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Published in:
Livestock Science

DOI:
10.1016/j.livsci.2017.03.018

First published: 28/03/2017

Document Version
Peer reviewed version

Link to publication

Citation for pulished version (APA):
March, MD., Shalloo, L., Roberts, DJ., & Ryan, W. (2017). Financial evaluation of Holstein Friesian strains within composite and housed UK dairy systems. *Livestock Science*, *200*, 14 - 22. https://doi.org/10.1016/j.livsci.2017.03.018

Financial evaluation of Holstein Friesian strains within composite and housed UK dairy systems

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ABSTRACT

Milk production in a volatile global economy requires matching suitable genotypes within efficient regimes to deliver optimal and cost effective dairy farming systems. Here, we determine and describe differences in profitability between two genetic merits of Holstein Friesian cows managed within contrasting regimes. Physical performance of the genotypes within composite and housed systems is determined using data from a long term experiment based in Scotland, and economic analysis is carried out by application of Moorepark Dairy Systems Model simulations. Scenarios explore profitability differences between the management types when applied to a fixed herd size of 200 cows and a limited land availability of 80ha. Sensitivity analysis describes the economic effect of changes in both feed costs and milk price. Results illustrate benefits within each dairy system depending on available resources, and show considerable differences in inputs, outputs, costs and profitability of each of the management types. On average, animals of an improved genetic merit achieve 4p more profit for every litre produced than those average merit cows in a housed system, and 2p more within composite systems. Average genetic merit cows consuming a high forage diet plus grazing can be profitable however losses are made when this genotype is confined and fed high levels of concentrates. Systems which utilize high levels of imported concentrate feeds producing large milk volumes can be more vulnerable in circumstances where purchased feed costs are high and the milk price offered is low.

Key Words: Dairy, feed system, genetic merit, profit

1. Introduction

Due to a favourable climate for forage growth, the UK has a long tradition of milk production and has been among the top ten world producers for over 50 years (FAOSTAT, 2014). While the country is currently self sufficient in liquid milk, it is anticipated that production increases necessary to fully supply domestic requirements by 2020 correspond to 5-6 billion litres of additional milk. Additional milk produced, could come from a combination of new entrant dairy farmers, increased cow numbers on existing farms, as well as a continued rise in average milk yield per cow at farm level.

Financial success in farming, as with other businesses, can be described as the value of the outputs minus the costs of production. The profitability of a dairy farm is determined by the economic environment, (milk price, feed costs, etc.) as well as the relative availability of the key factors of production (land, labour, etc.) and the level of technical efficiency to utilize resources efficiently (McCarthy et al., 2007; Kelly et al., 2012). In recent years production costs such as feed, fuel and fertilizers have tended to increase, while farm gate milk prices have not risen at the same pace (DairyCo, 2013a; Defra, 2013; Defra 2013a). Wilson (2011) provides detailed net margin analyses of farms in England, and demonstrates that wide ranging performance found across the dairy sector can largely be explained by differences in yields, labour use, and milk price, and he recommends further investigation by clustering data into management groups.

UK dairy farming can be characterised by a broad array of production methods that range from low input grazing to more intensive higher yielding confined systems, as well as more conventional composite systems that adopt a varied to housing and feeding (DairyCo, 2012). A composite system can be defined in this study as a regime with all year round calving, grazing cows when availability of grass is adequate, and housing during inclement winter months when animals are indoors being fed conserved forage and concentrate individually through a TMR. All year round production results in a “flat” milk supply profile as processors are able to maximize their production capacity (Geary et al., 2013) however there are implications in relation to calving system and ultimately costs of production. To compete in a global economy, with anticipated milk price volatility, production systems need to be efficient regardless of the level of scale (Dillon et al., 2008).

The tendency for dairy farm profitability to be affected by variations in production expenditure differs depending on the relative importance of the cost component, which in itself will vary between production system types (Chamberlain, 2012). Benchmarking of UK dairy systems highlights feeding costs, labour, herd depreciation and power and machinery as key expenditures, and shows the potential for profit within each management type regardless of herd size, or yields per cow (DairyCo, 2014). Chamberlain (2012a) evaluates the benchmarked data to illustrate differences in financial performance between top and bottom producers within composite, high producing and grass based regimes and provides system specific areas of focus to improve profitability by lowering significant cost components associated with the respective management types. These studies show that as milk price drops in a volatile milk price environment that the benefits associated with cost control increase. Potential effects on profitability within the systems, stemming from differences in genetic merit, are not included in the benchmarking analysis.

Genetic merit of Holstein Friesian dairy cow can effect attributes such as biological performance (Ross et al., 2015; Roche et al., 2006), health (Ouweltjes et al., 2007), and fertility (Pollot and Coffey, 2008) which have a large influence on farm scale economics (McCarthy et al., 2007). Within pasture based dairy management, the production and profitability effects of feeding system (FS), genotype of Holstein Friesian, and their interactions is well researched (Horan et al., 2004; McCarthy et al., 2007). The objective of this research is to determine and describe differences in profitability between two divergent genotypes of Holstein Friesian cows within housed and composite systems by application of the Moorepark Dairy Systems Model with Langhill herd data. The Langhill group of Holstein Friesian cows are based in Scotland and form part of a long term investigation to determine genetic line x feeding system interactions which are further described by Pollott and Coffey (2008).

2. Materials and methods

The Moorepark Dairy Systems Model (MDSM) (Shalloo et al., 2004), is used to assess the economic effects of institutional, technical and market change at farm level and in the past has been used to evaluate the effect different components of grass based dairy systems. Some examples include the economic and environmental effect of genetics (Shalloo et al., 2004; Ryan et al., 2011; O Brien et al., 2011) breed (Prendiville et al., 2011), system (Patton et al., 2012) and technology (Hutchinson et al., 2013). Production data for this exercise was gathered from the Langhill dairy systems experiment, lasting 5 years and farming with two divergent genotypes of Holstein Friesian cows fed on contrasting diets (Chagunda, 2009). The experiment was carried out at SRUC's Crichton Royal Farm, in Dumfries, Scotland which is located on a silty loam soil. Recent examples of the application of Langhill data illustrating environmental and health effects of dairy systems include (Toma et al., 2013, Ross et al., 2014; Randall et al., 2015).

2.1. *Dairy systems description*

Herd production data was used to model the economic performance of each system, focussing on the interaction between genotypes and feeding systems. The herds are comprised of two contrasting genetic lines, one selected for increased production of milk fat plus crude protein (CP) yield, the Select line (S) which represents the top 5% of UK genetics and the Control line (C) which corresponds to the UK average genetics. On average the herd will Approximately 50 experimental cows, calving all year round were equally allocated to a low forage (LF) diet within a confined system or a high forage (HF) diet in a composite system where cows were turned out in spring and grazed on average for 163 (+/- 13) days within a rotational grazing system when grass grass available was sufficient. Cows were fed the respective diets as a total mixed ration (TMR). In addition cows received concentrate in the milking parlour with the HF group being fed a TMR during the winter months and pasture in summer and the LF group fed TMR all year round. Table 1 shows average concentrate and forage dietary inputs, milk production, milk composition, live weight, and reproductive performance data between 2006 and 2010.

