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DAIRY GENETICS AND HEIFER MANAGEMENT

Proceedings of an AgriSearch seminar held at the Agri-Food and Biosciences Institute Hillsborough, 28th June 2010

Department of Agriculture and Rural Development
www.dardni.gov.uk

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Welcome

Having allocated funds for research projects on behalf of the local farming industry, AgriSearch is very keen to see the results of that research work disseminated to the relevant farmers within Northern Ireland.

The people invited to this seminar are in contact with dairy farmers during the course of their day-to-day work. We believe that you are in a position to help make farmers aware of the research results and to promote the uptake of advice that stems from the research.

A more efficient industry will be more competitive in the market and that is ultimately in the best interests of the economy of Northern Ireland.

The scientists at the Agri-Food and Biosciences Institute (AFBI) Hillsborough have put together this technical seminar. We trust that you will find it useful.

Welcome to the seminar and thank you for attending.

James Campbell

AgriSearch chairman

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Research on breeding goals for the Northern Ireland dairy industry

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Introduction

Dairy enterprises in Northern Ireland continue to change in response to today's fast moving and competitive market. Herd size has increased, on average, by 1.5 cows/year and currently stands at 75 cows (DARD, 2009) (Figure 1). Over 55% of dairy cows in Northern Ireland are now found in herds of over 100 cows (Table 1). At the same time milk production per cow has risen significantly. Over the period from 1986 to 2006 milk yield per cow increased, on average, by 110 litres/cow/year (from 4635 to 6830 litres/cow), equating to a 2.4% increase in production per annum (Figure 2). However, over the last couple of years there has been a slight reversal in the trend with a milk yield per cow of 6350 litres in 2009.

The long-term trend of increased milk production per cow has been the result of increases in the genetic potential of cows for milk production and increased levels of concentrate feeding rather than big changes in forage quality. The change in genetic merit for milk production is illustrated by the trends in Predicted Transmitting Abilities

(PTA's) for milk yield (Figure 3) and fat & protein yield (Figures 4 and 5) within milk recorded Holstein-Friesian cows in Northern Ireland. Over the period, milk yield PTAs increased on average by 41.8 kg per year. Changes in the genetic merit of milk recorded cows with genetic evaluations are likely to be followed across the entire dairy cow population and equate to an 84 kg increase in milk production/cow per annum.

Figure 1 Average dairy herd size 1981-2009 (DARD, 2009)

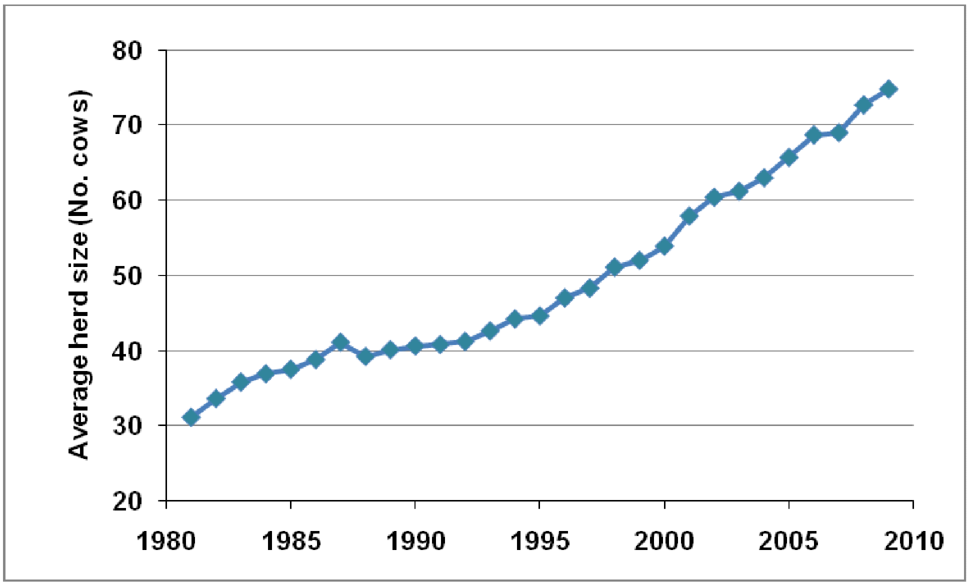


Figure 2 Average milk yield/cow 1981-2009 (DARD, 2009)

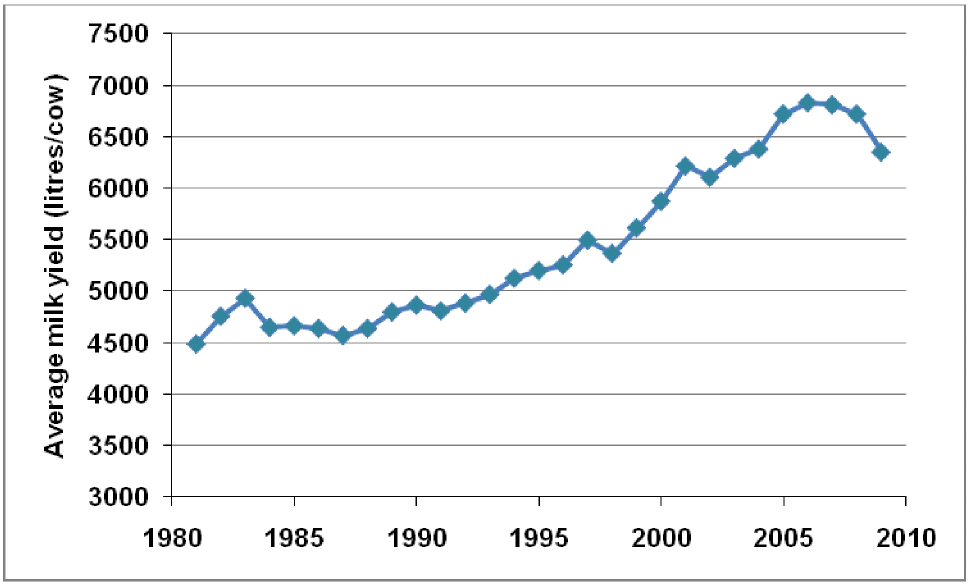
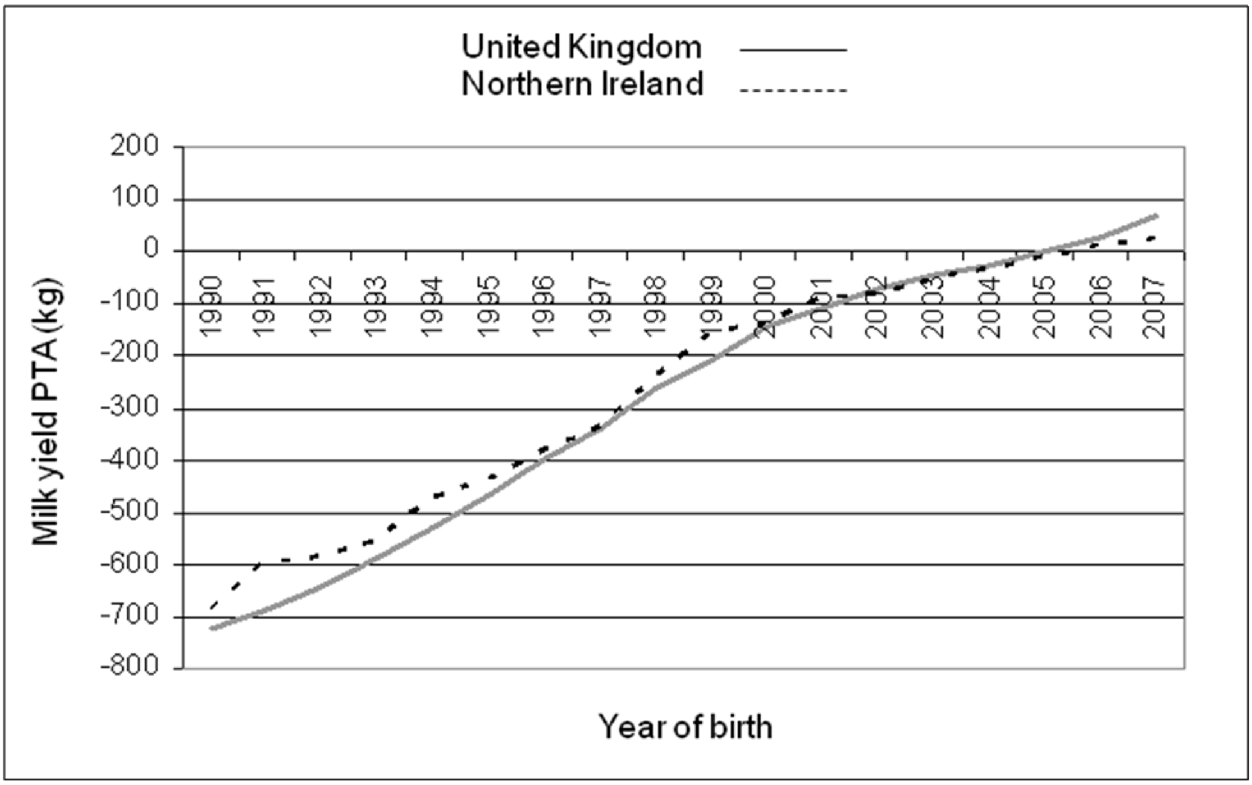


