open' as first calf heifers, than purebred Holstein cows, although conception to first service did not differ between genotypes in this study (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 within Norway genetic trends for both fertility and milk yield have improved in tandem. Within the current experiment the condition score data collected during lactations 1 – 3 suggest no difference between breeds in the extent of tissue mobilisation. Thus improved fertility within the current study is likely a direct reflection of the long term genetic selection for improved fertility within Norway. In addition, this is also likely in part to reflect the low incidence of fertility related diseases and reproductive disorders within 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). While equivalent values are not available for any Holstein population, it is expected that these values are very low.

Locomotion score

Although the NR cows had a higher locomotion scores than the HF cows in each of lactations 1 and 2, the actual difference in score between breeds was extremely small. Nevertheless, Baird *et al*. (2009) observed a similar effect, with NR cows having a locomotion score which was 0.1 units higher than for HF cows. However, in this latter study NR cows had a lower sole lesion score and lower white line score than HF cows, suggesting improved hoof health with the NR cows. Baird *et al*. (2009) proposed a possible explanation for the improved hoof health observed in that while the NR cows were lighter than the HF cows, they had longer and wider claws, resulting in a lower weight per unit of claw area. Indeed a similar explanation was provided by Anderson and Lundstrõm (1981) to explain the improved hoof health observed with Swedish Red cattle in comparison to Holstein cattle. In addition, Baird *et al*. (2009) suggested that the higher locomotion scores observed with the NR cows may simply reflect the fact that NR cows, as a breed, walk differently compared to HF cows, and as such the higher scores did not reflect poorer claw health. This was reflected in the fact that the proportion of animals on the current study culled for reasons related to 'feet and legs' was unaffected by genotype, while Ferris *et al*. (2008) also observed no difference in the incidence of lameness between NR and HF cows.

Longevity

There is no doubt that cow longevity, combined with annual milk production performance, are both key drivers of economic performance on dairy farms. Within the current study a greater proportion of NR cows calved for a sixth time compared to HF cows (0.272 vs 0.163, respectively). While the reasons for culling within the study were many and variable, with the exception of cows removed due to farmers leaving the study and for legislative reasons (tuberculosis and brucellosis), the key reasons for culling were infertility, udder structure, mastitis, injury and feet and legs. While 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 five year 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 to 1.9 lactations for the HF. In addition, within a single lactation Heins *et al*. (2006c) recorded improved survival of Scandinavian Red x Holstein crossbreds at 30, 150 and 305 days of lactation (98, 96 and 93% respectively), compared with pure bred Holstein cows (95, 91 and 86%, respectively). Each of these experiments demonstrate the potential of a much more broader selection index, such as the TMI adopted within Norway, to improve cow longevity.

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CHAPTER 2

A comparison of the hygienic quality of milk produced from Holstein-Friesian and Norwegian Red dairy cows

and

A comparison of the physical characteristics of milk from Norwegian Red and Holstein-Friesian dairy cows

A comparison of the hygienic quality of milk produced from Holstein-Friesian and Norwegian Red dairy cows

INTRODUCTION

While significant progress in milk production efficiency has been achieved in recent years with the Holstein-Friesian breed, it is now realised that dairy cow breeding programmes with a primary focus on yield have had a negative impact on fertility, health and longevity. In contrast, Norwegian dairy cattle (NRF) have been bred within multi-trait selection programmes for approximately 25 years, and as a consequence, the incidence of mastitis within Norway continues to decline, while fertility levels are increasing. In view of these positive trends, a study was established to evaluate NRF cows under Northern Ireland conditions. The performance of animals on this study during their first lactation has been described by Ferris *et al*. (2004). The objective of the current study was to examine the hygienic quality of milk of NRF and Holstein Friesian (HF) dairy cows during their second lactation.