Milk yield and milk composition for genotypes within feed systems were modelled for an average group for each month of calving rather than for individual cows. Cows were milked thrice daily and yields and milk composition were measured weekly. The systems were designed to allow each genotype to express its potential within each feed system largely unrestricted by limitations in feed supply. The ratios of feeds in the diets for the different systems were not influenced by milk yield, but the amount of feed offered was altered to meet the Net Energy (NE) of the system (Jarrige, 1989). The NE content of concentrate was determined using the feed unit for lactation (UFL) content of the ingredients (O'Mara, 1996). The NE values of the different feed stuffs were related to the in vitro DM digestibility whilst the NE content of the herbage was related to its chemical composition (Jarrige, 1989). Feed requirements evaluated from Langhill data were calculated using the MDSM to meet the net energy requirements for maintenance, milk production, pregnancy and body weight change across lactation (Jarrige, 1989) and were subsequently validated against the recorded data. Total concentrate DM intake averages derived from FS intake data were 3,572, 4,017, 1,209 and 1,272 kg respectively for the LFC, LFS, HFC and HFS groups respectively.

The proportion of cows removed from each herd comprised of cows that failed to become pregnant, as well as voluntary culling and cow mortality. Average calving intervals for the LFC, LFS, HFC, and HFS groups were 395, 411, 401 and 406 days respectively. For this analysis, parity structure was calculated to be representative of an actual replacement rate due to involuntary culling rate plus 10% of the remaining herd which were culled for voluntary reasons (Hutchinson et al., 2013). Actual parity structure in lactations 1,2 and 3+ was 38%, 27%, 35% and 38%, 32%, 30% for HFC and HFS groups respectively. Within the housed LF system the distribution of cows within lactations 1-3+ was 48%, 26%, 26% for S cows and 38%,31%,31% for C cows respectively. All replacements were brought onto the farm and rates used in the simulation of 30% and 32% for the C and S genotypes were comparable to DairyCo Milkbench average replacement rates for herds with similar production characteristics (DairyCo, 2012). Herd replacement rates from the systems study were not applied because the experimental protocol dictates that all milking cows remain in the experiment irrespective of production outcomes and exit the experimental herd after their third lactation as long as a replacement heifer is available.

2.2. *Moorepark Dairy Systems Model (MDSM)*

The MDSM integrates animal inventory and valuation, milk production, feed requirements, land and labour utilization, with an economic analysis. Land area was treated as an opportunity cost, with additional land rented in when required and leased out when not required for on-farm feeding of animals. Variable costs (fertilizer, contractor charges and veterinarian fees, artificial insemination, silage, and reseeding), fixed costs (machinery maintenance and running costs, farm maintenance, car, telephone, electricity, and insurance), and expenses were based on current prices (SAC 2012; DairyCo 2012). Table 2 shows cost assumptions applied in the MDSM for each production system.

2.3. *Parameters for economic comparison*

Labour costs included in the analysis were £37,500 per year (£15.00 per hour) for the first labour unit which represented the labour associated with management. Additional labour unit’s required for a general operative were priced at £25,000 per year (£10.00 per hour), based on standard industry average estimates for skilled agricultural labour (UK Government, 2013). One labour unit is defined as at least 2500 hours worked on the farm by a person over 18 years of age (DairyCo 2010; UK Government, 2013). The tasks within each system consisted of, milking and parlour washing, cow and calf care, grassland management, animal health, cleaning and miscellaneous. The time allocated to the different tasks was based on average labour estimates from O’ Donovan (2000); O’Brien et al. (2002 and 2007), and DairyCo (2010) and milking related labour increased by 33% as the number of milkings per cow per day increased from 2 to 3.

Forage production per hectare was estimated at 10 t of DM for pasture and grass silage in all systems (Bell et al., 2011) and herbage utilization was set at 84%. Purchased grass silage was valued at £100 t of DM. Maize silage and ammonia-treated wheat silage annual production was estimated at 10.2 t of DM / ha, and 11 t of DM / ha respectively (Bell et al., 2011) and was included at a cost of £116 and £110 t of DM when purchased onto the farm, respectively (SAC 2012; DairyCo 2012). Machinery and contracting costs were differentiated between FS based on the operations which took place on the farm.

Whilst housed, the HF and LF FS's were fed different proportions of ingredient in the TMR. The TMR was mixed and administered by contractors using a diet feeder to feed the average number of cows housed. The diet feeder capacity and feed output assumptions were based on one feeder administering feed for 200 cows in one hour. All slurry produced while cows were housed was applied by contractor and costs for slurry application were £35/hour with a spreading capacity of 19.8m^3 per hour. All male and female calves were sold at 1 month of age. The value of male Holstein Friesian calves was £60, the value of male and female beef breed calves was £200 and £150 respectively based on average market prices. Irrespective of genotype, all female calves were assumed sold for £250 with replacement heifers for both genotypes bought at market values of £1,300 throughout the year. The herds were bedded on sawdust, all year round for cows within the LF system, and in the winter months only for the HF herds. Profitable lifetime index (PLI) values for the LFS, HFS, LFC and HFC herds averaged 58.0, 57.3, -38.0, and -40.8 respectively.

The price schedule applied here was based on a typical UK liquid milk purchasing arrangement that comprises of a base value with bonuses and penalties. Bonus payments and penalties were implemented when milk constituents or hygienic quality deviated above and below a threshold, which was 37.0 g/kg of butterfat, and 30.0 g/kg of protein for composition. Payments for hygienic quality were penalized when mean bactoscan was >100,000 and somatic cell counts were greater than 325,000. A volume bonus derived from production scale added a minimum of 0.2p/l to daily total deliveries of between 900 and 999 litres, and increased up to a maximum bonus of 3.2p/l at daily totals of between 20,000 and 24,999 litres.

2.4. *System scenarios*

Two scenarios were simulated which centred on cows or land being limiting factors at farm level. In Scenario 1 (S1) land availability was limited to 80 ha and cow numbers were adjusted with the relationship between feed supply and feed demand while fully utilizing the land area. In Scenario 2 (S2) herd size was fixed at 200 cows and land area was adjusted to meet the feed requirements. All systems had the same pricing structure and a base milk price of 30p/l (MP1). Fresh weight purchased concentrate price was £275/T for the HF system, while the LF concentrate was 10% more expensive to take account of the higher specification concentrate used in this system. Land not utilized by the dairy system was leased out at £272 per hectare.

2.4. *Sensitivity analysis – Effect of milk and feed price variations*

Sensitivity analysis was undertaken to investigate the economic implications of feed and milk price volatility on overall profitability. Milk prices included in the sensitivity analysis were set at 25 p/l and 35p/l to represent a low (MP2), and high (MP3) milk price respectively and were similar to historic variations in milk price in the UK. For concentrate price, increases and decreases of 10% were applied to the base price of £275/T in CP2 and CP3 respectively and it was assumed that all production related variables were maintained as in CP1.

3. Results

Key herd output parameters and overall farm profitability from the simulated farm for the two genotypes managed on the different FS's in S1 and S2 are presented in Table 3 and Table 4.

