The effect of Holstein-Friesian genotype and feeding system on selected performance parameters of dairy cows on grass-based systems of milk production in Ireland.

Final Report
Project Number 4985

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Summary

The overall objective of this project was to assess, the effect of strain of Holstein-Friesian dairy cow, pasture-based feed system (FS) and their interaction on animal performance in terms of milk productivity and lactation profile, body weight (BW), body condition score (BCS), feed intake and energy balance (EB), reproductive performance and overall economic profitability.

The effect of strain of Holstein-Friesian (HF), feed system (FS) and parity on milk production, BW and BCS.

Three strains of HF were compared on three pasture-based feed systems over three consecutive years. The three strains of HF were: high production North American, high durability North American and New Zealand. The three grass-based feeding systems (FS) were: a high grass allowance system (MP FS), a high concentrate system (HC FS) and a high stocking rate system (HS FS). There was a separate farmlet for each FS and a total of 99, 117 and 117 animals were used in yr 1, 2 and 3 respectively, divided equally between strains of HF and FS. The high production cows produced the highest yield of milk, the New Zealand the lowest, while the high durability were intermediate. Milk fat and protein content were higher for the New Zealand strain than both the high production and high durability strains. The New Zealand strain had the lowest body weight and the highest condition score, while the high durability strain had the highest body weight and the high production strain had the lowest condition score. There was a significant strain of HF by FS interaction for yield of milk, fat and protein. The milk production response to increased concentrate supplementation (MP FS vs. HC FS) was greater ($P<0.05$) with both the high production and high durability strains (1.10 kg milk / kg concentrate for high production; 1.00 kg milk / kg concentrate for high durability) than the New Zealand strain (0.55 kg milk / kg concentrate). The results indicate that the optimum strain of HF will vary with feed system.

The effect of strain of HF, FS and parity on Dry matter (DM) intake and EB.

Individual animal intakes were estimated three times each year at pasture; in May (P1), in July (P2) and October (P3), corresponding on average to day 102, 177 and 240 of lactation, respectively. The HP cows achieved the highest milk yield, the NZ the lowest, while the HD was intermediate; the HP achieved the highest solid corrected milk yield with no difference between the NZ and HD strains. The grass DM intake of the HP strain was highest ($P<0.001$) in all feed systems. There was a significant strain x FS interaction for yield of milk, fat and protein, grass DM and total DM intake. The milk production response to the HC FS in P1 and P2 was significantly greater for both the HP and HD strains than for the NZ strain, while in P3 the response was highest for the HP, lowest for the NZ and intermediate for the HD. The reduction in pasture DM intake per kg of concentrate was greatest for the NZ strain, lowest for the HP and intermediate for the HD strain. The NZ strain also had the highest grass DM intake per kg bodyweight. The existence of strain x FS interactions for production and DM intake indicate that greater knowledge of both genotype and feed environment is required to predict animal performance.

The effect of strain of Holstein-Friesian cow and feed system on reproductive performance.

The effects of strain of HF, feed system and parity on milk production, body condition score, live-weight, energy balance and reproductive performance were studied using a repeated measures model with a factorial arrangement of strain of HF and feed systems. Associations between these variables and conception to first service (CONCEPT1), conception to first and second service (CONCEPT1_2), pregnancy rate at 6-weeks (PREG6) and overall pregnancy rate (PREG) were assessed using logistic regressions. When treatment means were compared, the NZ strain had a shorter gestation length and a higher CONCEPT1_2 than both the HP and HD strains. Similarly, the NZ strain had a higher PREG6 and PREG than the HP strain. Feed system had no significant effect on reproductive performance. The HP strain had the highest milk yield at first AI and peak milk yield, the NZ strain had the lowest milk yield while the HD strain was intermediate. The energy balance of the NZ strain was higher than that of the HP and HD strains. The NZ strain had the lowest live-weight and highest body condition score; the HD strain had the highest live-weight and the HP strain had the lowest body condition score. The results show that dairy cows with superior genetic merit for fertility traits have better reproductive performance.

The effect of strain of Holstein-Friesian cow and feeding system on postpartum ovarian function, animal production and conception rate to first service

Ovarian function was assessed using milk progesterone samples, collected from 117 cows in each of two successive years, with 81 animals being common to both years. Milk samples were collected thrice weekly, beginning day 5 post-calving and continued to day 26 after first AI. Data from animals subsequent to reproductive hormonal treatment were removed from the analysis. Feed system and strain of HF by feeding system interaction had no significant effect on re-establishment of ovarian activity and subsequent conception rate to first AI. Strain of HF had no significant effect on interval to commencement of luteal activity (CLA). The mean interval to CLA was 32.9 days (s.e. 1.18), ranged from 6 to 100 days, with 42 and 85 % of cows ovulating by day 26 and 60, respectively. The HD (62%) and NZ (57%) strains had a higher conception rate to first AI than the HP strain (40%), ($P<0.05$). Retrospective analysis categorised all cows into four quartiles based on interval to CLA (<20 days, 20 to 26 days, 27 to 44 days and >44 days). Cows in the first and fourth CLA quartiles had a longer calving to conception interval ($P<0.05$). Cows with abnormal progesterone profiles (38.4%) had an earlier mean calving date, with a similar submission rate and conception rate to first service compared to cows with normal hormonal profiles. There was no significant difference in luteal activity or reproduction performance, apart from calving to conception interval, between cows that conceived or did not conceive to first service. These results indicate that while conception rate to first service differed between strains of HF cow, this was not associated with differences in the onset and pattern of luteal activity post partum.

The effect of strain of HF, FS and parity on the shape of the lactation curve

The purpose of the present study was to investigate the influence of strain of Holstein-Friesian (HF) cow and feeding system (FS) on the lactation curve characteristics of spring-calving cows. The Wilmink model was used to analyse the lactation curves. Strain of HF, FS, parity and the interaction of strain of HF with FS had significant effects on lactation curve characteristics. In all three FS, the HP strain achieved the highest milk production post calving and peak yield, with the lowest persistency of lactation. In the HC system, milk production post calving and at peak yield were higher for all three strains. Offering higher levels of concentrate supplementation to the HP strain on a pasture-based system improved their persistency of lactation. The highest persistency of lactation was achieved with NZ strain. The highest milk production post calving and at peak and lowest persistency was achieved with third parity cows. The existence of strain by feed system interactions for lactation curve parameters clearly exhibits that the optimum system of production varies with strain of HF.

The influence of strain of HF cow and system of production on economic performance

The influence of strain of HF cow and system of production on economic performance was investigated using the Moorepark Dairy Systems Model (MDSM) under three different scenarios. The three production scenarios investigated were: EU milk quota applied at farm level (S1); EU milk quota applied at farm level with lower decoupled milk price under Luxembourg Agreement (S2); and in a scenario with EU milk quota applied at industry level with decoupled lower milk price under Luxembourg Agreement (S3). In S1, the highest farm profit was realised with the NZ strain in both the MP and HC systems. The results also show that with both the HP and HD strains, the farm profit in the HC system was greater than that in the MP system, while with the NZ strain the farm profit in the MP system was greater than in the HC system. Similar to S1, NZ strain had the highest farm profit again in S2 in both the MP and HC systems. However the results also indicate that the differential in farm profit in favour of the NZ strain over both the HD and HP increased in S3. The results of this study highlights the large influence of strain of cow on farm profitability, and the increasing advantage of profitable genetics in a lower milk price scenario. The results of this study show that to achieve maximum genetic progress the cow required for Irish seasonal pasture based system must be proven from pasture.

Introduction

The continued reform of the Common Agricultural Policy (CAP), the desire to make production more market focused and the obligation to tailor EU agricultural policy to facilitate future WTO agriculture negotiations, all suggest a more unstable and unpredictable time ahead for EU dairy farmers. The potential for dairy farmers to secure higher prices for their output to compensate for their increasing costs and downward pressure on product prices as a result of policies at EU level is very limited and hence, there is considerable interest in finding new ways of reducing costs and increasing efficiency at farm level. One of the strategies that may be adopted by some European dairy farmers is to develop a lower input pastoral dairy system that would be more environmental and animal welfare sustainable, have lower fixed costs and be labour efficient.

In broad terms, the breeding goal of most dairy farmers is to increase the profitability of their system of milk production. Most producers and breeders would add that this should be achieved without detriment to animal health and welfare and the environment. While there may be broad agreement on this aim, there is far less agreement on what the main components of profitability are, and how to improve them most efficiently. Until recently milk yield has been the main objective criterion for selection in most temperate countries. There is increasing evidence suggesting that cows selected solely on milk yield have reduced fertility performance (Hoekstra et al., 1994; Van Arendonk et al., 1991; Veerkamp et al., 2000, Royal et al., 2000). Reduced reproductive performance may result in increased replacement costs and reduced voluntary culling within the herd thus eliminating some or all of the benefits achieved from higher milk production potential. In grass-based systems, where the absolute milk yield levels tend to be lower, the economic benefit of higher genetic merit cows may be further reduced (Peterson, 1988).

Recent results from Moorepark (Buckley et al., 2000, Kennedy et al., 2003a) have shown that animals of high genetic merit for production traits of European/North American origin can achieve high milk production on pasture-based systems. However, the reproductive performance of the high genetic merit dairy cows was well below the optimum for seasonal calving systems of milk production. The increased milk yield associated with the higher milk production potential cows would not compensate financially for the increased culling which would result from the reduced fertility performance. Continued selection for higher milk yield must be questioned given the continuation of EU policy of milk quotas until 2015. Additionally, reduced milk prices will require dairy farmers to adopt lower cost systems of production with the trend in milk payment schemes increasing the emphasis on milk composition, especially milk protein.

Interactions between genotype and environment for phenotypic performance are becoming increasingly important as cattle genotypes are now being managed in a diverse range of environments world-wide. Until recently most experimental results have indicated little or no importance of breed or strain by feeding system interaction in temperate dairying systems (Holmes, 1995). The greater the genetic diversity among breeds or strains and the larger the differences between the environments in which they are compared, the greater the likelihood of genotype by environment interactions existing (Falconer, 1989).