MATERIALS AND METHODS

Two hundred and fifteen NRF cattle were imported into Northern Ireland as maiden heifers (3 – 15 months old), and placed on 19 commercial dairy farms (11 or 12 animals/farm). An equal number of 'home bred' Holstein-Friesian (HF) animals of similar ages were selected on each farm. On each individual farm, animals of both breeds were subject to the same rearing and management regimes pre-calving, and to the same feeding and management regimes post-calving. During their second lactation, milk samples were collected from a total of 260 animals (141 NRF and 119 HF), located on 16 of the participating farms. Two sampling periods (Year 1 and Year 2) were adopted due to the spread in ages of the animals at the start of the study. Animals were an average of 162 (s.d., 66.0) days calved at the time of sampling. Prior to either am or pm milking, the 'fore milk' from each quarter was manually removed, the teat end disinfected using mentholated spirits, and a milk sample (approximately 10 ml) collected in a sterile sample bottle. Animals were not sampled if they were suffering from clinical mastitis, or had been treated with antibiotics within the previous 5 days. Milk samples were analysed for somatic cells counts (SCC), and a sample was incubated for 24 hours at 37°C on calf blood agar to test for the presence of bacteria. If present, *Staphylococcus aureus, Streptococcus species and E. Coli*, three of the main mastitis causing bacteria in Northern Ireland, were identified. The effect of breed on somatic cell counts within each quarter, and across all quarters, were analysed by REML analysis, while binomial data were analysed using a regression technique and treatment differences tested using the t-test. For all parameters, farm and sampling occasion (Year 1 or Year 2) were included within the statistical model.

RESULTS AND DISCUSSION

SCC (log 10) were significantly lower with animals of the NRF breed, compared to animals of the HF breed ($P \leq 0.05$) in the front right, front left and back right quarters, and when examined across all quarters ($P < 0.001$) (Table 1). This is in agreement with the findings of McKeague *et al*. (2004).

Table 1 Hygienic quality of milk of HF and NRF dairy cattle

	HF	NRF	SEM	Sig
SCC (log 10)				
Front right	1.66	1.46	0.052	**
Front left	1.73	1.51	0.062	*
Back right	1.66	1.47	0.060	*
Back left	1.65	1.49	0.060	NS
All quarters	1.67	1.48	0.029	***
Proportion of cows with bacteria isolated				
Front right	0.34	0.28	0.036	NS
Front left	0.33	0.30	0.039	NS
Back right	0.42	0.30	0.039	*
Back left	0.35	0.37	0.039	NS
All quarters	0.36	0.31	0.020	NS
Proportion of infected quarters with:				
S. aureus	0.11	0.05	0.020	NS
Streptococcus species	0.20	0.19	0.027	NS
E. Coli	0.009	0.006	0.092	NS

The proportion of cows with bacteria isolated in the back right quarter was significantly higher for the HF breed than for the NRF breed ($P<0.05$), while not being different in any other quarter. When examined across all quarters, the proportion of cows with bacteria isolated were 0.36 and 0.31 for the HF and NRF breeds respectively ($P=0.087$), suggesting a trend towards a lower presence of bacteria in the udders of cows of the NRF breed. The proportion of infected quarters with either *S. Aureus, Streptococcus species* or *E. Coli* present did not differ significantly between breeds, although for cows with bacteria present, proportionally 0.11 and 0.05 of HF and NRF cows were infected with *S. Aureus* ($P = 0.052$).

CONCLUSIONS

When examined across all quarters, NRF cows had significantly lower SCC (log10) than HF cows, while the proportion of cows with no bacteria isolated tended to be lower for the NRF breed. Breed had no significant effect on the species of bacteria isolated within infected quarters.

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A comparison of the physical characteristics of milk from Norwegian Red and Holstein-Friesian dairy cows

INTRODUCTION

In contrast to the Holstein-Friesian (HF) breed, Norwegian dairy cattle (NRF) have been selected using a multi-trait selection programme for approximately 25 years. As a consequence of the latter, the incidence of mastitis within Norway continues to decline, while fertility levels are increasing. For this reason, NRF dairy cattle are currently being evaluated on Northern Ireland dairy farms in a study that involves a comparison with animals of the Holstein-Friesian breed. First lactation performance data have been presented by Ferris *et al.* (2004). While increased fertility and mastitis resistance are likely to improve an animal's longevity, it is important to assess differences between breeds in physical characteristics as these can also affect longevity. Consequently the physical characteristics of NRF and HF dairy cows involved in the present on-farm study were assessed.