3.1. *Scenario 1 - Land Area 80ha*

Constraining available land allowed herd numbers in the different FS's to vary based on their production demands and the capacity of the available land to meet those demands. The only feed stuff grown on the farm was grass, producing grazed grass and grass silage. All other forages and feed stuff's were purchased onto the farm which allowed the land available to be fully utilized for grass production. Due to the quantities of alternative forages and imported concentrate feeds, the LF FS was capable of carrying approximately double the number of cows than the HF FS. As genotype changed from C to S, the number of cows maintained within each system reduced by approximately 10%, because greater yields from the S genotype occur in conjunction with a higher demand for feed. Variations in herd size resulted in production output differences between feed system, the LF system averaged 3,886,441kg of milk, whereas the HF system averaged 1,417,064kg.

3.1.1 *Scenario 1 - Receipts*

Average milk returns were £1,263,307 and £458,424, for the LF and HF FS respectively as the LF system produced 64% more milk volume than the HF FS while utilizing the same area of land. Within each FS the highest milk sales stemmed from the S genotype which generated 8% more income from milk sales than the C genotype in the LF FS and 4% more income than C genotype in the HF FS. Differences in the number of cows managed within each FS affected livestock sales and the number of replacements required. Total livestock sales ranged from £48,527 to £119,293 as the number of cows increased with sales for the LF FS to nearly double those of the HF FS. On a per cow basis the livestock sales averaged £245 for the C genotype and £254 for the S genotype. Within each FS, the S genotype had 3% greater income from cull cow sales due to the extra bodyweight and numbers culled. The 2% lower replacement rate of the C genotype attracted 1% more in in calf sale values because a greater number of higher value calves were sold from C merit systems. Livestock sales ranged from 2.8 p/l to 4.1p/l (average 3.5p/l per system), which varied due to volume of milk produced and value of the livestock sold.

When all bonuses and penalties were included, total milk price received was 33.8, 34.1, 33.6 and 34.2 p/l for HFC, HFS, LFC and LFS systems respectively. Milk price bonuses constituted 3.9p/l on average for both the HF and LF FS's, because the HF systems received less bonus for volume, but more for fat, protein, and seasonal adjustments. The LFC system receives significantly less for non-volume bonuses and this brought down LFS. The C and S genotype received a mean milk price bonus of 3.7p/l and 4.2p/l respectively. The largest proportion of the milk payment bonus received by the HF and LF FS was for milk volume, which consisted of a bonus of approximately 2.5 and 3.0 p/l for the HF and LF FS respectively. No penalties were incurred for poor hygienic quality in this study.

3.1.2 *Scenario 1- Costs*

In a fixed land scenario, contrasting feed systems generated substantially different levels of costs with the main differences in these costs associated with purchased feed. The LF FS attracted the highest total feed costs due to the inclusion of more purchased feeds in the diet. However, in both FS's the S genotype attracted lower feed costs per litre because these animals produced an average of 20% additional milk per cow. Total feed costs were 12.0, 11.4, 20.0, 18.9 p/l for the HFC, HFS, LFC and LFS respectively. On a per cow basis, a 2% higher replacement rate for the S genotype compared to the C genotype gave rise to an additional 4% total replacement costs. However HF replacement costs averaged 6.3p/l whereas the LF replacements averaged 4.7p/l due to a dilution effect.

In S1, average total labour cost for the FS's were £117,642 and ranged from 3.5 to 6.4p/l depending on the FS and volume of milk produced. The LFS FS attracted the lowest per litre labour costs 3.5 p/l due to the greater volume of milk produced. However average total labour costs of £148,305 within the LF FS's were much higher than the average labour costs within the HF FS's of £86,979. Fixed costs for S1 varied with the volume of milk produced and ranged from 6.5 to 10.0p/l with differences arising from dilution effects. All systems were viewed to have similar farm infrastructure per cow but there were higher levels of cow places where cow numbers were larger. Total depreciation plus power and machinery costs averaged 6.5 and 5.0p/l for the HF and LF FS's respectively. Total costs of production for the different systems were, 35.9, 33.6, 38.9, and 35.1p/l for the HFC, HFS, LFC and LFS systems respectively. The LFC system had the highest total production costs (p/l) of all systems and the S genotype total production costs were on average 8% less than the C genotype due to the greater volume of milk produced.

3.1.3. *Scenario 1 - Profit*

In S1, utilizing all of the land available within contrasting systems of dairy production generated distinctly different total profits or losses within the different systems. The total profit for the different systems was £12,327, £46,404, -£115,112, and £32,993 for the HFC, HFS, LFC and LFS respectively. The most profitable system on a total farm basis was HFS which generated 40% more profit than LFS with 50% fewer animals and 65% less milk. The LFS system produced 6% more milk volume than LFC with 11% fewer cows in the herd. Within the HF system the S herd produced 2.5% more volume and generated 270% more profit with 7% fewer cows when compared to the C herd. In S1 the total profit was 1.0, 3.0, -3.1, and 0.8p/l, for the HFC, HFS, LFC and LFS respectively.

3.2. *Scenario 2– Fixed Herd Size*

In S2, each dairy herd size was set at 200 cows per system which resulted in the HF and LF systems not requiring the entire 80 ha of land for production. The land area required by each FS in S2 was 69, 74, 33, and 37 ha for the HFC, HFS, LFC, and LFS groups respectively and any land which was not required was leased out. Maintaining a fixed herd size resulted in lower production output differences between feed systems. Output ranged from 1,213,907kg from the HFC system, to 1,859,949kg for the LFS system.

3.2.1. *Scenario 2 Receipts*

As in S1, the highest milk sales stemmed from the LFS system which attracted approximately 21% higher milk returns than LFC. Average milk sales were £411,405 and £551,228 for the HF and LF FS's respectively and on average, when including both genotypes, the LF FS generated 34% more milk sales than the HF FS, from the same number of cows. Within the HF FS the S genotype produced 10% more volume and generated 12% more income from milk sales than the C genotype, from the same number of cows. With fixed herd sizes, replacement rates and cow live-weight affected livestock sales, which ranged from £48,527 to £51,091 for the different systems, with the S genotype having the greatest livestock sales.

Based on the pricing structure, the average milk price received was 33.0p/l, with a range of +- 0.3p/l. The average milk price bonus received per system was 3.0p/l. As in S1, the greatest proportion of the milk price bonus received in S2 was based on increased volume supplied, with all systems receiving between 2.4p/l, to 2.7p/l with the remaining bonuses and penalties implemented for milk composition and supply profile adjustment.

3.2.2. *Scenario 2 - Costs*

In S2, the main differences in costs were associated with replacement rates and purchased feed, which had an effect of genotype and feed system. Even though all systems had equal cow numbers there was a wide range of costs associated with the different systems depending on the level of production. Total feed costs ranged from £145,603 to £349,360 with feed costs representing between 38% and 60% of total production costs. Feed costs were 12.0p/l and 19.0p/l for the HF and LF FS respectively.

In S2, total labour costs for the different FS's were comparable at £76,830, £77,223, £80,412 and £80,798 for LFS, LFC, HFS and HFC respectively. Total labour costs range between 4.1p/l to 6.7p/l depending on the volume of milk produced. All other variable cost differences were mainly related to the level of production which increased as the input per cow increased. Fixed costs for S2 ranged from 6.7 to 10.4p/l as the volume of milk produced changed. The total cost of production for the different systems was 31.4, 29.5, 33.4, and 31.4p/l for the HFC, HFS, LFC and LFS systems respectively. Within the S genotype total production costs were 8% less than the C genotype in the LF system and 3% less in the HF system due to the greater volumes of milk produced, while the LF FS total production costs (p/l) were on average 5% more than the HF FS.