Table 1 Distribution of herd sizes in the Northern Ireland dairy industry (DARD, 2009)

Herd size	% farms	% of cows
Less than 50	41.7	14.4
50-99	31.8	30.0
100 cows plus	26.5	55.5

Figure 3 PTAs for milk yield (kg) by year of birth for milk recorded cows



It is well established that selection for production alone causes negative effects on health and fertility traits such as udder health (Heringstad *et al.*, 2003) and reproductive performance (Kadarmideen *et al.*, 2003). Until the early 2000's selection programmes were largely focussed solely on production traits. Thus it is not surprising that the PTA for calving interval in pedigree registered Holstein-Friesian females increased on average by about 5 days over the period from 1990 to 2000 (Figure 5). Thereafter, the decline in genetic merit for calving interval has slowed down as the index of total economic merit in the UK (Profitable Life Index (PLI)) began to incorporate fitness traits (Figure 6).

Figure 4 PTAs for protein yield (kg) by year of birth for milk recorded cows

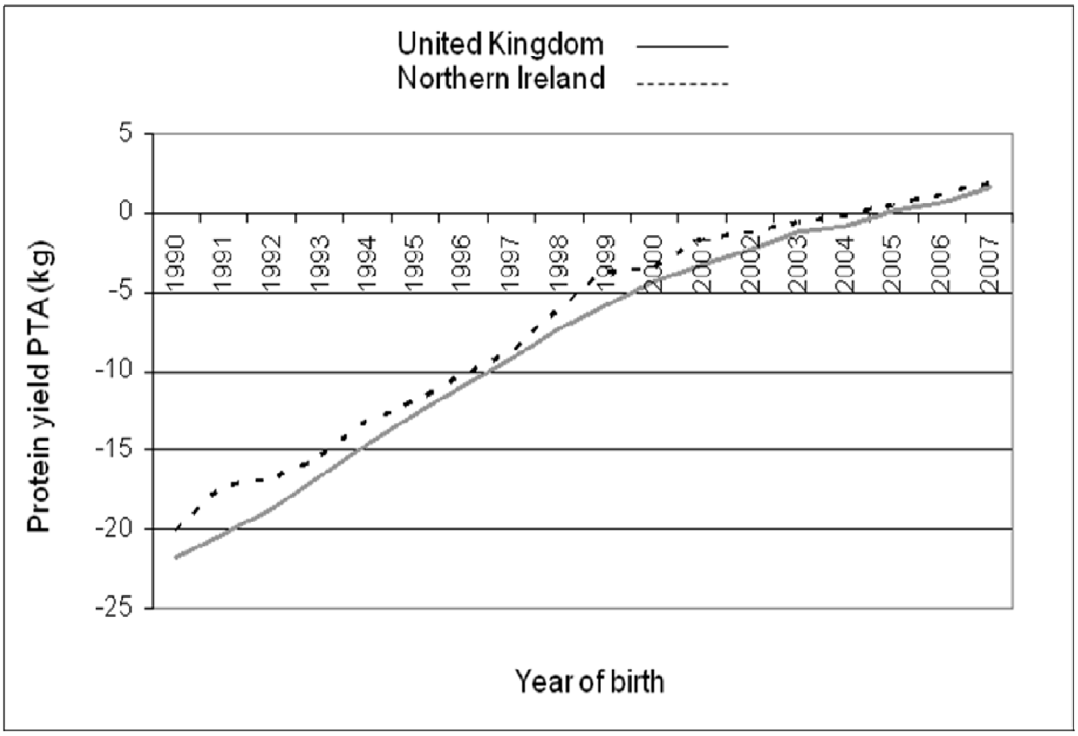


Figure 5 PTAs for calving interval (days) by year of birth for milk recorded cows

Breeding programmes in all of the main dairy producing countries are now broadening out their selection goals to include a growing range of non production traits. Selection indices are the best way to combine information relating to the growing number of traits which have now genetic information available. Each trait is weighted by its appropriate economic value. PLI continues to develop taking on board new traits and developments in the national farm model. In the last revision of the PLI, released in 2007, the PLI had a reduced emphasis on production traits and an increased weight on ‘fitness’ traits. Consequently, the predicted genetic response to selection on the revised PLI indicated that alongside increased production, lifespan will increase, somatic cell count will decrease, feet and legs and udder traits will improve and the decline in fertility traits will have nearly been brought to a standstill. The PLI reflects the profitability differences of progeny over their lifetime rather than per lactation as undertaken previously.