MATERIALS AND METHODS

Two hundred and fifteen Norwegian dairy cattle (NRF) were imported into Northern Ireland in 2000 as maiden heifers (3 – 15 months old), and placed on 19 commercial dairy farms (11 or 12 animals/farm). These animals had a mean total merit index (TMI) of 10.1 (s.d. 1.69). An equal number of 'home bred' Holstein-Friesian (HF) animals of similar ages were selected as 'pair mates' on each farm. On each individual farm, animals of both breeds were subject to the same rearing and management regimes post-calving. However each farm followed its own rearing, feeding and management regime.

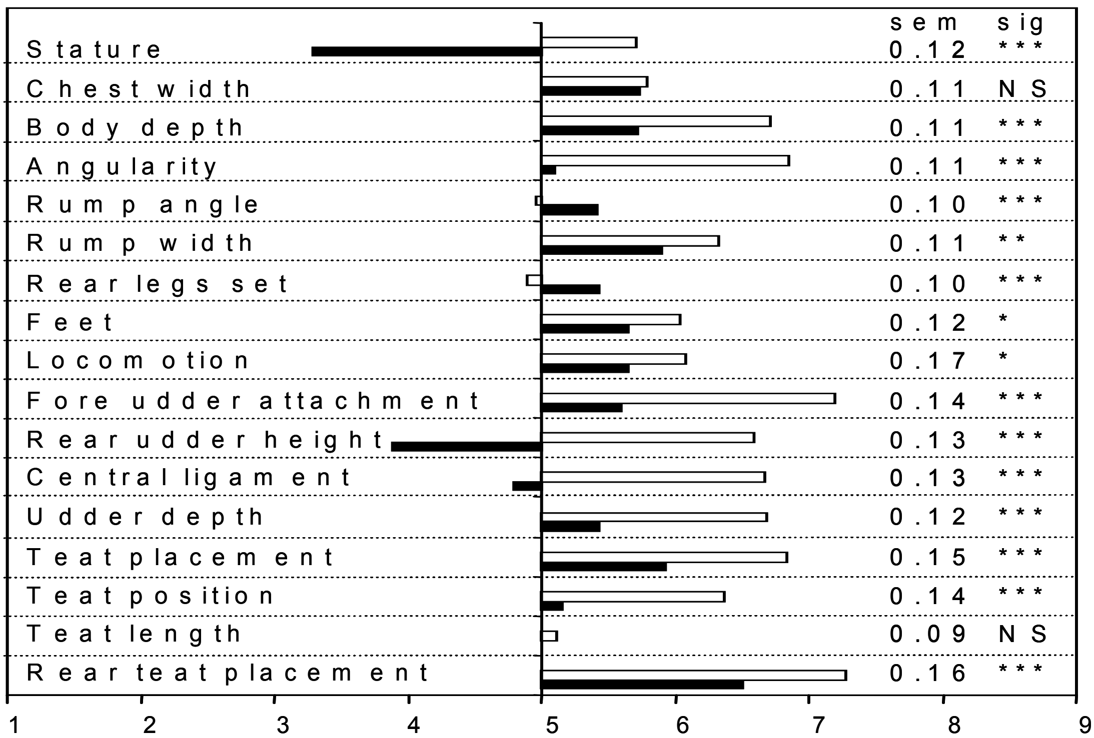
During the fourth year of the study (at which point 15 farms remained on the study) 141 NRF cattle and 107 HF cattle were assessed for physical traits and linear measures using the Holstein UK Type Classification system. Of the NRF animals assessed, 8, 78 and 64 were in their first, second and third lactations respectively, while the corresponding figures for the HF animals were 2, 64 and 40 respectively.

The linear assessment scored 17 traits relating to the cows' appearance (on a scale of 1 – 9) with the score given describing the degree of the trait, rather than its desirability. With the physical classification, 5 main functional areas of the cow were scored on a points scale, between 50 and 97. However, it is important to note that this physical classification evaluates the animal in comparison to the 'ideal' Holstein-Friesian, and as such, this may not be appropriate for the NRF breed. Physical classification and linear score data were analysed by ANOVA, with the results presented in Table 1 and Figure 1 respectively.