3.2.3. *Scenario 2 - Profits*

In S2, a fixed number of cows within contrasting systems of dairy production generated a wide range of total profits or losses. In S2, the total profit for the different systems ranged from a profit of £40,776 to a loss of £42,812 with the most profitable system being HFS. The total profit for all dairy systems was 0.5, 3.1, -2.8, and 1.1p/l, for the HFC, HFS, LFC and LFS respectively.

3.3 *Sensitivity analysis*

3.3.1. *Feed price volatility in S1 and S2*

In S1, applying MP1 and CP2, the effect of reducing concentrate feed costs by 10% caused total variable costs to reduce on average by £62,210 and £8,985 for the LF and HF systems respectively, compared to CP1. The reduction in concentrate costs resulted in a 76% increase in total profit for LFS however the LFC system still suffered a loss of -£992. Applying CP3 in S1, thus increasing the price of concentrate feed by 10%, results in reduced profits of £9,007, £8,622, £61,823 and £61,206, for HFC, HFS, LFC, and LFS respectively. The most profitable system in this case was HFS which generated a total profit of £37,782, while LFC made a substantial loss of £176,936 (Table 5)

In S2, the effect of reducing concentrate feed costs by 10% caused total variable costs to reduce for all systems on average by £8,072 and £27,389 for the HF and LF systems respectively. This cost reduction increased the margin per litre by 0.65p for HF systems, and due to a greater reliance on purchased feeds 1.6 p/l for LF systems. The LFS, HFS and HFC returned a profit of 3.8, 2.7 and 1.3 p/l while the LFC system lost 1.1p/l. Similarly in S2, increasing feed costs by 10% caused production costs to increase by 4% and 2% for LF and HF feed systems respectively, and this increase in costs reduced profitability for all systems by a mean of £17,498. Applying CP3 in S2 meant that the only feasible system was HFS with total profits of £32,751 equivalent to 3.26 p/l profit. Losses amongst the other systems were 0.05, 0.4 and 4.4 p/l for the HFC, LFS and LFC systems respectively (Table 6).

3.3.2. *Milk price volatility in S1 and S2*

In S1 MP2 CP1, the milk price sensitivity analysis highlighted that reducing milk price resulted in all dairy systems becoming loss making with total losses ranging from £23,552 in the HFS system to £301,999 in the LFC system. These figures represent an average reduction in total profit of £69,047 for the HF systems and £191,756 for the LF systems. The S genotype had approximately 4% less losses than the C genotype. In S1 MP3 CP1, the effect of increasing milk price allowed all systems to generate profits which ranged from £80,645 for HFC to £229,012 for LFS. The LFS followed by the LFC systems were most profitable due to the greater volume of milk produced, the LF FS generated over 100% more total profits than the HF FS (Table 5).

In S2, applying MP2 and CP1, the effect of reducing milk price to £0.25, resulted in losses for all systems which ranged from £24,330 for HFS to £120,449 for LFC. Reducing the MP in S2 resulted in total profit reductions of £59,096 to £91,476 for HFC and LFS respectively. The total profit ranged from a loss of 7.0p/l, to a loss of 1.8p/l. In S2, the effect of increasing base milk price to 35p/l resulted in increased total profit for all systems on average by £73,009 ranging from an increase of £59,096 to £91,172 for HFC and LFS respectively (Table 6).

4. Discussion

The motivation behind this research was to quantify the influence of genetic merit and management regime on the profitability of contrasting milk production systems and to identify their sensitivity to feed and milk price volatility. Biological herd performance data generated by the Langhill systems experiments and simulated within the MDSM alongside industry average figures, describe the differences in financial performance under two scenarios which applied a range of milk prices and feed costs. The MDSM simulations were based on limiting factors of available land and/or a fixed herd size, which affected total output, costs and ultimately profit.

4.1. *Comparison of Simulated Outputs*

In both scenarios, as milk price and feed price changed within all systems, simulations generated per litre net margins in a range of 9p/l profit to a 9p/l loss and similar findings were outlined by DairyCo (2014), where net margins ranged from a loss of 10p/l to a net profit of 10p/l. Wilson (2011) found net profits and losses of approximately 6p/l depending on the costs associated with production and the level of efficiency at which resources are utilized. Dairy system profitability varies depending on the level of production and the operating efficiency of the system (Wilson, 2011; Kelly et al., 2012). Results generated here were in line with farm revenue figures reported in the UK (DairyCo, 2014; Wilson, 2011), and Table 7 shows that the MDSM seems to provide a reliable indication of profitability of diverse genetic merits within housed and composite regimes.

Total fixed costs averaging 9.8 and 6.8 p/l for HF and LF FS's simulated by the scenarios are lower than Milkbench estimates which lie between 11.4 to 18.1p/l for composite and high output systems (Table 7). However this variation could stem from large differences in herd size, higher milk yields per cow and thrice daily milking differences. The maximum Milkbench high output herd size was 211 and the maximum yield was 8,959 litres per cow per year (DairyCo, 2012). However it is possible that this study has not fully captured fixed costs associated with confined systems due to assumptions made regarding contractor use, milking and housing facilities and labour requirements.

Simulated feed costs across the scenarios averaged from 10.8 to 21.7p/l which is higher than the 9.8 to 13.1p/l range (Table 7) found in the composite and high output farms surveyed for the DairyCo Milkbench study (DairyCo, 2014). However, in the HF FS, the feed costs averaged 11.7p/l and an average feed cost of 19.5p/l for the LF FS system reflects an average concentrate input of 4,060kg DM whereas the Milkbench average was 2,625kg DM (DairyCo, 2014). Herd replacement costs generated by S1 and S2 ranged from 4.0 to 6.4p/l at rates of 30% and 32% for Control and Select cows respectively which compare favourably with the Milkbench figure of 4.2p/l in a composite system with a 30% replacement rate. A replacement rate difference of 2% was applied in the MDSM however some studies have shown greater replacement rate differences associated with genetic selection for milk production (Horan et al., 2004; Evans et al., 2006).

The cost of replacing a cow are second only to feed costs and high replacement rates result in fewer cost reduction opportunities at farm level. Decreasing voluntary culling of all but the least productive animals can extend breeding opportunities (Heikkila et al., 2008) and could increase longevity in a herd especially if carried out in conjunction with importing heifers with more favourable genetic merits. Research suggests that economically beneficial optimal culling policies should not be based solely on potential to produce milk and should also include health characteristics (Stott and Kennedy, 1993). Labour costs simulated in the model averaged 6.2 and 4.3 p/l for HF and LF systems (Table 7) and are comparable to a 3.7 to 10.8 scale reported for labour costs within composite and high producing systems (DairyCo, 2014) and also TMR systems (DairyCo, 2010). The simulations results sit at the lower end of the Milkbench range because labour costs have been diluted by larger herd sizes and by the extra volume generated by thrice daily milking. This study could be improved by more detailed information regarding differences in labour requirements between feed systems and genotypes.