The studies presented here assess the effect of strain of Holstein-Friesian dairy cow, pasture-based system and their interaction on animal performance in terms of:

(1) Milk production, body weight and body condition score
(2) Feed energy intake and energy balance through lactation
(3) Reproductive performance
(4) Luteal function
(5) Lactation profile and persistency
(6) Economic performance

Strain of Holstein-Friesian By Pasture-Based Feed System Interaction for Milk Production, Bodyweight and Body Condition Score

Materials and Methods

This analysis was carried out over a three-year period (2001 to 2003).

Animals

Three strains of HF cow were compared: high production North American (HP), high durability North American (HD) and New Zealand (NZ). The mean pedigree index (PI) each strain studied is displayed in Table 1. To create the HP strain, the top 50% of HF cows in the Moorepark herd (based on pedigree index for milk production) were inseminated with semen from five North American HF sires.

Table 1. *The mean pedigree index for the three strains of Holstein-Friesian cows studied based on their Predicted Differences*[†] *(PD) (and SD) for milk production, survival and calving interval*

Strain	High Production	High Durability	New Zealand
Milk (kg)	+194(90.8)	+76(61.4)	+52(56.0)
Fat (kg)	+9.0(2.96)	+6.3(2.84)	+8.6(2.66)
Protein (kg)	+8.8(2.39)	+5.7(1.58)	+4.2(1.33)
Fat (g/kg)	+0.3(0.53)	+0.7(0.56)	+1.3(0.58)
Protein (g/kg)	+0.4(0.23)	+0.6(0.30)	+0.5(0.21)
Survival (%)	-0.5(1.11)	+0.4(0.51)	+1.2(0.62)
Calving interval (days)	+0.44(1.57)	-1.2(0.71)	-1.6(0.86)

[†]All PDs were obtained from the February 2004 international evaluations of the Animal Centre, Uppsala, Sweden using the MACE (multi-trait across-country evaluation). The PD for each cow was calculated as 0.50 x sire PD + 0.25 x maternal grand sire PD + 0.125 x maternal great grand sire PD.

The five sires chosen were the five highest sires available in Ireland at the time based on their relative breeding index (RBI); this was the index used in Ireland at the time, and was based on combined predicted difference (PD) for milk, fat, and protein yields and protein content (Irish Cattle Breeding Statistics, 1999). Therefore the HP strain was selected to illustrate what would happen if Irish dairy farmers continued to select animals aggressively for increased milk production. The average proportion of North American HF genes in the HP strain was 90%, with the remaining genes being Friesian. To create the HD strain, the bottom 50% of HF cows in the Moorepark herds (based on pedigree index for milk production) were inseminated with semen from five North American HF sires, chosen on a combination of their pedigree indices for milk production, fertility and linear (muscularity) traits. The dams used to generate this strain were representative of the HF cow that existed on most Irish dairy farms at the time. Therefore the HD strain was generated to represent a more balanced breeding policy including some indicators/fertility traits as well as milk production traits. The average proportion of North American HF genes in the HD strain was 80%, with the remaining genes being Friesian. The NZ animals were imported as embryos from New Zealand and implanted into 13-month-old HF heifers at Moorepark. The NZ embryos were generated by mating high genetic merit New Zealand HF cows (expressed in the New Zealand genetic evaluation system, Breeding Worth) with five high genetic merit New Zealand HF sires. On average, 87·5% of the NZ strain genes was of New Zealand HF ancestry. Jersey genes contributed up to a maximum of 12.5%, with the remaining genes of North American HF ancestry. The NZ strain represents a Holstein-Friesian strain that was selected within a pasture based seasonal system, using an index that combined milk production and other traits of economic importance. The sires and dams used to generate each strain were representative of the top 10% of animals within their respective countries on overall genetic merit. The three strains were created not to be representative of any given existing strain of HF but merely to represent the consequences of various selection strategies on subsequent animal performance in pasture-based systems.

A total of 99, 117 and 117 animals were used in Year 1, Year 2 and Year 3 respectively, divided equally between strains of HF and FS. The number of animals of each strain of HF and FS over the three years of the study is displayed in Table 2. In 2001 all 99 cows were parity one; in 2002, 45 animals were parity one and 72 parity two; while in 2003, 9 animals were parity one, 45 parity two and 63 parity three. A total of 59 animals remained in the same FS for the three-year duration of the study. All primiparous cows were on a similar feeding regime for the first four weeks of lactation. Animals were selected within strain into groups of three, on the basis of calving date, milk production in the first four weeks of lactation and BW and then randomly assigned to one of three systems. Once allocated, animals were retained on the same FS in subsequent lactations.

Table 2. *The number of dairy cow records included in the three-year analysis.*

Group	Strain of Holstein-Friesian			Feed system (FS)		
	HP	HD	NZ	MP	HS	HC
Number of lactation records						
Parity 1	51	51	51	51	51	51
Parity 2	39	39	39	39	39	39
Parity 3	21	21	21	21	21	21

HP = High production, HD = High durability, NZ = New Zealand, MP = Moorepark feed system, HS = High stocking rate feed system, HC = High concentrate feed system

Feed Systems

There was a separate farmlet for each of the three systems of production. The three systems compared were: a high grass allowance FS typical of spring calving herds in Ireland (MP FS, control); a higher concentrate system FS (HC FS) and a higher stocking rate system (HS FS). Approximately 1.0 ton of grass silage DM per cow was required during the housing period. The MP FS had an overall stocking rate of 2·47 cows/ha, a nitrogen (N) fertiliser input of 290 kg N/ha (from early-January to late-September) and received 368 kg concentrate /cow in early lactation with the remainder of the diet coming from grazed grass. The HC FS had a similar overall stocking rate and N input as the MP FS but a concentrate input of 1452 kg/cow. The HS FS group had similar concentrate (364 kg/cow) and N inputs as the MP FS but at a higher overall stocking rate of 2·74 cows/ha. The ingredient composition of the concentrate feed (kg/t as fed) was as follows: barley 250, corn gluten 260, beet pulp 350, soya-bean meal 110, and minerals plus vitamins 30. The MP FS and HC FS feeding systems were designed to allow each strain to express its potential largely unrestricted by limitations in feed supply. The aim of the HS FS was graze to a lower post-grazing surface sward height (PGSSH) than either the MP FS or HC FS. In all three years, animals were turned out to grass during the day beginning in early February, and during day and night beginning in early March. Animals were on grass day and night until mid-November, when they were housed only at night. After December 1, they were housed day and night. During the housed period animals were fed grass silage ad libitum. The concentrate supplementation pattern for each system is shown in Table 3.

Table 3. *Concentrate supplementation strategy[†] (kg per cow per day).*

Feeding system	Calving to March 15	March 15 to March 31	April 1 to earl May	Early May to end (lactation
Moorepark	6	4	2	0
High stocking rate	6	4	2	0
High concentrate	8	8	6	4

[1]All primiparous animals were maintained on 7kg per day for a pre-experimental period of 4weeks

Statistical Analysis

Data were analysed using repeated measures models (PROC MIXED) described below using the statistical procedures of SAS (SAS, 2002). Cow was included as a random effect while year, parity, strain of HF, and feed system were included as fixed effects. Each year, the newly introduced animals were selected within strain and parity, on calving date and pre-experimental milk yield. Animals present from previous years were maintained in the same feed system. To improve the accuracy of the models, pre-experimental milk yield, BW and BCS were used as covariates specific to the traits being analysed.

For the milk production variables the covariates used were pre-experimental milk production, individual animal PD milk production and calving date for each animal on the study. BW and BCS models included covariates for pre-experimental BW and condition score, gestation length and calving date. Owing to the differences between strains in terms of the pre-experimental values, these covariates were centered within strain prior to inclusion. That is, the deviations from the strain mean were used as the covariates. The incorporation of individual animal covariates within the model reduced the residual error term, therefore explaining more of the variation within strains.

Grazing Management

The experimental area was a permanent grassland site containing greater than 80% perennial ryegrass (*Lolium perenne*). Each system consisted of 18 paddocks of on average 0.89 ha for MP FS and HC FS and 0.81 ha for HS FS. Within each paddock the three strains grazed separate areas that were defined using temporary electric fences. In the MP FS and HC FS the sub-paddocks for both the HD and NZ strains were 0·29 ha, for the HP strain they were 0·31 ha. In the HS FS, both the HD- and NZ-strain sub-paddocks were 0·26 ha and the HP-strain sub-paddocks 0·28 ha. Previous measurements had established that these allocations were likely to achieve common PGSSH for each strain. Grazing management was similar to that outlined previously (Dillon et al., 1995). Grass silage was harvested from 0·45 and 0·35 of feeding system areas in late-May (first silage harvest) and early-July (second silage harvest), respectively. For the remainder of the season all of the area within the feeding system was available for grazing. A rotational grazing management system was practised. Residency time was determined by the achievement of pre-determined pasture allowances (kg DM/cow/day) within a target PGSSH (7-8cm for the MP FS and HC FS; 6-7 cm for the HS FS). Target PGSSHs were reached in residency times that ranged from 1·5 to 2·5 days/sub-paddock over the experimental period. Grazing management was facilitated by weekly monitoring of farm grass cover.

The sub-paddock residency time of the cows in both the HS FS and MP FS was the same i.e. similar grazing rotation; therefore the cows in the HS FS were forced to graze to a lower PGSSH throughout the grazing season. The grazing rotation in the HC FS moved independently to that in the MP FS and HS FS, however the HC FS group grazed to a similar PGSSH as the animals on MP FS. Pasture quality was maintained in this system by removing surplus grass throughout the experiment as silage.