Figure 6 PTAs for lifespan (lactations) by year of birth for milk recorded cows

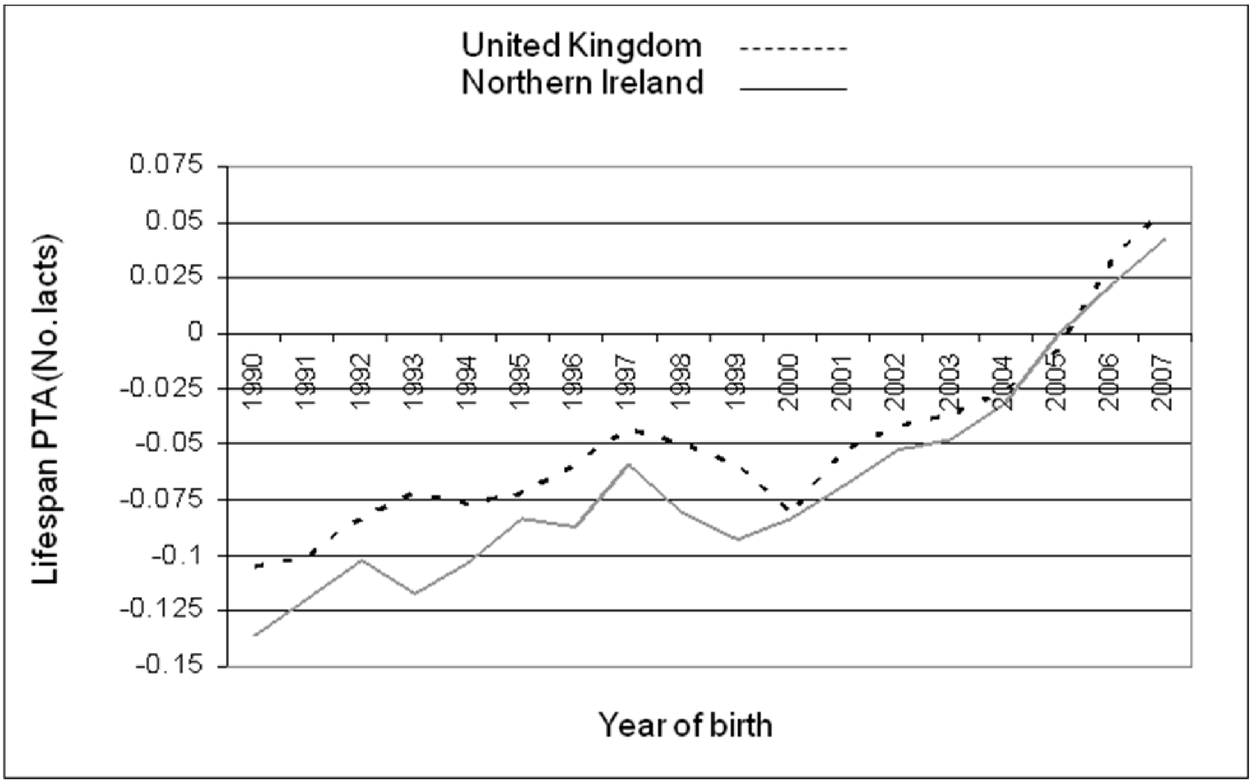
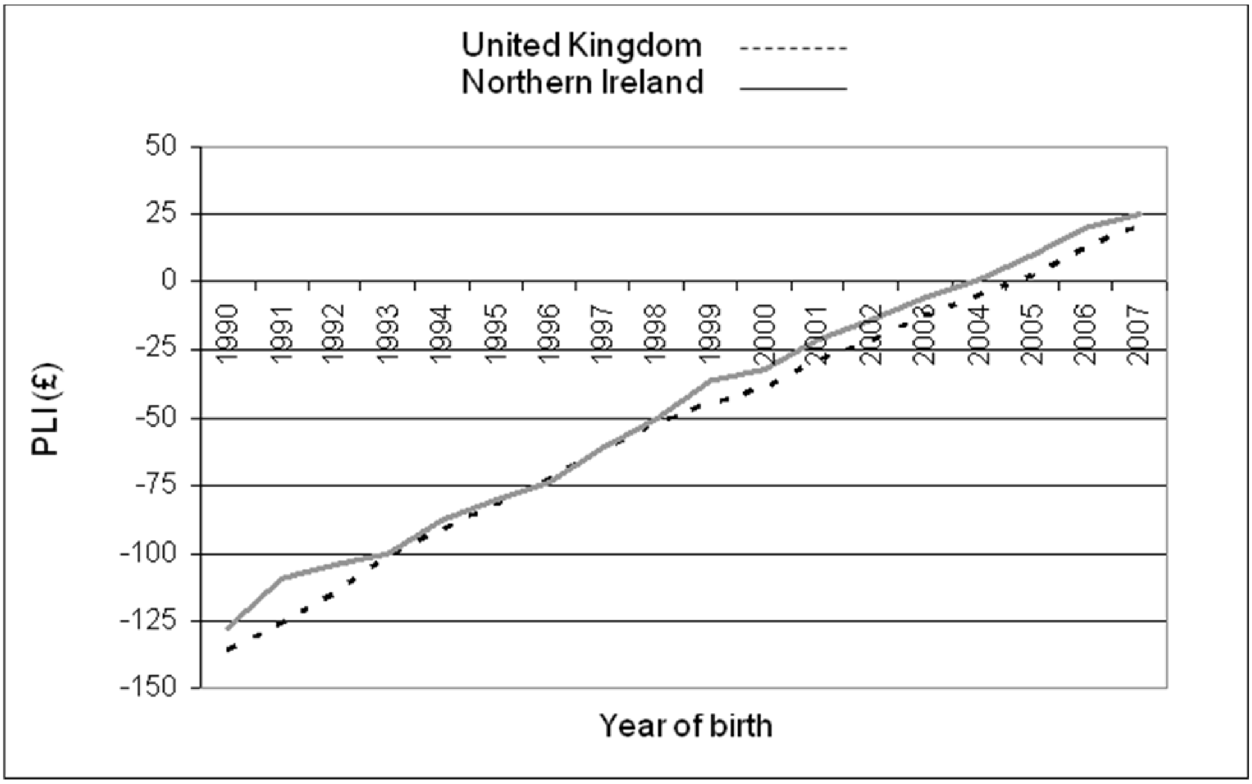


Figure 7 PLIs (£) by year of birth for milk recorded cows



The relative economic values for traits within selection indices are determined from national farm models. These models continually develop to take into consideration changing market outlooks, new environmental considerations and developments in production systems. This is an important on-going activity to ensure that index weights are appropriate for the markets being addressed and that index weights remain appropriate for the majority of producers. To inform future developments in the PLI, AFBI and SAC have recently undertaken a study examining the relative economic values for production and non production traits for an 8000-litre system with costs and returns considered representative of a Northern Ireland system. The objective of this paper is to review the findings of this work and to evaluate changes in the relative weightings of individual traits where they occur.

Current PLI

To underpin developments in the PLI in 2007, SAC investigated economic values for traits within alternative production systems models (intensive versus extensive production system; liquid versus cheese payment contract). On the basis of this work, DairyCo (previously MDC) after consultation with industry representatives decided to adopt a single index based on the intensive (cheese) system for the main national ranking. The model is based on a farm that utilises summer grazing and winter housing (comparable to the system on which the previous model was adopted).

Selection traits and their relative economic values within the PLI are detailed in Table 2. A broader index, such as PLI, was shown by Stott *et al.* (2005) to have clear financial benefits for the farming industry together with improvements in animal health and welfare of benefit to society as a whole. The current overall weighting on production traits in PLI is approximately 50%, with over 50% weighting on fitness traits.

Table 2 Goal traits, relative economic values (REVS) and index traits for the UK dairy selection index, £PLI released in August 2007 (source: DairyCo breeding+)

Trait group	Goal trait	REVs	Index trait
Production	Milk yield (1% ↑)	-0.027	305-day milk yield (kg)
	Milk fat yield (1kg ↑)	0.80	305-day milk fat yield (kg)
	Milk protein yield (1kg ↑)	1.71	305-day milk protein yield (kg)
Longevity	Lifespan (+1 lactation)	25.46	Lifespan (no. of lac^{ns} survived)
Health	Lameness (1% ↓ in incidence)	0.91	Locomotion score (linear scale) Feet & legs score (linear scale)
	Mastitis (1% ↓ in incidence)	0.96	Somatic cell count (count) Udder score (linear scale)
Fertility	Calving interval (+1 day)	-0.35	Calving interval (lac^{n} 1-2, days)
	Conception (1% ↑ cr)	2.16	Non-return rate 56 days (0/1)

The current PLI economic evaluations are based on the outputs from a bio-economic whole herd model described by Santarossa *et al.* (2004). The approach takes a whole herd, rather than an individual milking cow, perspective which makes it easier to incorporate traits representing ‘fertility’ that affect herd management as well as individual cow performance. The method of Santarossa *et al.* (2004) is also based on concepts of natural resource economics and so addresses issues of sustainability. Economic values of traits in the current PLI index are produced for a 'typical' commercial dairy herd with biological and herd parameters from a 'typical' herd were sourced from literature, reports etc. and validated by industry via DairyCo breeding+.

The next section of this report will present the default values underpinning the current PLI alongside values considered representative of a selected 8000 litre Northern Ireland system.

Default values within the PLI model

In considering default values for an 8000 litre Northern Ireland system, it must be considered that the index weights must be appropriate for farm and market circumstances likely to prevail over the next 3-15 years. Brief explanations to the assumptions, summarised in Table 3, used for the Northern Ireland system are detailed in the following section.

It should be noted that the PLI model represents a fixed farm system and that there are critical "tipping points" in the model that may cause the solution to move to a non-desirable set of outputs. For example, markedly increasing the values of animals removed from the system (cull cows, heifers, male calves) may move the financial performance of the system to focus on producing these types of animals rather than milk and therefore relative economic values could be negative for milk components. Therefore the results of the model need to be considered in a measured manner with appropriate discussion with stakeholders.