4.1. *Influence of Genetic Merit on Profit*

Studies with similar objectives highlight the influence of genetics on farm profitability within various types of grass based FS's (Shalloo et al., 2004a; McCarthy et al., 2007; Roche et al., 2006). On average, with equal herd sizes, the S merit produced 11.5% more milk than the C merit in the composite HF FS and 21.4% more milk than the C merit in the confined LF FS. When comparing systems with an equal land area of 80ha the S merit produced 3.8% more milk on average than the C merit in the composite HF FS and 8.4% more milk on average than the C merit in the confined LF FS. The scenario comparison of diverse Holstein Friesen strains, within traditional UK composite and high output confined dairy FS's presented here, shows the C merit attains an average of 57.8% less profit than the S merit within the HF FS. In the confined LF FS the C merit achieved an average of 78.4% less profit compared to the S merit. Across all scenarios, when milk price to feed cost ratio is plotted against per litre profitability and linear regression applied, on average, the S merit attains 4p more profit than a C merit when placed in a housed regime and 2p more profit than a C merit when in a composite regime (Fig. 1) which suggests a scaling effect. Figure 1 highlights that irrespective of feeding system, S merits become profitable at a lower milk price to feed cost ratio than the C merit. Confining a herd of average UK genetic merit Holstein Friesian cows and offering a high concentrate diet would only deliver substantial profit at high milk price to feed costs ratios albeit with a large herd size and significant increased cost at farm level.

4.2. *Influence of Feed System on Profit*

Herd profitability, is to some extent governed by the combined effect of the genetic potential of the animal, and the feed system adopted by the farmer (Holmes et al., 2002). McCarthy (2007) highlights the inaccuracy of generalizing differences in economic effects derived from diverse genetics across a range of management systems and this can be seen from the variation in profitability achieved by cows of the same merit within the HF and LF feed systems. Scenario results showed a greater difference in profits and losses between the S and C genotypes in the LF FS compared with the HF FS which arises from the cost and levels of purchased feeds. Whilst the LF system has the capacity to achieve greatest profits, particularly at high milk to feed price ratios, the inverse is true at low ratios where the propensity for losses within the LF system can be much higher. Potential yields from cows of lower or higher genetic merits are not sufficient to justify higher feed costs associated with intensive confined systems.

Volume based milk pricing policies, as operated within the UK dairy industry, incentivise systems of production that deliver high output. Encouragements for volume in the liquid milk market largely stem from the ability of processers to reduce transport costs and carbon emissions by attaining a full tanker from the lowest number of farms. Quinlan (2013) suggest that a volume based bonus as operated in the UK can dramatically exaggerate the economies of scale associated with larger volume based collections. The distribution of system profitability estimated by the model can be described as a function of revenues from milk plus livestock sales minus fixed and variable costs. Scenario 1 results showed that whilst absolute revenue attained from the HFS system was much less than the LF FS's, the HFS profits and margin per litre are higher (Table 3).

This study assumed that grass growth was 10 t DM/Ha and no effect of grass growth was included in the simulation even though it is appreciated that a wide variation in silage and grazing yields exists. A key feature of increasing output in the future will centre on expanding forage production and the cost of forages in both FS's discussed here could be reduced by improving growth and utilization of grass. Improved yields by increasing t DM/Ha in conjunction with increased forage quality will reduce costs as well as the requirement for land. Improving pasture management, for example by utilizing grass measurement techniques could increase production from forage (O'Donovan et al., 2002).

At farm level, moving from a profitable genetically select herd in a HF grazing system to a LF management regime will result in greater exposure to both input and output price volatility albeit with a propensity to generate large profits at high milk price to feed costs ratios (Fig. 1). Even though total attainable profit could be greater in LF FS's, scenarios applied in this study show the HFS FS was always more profitable on a per litre basis and not as exposed to milk and concentrate price volatility. When a milk to feed price ratio is applied as in Figure 1, the effect of difference in FS concentrate price within the model is apparent because when milk price is high and feed cost low the LFS system achieves equivalent profitability at a slightly lower ratio than in the HFS system.

As with most modelling tasks, limitations are inherent within the process and can cause aspects of the model to appear imperfect. Examples of weakness in this financial simulation could be the assumption that herbage (grazed grass and silage) production and utilisation were the same for both systems and also that contractors would carry out feeding operations. These assumptions could have led to underestimated fixed costs. Breeding objectives also vary as different countries can adopt diverse goals, and whilst the FS's described here would not be applicable to smallholder farmers the regimes are not dissimilar to those practised across the world including the EU, New Zealand and North America.

5. Conclusions

The simulation model applied here allows a financial comparison of contrasting UK dairy systems selling liquid milk and generates results consistent with similar benchmarked analysis. Model outputs highlight the economic consequences of biological change under controlled management, and evaluate financial performance under a combination of scenarios. Observed differences can be attributed to genetics, feed system or a combination of both. Results illustrate that genetic selection for increased production leads to substantial improvement in financial performance compared to an average UK merit when there is little deterioration in herd fertility, because increasing cow longevity or reducing replacement rate decreases production costs regardless of feed costs. Scenarios show that higher yields are not a solution if they are derived at the expense of feed costs. Systems operating on low cost inputs will be more financially sustainable under fluctuating milk and feed prices. Results emphasise the importance of dairy system selection at farm level and allude to the susceptibility of regimes interested in high volume production that is often encouraged by processors. In order to endure a volatile price environment, farmers operating continuously housed systems could retain a proportion of profits at high price ratios or modify their system in periods of low ratios. This research does not represent a complete range of dairy regimes found in the UK and the results presented here raise a question as to whether greater profitability could be achieved by high producing cows in dairy systems with lower concentrate inputs that focus on grazing, albeit with lower yields. Whilst this was outside the remit of this work, the model will allow follow on studies looking at increased forage based systems. Further research could also be carried out to assess the financial outcomes of reduced replacement rates across the systems.

ACKNOWLEDGEMENTS

This research was funded by the AHDB Research Partnership on Grassland Forage and Soils. SRUC receives grant-in-aid from the Scottish Government. The authors are grateful to two anonymous reviewers, Professor Alistair Stott and Anne Bray (SRUC, Edinburgh, UK) for their comments, and to staff and technicians at Crichton Royal Farm.

REFERENCES

Bell, M.J., Wall, E., Russell, G., Simm, G., Stott, A.W., 2011. The effect of improving cow productivity, fertility, and longevity on the global warming potential of dairy systems. J. Dairy Sci. 94, 3662–3678. doi:10.3168/jds.2010-4023

Chagunda, M.G., Römer, D.A.M., & Roberts, D.J., 2009. Effect of genotype and feeding regime on enteric methane, non-milk nitrogen and performance of dairy cows during the winter feeding period. Livest. Sci., 122, 323-332.

Chamberlain, T., 2012. Understanding the economics of dairy farming part 1: Income costs and profit. Livest. 17(5), 30-33 doi:10.1111/j.2044-3870.2012.00137.x

Chamberlain, T., 2012a. Understanding the economics of dairy farming part 2: Identifying the factors that drive profitability. Livestock 17(6), 25-28 doi:10.1111/j.2044-3870.2012.00150.x

DairyCo, 2010. Labour efficiency project. The Dairy Group, New Agriculture House, Blackbrook Park Avenue, Taunton, Somerset, TA1 2PX. Accessed Apr. 20, 2016. http://dairy.ahdb.org.uk/media/394099/labour%20efficiency%20report%20oct10%20no%20details.pdf.