Animal Measurements

During the three years of the study, individual milk yields were recorded on five consecutive days per week. The milk fat, protein and lactose concentrations were determined using a Milkoscan 203 (Foss Electric DK-3400, Hillerod, Denmark), from successive morning and evening samples collected once weekly. The BW of each animal was recorded weekly. Each BW was recorded electronically, using portable weighing scales and Winweigh software package (Tru-Test Limited, 241 Ti Rakau Drive, Aukland, New Zealand). The scales were calibrated weekly against known weights. The BCS was recorded every 3 weeks during the lactation on a 0 to 5 scale (0 = emaciated, 5 = extremely fat) with increments of 0.25 as outlined by Lowman et al. (1976). The first BW and BCS data were recorded 24-hr post partum.

Feed Measurements

Pre-grazing herbage yield (above 4 cm horizon) was determined on each grazing paddock based on four strips (0.80 m wide; 4.5 to 5.5 m long) of grass cut with an Agria mower (Agria-Werke, GmbH, D-74215, Mockmuhl/Wurtt, Germany). The grass from each strip was weighed and sampled and a sub-sample was dried over night at 90°C for DM determination. The remaining herbage samples from each paddock were bulked and a further sub-sample taken (ca. 100 g) and freeze-dried and used for chemical analysis. During each rotation, a total of 30 pre-grazing sward surface heights were recorded for each strain within each paddock immediately prior to grazing with a further 30 post-grazing sward surface heights taken immediately post grazing (Hutchings, 1991).

Chemical analysis

The composite herbage samples for each week were analysed for modified acid detergent fibre (MADF), organic matter digestibility

(OMD) and Kjeldahl nitrogen. Similarly in periods of silage supplementation, a composite grass silage sample for each week was analysed for residual moisture, dry matter digestibility (DMD), Kjeldahl nitrogen, MADF, NDF. Concentrates were sampled weekly, bulked over each month, and analysed for DM, total nitrogen, crude fibre, NDF, oil and ash.

Results

Milk Production

There was a significant effect of strain of HF, FS and interaction between strain of HF and FS for all milk yield variables measured (Table 4). The HP strain had the highest total lactation milk yield (6,958 kg), the NZ strain the lowest (6,141 kg), while the HD strain were intermediate (6,584 kg). The HP strain had the highest solids corrected milk yield (Tyrell and Reid, 1965; SCM) (6,629 kg), while no difference was observed between the HD (6,359 kg) and NZ strains (6,278 kg). The HP strain also had the highest peak milk yield (34.8 kg), total protein (241 kg) and total lactose yields (326 kg) with the NZ strain the lowest (30.2, 224, 288 kg, respectively), while the HD strain was intermediate (32.8, 235, 308 kg, respectively). The HP strain also produced more fat over the lactation (279 kg) with no significant difference between the HD (268 kg) and NZ strains (275 kg).

Similarly, FS had a significant effect on all milk production parameters. The cows in HC FS produced the highest yield of milk (7,199 kg), SCM (7,040 kg), peak milk (34.4 kg), protein (259 kg) and lactose (341 kg), with HS FS the lowest (6133, 6025, 31.2, 216 and 285 kg, respectively), while the MP FS was intermediate (6352, 6200, 32.1, 225 and 296 kg, respectively). The cows in the HC FS also produced the highest yield of fat over lactation (296 kg) with no significant difference between the MP FS and HS FS (265 and 260 kg, respectively). Significant interactions between strain of HF and FS were observed for all milk yield variables.

The interaction between strain of HF and FS arose due to the difference in response to both stocking rate and concentrate supplementation between strains. The differential in response is presented in Figure 1 below. The reduction in daily milk production in the HS FS was similar for both the HD and NZ strains (reducing daily milk yield by 0.5 and 0.6 kg/day, respectively relative to the MP FS). In comparison, a greater sensitivity to the HS FS was observed among the HP strain over this period, with average daily milk production being reduced by 1.2 kg/day. A greater reduction in daily SCM, fat and lactose yield was also observed among the HP strain (with reductions in daily production of 1.3 kg, 70 g and 58 g, respectively) compared to the HD (0.3 kg, 24 g and 32 g) and NZ strains (0.7 kg, 16g and 37 g, respectively). The HS FS had a similar affect on all strains in terms of protein yield and milk composition. The milk production response to increased concentrate supplementation was significantly greater for both the HP and HD strains (1.08 kg milk / kg concentrate for HP; 1.00 kg milk / kg concentrate for HD) than the NZ strain (0.43 kg milk / kg concentrate for NZ). Similar trends were observed in terms of daily SCM, protein and lactose yields. The HD strain displayed a greater response in fat yield compared to the HP and NZ strains.

Table 4. *Effect of strain of Holstein-Friesian, Feed system (FS), and interaction between strain of HF and FS on milk production (2001-2004).*

	HP			HD			NZ				Significance‡		
Feed system (FS)	MP	HS	HC	MP	HS	HC	MP	HS	HC	SEM	S	F	S x F
Total milk yield (kg/cow)	6900	6645	7893	6495	6439	7434	6093	5898	6352	124.8	***	***	***
SCM yield (kg/cow)	6489	5999	7376	5976	6012	7074	6120	6065	6648	104.5	***	***	***
Maximum yield (kg/cow/day)	34.5	32.7	37.2	32.1	31.1	35.2	29.8	29.8	31.0	0.53	***	***	*
Fat yield (kg/cow)	281	267	318	263	264	296	268	265	284	5.1	*	***	**
Protein yield (kg/cow)	241	232	278	231	229	268	224	212	236	3.6	***	***	***
Lactose yield (kg/cow)	319	309	374	301	300	348	284	275	302	6.0	***	***	***
Milk composition (%)													
Fat	4.03	4.08	4.02	4.08	4.06	3.99	4.33	4.50	4.49	0.07	***	*	
Protein	3.49	3.51	3.54	3.58	3.56	3.59	3.69	3.61	3.71	0.04	***	*	
Lactose	4.63	4.67	4.73	4.63	4.66	4.68	4.65	4.67	4.76	0.02		***	

HP = High production, HD = High durability, NZ = New Zealand, MP = Moorepark feed system, HS = High stocking rate feed system, HC = High concentrate feed system, S = Strain of Holstein-Friesian, F = effect of feed system, S X F = effect of interaction between strain of Holstein-Friesian and feed system.

Table 5. *Effect of strain of Holstein-Friesian on milk production response to concentrate supplementation.*

Strain of Holstein-Friesian	HP	HD	NZ	Significance
Daily milk yield response (kg/kg)	1.08[a]	1.00[a]	0.43[b]	*
Daily SCM yield response (kg/kg)	0.92[a]	0.86[a]	0.51[b]	*
Daily fat yield response (g/kg)	25[a]	38[b]	20[a]	*
Daily protein yield response (g/kg)	37[a]	42[a]	22[b]	*
Daily lactose yield response (g/kg)	58[a]	56[a]	26[b]	**

HP = High production, HD = High durability, NZ = New Zealand

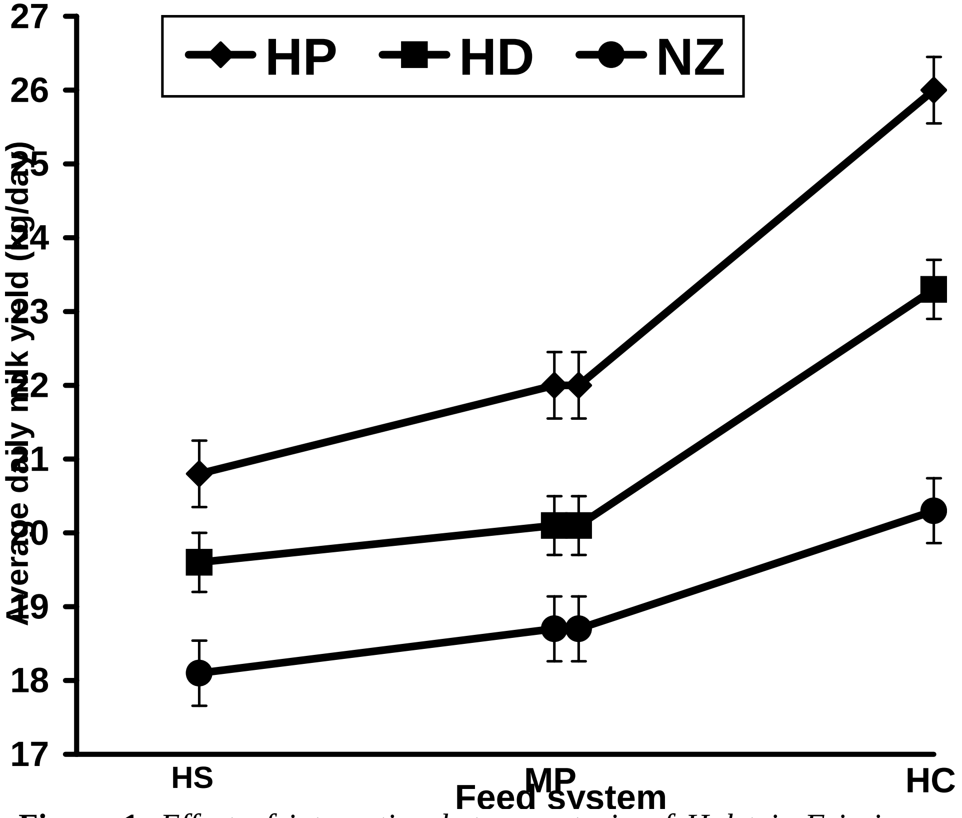


Figure 1. *Effect of interaction between strain of Holstein-Friesian cow and feed system on average daily milk production.*

BW and BCS

The effects of strain of HF and FS on BW and BCS are displayed in Table 6. Immediately post partum both the HP and HD strains (553 and 556 kg, respectively) were heavier than the NZ strain (517 kg). The HD strain were heaviest at nadir BW and at drying-off (500 and 596 kg, respectively), the NZ strain the lightest (463 and 553 kg, respectively), while the HP strain were intermediate (491 and 570 kg, respectively). The NZ strain had the highest BCS immediately post partum (3.37), at nadir BCS (2.84) and at drying-off (3.13), the HP strain the lowest (3.17, 2.45 and 2.68, respectively), while the HD strain were intermediate (3.24, 2.65 and 2.93, respectively). Strain of HF had no significant effect on BW change from calving to nadir BW, however the HP strain lost significantly more body condition (-0.73) from calving to nadir, compared to the HD (-0.59) and NZ strains (-0.55). The HD strain had a greater BW gain from nadir BW to the end of lactation (95.7 kg), compared to both the HP (82.8 kg) and NZ strains (86.1 kg), with no difference in condition score gain between strains.