Herd size

Herd size in Northern Ireland, as presented previously, has shown a long term trend of increasing and now stands at 75. The average size of CAFRE benchmarked herds is 114. A default value of 115 cows was chosen for the Northern Ireland system. This represents the current average for benchmarked herds and, using current rates of change (for benchmarked farms), the national average extrapolated for 10 years time.

Table 3 Herd assumptions for the first analysis undertaken by the PLI model

Parameter	Value used for PLI (2007)	Value used for NI study (2010)
Cows milking	125	115
Land (ha)	80	55
Stocking rate (CE/ha)	2.1	2.1
Purchase land price (£)/ha	7,250	24,870
Rented land price (£)/ha	100	184
Quota owned (litres)	750,000	920,000
Quota purchase price (p)	2.0	0.0
Quota lease price (p)	0.2	0.0
Mastitis incidence (%)	14	24
Lameness incidence (%)	6	10
Replacement rate (%)	25.8	27
1st lact. milk yield (litres)	7750	7179
Fat %	3.8	4
Protein %	3.22	3.3
Concentrate (tonne)*	155	220
Barley (tonne)	70	150
Soya (tonne)	155	263
Calf price (blend)	90	30 (HF bull)
In-calf heifer purchase (£)	950	950
Blend price semen (£)	12	12 (dairy)
Nitrogen fertiliser (p/kg)	45	105
N per ha.	225	230
Dry matter grass produced	10	8-11
Fat premium (p/l)	1.65	1.80
Prot. Premium (p/l)	2.60	3.20
Vol. payment (ppl)	1.40	5.624
Lump sum (p/l)	0.60	0
Milk price (p/l)	17 (3.9% fat & 3.3% protein)	23 (4% fat & 3.3% protein)

Stocking rate

In the PLI model, stocking rate is not fixed, but allowed to find its own level. Based on the parameters for the Northern Ireland system, a stocking rate of 2.1 CE/ha was determined from the model. This appears to be appropriate considering that the average stocking rate for dairy farms in the Farm Business Survey (DARD, 2009) was 1.98 cows/ha. For CAFRE benchmarked farms, an average of 2.31 cows/ha was reported.

Land price

A land purchase price of £24,870/ha was used for the Northern Ireland system. This price relates to the average for 2006 (Farm Business Data, 2009). An average land rental price for grassland of £184/ha was taken which relates to the average for 2007 (Farm Business Data, 2009).

Quota

Within this modelling work, it was assumed that the industry will be operating in a quota free scenario.

Mastitis incidence

This trait represents the percentage of cows affected by mastitis at some stage during their lactation. Values from a range of published studies (DAISY reports 2, 4 and 5; Kossabibati *et al.*, 1998; Peeler *et al.*, 2002) were used to determine an average value of 24%.

Lameness incidence

Survey work on farms across Northern Ireland has shown an average prevalence of lameness of 34% i.e. on a spot visit approximately one third of cows had abnormal locomotion (Baird *et al.*, 2009). However, in the PLI model the trait definition for lameness refers to the number of cows individually treated for foot problems above and beyond routine whole herd measures such as foot baths. Thus the economic trait under consideration is the additional cost required to individually treat a lame cow. In light of this, a value of 10% was used for the Northern Ireland system which represents a mid range value from a recent UK study (Defra Expanding Indices Project).

Replacement rate

A detailed survey of 19 dairy farms in Northern Ireland reported an annual replacement replacement rate of 26.5% (Mayne *et al.*, 2002). This is similar to that reported on CAFRE benchmarked farms (28%). For the Northern Ireland system a value of 27% was taken as the default value. In terms of culling it was assumed that 20% was voluntary and 80% involuntary, which is in line with Mayne *et al.* (2002).

Days to first service

Mayne *et al.* (2002) reported average days to first service of 84 days from a study of 19 dairy herds. This is similar to that reported for CAFRE benchmarked autumn calving herds (78 days). For the Northern Ireland system, a value of 80 days was taken as the default value.

Conception rate

An average conception rate of 38% was reported for 19 dairy herds by Mayne *et al.* (2002). This was taken as the default value for the Northern Ireland system.

Semen

An average price per dairy straw of £12 was taken with an average price per beef straw of £5. These values were determined after consultation with the breeding industry in Northern Ireland.

Nitrogen cost

A nitrogen cost per kg (C.A.N. – 27% N) of £1.05 p/kg was used. This price relates to the year 2008 (Farm Business Data, 2009).

Herd yield

Economic modelling work in Northern Ireland indicates in a non-quota scenario 7,000-8,000 litre systems are optimum over a range of milk pricing, input price scenarios (Anderson *et al.*, 2009). These moderate input systems operate somewhere between the extremes of those systems adopted in the US and NZ. These mixed housing plus grazing systems benefit from the cost advantages of grazed grass, while at the same time spreading often unavoidable overhead costs over a moderately high output. Appropriate yields for such a system, and used as default values, are 7179, 8141, and 8457 litres for parities 1, 2 and 3+, respectively. A butterfat % of 4.0 and protein % of 3.30 was used for the Northern Ireland system.

Milk pricing

For the Northern Ireland system, a pricing schedule from one of the main dairy processors (United Dairy Farmers) was used. The price schedule was based on a milk price of 23 pence per litre which was the average annual milk price in the calendar year 2008 (DARD, 2009).

Mature body weight

For the Northern Ireland system, a default value of 625 kg was taken for the mature weight of the cows (when non-pregnant). This corresponds with recordings from the AFBI Hillsborough herd.

Concentrate feeding

For the 8,000 litre system under examination, a concentrate input of 2 tonnes was assumed. This equates to that used in economic modelling work linked to the current study (Anderson *et al.*, 2009). For concentrate price, a default value of £220/tonne was used (Farm Business Data, 2009). For barley and soya, a cost of £150 and £263, respectively was taken (Farm Business Data, 2009)

Calf price

A price of £30/head was taken for a Holstein/Friesian purebred bull calf. For continental calves, values of £120 and £160/head were taken for heifer and bull calves, respectively. These prices relate to the year 2008 (Farm Business Data, 2009).

In-calf heifer purchase

An in-calf dairy heifer purchase price of £950/hd was taken. This relates to the year 2008 (Farm Business Data, 2009).

Tonne of grass dry matter utilised

For grazing and silage utilised herbage dry matter yields of 8 and 11.5 tonnes DM/ha were taken for the Northern Ireland systems. These assumptions are based on a review by Carson *et al.* (2008).

N per ha

A fertiliser nitrogen input of 230 kg N/ha was used for the Northern Ireland system based on Farm Business Data (DARD, 2009).

Outputs from the bioeconomic model

Milk traits

In the UK, the milk production traits currently analysed for genetic evaluations are milk yield, fat yield, protein yield, fat percent, protein percent and persistency. Traits used within national dairy selection indices, including the PLI are, in the main, formulated with component yields rather than percentages, because their economic values are independent. Bio-economic models are used to estimate the marginal feed costs associated with genetic gains in milk and component yields. The analyses of these traits use the individual test day records for each of the first five lactations. PTAs are then adjusted to the current base, which is for cows born in 2005.

All selection indices have a negative weighting on milk volume. This trait represents the water fraction of milk and attached to it are the costs of levies, transportation and cooling. The negative weighting on milk yield is significantly greater in an index for a Northern Ireland system compared with the current PLI (Table 4). This is likely to be attributed to the higher input costs in the Northern Ireland system resulting in an increased feed cost per additional kg of milk produced.

In an index for the Northern Ireland system, the milk fat economic value dropped substantially relative to protein. This is mainly due to differences in the milk price schedules and feed costs. The relative economic value for protein is very similar in both indices.