DairyCo, 2012. Profiting from efficient milk production: Key findings of the Milkbench+ dairy benchmarking programme regarding the efficiency of dairy production in Britain. Agriculture and Horticulture Development Board, Warwickshire, UK. Accessed Apr. 20, 2016. http://dairy.ahdb.org.uk/non_umbraco/download.aspx?media=11427

DairyCo, 2013a. Farmgate milk prices. Agriculture and Horticulture Development Board, Warwickshire, UK.

DairyCo, 2014. Milkbench evidence report: Analysis of the Milkbench+ and international dairy benchmarking data for 2012/13. Agriculture and Horticulture Development Board, Warwickshire, UK.

Defra (Department for Environment, Food and Rural Affairs). 2013. United Kingdom milk prices and composition of milk. Accessed Apr. 20, 2016. https://www.gov.uk/government/publications/uk-milk-prices-and-composition-of-milk

Defra (Department for Environment, Food and Rural Affairs). 2013a. API – Index of the purchase prices of the means of agricultural production historic data for years 2003 to 2012. Accessed Apr. 20, 2016. https://www.gov.uk/government/publications/agricultural-price-indices

Dillon, P., Hennessy, T., Shalloo, L., Thorne, F., Horan, B., 2008. Future outlook for the Irish dairy industry: A study of international competitiveness, influence of international trade reform and requirement for change. Int. J. Dairy Technol. doi:10.1111/j.1471-0307.2008.00374.x

Evans, R.D., Wallace, M., Shalloo, L., Garrick, D.J., Dillon, P. 2006. Financial implications of recent declines in reproduction and survival of Holstein-Friesian cows in spring-calving Irish dairy herds. Agric. Syst. 89, 165–183. doi:10.1016/j.agsy.2005.08.008

FAOSTAT. 2014. Commodities production countries by commodity; milk whole fresh cow. Accessed Apr. 20. 2016. http://faostat.fao.org/site/339/default.aspx

Geary, U., Lopez-villalobos, N., Garrick, D.J., Shalloo, L., 2013. Spring calving versus split calving: effects on farm, processor and industry profitability for the Irish dairy industry. J. Agric. Sci. 152, 448-463. doi:10.1017/s0021859613000397

Heikkilä, A.-M., Nousiainen, J.I., Jauhiainen, L., 2008. Optimal replacement policy and economic value of dairy cows with diverse health status and production capacity. J. Dairy Sci. 91, 2342–52. doi:10.3168/jds.2007-0736

Holmes, C., Brookes, I., Garrick, D., Mackenzie, D., Parkinson, T., Wilson, G., 2002. Milk production from pasture - principles and practices. Massey University, New Zealand.

Horan, B., J.F. Mee, J.F. M. Rath, M., O'Connor, P., Dillon, P., 2004. The effect of strain of Holstein-Friesian cow and feed system on reproductive performance in seasonal-calving milk production systems. Anim. Sci. 79:453-467.

Hutchinson, A., Shalloo, L., Butler, S.T., 2013. Expanding the dairy herd in pasture-based systems: The role for sexed semen use on virgin heifers. J. Dairy Sci. 96:1312–1322.

Jarrige, R., 1989. Ruminant Nutrition. Recommended allowances Kelly, E., Shalloo, L., Geary, U., Kinsella, A. Thorne F.,

Wallace, M. 2012. Technical and scale efficiency of Irish dairy farms – the effects of size, intensification and specialisation. J. Agric. Sci. 150: 738-754.

McCarthy, S., Horan, B., Dillon, P., O'Connor, P., Rath, M., Shalloo, L., 2007. Economic comparison of divergent strains of Holstein-Friesian cows in various pasture-based production systems. J. Dairy Sci. 90, 1493–1505. doi:10.3168/jds.S0022-0302(07)71635-1

O'Brien, B., Gleeson, D., O'Donovan, K., Kinsella, J., Ruane, D.J., 2002. An examination of labour utilisation on Irish dairy farms. Project report no 4678. Teagasc Moorepark Dairy Production Research Centre.

O'Brien, B., Gleeson, D., Ruane, D.J., Kinsella, J., O'Donovan, K., 2007. Labour demand and supply on Irish dairy farms, with reference to specific scale dependent work routines. WIRE - Women in Rural Enterprise, Newport, UK, Journal of Rural Enterprise and Management 3, 33-44.

O’Brien, D., Shalloo, L., Buckley, F., Horan, B., Grainger, C., Wallace, M., 2011. The effect of methodology on estimates of greenhouse gas emissions from grass-based dairy systems. Agric. Ecosyst. Environ. 141, 39–48. doi:10.1016/j.agee.2011.02.008

O’ Donovan, K., 2000. Dairying 2000: Opportunities for the new millennium: Labour use study. National Dairy Conference Silver springs Hotel Cork.

O’Mara, F., 1996. A net energy system for cattle and sheep. Department of Animal Science and Production, Faculty of Agriculture, University College Dublin, Belfield, Dublin 4.

Ouweltjes, W., Beerda, B., Windig, J., Calus, M. L., Veerkamp, R., 2007. Effects of management and genetics on udder health and milk composition in dairy cows. J. Dairy Sci. 90, 229-238. doi:10.3168/jds.s0022-0302(07)72624-3

Patton, D., Shalloo, L., Pierce, K.M., Horan, B., 2012. A biological and economic comparison of 2 pasture-based production systems on a wetland drumlin soil in the northern region of Ireland. J. Dairy Sci. 95, 484–95. doi:10.3168/jds.2011-4558

Pollott, G.E., Coffey, M.P., 2008. The effect of genetic merit and production system on dairy cow fertility, measured using progesterone profiles and on-farm recording. J. Dairy Sci. 91, 3649–3660. doi:10.3168/jds.2007-0913

Prendiville, R., Shalloo, L., Pierce, K.M., Buckley, F., 2011. Comparative performance and economic appraisal of Holstein-Friesian, Jersey and Jersey × Holstein-Friesian cows under seasonal pasture-based management. Irish J. Agric. Food Res. 50, 123-140.

Quinlan, C., 2013. Optimisation of the food dairy co-op supply chain. A dissertation presented to the Department of Food Business and Development, National University of Ireland, Cork.

Randall, L., Green, M., Chagunda, M., Mason, C., Archer, S., Green, L., Huxley, J., 2015. Low body condition predisposes cattle to lameness: An 8-year study of one dairy herd. J. Dairy Sci. 98(6), 3766-3777. doi:10.3168/jds.2014-8863

Roche, J.R., Berry, D.P., Kolver, E.S., 2006. Holstein-Friesian strain and feed effects on milk production, body weight, and body condition score profiles in grazing dairy cows. J. Dairy Sci. 89, 3532–3543. doi:10.3168/jds.S0022-0302(06)72393-1

Roibas, D., & Alvarez, A. (2011). The contribution of genetics to milk composition: Evidence from Spain. Agric. Econ. 43(2), 133-141. doi:10.1111/j.1574-0862.2011.00571.x

Ross, S. A., Chagunda, M. G., Topp, C. F., Ennos, R., 2014. Effect of cattle genotype and feeding regime on greenhouse gas emissions intensity in high producing dairy cows. Livest. Sci. 170, 158-171. doi:10.1016/j.livsci.2014.09.011

Ross, S.A., Chagunda, M.G.G., Topp, C.E., Ennos, R., 2015. Biological efficiency profiles over the lactation period in multiparous high-producing dairy cows under divergent production systems. Arch. Anim. Breed. 58(1), 127-35. doi:10.5194/aab-58-127-2015

Ryan, W., Hennessy, D., Murphy, J.J., Boland, T.M., Shalloo, L., 2011. A model of nitrogen efficiency in contrasting grass-based dairy systems. J. Dairy Sci. 94, 1032–1044. doi:10.3168/jds.2010-3294

Scottish Agricultural College (SAC), 2012. The farm management handbook 2011-2012. SAC Consulting, West Mains Road, Edinburgh, EH9 3JG.