Feed system also had a significant effect on BW and BCS. The cows in the HC FS were heaviest at nadir BW (491 kg) and at drying-off (586 kg) while no difference was observed between the MP FS and HS FS at nadir BW (482 and 481, respectively) or at drying-off (567 and 566, respectively). The HC FS had the highest nadir BCS (2.77) and at drying-off (3.03), with both the MP FS and HS FS groups having the same BCS at nadir (2.59) and at drying-off (2.84 and 2.87, respectively) systems. Cows in the HC FS gained more BW between nadir BW and drying-off (96.0kg) compared to the HS FS and MP FS (84.0 and 83.3 kg, respectively). Similarly the cows in the HC FS also lost significantly less BCS from calving to nadir (0.51), compared to the HS FS and MP FS (0.64 and 0.72, respectively).

Table 6. *Effect of strain of Holstein-Friesian and FS on body weight (BW) and body condition score (BCS).*

Strain of HF	HP			HD			NZ				P value	
Feed system (FS)	MP	HS	HC	MP	HS	HC	MP	HS	HC	SEM	S	F
BW post-calving (kg)	557	553	548	556	546	568	511	518	521	6.0	***	
BW at drying-off (kg)	557	569	584	593	582	613	550	546	562	6.9	***	***
BW at nadir (kg)	490	486	496	497	492	512	460	464	464	5.2	***	*
BCS post-calving	3.20	3.14	3.16	3.32	3.16	3.26	3.39	3.37	3.38	0.040	***	*
BCS at drying-off	2.58	2.65	2.82	2.87	2.88	3.05	3.07	3.09	3.24	0.057	***	***
BCS at nadir	2.35	2.43	2.56	2.61	2.56	2.79	2.82	2.77	2.94	0.049	***	***
BW change: Calving to nadir (kg)	65.7	67.5	50.5	55.6	57.0	55.0	52.4	55.2	56.7	5.28		
BW change: Nadir to drying-off (kg)	67.7	80.1	90.0	93.3	89.9	102.7	91.0	79.9	95.3	5.16	***	**
BCS change: Calving to nadir	-0.85	-0.73	-0.60	-0.69	-0.63	-0.46	-0.61	-0.57	-0.47	0.045	***	***
BCS change: Nadir to drying-off	0.21	0.19	0.27	0.22	0.28	0.19	0.24	0.28	0.28	0.042		

HP = High production, HD = High durability, NZ = New Zealand, MP = Moorepark feeding system, HS = High stocking rate feeding system, HC = High concentrate feeding system, L = effect of parity, S = Strain of Holstein-Friesian, F = effect of feed system, GX F = effect of interaction between genotype and concentrate feed level.

Conclusion

Strain of HF, FS, parity and the interaction of strain of HF and FS had a significant effect on the milk production of spring-calving cows in pasture-based systems. The data shows that in a grass-based system, aggressive selection for increased milk production (HP strain) in the North American HF has resulted in an animal with higher milk production, greater response to additional concentrate supplementation but with greater BW and BCS loss post-calving. The NZ strain selected on a grass-based system for increased fat and protein yield in a given volume of milk had the lowest milk volume, highest milk composition, poorest response to concentrate, lowest BW and highest BCS. The HD strain was intermediate for milk production and composition, had the highest BW and was intermediate for BCS. The existence of strong interactions between strain of HF and FS for milk production demonstrates that the optimum strain of HF will vary with system of milk production. These results show that the prediction of animal performance must be based on knowledge of both feed system and genotype.

The Effect of Strain of Holstein-Friesian Dairy Cow and Pasture-based system on Grass DM Intake.

Materials and Methods

The present analysis was carried out at Moorepark Research Centre in the Republic of Ireland over a three-year period (2001 to 2003).

Animal measurements

Individual animal intake was measured on three occasions while at pasture; measurement period I (P1) was in early-May, measurement period 2 (P2) in late-July and measurement period 3 in early- October (P3), corresponding on average to day 102, 177 and 240 of lactation respectively. Individual animal intakes were estimated using the n-alkane technique (Mayes *et al.,* 1986) as modified by Dillon and Stakelum (1989).

In P1, P2 and P3 the HG FS and HS FS groups received no concentrate while the HC group received 3.78, 3.73 and 3.48 kg of concentrate DM per day, respectively. The requirements of each animal were estimated in fill units (UFL) based on bodyweight and milk production during the study period using the Net Energy system (Jarrige, 1989). The energy balance (EB) of each animal was calculated as the difference between feed requirement and feed intake.

Results

Intake and energy partition

The effects of strain of HF and FS on intake are displayed in Table 7. The HP strain achieved the highest grass DM intake (17.5 kg/day), total DM intake (18.8 kg/day), grass OM intake (16.0 kg/day) and total OM intake (17.2 kg/day; P<0.001) with no significant difference between the HD (16.8, 18.1, 15.4 and 16.5 kg/day, respectively) and NZ strains (16.5, 17.7, 15.1 and 16.3 kg/day, respectively). The highest grass DM and OM intakes were achieved in the HG FS (17.5 and 16.0 kg/day, respectively). Concentrate supplementation (HC FS) resulted in a reduction in grass DM and OM intake (16.0 and 14.8 kg/day, respectively). When animals were maintained at a higher stocking rate (HS FS) a smaller reduction in grass DM and OM intake was observed (17.1 and 15.8 kg/day, respectively). Concentrate supplementation resulted in a significant increase in total DM (19.7 kg/day) and OM (18.1 kg/day) intake relative to the HG FS.

There was a significant strain of HF by FS interaction for all daily intake variables measured. Compared to the MP FS, the GDMI of the HD and NZ strains in the HC FS were reduced by 1.3 and 1.9 kg DM respectively, compared to 0.7 kg DM for the HP strain. The HP strain achieved the highest grass DM intake/ 100kg BW $^{0.75}$(0.166 kg/kg), with the HD strain the lowest (0.157 kg/kg) and the NZ strain intermediate (0.163 kg/kg, respectively). The NZ strain achieved the highest DM intake per 100 kg BW (adjusted for BCS) (3.23 kg/ 100 kg BW); the corresponding values for the HP and HD strains were 3.15 and 3.02 kg/ 100 kg BW adjusted for BCS respectively.

The HP strain achieved the highest energy intake (18.4 UFL/day), with no difference between the HD and NZ strains (17.7 and 17.5 UFL/day, respectively). The cows in the HC FS achieved the highest energy intake (19.3 UFL/day), the cows in the HS FS group achieved the lowest (16.9 UFL/day), while the cows in the HG FS were intermediate (17.4 UFL/day). The highest EB was achieved by the NZ strain (2.7 UFL/day), the lowest with the HD strain (2.4 UFL/day), while the HP strain was intermediate (2.5 UFL/day).

Effect of stage of lactation on DM intake and energy balance

Significant strain of HF by FS interactions existed for grass DM and total DM intake in P1 only (Table 8). On pasture with no concentrate supplementation (HG FS and HS FS), the HP strain had the highest grass DM in all periods with no difference between the HD and NZ strains. In the HC FS, the total DM intake of the HP strain was the highest with the NZ strain lowest in P1 and P2, but similar to the HD strain in P3. The cows in the HC FS had the highest total DM intake, and lowest grass DM intake in all periods, with the highest grass DM intake achieved by the HG FS group in all periods.

EB increased with increasing stage of lactation. In P1, the NZ strain had the highest estimated EB (+1.2 UFL), the HP strain the lowest (0.2 UFL), while the HD strain were intermediate (0.4 UFL). In P2, the EB of both the HP and NZ strains were similar, while that of the HD were lower. In P3, there was no significant effect of strain of HF on EB. In P1 and P2 the cows in the HC FS achieved the highest EB, while in P3, FS had no effect.

The HP strain also displayed the lowest substitution rate (SR), with the NZ strain the highest, while the HD strain are intermediate (Table 9). The SR decreased with increasing lactation stage for the HP strain. While the HD strain had a similar SR to the HP stain in P1 and P2; in P3 the SR was intermediate between the HP and NZ strains.

Table 7. *Effect of strain of Holstein-Friesian (HF) and Feed system (FS) on intake, feed utilization and energy partitioning and balance.*

	HP			HD			NZ				Significance‡		
Feed System (FS)	HG	HS	HC	HG	HS	HC	HG	HS	HC	SEM	S	F	S x F
Daily intake:													
Concentrate DM (kg/cow)	0	0	3.7	0	0	3.7	0	0	3.7				
Grass DM (kg/cow)	17.9	17.5	17.1	17.5	17.1	15.8	17.5	16.7	15.2	0.25	***	***	*
Total DM (kg/cow)	17.9	17.5	20.8	17.5	17.1	19.5	17.6	16.7	18.9	0.25	***	***	*
Grass OM (kg/cow)	16.3	16.1	15.7	15.9	15.8	14.6	16.0	15.4	14.0	0.23	***	***	*
Total OM (g/cow/day)	16.3	16.1	19.1	15.9	15.8	17.9	16.0	15.4	17.4	0.23	***	***	*
Diet DMD (g/kg)	771	772	779	766	764	784	766	776	782	0.12		***	
Diet OMD (g/kg)	792	801	808	789	794	804	798	794	803	0.12		***	
GDMI/ 100kg ABW	3.23	3.18	3.03	3.14	3.12	2.79	3.42	3.29	2.98	0.049	***	***	*
GDMI/ 100 kg $BW^{0.75}$	0.16	0.16	0.18	0.15	0.15	0.17	0.16	0.16	0.17	0.002	***	***	+
Daily energy partitioning													
Energy intake (UFL/cow):	17.7	17.3	20.3	17.1	16.9	19.2	17.1	16.4	18.7	0.26	***	***	*
Maintenance (UFL/cow)	5.6	5.6	5.7	5.7	5.6	5.8	5.5	5.4	5.5	0.06	***	**	
Milk production (UFL/cow)	10.0	9.4	11.5	9.2	9.0	10.6	9.3	8.7	10.0	0.21	***	***	:
Daily energy balance (UFL)	2.1	2.3	3.1	2.3	2.3	2.7	2.6	2.4	3.2	0.24		***	

GDMI= Grass DM intake, HP = High production, HD = High durability, NZ = New Zealand, HG = High Grass Allowance FS, HS = High stocking rate FS, HC = High concentrate FS, S = effect of strain of HF, F = effect of feed system, S X F = effect of interaction between strain of HF and feed system. †Significance: ***= P<0.001, *=P<0.05, + = P<0.10.