Table 4 Relative economic values (£/kg) for milk traits in the current PLI and in an index for a NI system

Milk traits	Current PLI	Index for a NI system
Milk	-0.027	-0.059
Fat	0.80	0.18
Protein	1.70	1.74

Longevity

This is one of the most complex traits of measurement, analysis and derivation of economic weights. Contributing to the complexity is the fact that selection of breeding animals must be done early in life-cycles, long before herd life is known. Selection, therefore depends upon information from ancestors, forecasts of herd life based on individuals own conformation and early performance records and on PTA for correlated traits. The economic weight for herd life also depends upon what other traits are used in the index. For example, higher economic values are used when an index does not include reproduction or health.

In the UK longevity (lifespan) is measured directly from daughter survival (number of lactations survived (milk recorded) and where these are not available, type traits associated with longevity – leg and foot composite, mammary composite and somatic cell count. The economic value for survival is greater in the current PLI compared with an index for the Northern Ireland system (Table 5). The reasons for this are linked to the increase weighting to fertility which occurs and are discussed later.

Table 5 Relative economic values (£/kg) for longevity, health and fertility traits in the current PLI and in an index for a NI system

Health/fertility traits	Current PLI	Index for a NI system
Lifespan (+1 lactation)	25.46	14.87
Lameness (1% ↓ in incidence)	0.91	1.29
Mastitis (1% ↓ in incidence)	0.96	0.96
Calving interval (+1 day)	-0.35	-0.79
Conception (1% ↑ in conception rate)	2.16	2.01

Lameness

As discussed previously, within the PLI model lameness is defined as the percentage of cows over their lactation which have been individually treated for foot problems above and beyond routine whole herd measures such as foot baths. Where lameness data are not available legs and feet composite are taken to predict lameness. The genetic correlation between lameness and legs and feet is taken as 0.95.

The increase in the relative economic value for lameness in the Northern Ireland system can be attributed to the higher incidence value used in the model (10 compared with 6%).

Mastitis

In the PLI model, somatic cell count and udder composite are used as udder health traits. There is strong evidence of a direct relationship between somatic cell count and the incidence of clinical mastitis. Consensus now is that the genetic correlation of somatic cell score (SCS) (log SCC) with clinical mastitis is 0.7±0.10 (Shook, 2006). Furthermore, heritability for somatic cell count (0.14) has been found to be higher than with clinical mastitis (0.03 to 0.06) which also favours somatic cell score as a viable indicator on which to base direct selection against clinical mastitis. In addition to SCC, the PLI model includes udder composite as a goal trait to reduce the incidence of mastitis. Bulls that transmit more shallow (relative to the hock) udders, that are more tightly attached, have daughters with lower rates of clinical mastitis (Rodgers *et al.*, 1998).

The relative economic values for mastitis in both indices are similar (Table 5).

Fertility traits

Correlations for fertility traits are consistent and small, but always favourable with somatic cell score and longevity and nearly always unfavourable with angularity or dairy form. As discussed previously, selection for high yield alone has resulted in moderate to large declines in fertility traits across time.

Economic values for calving interval are affected by (1) herd fertility level i.e. higher economic values for poorer reproductive performance in the default scenario, (2) replacement costs of animals and cull cow values, (3) lactation yields and (4) feed costs. The overall net effect of these factors is that the economic value for calving interval is significantly less (more negative) in the selection index for the Northern Ireland system compared with the current PLI.

With respect to calving interval, Stott *et al.* (2007) reported that the law of return to scales can be observed. A large denominator from 391 days calving interval with a conception rate of 40% (PLI assumption) to 393 days using the 38% conception rate in the Northern Ireland model resulted in a smaller marginal product and therefore more negative economic value. Given a lower conception rate and fixed overall cull, the reasons for culling other than fertility decreases. Since the culling for other reasons is employed to simulate a change in lifespan, the change required is smaller compared with a conception rate of 40% and thus a smaller change on the input factor leads to a smaller value of the marginal product i.e. the relative economic weight for lifespan declines.

Calving traits

In the UK two genetic indexes for calving ease have recently been introduced (Jan 2010). Direct Calving Ease (dCE) gives a prediction of the ease with which a calf by that sire will be born. Maternal Calving Ease (mCE) refers to the ease with which a daughter of that sire will give birth (mCE). Both indices are expressed on a scale of -4 to +4 around a breed average of zero, with positive figures indicating that calvings are predicted to be easier than average and negative figures predicting more difficult calvings.

It is important to be aware of the negative genetic relationship between dCE and mCE. Within a breed female calves born more easily are expected to show greater difficulties when giving birth as dams, possibly because of reduced pelvic dimensions. Hence selection for both direct and maternal genetic components of calving ease is the best way forward.

These national evaluations for calving traits will facilitate breeding to improve calving ease longer term and will pave the way for its possible inclusion in PLI in the future.

Beef traits

Future developments of the PLI may include the incorporation of beef traits. Such developments are likely to be correlated with further decreases in the weighting for milk production and increases in health and fertility traits. A recent study for DairyCo (http://www.dairyco.org.uk/library/research--development/production/muscling-on-holsteins.aspx) showed the feasibility for selecting Holstein dairy cows for carcass traits. It demonstrated that if proofs for carcass traits were available and these were included in the PLI model the index would be expected to reduce the relative emphasis on milk yield and have favourable expected responses on fitness traits in the dairy cow. However, the lack of routinely available information from the abattoir linked to genetic evaluations means that carcass trait proofs are not currently available in the UK.

Response to selection to selected indices

Expected responses to selection on the index based on Northern Ireland assumptions are detailed in Table 7. Although in places the relative economic values do not appear to be too different, the expected responses in the component traits are significant. The alternative index weights are expected to change the direction of response in milk yield, such that the milk yield, and it's components, are expected to reduce. This loss of performance in milk yield allows the expected response in fertility to shift to be favourable. This represents the sensitivities in the biological assumptions in the fixed farm model. The change in the fertility assumption, coupled with increased lameness and mastitis prevalence, in the model results in a "tipping point" in the longevity component of the model, such that the poorer fertility means that there is significant pressure on sourcing sufficient potential replacements from within the herd. This really pushes the relative emphasis in trying to optimising herd profit to improving fertility.

Table 7 Response in goal traits using PLI and selection index for a Northern Ireland system

	PLI	Selection index for a NI system
Milk (kg)	79.4	-62.6
Fat (kg)	3.94	-0.54
Protein (kg)	2.96	-0.40
Lifespan (no. lacts)	0.06	0.05
Mastitis (incidence)	0.0015	-0.0030
Lameness (incidence)	0.0007	0.0002
Calving Interval (days)	0.37	-0.55
NR 56 (%)	-0.003	0.003
Correlated traits		
Condition score	-0.021	0.021
Somatic cell count	-0.0045	-0.0025
Legs and feet score	0.005	0.026
Udder score	0.015	0.013
Locomotion score	0.008	0.009

Due to the significant changes in the expected responses when using the relative economic values derived from the Northern Ireland system, the sensitivities in the model were explored. Overall, the model was highly sensitive to the assumed input

and output costs (e.g. feed costs, calf price). As these do vary significantly between years, the costs were reverted to the original PLI assumptions so the impact of altering the assumptions in the biological performance could be explored.
The expected genetic responses for 2 different scenarios of the model were examined (Table 8). This was from a base of no changes in the base assumptions of the PLI model other than for Northern Ireland assumptions for land and quota included. Apart from fertility parameters, the major default values that caused changes in the relative economic values within the index were changes in the assumptions for the incidence of lameness and mastitis. The changes in the mik production assumptions had relatively little effect on expected genetic responses.

Conclusions and next steps

The next steps in this programme are for the data from this project to be thoroughly discussed by a stakeholder group comprising of representatives of the dairy breeding industry in Northern Ireland, milk processors along with AFBI and CAFRE. The conclusions from these discussions will then be forwarded to DairyCo, who have been involved in all stages of this work. DairyCo has overall responsibility for genetic evaluations in the UK and will be able to use information from this programme in planned advancements for the PLI.