Shalloo, L., Dillon, P., Rath, M., Wallace, M., 2004. Description and validation of the Moorepark Dairy System Model. J. Dairy Sci. 87, 1945–59. doi:10.3168/jds.S0022-0302(04)73353-6

Shalloo, L., Kennedy, J., Wallace, M., Rath, M., Dillon, P., 2004a. The economic impact of cow genetic potential for milk production and concentrate supplementation level on the profitability of pasture based systems under different EU milk quota scenarios. J. Agric. Sci. 142:357-369.

Stott, A.W., Kennedy J.O., 1993. The economics of culling dairy cows with clinical mastitis. Vet. Rec. 133, 494–499.

Toma, L., March, M., Stott, A., Roberts, D., 2013. Environmental efficiency of alternative dairy systems: A productive efficiency approach. J. Dairy Sci., 96(11), 7014-7031. doi:10.3168/jds.2013-6911

United Kingdom Government, 2013, Agricultural workers rights. Accessed Apr.20.2016

https://www.gov.uk/agricultural-workers-rights/pay-and-overtime

Wilson, P., 2011. Decomposing variation in dairy profitability: the impact of output, inputs, prices, labour and management. J. Agric. Sci. 149, 507–517. doi:10.1017/S0021859610001176

Table 1. Key production values for Select and Control genotypes managed under Low and High Forage feed systems

Characteristic [b]	Production System [a]			
	HFC	HFS	LFC	LFS
Average milk yield, kg/cow	6833	7575	8824	10553
Fat yield per cow, g/kg	38.1	40.1	36.2	38.7
Protein yield per cow, g/kg	31.5	32.9	30.8	33.1
Lactose yield per cow, g/kg	43.5	43.1	43.1	43.0
Butterfat, %	3.81	4.01	3.62	3.87
Protein, %	3.15	3.29	3.08	3.31
Milk solids, kg/ cow	475	553	591	757
Average weight, kg/cow	580	608	614	625
Total kg grazed grass per cow	1650	1815	0	0
Total kg DM silage per cow	2173	2311	2085	2353
Total kg DM maize per cow	678	723	623	709
Total kg DM alkalage per cow	678	723	415	472
Total kg DM concentrate per cow	1288	1334	3813	4309
Total mixed ration ME[c] MJ/kg DM	11.4	11.4	12.2	12.2

[a] HFC=High Forage Control, HFS=High Forage Select, LFC=Low Forage Control, LFS=Low Forage Select

[b] DM = Dry matter

[c] ME = Metabolisable energy

Table 2. Assumptions applied in the MDSM for Select and Control genotypes of Holstein-Friesian cows managed under a High or Low Forage feed system.

Item [b]	Production System [a]			
	HFC	HFS	LFC	LFS
Replacement heifer price, £	1,300	1,300	1,300	1,300
Labour, hrs/cow/year	34.1	34.0	32.4	32.2
Milk price, ppl £	0.30	0.30	0.30	0.30
Average culled cow price, £/cow	306	321	324	330
Average male calf price, £/calf	74	73	74	73
Concentrate cost fresh weight, £/tonne	275	275	303	303
Silage cost, £/tonne DM	100	100	100	100
Maize cost, £/tonne DM	116	116	116	116
Alkalage cost, £/tonne DM	110	110	110	110
Maize yield, DM/ha	10.2	10.2	10.2	10.2
Alkalage yield, DM/ha	11.0	11.0	11.0	11.0
Opportunity land cost, £/ ha	272	272	272	272
Replacement rate %	30	32	30	32
Total services per cow	2.5	2.5	2.5	2.5

[a] HFC=High Forage Control, HFS=High Forage Select, LFC=Low Forage Control, LFS=Low Forage Select

[b] DM = dry matter

Table 3. Key outputs for Scenario 1 (S1) at a milk price of 30ppl for the Select and Control genotypes managed under Low and High Forage feed systems.

Variable	Production System [a]			
	HFC	HFS	LFC	LFS
Farm area, ha	80	80	80	80
Total land required, ha	80	80	80	80
Livestock (incl. young stock)	231	215	482	430
Cows calving	206	190	429	380
Stocking rate, cows/ha	2.88	2.69	6.02	5.38
Milk produced, kg	1,399,634	1,434,494	3,773,992	3,998,890
Milk sales, kg	1,372,792	1,409,480	3,717,945	3,948,838
Fat sales, kg	52,261	56,502	134,493	152,658
Protein sales, kg	43,181	46,374	114,514	130,536
Milk returns, £	449,850	466,997	1,213,671	1,312,943
Livestock sales, £	55,951	54,311	119,293	109,845
Replacement costs, £	89,154	89,927	178,390	187,770
Total labour costs, £	89,390	84,568	187,113	168,820
Total fixed costs, £	139,802	132,800	281,291	256,275
Concentrate costs, p/l	0.065	0.061	0.163	0.154
Total feed costs, p/l	0.12	0.11	0.20	0.19
Total costs, £	502,753	483,002	1,448,077	1,387,958
Margin per cow, £	53.5	215.9	-239	77
Margin per litre, p/l	0.009	0.032	-0.031	0.008
Total profit, £	12,327	46,404	-115,112	32,993

[a] HFC=High Forage Control, HFS=High Forage Select, LFC=Low Forage Control, LFS=Low Forage Select.

Table 4. Key outputs for Scenario 2 (S2) at a milk price of 30ppl for the Select and Control genotypes managed under Low and High Forage feed systems.

Variable	Production System [a]			
	HFC	HFS	LFC	LFS
Farm area, ha	80	80	80	80
Total ha used	69	74	33	37
Livestock (incl. young stock)	200	200	200	200
Cows calving	178	177	178	177
Stocking rate, cows/ha	2.88	2.69	6.02	5.38
Milk produced, kg	1,213,907	1,335,034	1,567,598	1,859,949
Milk sales, kg	1,190,627	1,311,754	1,544,318	1,836,669
Fat sales, kg	45,326	52,585	55,864	71,004
Protein sales, kg	37,451	43,159	47,566	60,714
Milk returns, £	388,966	433,845	498,326	604,251
Livestock sales, £	48,527	50,545	49,551	51,091
Replacement costs, £	77,994	82,972	77,994	82,972
Total labour costs, £	80,798	80,412	77,223	76,830
Total feed costs, p/l	0.12	0.11	£0.20	0.19
Concentrate costs, p/l	0.065	0.061	0.163	0.154
Total fixed costs, £	126,236	126,197	123,881	124,425
Total costs, £	430,086	442,048	590,558	633,366
Margin per cow, £	31.8	203.9	-214.1	104.8
Margin per litre, p/l	0.005	0.031	-0.027	0.011
Total profit, £	6,354	40,776	-42,812	20,957

[a] HFC=High Forage Control, HFS=High Forage Select, LFC=Low Forage Control, LFS=Low Forage Select.