Table 1 Physical Characteristic scores for NRF and HF dairy cows

	NRF	HF	SEM	SIG.
Body frame	79	84	0.39	***
Body rump	82	84	0.39	**
Dairy	79	84	0.36	***
Legs & feet	80	82	0.43	***
Mammary	76	84	0.66	***

Figure 1 Linear scores for NRF (■) and HF (□) dairy cows



RESULTS AND DISCUSSION

From Figure 1, animals of the NRF breed were shorter in stature than animals of the HF breed ($P<0.001$), while chest width was unaffected by breed ($P>0.05$). The NRF breed showed less depth of body than the HF breed and were less angular ($P<0.001$). The NRF breed had more slope to their rumps than the HF breed, whilst the HF breed had more rump width ($P<0.01$). Breed had a significant effect on rear legs set ($P<0.001$), while the HF breed had a higher score for feet and for locomotion ($P<0.05$). With the exception of teat length which was unaffected by breed ($P>0.05$), animals of the HF breed had a higher score for all other udder-related traits ($P<0.001$). In terms of physical characteristics (Table 1), animals of the HF breed scored significantly higher than animals of the NRF breed in each of the functional areas ($P\leq0.01$) assessed.

CONCLUSIONS

For most of the linear measures assessed, animals of the HF breed had significantly higher scores than animals of the NRF breed. Although animals of the HF breed had a higher score for each of the physical characteristics assessed, it is important to note that the scoring system used was developed for the perceived 'ideal' within the HF breed, and as such this system may be inappropriate for animals of the NRF breed.

ACKNOWLEDGEMENT

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TECHNOLOGY TRANSFER ASSOCIATED WITH THE PROJECT

PUBLICATIONS IN CONFERENCE PROCEEDINGS

McKeague, J.A. and Ferris, C.P. (2004) A comparison of the physical characteristics of Norwegian dairy cows and Holstein-Friesian dairy cows. *Proceedings of Agricultural Research Forum of the Irish Grassland and Animal Production Association, Tullamore, Ireland*. Page 83.

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PROGRESS REPORTS

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Details of visiting groups that were updated on the project (since records commenced in 2005)

Date	Name of visiting group	Topic
26-Apr-05	CARAS	Environmental issues, NRF cows
09-May-05	Chrisanya Robins and Phil Shannon, Dairy Extension Officers, Australia	Phosphorus, NRF cows, labour
06-Jun-05	National Agriculture dairy club	Reducing N and P losses from dairy systems, Comment on 8000 litres/cow on 1 tonne concentrates, evaluation of NRF dairy cows
15-Jun-05	Mr Mike Frawley, advisor with Dan O'Connor, Feed Millers, Limerick	Reducing N and P losses from dairy systems, Breed comparison studies
21-Jun-05	Wexford Dairy discussion group	Reducing N and P losses, breed comparison studies
24-Jun-05	Mr Dennis Johnston, WCROC	N and P studies, breed comparison studies
07-Jul-05	Bill Wales, Christie Ho, Kyabram, Australis	Phosphorus, NRF, Labour
19-Sept-05	Jennifer Burke, Massey University, N. Zealand	Phosphorus/NRF/Labour
22-Nov-05	Mr Barton Ruth, Eisenhower Scholar	Environmental issues, Breed comparison studies
30-Nov-05	Marie Haskell and Fiona Lang, SAC	Overview of dairy research, Feed barriers discussions
5-Dec-05	Mr Les Hansen, US.	On-farm NRF project
8-Dec-05	UFU, Dairy Committee	P, NRF, Labour
26-Jan-06	Adrian Van Bysterveldt, Dexcel	Dairy Systems study, Breed comparisons, P
01-May-06	Richard Dewhurst, Lincoln University, NZ.	Overview of P, labour and breed comparison studies
20-Jun-06	UDF, Council members	P, NRF and labour studies. New Spring Systems study
03-Jul-06	Mrs Clare Cooper, NZ postgraduate student	Once day milking, Spring Systems, NRF
09-Aug-06	Presentation to CARAS, Laughlin farm, Kilrea	On-Farm NRF project
15-Aug-06	Prof. Wayne Kellog, University of Arkansas	Breed comparison, barriers studies, Labour studies
12-Sep-06	Cheshire Grassland Society (Mr D Hughes)	Spring systems, P, NRF
04-Oct-06	Mr James and Chris Hill, Australia	NRF, Spring systems, Barriers, Labour
20-Oct-06	Mr Friefrich Fuhrer, Mr Peter Kreuzhuber, Mr Jim Hamilton, Fleckvieh Austria	NRF and Jersey crossbreds
23-Nov-06	Third year Greenmount students	NRF and crossbreeding, including Spring systems
29-Jan-07	Wexford Farmers	On farm NRF
27-Feb-07	Caledon dairy discussion group	Barriers, NRF, Spring systems
08-Mar-07	Jack Kennedy, IFJ	Barriers, spring systems, NRF
26-Mar-07	J. Thompsons Group	Barriers, Spring Systems, NRF
03-Apr-07	Mr Paul McGill, New Zealand Farmer	Breed comparison studies, Barriers, Systems