As part of the developments in the PLI, work from the Defra funded 'Expanding Indices project' will be used as well as data from the current study. The economic model for the fixed farm model will also be examined and updated. This will be done for a number of reasons:

1. It is likely that the range of traits available to dairy farmers has and will increase (calving ease, mastitis).
2. There is potential for the definition of lifespan to change as the project is exploring how industry data (e.g. BCMS and APHIS) may be used to define the total days of life rather then lactation number from the milk records.
3. Update the assumptions and further explore the sensitivities in the model for ranges of farming systems.

Table 8 Relative economic values (REVs) and expected responses in goal traits for changes in the biological assumptions in a step manner

	PLI model with NI assumptions for:-					
	Land & quota		Land & quota Lameness & mastitis		Land & quota Lameness & mastitis Milk production	
	REVs	**Expected Response**	**REVs**	**Expected Response**	**REVs**	**Expected Response**
Milk (kg)	0.017	109.98	-0.045	98.5	-0.038	99.3
Fat (kg)	6.72	4.60	1.65	4.43	0.09	4.33
Protein (kg)	7.99	3.45	2.93	3.32	1.37	3.32
Lifespan (no. lacts)	33.18	0.009	38.12	0.031	31.36	0.037
Mastitis (incidence)	6.30	0.0032	1.23	0.0026	-0.33	0.0026
Lameness (incidence)	6.63	0.0001	1.56	0.0004	1.29	0.0005
Calving Interval (days)	-0.44	0.59	-0.44	0.53	-0.44	0.50
NR 56 (%)	2.65	-0.004	2.65	-0.004	2.31	-0.004
Correlated traits						
Condition score		-0.032		-0.028		-0.028
Somatic cell score		-0.004		-0.004		-0.004
Legs & feet score		-0.002		-0.0002		0.0003
Udder score		0.001		-0.009		0.010
Locomotion score		0.0068		0.007		0.007

There are clear advantages in having a single national index of total economic merit. This is the most cost-effective option for genetic improvement, will lead to the greatest genetic gain towards agreed selection goals and is the easiest to manage in terms of technology transfer. The industry in Northern Ireland should continue to use the current PLI with consideration given to the application of an independent threshold value for fertility to take on-board the fact that this study has shown that reproductive performance, in particular, will command a higher weighting in a selection index for a Northern Ireland system. Listings of sires based on PLI with independent culling levels for fertility index would facilitate the selection of bulls for the use in this type of system.

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The performance of Jersey crossbred cows within grassland based milk production systems

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Introduction

The high milk production potential, and high efficiency for milk production, of the Holstein cow has led to the dominance of the Holstein breed in many parts of the world. However selection programmes which resulted in these high levels of milk production efficiency largely ignored functional traits. The subsequent decline in fertility, health and longevity within the Holstein population has now been thoroughly documented. As a result of this, part of the additional benefits gained with the Holstein breed through increased milk production efficiency have been lost through poorer cow health and longevity.

There are a number of approaches by which these problems might be tackled, including, the adoption of improved nutritional and management strategies, and genetic approaches. With regards the latter, three broad strategies are often proposed, namely: 1) improved within-breed selection programmes, 2) breed substitution (the introduction of an alternative breed to replace the Holstein breed) and 3) crossbreeding. This paper will focus on crossbreeding, and in the most part will examine data from AFBI Hillsborough research programmes.

Crossbreeding

Crossbreeding is defined as mating of parents of two or more different breeds, strains or species together (Simm, 2000). While the practice of crossbreeding is widespread within many other livestock enterprises, the adoption of crossbreeding within most dairy sectors has been limited. One notable exception to this is the New Zealand dairy sector where approximately 35% of the national dairy herd is crossbred. Nevertheless, interest in crossbreeding has increased in recent years in many countries. This interest has arisen not just in countries where the dairy industry is 'low input grassland' based, but also in countries where much higher input systems are common, for example within the United States of America and parts of Northern Europe.

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

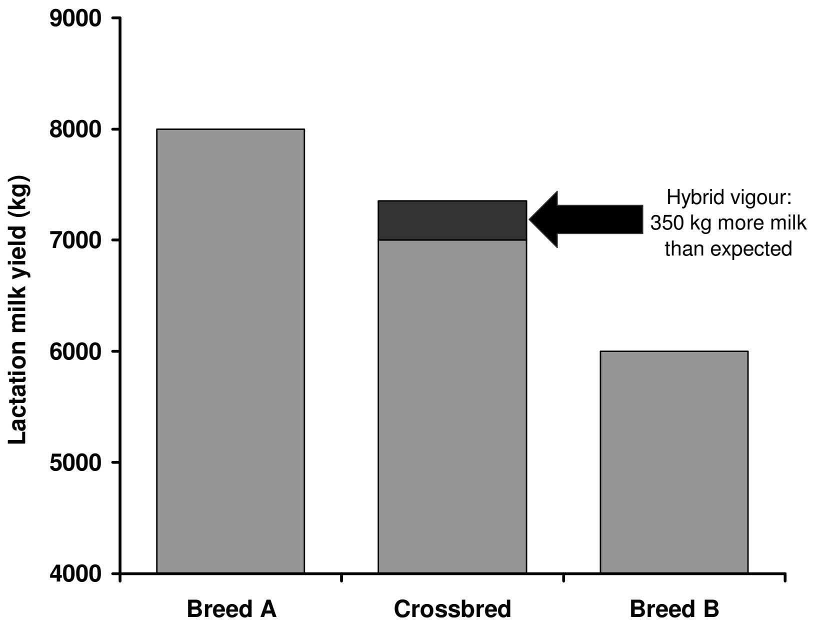
1) <u>Breed complementarity</u>:
This refers to the introduction of desirable genes from a second breed which may be absent or occur at a low frequency in the recipient breed. The obvious example of this is the use of Jersey cattle within crossbreeding programmes as a means of improving milk composition. Breed complimentarity can also apply to functional traits such as fertility and health, and it is for this reason there is a growing interest in the use of the Scandinavian breeds within crossbreeding programmes.

2) <u>Beneficial effects of hybrid vigour</u>:
Hybrid vigour describes the additional performance benefits that can be obtained with a crossbred animal, over and above the mean of the two parent breeds. For example, if Breed A has a lactation yield potential of 6000 litres, and breed B has a lactation yield potential of 8000 litres, the offspring of the two breeds might be expected to have a lactation yield potential of approximately 7000 litres (Figure 1). However, in the example given the actual production of the crossbred cow is 7350 litres, with the extra 350 litres of milk over and above that expected being due to hybrid vigour. The extent of hybrid vigour varies between traits. For example, for traits such as milk yield and milk composition, hybrid vigour is normally estimated

to be between 3–6%, while for traits such and fertility, health and longevity, hybrid vigour may be between 6–15%, depending on the degree of genetic differences between the parent breeds.

3) <u>To reduce levels of inbreeding</u>:
Levels of inbreeding within the UK Holstein Friesian population increased by approximately 0.17% per year during the decade up until 2002, with average inbreeding for females being 2.64% in 2002 (Kearney *et al.,* 2004). In contrast, the level of inbreeding within the US Holstein population was 5% in 2003. The negative consequences of inbreeding are inbreeding depression, an increase in undesirable recessive disorders, and a loss in genetic variation. For example, a number of studies have shown an unfavourable association between performance for production traits and non-production traits, with increasing inbreeding depression. Crossing with a second breed is one option by which levels of inbreeding can be rapidly reduced.

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



Crossbreeding research at AFBI Hillsborough

During the last few years a number of studies have been undertaken by AFBI to examine the potential of crossbreeding as a means of improving the profitability of the Northern Ireland dairy sector. The majority of these studies have involved comparisons of pure bred Holstein cows with Jersey x Holstein crossbred cows.

Two of the AFBI studies have examined the energetic efficiency and grazing efficiency of Jersey crossbred cows compared to straight bred Holstein cows, while the remaining three studies have sought to compare the production, health and fertility performance of these two cow genotypes when managed under a range of production systems. Key outcomes of these studies are reviewed within this paper. In addition, the paper concludes by examining some of the key issues that need to be considered before embarking on a crossbreeding programme.