Table 8. *Effect of strain of Holstein-Friesian (HF) and feed system (FS) on intake and energy balance during each measurement period.*

	HP			HD			NZ				Significance‡		
Feed System (FS)	HG	HS	HC	HG	HS	HC	HG	HS	HC	SEM	S	F	S x F
Measurement period 1													
GDMI (kg/cow/day)	16.7	16.2	16.1	16.3	15.9	14.9	16.7	15.8	14.6	0.29	*	***	*
TDMI (kg/cow/day)	16.7	16.2	19.8	16.3	15.9	18.6	16.7	15.8	18.3	0.30	*	***	*
Daily energy balance (UFL)	-0.1	-0.5	1.1	0.0	0.2	1.1	1.0	0.8	1.8	0.31	***	***	
Measurement period 2													
GDMI (kg/cow/day)	18.2	17.9	17.5	17.2	17.5	16.5	17.4	17.2	15.9	0.35	***	***	
TDMI (kg/cow/day)	18.2	17.9	21.2	17.2	17.5	20.2	17.4	17.2	19.6	0.35	***	***	
Daily energy balance (UFL)	2.7	3.0	3.7	2.3	2.9	3.1	2.7	3.4	3.7	0.33	**	***	
Measurement period 3													
GDMI (kg/cow/day)	19.7	18.8	18.1	19.2	18.5	16.4	18.7	17.9	15.6	0.37	***	***	
TDMI (kg/cow/day)	19.7	18.8	21.8	19.2	18.5	20.1	18.7	17.9	19.3	0.37	***	***	
Daily energy balance (UFL)	4.9	4.6	5.1	5.0	4.5	4.9	4.4	4.2	4.3	0.34			

GDMI= Grass DM intake, TDMI= Total DM intake, HP = High production, HD = High durability, NZ = New Zealand, HG = High Grass Allowance FS, HS = High stocking rate FS, HC = High concentrate FS, S = Strain of HF, F = effect of feed system, S X F = effect of interaction between strain of HF and feed system. †Significance: ***= P<0.001, **= P<0.01, *=P<0.05, + = P<0.10.

Table 9. *Effect of concentrate supplementation on milk production response and substitution rate for grass DM intake during each intake measurement period*

Strain of Holstein-Friesian	HP	HD	NZ	Significance
Measurement period 1				
Milk response (kg milk /kg concentrate)	0.93^{a}	0.87^{a}	0.45^{b}	*
Substitution rate (kg pasture/kg concentrate)	0.24^{a}	0.40^{ab}	0.61^{b}	*
Measurement period 2				
Milk response (kg milk /kg concentrate)	1.07^{a}	1.04^{a}	0.56^{b}	*
Substitution rate (kg pasture/kg concentrate)	0.16^{a}	0.22^{a}	0.43^{b}	*
Measurement period 3				
Milk response (kg milk /kg concentrate)	1.26^{a}	0.86^{b}	0.34^{c}	**
Substitution rate (kg pasture/kg concentrate)	0.17^{a}	0.46^{b}	0.49^{b}	*

HP = High production, HD = High durability, NZ = New Zealand.
[†]Significance: **=P<0.01, *=P<0.05.

Conclusion

Strain of Holstein Friesian, FS and their interaction had a significant effect on the milk production, DM intake and EB of spring-calving cows in pasture-based systems of production. This study shows that in a grass-based system, aggressive selection for increased milk production (HP strain) resulted in animals with higher milk production but with only small increases in pasture intake. Such animals are unable to meet their energy requirements for milk production in early lactation. More moderate selection for milk production (HD or NZ strains), results in animals with lower milk production, lower responses to concentrate, higher substitution rates and better energy balance at pasture.

The enhanced intake capacity per kg of BW of the NZ strain is desirable, as it should in theory result in greater feed efficiency ceteris parabus as greater intake as a proportion of size (maintenance requirements) will result in a greater proportion of total intake being available for increased productivity. Given the diversity that exists in genotype sensitivity in terms of DM intake and performance to a given environment, the prediction of genetic potential in future must be based on genotype and environment specific knowledge.

The effect of strain of Holstein-Friesian cow and feed system on reproductive performance.

Materials and Methods

This analysis was carried out at Curtins Farm, Moorepark, Co. Cork, Ireland over a three-year period from 2001 to 2003.

Reproductive management

Immediately post-calving and continuing until the end of the breeding season, cows were visually observed three times daily for signs of oestrus. At approximately 35 to 42 days post-partum each cow was examined to detect ovarian or uterine disorders using trans-rectal ultrasound imaging (ALOKA SDD 500V scanner with a 5MHz transducer, ALOKA Ltd., Tokyo, Japan). Cows with reproductive disorders (such as endometritis, pyometra or ovarian cysts) were recorded and treated appropriately.

Cows were inseminated, by artificial insemination (AI) only, over a 13-week period, starting in late April each year. Once mating started, oestrous detection was carried out four times daily (at am and pm milkings and 1200h and 2000h). Tail paint was used as an aid to oestrous detection and was re-applied twice weekly. The same experienced professional AI technician was used for all inseminations. Cows detected in oestrus for the first time at either 1200h or 2000h or at evening milking were inseminated the following morning. Cows detected in oestrus for the first time at the morning milking were inseminated that morning. All cows were inseminated with frozen-thawed semen from sires of their own genetic strain to generate replacement heifers. Once the sires intended for use during the breeding season were selected, a sample of frozen-thawed straws from each sire was examined for sperm motility and percentage of live sperm. Only sires with semen with greater than 50% sperm motility and greater than 60% of live sperm post-thaw were used for AI. The average motility and percentage of live sperm present in the semen used did not differ between strains.

Pregnancy detection was performed by ultrasound imaging at 30 to 37 days and again 60 to 67 days after AI. A final manual pregnancy examination was carried out 150 days after the beginning of the breeding season.

Reproductive measurements

The following reproductive measurements were calculated; gestation length (interval in days from successful insemination to subsequent parturition), mean calving date, calving to first observed oestrous interval (interval in calving to when standing oestrus was observed for the first time), 24-day submission rate (proportion of calved cows submitted for artificial insemination in the first 24 days of the breeding season), number of cows treated for reproductive disorders, calving to first service interval (interval (days) from calving to first service); calving to conception interval (interval (days) from calving to conception (excluding cases of late embryo mortality)), services per cow (number of serves received by each cow during the breeding season), conception rate to first service (COCEPT1), conception rate to second service (COCEPT2), conception rate to first and second service (COCEPT1_2), pregnancy rate after 6-weeks of AI (PREG6), incidence of late embryonic mortality, and overall pregnancy rate as a percentage of the cows initially inseminated, detected by rectal palpation 150 days after the start of the breeding season (PREG). COCEPT1, COCEPT2 and COCEPT1_2 were based on ultrasonographic pregnancy detection on cows that had not been re-inseminated within 30 to 37 days of the previous insemination and included cows that subsequently suffered embryonic mortality. Late embryonic mortality was calculated as the proportion of pregnancies that degenerated between ultrasonographic examinations at day 30 to 37 post AI and day 60-67 post AI. PREG6 was calculated as the percentage of all cows in the herd that conceived during the first 6 weeks of the breeding season and maintained the pregnancy to term. This is a measure of overall reproductive efficiency and encompasses the submission and conception rates in the first half of the breeding season.

Results

Effect of strain of HF and feed system on reproductive performance

There was no significant effect of feed system, interaction between strain of HF and feed system or interaction between strain of HF and parity for any of the reproductive variables measured and therefore only the main effects of strain and feed system are shown. Both the HD and NZ strains had an earlier mean calving date (49.6±2.66 and 43.4±2.75 day of year, respectively) compared to the HP strain (56.6±2.62 day of year). The NZ strain had a significantly shorter gestation length (278±0.8 days) than the HP (285±0.8 days) and HD (284±0.7 days) strains (Table 10).

No significant differences were detected between strains in the interval from calving to first observed oestrus, 24-day submission rate, services per cow, calving to conception interval or the incidence of late embryonic mortality. No significant differences were detected between strains in conception rate to first service (Table 11). The NZ strain had a higher CONCEPT2 (59%) than the HP strain (39%) and the HD strain (40%). The NZ strain also had a significantly higher CONCEPT1_2 (84%), PREG6 (73%) and higher overall PREG (91%) than the HP strain (69, 59 and 79%, respectively), with the HD strain being intermediate (77, 66 and 85%, respectively). The proportion of cows treated for reproductive disorders were not significantly different between strains.