Table 5. Sensitivity analysis for S1 with a land area of 80 ha under a range of concentrate costs and milk prices.

FS [d]	Concentrate 2 [a]			Concentrate 1 [b]			Concentrate 3 [c]		
	MP2[e]	MP1 [f]	MP3[g]	MP2	MP1	MP3	MP2	MP1	MP3
					Milk Returns £				
HFC	381,211	449,850	518,490	381,211	449,850	518,490	381,211	449,850	518,490
LFC	1,027,773	1,213,671	1,399,568	1,027,773	1,213,671	1,399,568	1,027,773	1,213,671	1,399,568
HFS	396,523	466,997	537,471	396,523	466,997	537,471	396,523	466,997	537,471
LFS	1,115,501	1,312,943	1,510,385	1,115,501	1,312,943	1,510,385	1,115,501	1,312,943	1,510,385
					Feed Costs p/l				
HFC	0.114	0.114	0.114	0.120	0.120	0.120	0.127	0.127	0.127
LFC	0.184	0.184	0.184	0.200	0.200	0.200	0.217	0.217	0.217
HFS	0.108	0.108	0.108	0.114	0.114	0.114	0.120	0.120	0.120
LFS	0.173	0.173	0.173	0.189	0.189	0.189	0.204	0.204	0.204
					Total Costs £				
HFC	483,570	483,068	482,567	492,751	492,249	491,747	501,931	501,429	500,928
LFC	1,386,903	1,385,574	1,384,245	1,449,066	1,447,737	1,446,408	1,511,229	1,509,900	1,508,571
HFS	464,940	464,422	463,905	473,731	473,213	472,695	482,521	482,003	481,485
LFS	1,326,720	1,325,297	1,323,875	1,388,977	1,387,554	1,386,132	1,451,233	1,449,811	1,448,388
					Total Profit £				
HFC	-46,804	21,334	89,472	-55,811	12,327	80,465	-64,817	3,321	71,459
LFC	-239,836	-53,995	130,574	-301,999	-115,112	69,456	-364,162	-176,936	8,429
HFS	-14,930	55,027	124,983	-23,552	46,404	116,360	-32,175	37,782	107,738
LFS	-101,821	94,198	290,218	-163,631	32,993	229,012	-225,887	-28,213	167,806
					Total Profit p/l				
HFC	-0.033	0.016	0.066	-0.040	0.010	0.059	-0.046	0.003	0.053
LFC	-0.065	-0.015	0.035	-0.081	-0.031	0.019	-0.098	-0.048	0.002
HFS	-0.010	0.040	0.089	-0.016	0.034	0.083	-0.022	0.027	0.077
LFS	-0.026	0.024	0.073	-0.041	0.008	0.058	-0.057	-0.007	0.042

[a] Concentrate cost 1: High Forage = £275.00, Low Forage = £302.50. [b] Concentrate cost 2: High Forage = £247.50, Low Forage = £272.50.[c] Concentrate cost 3: High Forage = £302.50, Low Forage = £332.75.
[d] FS = Feed Systems; HFC=High Forage Control, LFC=Low forage Control, HFS=High Forage Select, LFS = Low forage Select. [f] MP1 = 30p/l, [e]MP2 = 25p/l, [g]MP3 = Milk Price 35p/l.

Table 6. Sensitivity Analysis for S2 with a fixed herd size under a range of concentrate costs and milk prices.

FS [d]	Concentrate 2 [a]			Concentrate 1 [b]			Concentrate 3 [c]		
	MP2[e]	MP1 [f]	MP3[g]	MP2	MP1	MP3	MP2	MP1	MP3
	Milk Returns £								
HFC	329,435	388,966	448,497	329,435	388,966	448,497	329,435	388,966	448,497
LFC	421,110	498,326	575,542	421,110	498,326	575,542	421,110	498,326	575,542
HFS	368,257	433,845	499,433	368,257	433,845	499,433	368,257	433,845	499,433
LFS	512,418	604,251	696,084	512,418	604,251	696,084	512,418	604,251	696,084
	Feed Costs p/l								
HFC	0.113	0.113	0.113	0.120	0.120	0.120	0.126	0.126	0.126
LFC	0.183	0.183	0.183	0.199	0.199	0.199	0.216	0.216	0.216
HFS	0.108	0.108	0.108	0.114	0.114	0.114	0.12	0.12	0.12
LFS	0.172	0.172	0.172	0.188	0.188	0.188	0.203	0.203	0.203
	Total Costs £								
HFC	422,559	422,124	421,689	430,521	430,086	429,651	438,484	438,049	437,614
LFC	565,289	564,737	564,185	591,110	590,558	590,006	616,930	616,378	615,826
HFS	434,349	433,867	433,385	442,530	442,048	441,566	450,711	450,229	449,747
LFS	605,071	604,409	603,747	634,027	633,366	632,704	662,984	662,322	661,661
	Total Profit £								
HFC	-44,931	14,165	73,262	-52,742	6,354	65,450	-60,554	-1,458	57,639
LFC	-94,629	-17,425	59,238	-120,449	-42,812	33,852	-146,269	-68,501	8,466
HFS	-16,305	48,801	113,906	-24,330	40,776	105,882	-32,354	32,751	97,857
LFS	-41,747	49,425	140,597	-70,519	20,957	112,129	-99,476	-7,511	83,661
	Profit p/l								
HFC	-0.037	0.012	0.062	-0.043	0.005	0.054	-0.050	0.00	0.047
LFC	-0.060	-0.011	0.039	-0.077	-0.027	0.022	-0.093	-0.044	0.005
HFS	-0.012	0.037	0.087	-0.018	0.031	0.079	-0.024	0.025	0.073
LFS	-0.022	0.027	0.077	-0.038	0.011	0.060	-0.053	-0.004	0.044

[a] Concentrate cost 1: High Forage = £275.00, Low Forage = £302.50. [b] Concentrate cost 2: High Forage = £247.50, Low Forage = £272.50. [c] Concentrate cost 3: High Forage = £302.50, Low Forage = £332.75.
[d] FS = Feed Systems: HFC=High Forage Control, LFC=Low forage Control, HFS=High Forage Select, LFS = Low forage Select. [e] MP1 = 30p/l, [f]MP2 = 25p/l, [g]MP3 = Milk Price 35p/

Table7. Key model outputs compared to UK benchmark range for composite and high outputs systems p/l.

Financial Comparison p/l	S1 & S2 Average		Benchmark Range [a]	
	High Forage	Low Forage	Minimum	Maximum
Feed Costs	11.7	19.5	9.8	13.1
Replacement cost	6.3	4.8	2.7	4.1
Total variable cost	14.3	21.7	12.9	16.5
Labour costs	6.2	4.2	3.5	6.6
Total fixed costs	9.8	6.8	11.4	18.1

[a]DairyCo (2014)