Are crossbred cows energetically more efficient than Holstein cows?

This was one of the first questions addressed within the AFBI research programme, in an experiment involving eight first lactation Holstein cows and eight first lactation Jersey x Holstein cows. Diets offered within this study contained either high or low concentrate proportions (70 and 30% concentrates on a DM basis, respectively), with nutrient utilisation and energy metabolism measurements being undertaken during both early and late lactation. The overall effect of genotype on nutrient utilisation is presented in Table 1.

Table 1 Effect of dairy cow genotype on nutrient digestion and energy utilisation (after Yan *et al.* 2008)

	Genotype			
	Holstein	Jersey x Holstein	s.e.	Sig.
Digestibility coefficients				
Dry matter	0.795	0.795	0.0033	NS
Energy	0.776	0.778	0.0037	NS
Energy utilisation (proportional basis)				
Milk E/ME intake	0.320	0.332	0.0076	NS
Methane energy/ME intake	0.098	0.098	0.0026	NS
Energy balance/ME intake	0.032	0.048	0.0136	NS
Efficiency of ME use for lactation (k_l)	0.58	0.58	0.010	NS

None of the digestibility coefficients, or energy utilisation parameters examined was affected by cow genotype. Thus Jersey crossbred cows and Holstein cows appear to digest their food and utilise the digested nutrients with similar efficiencies. These findings are in agreement with the results of previous AFBI experiments which compared Holstein cows of high and medium genetic merit for milk production (Ferris *et al.*, 2000) and Norwegian and Holstein cows (Yan *et al.,* 2006).

In a further study involving grazing cows of both genotypes, the effect of genotype on methane production was measured using the SF6 technique. While the results of this study clearly demonstrated that methane production per litre of milk produced decreased with increasing milk output, methane production was unaffected by genotype, again highlighting that there appears to be no fundamental difference between genotypes in terms of this aspect of energetic efficiency.

Are crossbred cows more efficient feeders than pure bred cows?

Although it is often suggested that crossbred cows, especially Jersey crossbred cows, are more efficient feeders than Holstein cows, there is relatively little information to support this belief. To address this issue, a study was conducted to compare the feeding behaviour of Holstein and Jersey crossbred cows within both an indoor and grazing environment. Within the indoor environment the Holstein cows had a higher intake than the crossbred cows (Table 2). However, when expressed on a metabolic body weight basis (live weight$^{0.75}$), there were no differences between genotypes in terms of food intake. In addition, the two cow genotypes did not differ in terms of time spent feeding, number of feeding bouts/day or the average duration of each feeding bout.

Measurements undertaken on grazing cows highlighted that total DM intake did not differ between genotypes, even though the Holstein cows weighed approximately 70 kg more than the crossbred cows. While the smaller crossbred cows consumed less herbage per minute, due to their tendency to have lower intakes per bite, they grazed for longer each day, and as such had significantly more grazing bites/day than the Holstein cows. In addition, although they had fewer grazing bouts/day, the mean duration of each grazing bout was longer. Thus by modifying their grazing behaviour, these smaller cows were able to achieve similar herbage intakes as the much larger Holstein cows. The findings of this experiment helps to explain some of the results of the production studies described below.

Table 2 Effect of dairy cow genotype on feed intake and feeding behaviour (after Vance *et al.*, 2010)

	Genotype			
	Holstein	Jersey x Holstein	s.e.d.	Sig.
Confinement				
Total DM intake (kg/day)	18.5	17.1	0.67	*
Feed intake/kg live weight$^{0.75}$ (kg)	0.17	0.18	0.005	NS
Total feeding time (minutes/day)	248	236	18.0	NS
Total number of feeding bouts/day	16.1	16.0	1.04	NS
Average duration of each feeding bout (minutes)	16.1	15.2	1.13	NS
Grazing				
Grass intake (kg DM/day)	17.0	16.3	0.63	NS
Feed intake/kg live weight$^{0.75}$	0.172	0.178	0.0051	NS
Grazing time (minutes/day)	531	582	18.9	**
Grazing bites/minute	62	62	1.4	NS
Grazing bites/day	32910	36346	1393.0	**
Grazing bouts/day	9.3	7.7	0.45	**
Mean duration of each grazing bout (minutes)	60.0	82.7	4.69	*
Grass DM intake/minute (g)	29	26	1.5	*
Grass DM intake/bite (g)	0.47	0.42	0.030	NS

Performance of spring calving crossbred cows within a grazing system (Experiment 1)

The performance of Holstein cows and Jersey x Holstein crossbred cows was compared in a three year study at AFBI Hillsborough. This experiment involved spring calving cows (mean lactation number, 1.9), and these were managed within three grassland-based systems which differed in concentrate inputs. Cows on the ‘Low’, ‘Medium’ and ‘High’ concentrate input systems were offered either 6.0, 8.0 or 10.0 kg concentrate/day until turnout, with this then reduced to either 0, 2.5 or 5.0 kg concentrate/cow/day during the grazing period. Full lactation concentrate inputs were approximately 525, 1050 and 1650 kg for the Low, Medium and High concentrate input systems respectively. The study involved a total of 105 and 92 lactation measurements for the Holstein and Jersey x Holstein cows respectively.

There were no significant interactions between cow genotype and concentrate feed level for any of the parameters examined. Thus in most cases, only the main effects of genotype are presented within this paper.

Milk production

This study involved spring calving cows, and as such, intakes were measured for only a relatively short period prior to turnout. Nevertheless, cow genotype had no effect on dry matter intake in early lactation (Table 3). The low intakes recorded reflect the fact that these intakes are for the early post calving period only. Across the three concentrate feed levels examined the Holstein cows produced 625 kg more milk than the Jersey crossbred cows, thus highlighting the potential loss in milk volume associated with crossbreeding. The crossbred cows on the other hand produced milk with a significantly higher fat and protein content than the Holstein cows, and when performance was examined on the basis of milk solids production, the yield of fat + protein did not differ between the two genotypes.

That there was no significant interaction between cow genotype and the milk production response to concentrate feed level is perhaps surprising (Figure 2). The expectation might have been that the crossbred cows would have been unable to continue to respond in terms of milk production at higher levels of supplementation, as was the case in a previous Hillsborough study involving Norwegian and Holstein cows (Keady *et al.*, 2001). In this latter study, which involved high and low concentrate input systems (approximately 2.7 and 1.5 t concentrate/cow, respectively), the Norwegian cows were unable to respond fully to the high concentrate feed levels offered, and instead partitioned an increasing proportion of nutrients consumed to body condition. However the high concentrate input system adopted by Keady *et al.* (2001) involved a considerably higher concentrate input than the 'High' input system examined within the current study. The findings of the current study clearly demonstrate that within the range of systems examined, Jersey crossbred cows can compare favourably with Holstein cows in terms of performance.