Table 10. *Effect of strain of Holstein-Friesian and feed system on time-dependant reproductive parameters (2001-2004).*

	Strain of HF			s.e.	Sign.[†]	Feed system			s.e.	Sign.[†]
	HP	HD	NZ			MP	HS	HC		
Gestation length (days)	285[a]	284[a]	278[b]	0.8	***	283	282	281	0.8	
Calving day (day of year)	58[a]	51[b]	49[c]	2.7	**	53	54	52	2.2	
Calving to first oestrus (days)	45	40	39	2.2		39	42	43	2.2	
Calving to service interval (days)	78	74	76	1.1		92	100	100	1.1	
Services per cow (no.)	2.07[a]	1.79[b]	1.61[b]	0.199		1.86	1.77	1.83	0.083	
Calving to conception (days)	99	97	96	3.1		92	100	100	3.1	

HP = High production, HD = High durability, NZ = New Zealand, MP = Moorepark feed system, HS = High stocking rate feed system, HC = High concentrate feed system, s.e. = standard error for comparison between strain of Holstein-Friesian and between feed systems, [a b] Means with different superscripts within the same row are significantly different (P<0.05). [†]Significance: ***= P<0.001, **= P<0.01.

Table 11. *Effect of strain of Holstein-Friesian and feed system on reproductive performance (2001-2004).*

	Strain of HF			Sign.[†]	Feed system			Sign.[†]
	HP	HD	NZ		MP	HS	HC	
24-day submission rate (%)	78	90	88		90	79	87	
Cows treated for a reproductive disorder (%)	37	24	23		26	33	26	
Conception rate to first service (%)	45[a]	54[ab]	62[b]	**	56	51	54	
Conception rate to second service (%)	30[a]	41[b]	59[c]	**	37	51	37	
Conception rate to 1st and 2nd service (%)	63[a]	75[b]	84[c]	***	73	78	71	
6-week pregnancy rate (%)	54[a]	65[b]	74[b]	***	66	65	61	
Late embryo mortality (%)	11	9	6		5	12	9	
Overall pregnancy rate (%)	74[a]	86[b]	93[c]	***	84	82	86	

HP = High production, HD = High durability, NZ = New Zealand, MP = Moorepark feed system, HS = High stocking rate feed system, HC = High concentrate feed system, s.e. = standard error for comparison between strain of Holstein-Friesian and between feed systems [a b] Means with different superscripts within the same row are significantly different (P<0.05). [†]Significance: *=P<0.05, + = P<0.10.

Conclusions

Strain of HF had a significant effect on reproductive performance. Both the NZ and HD strains, selected for lower milk production and better reproductive traits, had better reproductive performance than a North American HF strain selected for high milk production. The results suggest that offering higher levels of concentrate supplementation may not alleviate the reduced reproductive performance the North American HF strain selected for high milk production. The results of this study do not suggest that North American HF genes should be excluded from the Irish national progeny testing program, rather it suggest that fertility traits be included in the national evaluation system and the national selection index. The study illustrates that genetics proven in pasture-based systems where compact seasonal calving is a pre-requisite, such as New Zealand, can be utilised to improve reproductive efficiency in the Irish national dairy herd.

The effect of strain of Holstein-Friesian cow and feeding system on postpartum ovarian function, animal production and conception rate to first service.

Materials and Methods

This analysis was carried out at Curtins farm, Moorepark Research Centre from January 2002 to June 2003.

Milk sampling and progesterone analysis

Milk samples, representative of the whole milking, were collected thrice weekly on Mondays, Wednesdays and Fridays during morning milking. Sampling began 5 days post partum and continued until 26 days after first AI. Immediately post milking, one potassium dichromate preservative tablet (Lactab Mark III, Thompson & Capper Ltd., Chesire, England) was added to each sample and was subsequently stored at 4°C until analysis. Milk progesterone concentrations were measured in representative unextracted samples of whole milk using enzymeimmunossay (Ridgeway Science Ltd, Rodmore Mill farm, Alvington, Gloucestershire, UK) based on the method of Sauer et al. (1986). The intra-assay co-efficient of variation for quality control was 15.7% and the inter-assay co-efficient was 13.7%. The sensitivity, calculated using the absorption of the blank standard minus 2 standard deviations, was 0.5ng/ml.

Defining luteal activity

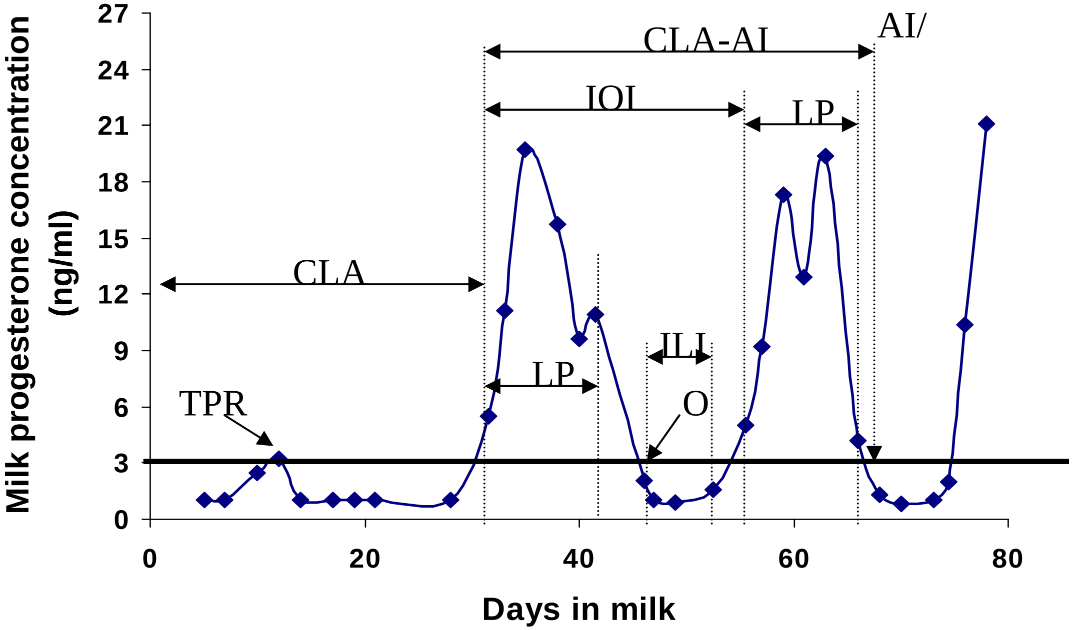
Endocrine parameter definitions were calculated based on the work of Royal et al. (2000) and Opsomer et al. (1998). These parameters are illustrated in Figure 2. Data for luteal parameters from cows that received hormonal treatments between calving and 26 days after first AI were excluded from the analysis subsequent to treatment, as the consequences of any treatment on progesterone profiles could not be determined. The following reproductive parameters were monitored using milk progesterone profiling:

Commencement of luteal activity post-partum (CLA): the number of days from calving to the first day of luteal activity
Luteal phase (LP): The average duration of luteal activity
Inter-ovulatory interval (IOI): the length of the interval between ovulations

Interval between commencement of luteal activity and first AI (CLA-AI): This is the interval from the initiation of the first luteal phase post partum to the day of first service.

Inter-luteal interval (ILI): The length of the interval between luteal phases.
Atypical ovarian hormone patterns: Irregular progesterone profiles were recorded where CLA $\geq$45 days post partum, where the ILI $\geq$12 days, where LP $\geq$19 occurs during the first luteal phase post partum, and where LP $\geq$19 occurs during the second and subsequent oestrous cycles post partum.
Embryonic mortality: Two types have been classified; fertilization failure/ early embryo mortality (FF/EEM) and late embryo mortality (LEM).

Figure 2. *Reproductive parameters monitored using milk progesterone profiling.*
Abbreviations: TPR = Transient progesterone rise, CLA= Commencement of luteal activity, LP = Luteal phase, CLA-AI = Commencement of luteal activity to AI interval, O = Ovulation, IOI= Inter-ovulatory interval, ILI= Inter-luteal interval.



Results

Overall, feeding system or the interaction of strain of HF by feeding system did not significantly affect the traditional or endocrine fertility parameters measured, therefore the effects of strain of HF and parity are presented.

Progesterone profiles

Strain of HF had no significant effect on CLA (Table 12). The mean CLA for all animals was 32.9 (s.e. 1.18) days, with the median of 27.3 days. CLA values ranged from 6 to 100 days with 42 and 85 percent of cows ovulating by day 26 and 60, respectively. The data were positively skewed (co-efficient of skewness of 1.18). Parity had an effect on CLA. The CLA value for first lactation animals (46 days) was longer than for second (32 days) and third (31.1 days) lactation animals. The frequency distribution of CLA is displayed in Figure 6.2. A total of 88 animals (37.6%) had one milk progesterone sample ≥3 ng/ml before the commencement of luteal activity with no significant difference between strains. The NZ strain had a shorter gestation length and consequently had an earlier mean calving date. The NZ group had more luteal phases because of their earlier calving date. Strain of HF had no significant effect on the percentage of cows displaying atypical hormonal patterns or the proportion of cows suffering early or late embryo mortality.

Table 12. *The effect of strain of Holstein-Friesian dairy cow on postpartum luteal activity based on the analysis of milk progesterone concentrations.*

	HP	HD	NZ	SEM	P Value
CLA (days)	33.6	34.2	37.7	2.32	N.S.
CLA to AI interval (days)	41.5	44.2	48.3	2.73	N.S.
First luteal phase length (days)	13.7^{a}	14.3^{a}	11.4^{b}	0.83	*
All luteal phase length (days)	14.3	14.0	13.5	0.52	N.S.
Luteal phases (No.)	2.28^{a}	2.39^{a}	2.77^{b}	0.122	*
First IOI length (days)	21.7	22.3	20.1	1.03	N.S.
First ILI length (days)	7.4	7.8	7.9	0.63	N.S.
Atypical hormonal patterns (%)	39	34	42		N.S.
Transient progesterone rises (%)	32	40	40		N.S.
Early embryo mortality (%)	43	27	32		N.S.
Late embryo mortality (%)	17	11	11		N.S.

CLA= Commencement of luteal activity, IOI= Inter-ovulatory interval, ILI= Inter-luteal interval, $^{a\ b\ c}$ Means with different subscripts within the same row are significantly different (P<0.05). P Values: N.S. = Non-significant, * = P<0.05.