06-Jun-07	Association of Veterinary Practitioners in Northern Ireland	NRF study, Jersey crossbred study
12-Jun-07	The Cowboys, Scottish dairy farmers	Spring Systems, NRF cows
26-Jun-07	Frank Wright	Systems, Breeds, P
26-Jun-07	Scottish Farmers	Breeds/Systems
27-Jun-07	Hybrid Dairy group, Cornwall	Systems/Breeds
27-Jun-07	AgriTech Group	Systems/Breeds
04-Jul-07	Dr Lewis McClinton	Overview of breed research programme
17-Jul-07	Dairy Hygiene Inspectorate	NRF and Spring Systems study
05-Sep-07	Kingshay/Farm Gate Nutrition	P, Systems, Jx, NRF
06-Dec-07	CAFRE Students	NRF, Crossbreeding
11-Dec-07	Adrain Caine Consultant + farmers	NRF, Crossbreeding
05-Feb-08	BOCM Pauls, Technical Forum (Brian Martin)	NRF, Systems, Barriers
04-Apr-08	Prof John Comerford	P, Breeds
23-May-08	Chilean Farmers	Slurry spreading/NRF cows
26-Aug-08	Enniskillen dairy farmers	NRF, Jersey crossbreds
04-Sep-08	Mid and West Wales Agriculture Discussion Group	P and breeds/crossbreeding
10-Sep-08	Hugh Black + 6 dairy farmers	Overview, P, breeds, barriers
03-Oct-08	Navan Grazing Group	Spring systems/NRF
18-Feb-09	UFU Milk Committee	Overview + NRF
06/05/2009	Black lion dairy discussion group, Meath	Crossbreeding/NRF
30/09/2009	Farmers from Welsh Borders and Shropshire	Norwegian cows, crossbreeding
20/01/2010	United Feeds Rep.	Norwegian cows, crossbreeding, environmental issues
28/01/2010	YFC Ulster Livestock Seminar	Dairying - its not all black and white
03/02/2010	Navan dairy farmers	Jersey crossbreeding, NRF and environmental issues
14/04/2010	Frank Buckley, Blathnaid O'Loughlin and Matthew Deighton, Moorepark	Dairy cow genetics- overview
15/04/2010	Karen Wonnacot, MDC	Genetics and environmental issues
14/05/2010	Chilean visitors	Overview, genetics, environment
26/05/2010	Belfast Met students	Overview, genetics, environment
28/05/2010	Tom Phillips and student	Overview, genetics, environment
10/06/2010	Scottish dairy farm managers	Environmental issues/genetics
29/06/2010	Dairy Co Field staff	Environment and genetics
01/09/2010	Dr John Roche, Dairy NZ	Genetics and environmental issues, plus overview
08/10/2010	Julia Lee: Postdoctoral student from DairyNZ	Environmental issues/genetics