Conclusion

Strain of Holstein-Friesian did not influence on the interval to commencement or subsequent pattern of ovarian activity, but did influence conception rate to first service. Feed system had a significant effect on milk production but did not influence endocrine activity or reproductive performance. This data shows that when animals receive sufficient quantities of high quality pasture, increasing the energy density of the diet through concentrate supplementation does not result in improved reproductive performance. The results also show that very early ovulation post partum (CLA <21 days) is associated with a prolonged calving to conception interval. Cows with abnormal progesterone profiles had similar milk production, liveweight, and body condition score to cows with normal progesterone profiles. The results of the present study also show that postpartum progesterone profiles did not differ between cows pregnant and not pregnant to first service.

The Effect of Strain of Holstein-Friesian and Feeding System on Lactation Curves Characteristics of Spring Calving Dairy Cows.

Materials and methods

Calculations

The Wilmink (1987) exponential model based on a non-linear parametric curve was fitted to daily milk, fat, protein, lactose and MS yield:

$y_t = a + be^{-0.05t} + ct$

In this model, *a*, *b* and *c* are parameters to be estimated and relate to the intercept, incline and decline parameters, respectively. In this equation, y_t represents the milk production at day *t* of lactation. Peak milk, fat, protein, lactose and MS yields were extrapolated from the lactation curves as well as the interval from calving to their occurrence.

Results

Effect of strain of HF and FS on lactation parameters

There was significant strain, FS, and strain by FS effects observed for all lactation parameters analysed. The effects of strain of HF, FS and strain of HF by FS interaction for the lactation parameters estimated are displayed in Figures 3 and 4.

For milk yield, the HP strain had the highest post-calving yield, the NZ strain had the lowest, while the HD strain was intermediate. The HC system, across all strains, had the highest post-calving yield for milk yield, the HS system had the lowest, while the MP system was intermediate. There was a significant interaction between strain of HF and FS for the increase in production between calving and peak production for milk, protein, lactose and MS yield. For milk yield, the greatest increase between calving and peak milk production was obtained with the HP strain, while both the HD and NZ strains displayed similar values. The greatest increase was obtained in the HC system, least in the HS system), while the MP system was intermediate. The increase from calving to peak for the HP animals in the HC system compared to the MP system was much greater than was observed with either of the other two strains and resulted in a significant strain of HF by FS interaction.

Both strain of HF and FS had a significant effect on the decline in milk production from peak to the end of lactation. The greatest decline in milk production from peak to the end of lactation was obtained with the HP strain, the lowest with the NZ strain while the HD strain was intermediate. The decline in the HS system was less than in both the HC and MP systems. The decline in MS yield from peak to the end of lactation was reduced in the HC system for both the HD and HP strains, while it was greatest with the NZ strain. Similarly, the decline in MS yield was much lower in the NZ strain in the MP system compared to both the HP and HD strains.

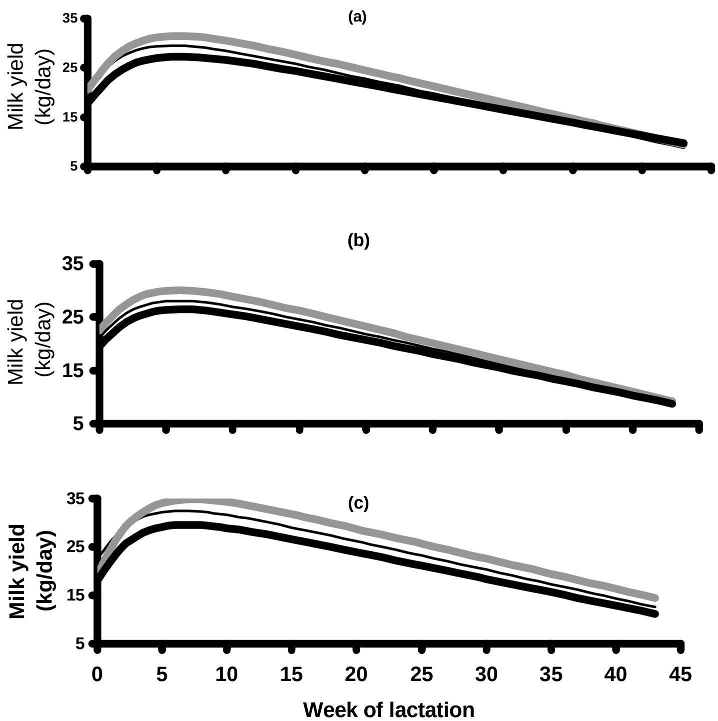


Figure 3. *Effect of strain of Holstein-Friesian on the lactation curve for milk yield for the*

HP, ▬▬▬ *HD* ——— *and NZ* ▬▬▬

strains in the (a) Moorepark, (b) High stocking rate and (c) High concentrate feeding systems.

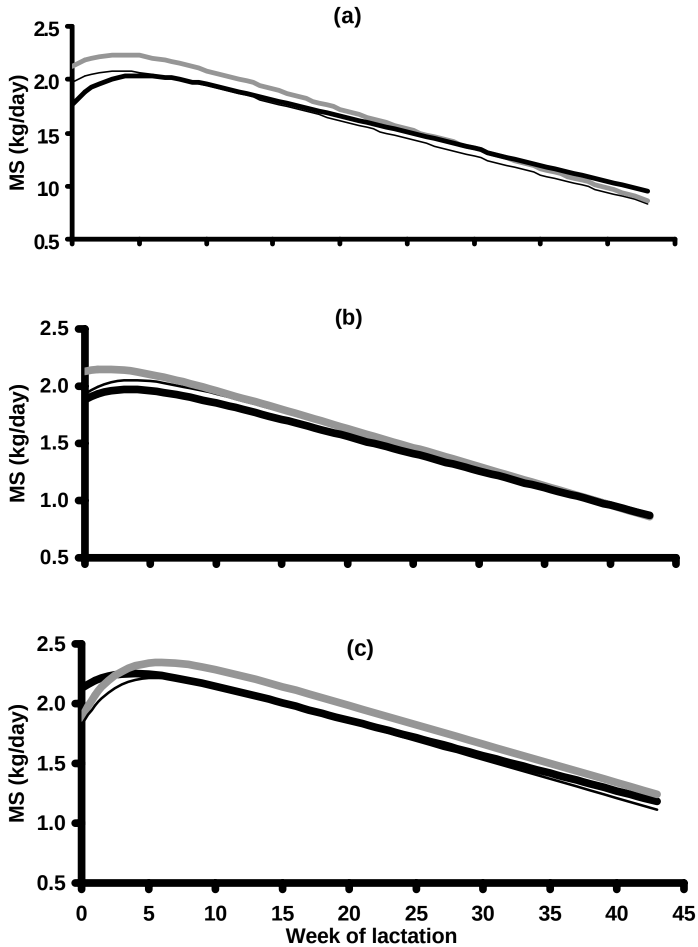


Figure 4. *Effect of strain of Holstein-Friesian on the lactation curve for milk solids (MS) yield for the HP HD , and NZ strains in the (a) Moorepark, (b) High stocking rate and (c) High concentrate feeding systems.*

Conclusion

Strain of HF, FS, parity and the interaction of strain of HF and FS had a significant effect on lactation curve characteristics of spring-calving cows in pasture-based systems of production. The data shows that in a grass-based system, aggressive selection for increased milk production (HP strain) in the North American HF has resulted in an animal with higher milk production post-calving and at peak but with poorer persistency of lactation. The NZ strain selected on a grass-based system for increased MS yield in a given volume of milk had the lower production post calving and at peak with a more persistent lactation curve. This data shows that offering higher levels of concentrate supplementation to high production North American HF cows on pasture-based system will improve their persistency of lactation.

The effect of strain of Holstein-Friesian and Feed system on Farm Profitability.

The optimum cow for any given system of production is the cow that results in the greatest farm profit within that environment. Such genetics can only be identified by combining all traits (production and health) of economic significance in a weighted index of economic merit and selecting sires from the top of this index.

Materials and Methods

The economic efficiency of three strains of Holstein-Friesian dairy cows in three pasture-based systems of milk production was compared using the Moorepark Dairy Systems Model (MDSM). Table 13 shows the performance data for the three strains included in the analysis.

When these animals were monitored on a low concentrate (MP system = 300kg conc. per cow) and a high concentrate (HC system = 1,500kg conc. per cow), the performance of the herds is shown in Table 8.1.

Table 13. *The milk production performance of the three strains in a 300-day lactation.*

System	MP system			HC system		
Strain of HF	HP	HD	NZ	HP	HD	NZ
Milk (kg/cow)	6900	6495	6093	7893	7434	6352
Fat content (%)	4.03	4.08	4.33	4.02	3.99	4.49
Protein content (%)	3.49	3.58	3.69	3.54	3.59	3.71

In real terms however, the milk production differential between strains outlined above would not be realised at farm level due to differences in fertility performance. The 6-week pregnancy rate and overall pregnancy rate was 54 and 74%, respectively for the HP strain, 65 and 86%, respectively for the HD strain and 74 and 93%, respectively for the NZ strain. When this fertility data is used to determine the expected performance of each strain at farm level, the performance data in Table

14 results. It is this performance data that is used to calculate the economic performance of the various groups.

Table 14. *The effect of strain of Holstein Friesian on milk production, liveweight and reproductive performance.*

Feed system	MP			HC		
Strain	HP	HD	NZ	HP	HD	NZ
Milk Production						
Milk (kg/cow)	6,235	6,113	5,865	7,136	6,969	6,107
Fat (g/kg)	40.3	40.8	43.3	40.2	39.9	44.9
Protein (g/kg)	34.9	35.8	36.9	35.4	35.9	37.1
Lactose (g/kg)	46.3	46.3	46.5	47.3	46.8	47.6
Average live-weight (kg)	525	539	506	529	549	506
Reproduction						
Gestation length (days)	284	284	278	284	284	278
42-day in-calf rate (%)	54	65	74	54	65	74
Overall pregnancy rate (%)	74	86	93	74	86	93
Total services per cow	2.07	1.79	1.61	2.07	1.79	1.61

Results

***Financial Performance*.**

The economic performance was calculated for two milk production scenarios in both the MP and HC systems. The milk production scenarios investigated were: EU milk quota applied at current (2004) milk prices (S1) and EU milk quota applied at farm level with lower decoupled milk price under Luxembourg Agreement (S2). Farm net profit included total receipts less total costs including a notional charge for full labour costs. Table 15 shows the key assumptions used in the farm model for the three scenarios.

Table 15. *Assumptions used in the model farm for the three scenarios.*

Strain of Holstein Friesian	HP	HD	NZ
Farm size (ha)	40.0	40.0	40.0
Quota (kg)	468,000	468,000	468,000
Reference fat (g/kg)	36	36	36
Gross milk price S1(c/kg)	26.7	26.7	26.7
Gross milk price S2 (c/kg)	22.3	22.3	22.3
Price protein to fat	2.00	2.00	2.00
Quota lease price (c/kg)	7.0	7.0	7.0
Replacement Heifer price (€)	1,397	1,397	1,397
Reference cull cow price S1 (€)	382	391	371
Reference cull cow price S2 (€)	270	270	257
Reference male calf price S1(€)	208	208	163
Reference male calf price S2(€)	102	102	64
Labour costs (€/month)	1,905	1,905	1,905
Concentrate costs S1 (€/tonne)	210	210	210
Concentrate costs S2 (€/tonne)	189	189	189
Opportunity cost of land S1 (€/ha)	471	471	471
Opportunity cost of land S2 (€/ha)	267	267	267

Table 16 shows the key herd output parameters from the model for the three strains for both the MP and HC systems at current milk prices (S1). The highest overall farm profit was observed with the NZ strain in the MP system. In the S1 scenario, the highest farm profit was realised with the NZ strain in the MP system and with the HD strain in the HC system. In the MP system, the NZ strain farm profit was €18,071 and €3,769 greater than with the HP and HD strains, respectively, while in the HC system the HD strain farm profit was €7,352 and €1,966 higher than the HP and NZ strains, respectively. The results also show that with both the HP and HD strains, the farm profit in the HC system was greater than that in the MP system, while with the NZ strain the farm profit in the MP system was greater than in the HC system.

Table 16. *Key herd parameters in a fixed quota scenario using present milk prices for three strains of Holstein Friesian cows; High Production (HP), High Durability (HD) and New Zealand (NZ) within the Moorepark (MP) and High Concentrate (HC) feeding system.*

Feed System	*MP*			*HC*		
Strain of Holstein-Friesian	HP	HD	NZ	HP	HD	NZ
Milk price (c/kg)	28.9	30.4	31.8	29.9	30.2	32.3
Total hectares used	35.8	36.4	35.6	28.9	29.5	27.8
Quota lease (kg)	-	-	-	-	-	-
# Cows calving	71.3	72.1	71.5	62.3	64.2	66.5
Livestock units (LU)	81.3	82.9	82.5	71.0	73.8	74.5
Stocking rate (LU/ha)	2.27	2.27	2.31	2.46	2.50	2.68
Labour units (h)	2,809	2,827	2,809	2,513	2,569	2,643
Milk produced (kg)	444,728	441,025	419,187	444,739	447,585	406,334
Milk sales (kg)	431,609	427,756	406,041	433,277	435,773	394,895
Fat sales (kg)	17,402	17,443	17,604	17,384	17,355	17,684
Protein sales (kg)	14,445	15,328	15,012	15,349	15,658	14,697
Milk returns (€)	124,885	130,050	129,078	129,908	131,551	127,440
Livestock sales (€)	41,501	39,166	34,973	36,341	34,921	32,587
Total costs (€)	133,581	122,270	113,399	127,436	120,415	115,964
Total profit per farm (€)	32,965	47,267	51,036	39,027	46,379	44,413
Margin per cow (€)	462	655	714	626	722	668
Margin per kg milk (cents)	7.6	11.1	12.6	9.0	10.6	11.3
Feed costs per kg milk (cer	5.38	5.11	4.99	6.15	3.38	7.06
Replacement costs (€)	33,237	23,103	15,643	29,117	20,566	14,561
Labour costs	34,631	34,957	34,688	30,985	31,752	32,688

Similar to the S1 scenario, the NZ strain achieved the highest farm profit again within a lower milk price (S2) scenario for the MP with the HD strain highest in the HC system (Table 17). Importantly, these results also indicate that in the MP system the differential in farm profit in favour of the NZ strain over both the HD and HP increases as milk price is reduced. In the MP system, the NZ strain farm profit in the S2 scenario was €19,024 and €4,642 greater than the HP and HD strains, respectively. The HD strain farm profit was €7,840 and €719 greater than the HP and NZ strains, respectively in the HC system. The results of this study highlight the large influence strain of cow has on farm profitability, and that this influence becomes even more important at lower milk prices.

Table 17. *Key herd parameters in a fixed quota scenario using present milk prices (S1) and in a reduced milk price scenario (S2) for three strains of Holstein Friesian cows; High Production (HP), High Durability (HD) and New Zealand (NZ) with the Moorepark feeding system.*

Feed System	MP			HC		
Strain of Holstein-Friesian	HP	HD	NZ	HP	HD	NZ
Milk price (c/kg)	24.1	25.4	26.5	25.0	25.2	26.9
Total hectares used	35.8	36.4	35.6	28.9	29.5	27.8
Quota lease (kg)	-	-	-	-	-	-
# Cows calving	71.3	72.1	71.5	62.3	64.2	66.5
Livestock units (LU)	81.3	82.9	82.5	71.0	73.8	74.5
Stocking rate (LU/ha)	2.27	2.27	2.31	2.46	2.50	2.68
Labour units (h)	2,809	2,827	2,809	2,513	2,569	2,643
Milk produced (kg)	444,728	441,025	419,187	444,739	447,585	406,334
Milk sales (kg)	431,609	427,756	406,041	433,277	435,773	394,895
Fat sales (kg)	17,402	17,443	17,604	17,384	17,355	17,684
Protein sales (kg)	14,445	15,328	15,012	15,349	15,658	14,697
Milk returns (€)	104,080	108,443	107,682	108,308	109,686	106,334
Livestock sales (€)	35,268	33,676	30,311	30,871	30,017	28,238
Total costs (€)	133,940	122,451	113,756	127,881	120,679	116,303
Total profit per farm (€)	5,407	19,789	24,431	11,303	19,143	18,424
Margin per cow (€)	76	274	342	181	298	277
Margin per kg milk (cents)	1.3	4.6	6.0	2.61	4.39	4.68
Feed costs per kg milk (cer	4.99	5.15	5.23	6.26	6.44	7.15
Replacement costs (€)	33,237	23,103	15,643	29,117	20,566	14,561
Labour costs	34,631	34,957	34,688	30,985	31,752	32,688

Conclusions

The purpose of this paper is not to recommend any given existing strain of HF for use in Irish pasture-based systems. The optimum genetics and production system is that combination which results in the greatest farm profit within that production environment. This paper demonstrates the magnitude of variation in farm profit arsing from various genetic selection strategies and production system choices and shows that genetic selection for increased milk production (HP strain) in conjunction with increased concentrate supplementation within Irish pasture-based systems will result in reduced profitability in future years relative to selection on a combination of production and reproductive traits (HD and NZ strains) with systems of low concentrate supplementation. These results validate the use of EBI as a valuable genetic selection tool but suggest that the weighting on fertility traits needs to be increased within the index to reflect the true value of fertility to farm profitability.

4. Implications

The purpose of this project report is not to recommend any given strain of HF for use in Irish pasture-based systems, but rather to demonstrate the magnitude of genetic variation that exists within the Holstein-Friesian population. Such large genetic variation is advantageous, as it will permit a greater response to selection using an index of economic merit for any given selection intensity or heritability.

This study also permits us to identify the characteristics of the optimum cow for a pasture-based system. In such a system, desirable characteristics include:

- High yield of good quality milk achieved from a predominantly pasture diet
- Persistent lactation profile without extreme peaks and troughs
- Good reproduction and health is essential to reduce the number of replacements animals that must be reared and maximise the utilization of grass by matching peak feed demand to peak grass growth

- Maintain adequate body condition through lactation on pasture without mobilising a large proportion of body reserves to meet production requirements
- High grass DM intake capacity in order to achieve high milk output without depleting body reserves through severe negative energy balance

This study shows that substantial differences exist between genotypes in terms of their sensitivity to the same environmental treatment. This implies that genetic, nutritional and physiological evaluation models must be based on environment specific estimates of trait expression. In terms of genetic evaluation models, such an evaluation would permit greater international genetic progress through the selection of the most appropriate genetics for a given environment.

Currently, INTERBULL use the multiple trait across country evaluation (MACE; Schaeffer, 1994) procedure to estimate an international evaluation for each sire on the scale of each member country based on the performance and number of progeny in each country and the genetic correlations between countries. The correlations between countries are less than unity, implying differences in trait definitions, differences in data collection and analysis procedures between countries and/or the existence of GxE interactions between countries. The MACE procedures treat the “same” trait in different countries as separate traits. No account is taken of GxE interactions within country despite differences in environmental conditions within country being as large as differences in conditions between countries (Hayes et al., 2003). Similarly, data originating from herds in close proximity but on opposite sides of a countries borders are treated as different traits despite their usually common climate and systems of production. Recent studies (Weigel and Rekaya, 2000; Zwald et al., 2003) have grouped herds from similar environmental characteristics together thereby facilitating a borderless genetic evaluation in dairy cattle. Such techniques, if adopted, could increase genetic progress through improved accuracy of genetic evaluations for each specific management environment.

The results obtained in this thesis suggest that until such time as environment sensitive cross-country evaluation techniques are adopted, genotypes should be selected from within the management system for which they are intended.

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