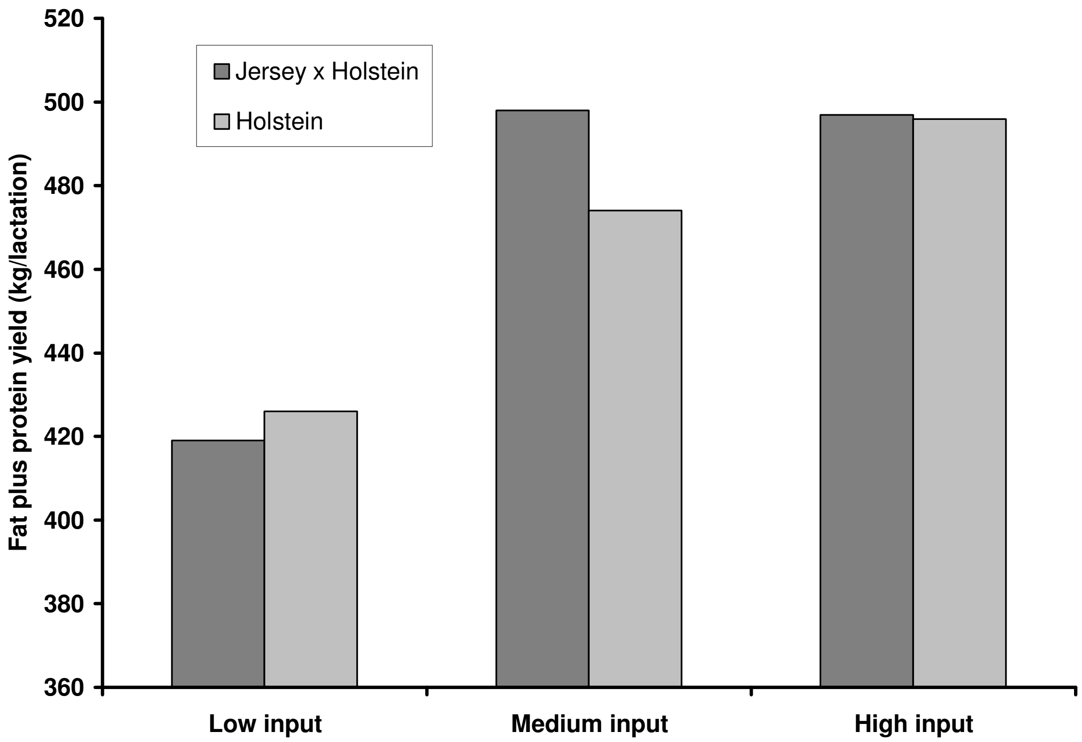
Table 3 Effect of dairy cow genotype and management system on full lactation milk production (mean performance across the 'Low', 'Medium' and 'High' concentrate input systems)

	Genotype			
	Holstein	Jersey x Holstein	s.e.d.	Sig.
Lactation length (days)	305	302	4.6	NS
Total concentrate intake (kg)	1065	1058	31.3	NS
DM intake pre turnout (kg/day)†	15.3	15.3	0.33	NS
Milk yield (kg)	6252	5627	175.2	***
Milk composition (g/kg)				
Fat	42.0	47.8	0.73	***
Protein	33.0	35.9	0.34	***
Milk fat + protein yield (kg)	467	471	134	NS
SCC (000/ml)	218	173	36.7	NS
SCC (000/ml) $\log^{10}$	2.17	2.14	0.055	NS

† Mean of Systems 1 and 2 only

Somatic cell counts did not differ between the two cow genotypes in this study, and indeed similar findings have been observed in previous studies involving comparisons of Holstein and Jersey crossbred cows (Heins *et al.*, 2008; Prendiville *et al.*, 2010).

Figure 2 Fat plus protein yield response with Holstein and crossbred cows within a 'Low', 'Medium' and 'High' concentrate input system

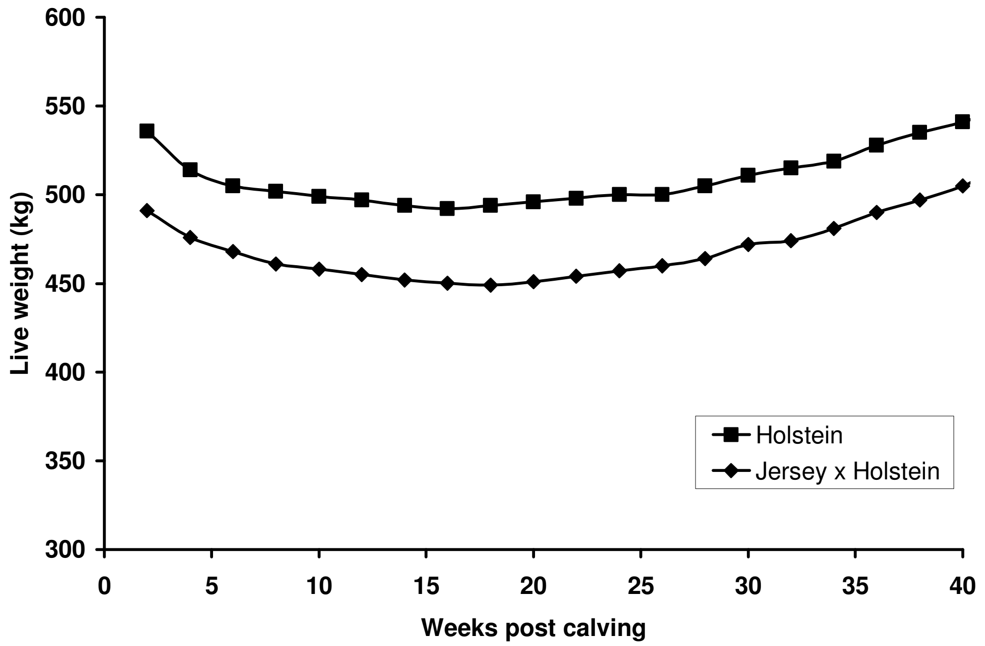


Body tissue reserves

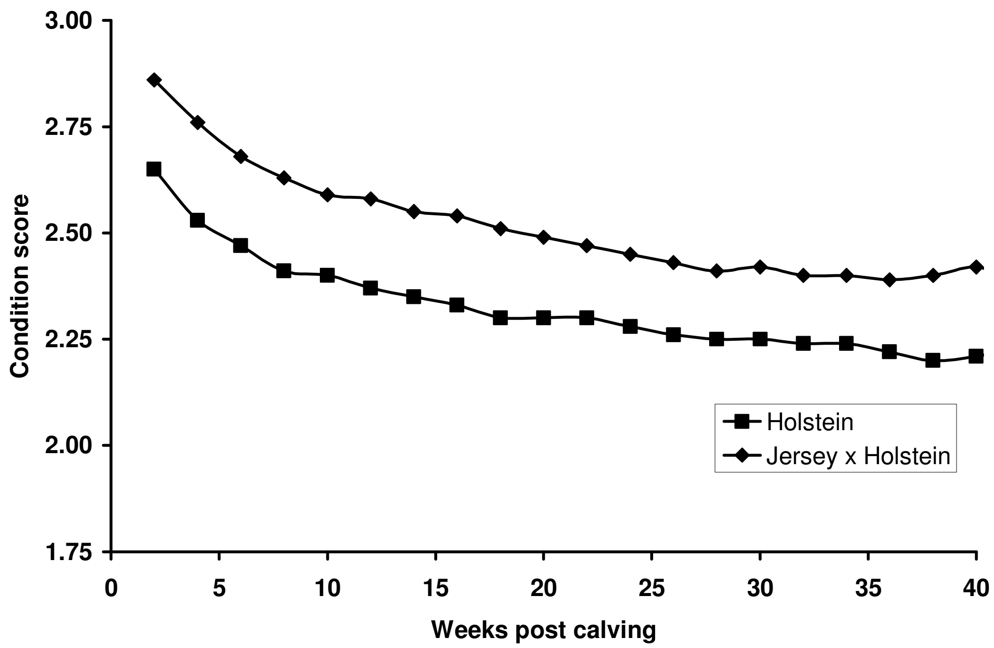
Throughout the lactation the crossbred cows were on average 44 kg lighter than the Holstein cows. That this difference in live weight did not result in a significant difference in dry matter intake is perhaps surprising, and highlights the higher intake potential of the crossbred cows per unit of body weight. However, despite being lighter, the crossbred cows had a body condition score that was 0.2 units higher than the Holstein cows. Nevertheless, the changes in body condition score and live weight throughout the lactation followed a similar pattern with both genotypes (Figure 3), thus suggesting that similar levels of tissue mobilisation (early lactation) and tissue gain (late lactation) occurred. This would also suggest that the extent of negative energy balance experienced by both genotypes was similar, with this being supported by blood metabolite data recorded during these experiments.

Figure 3 Changes in live weight (a) and body condition score (b) of Holstein and Jersey x Holstein crossbred cows throughout the first 40 weeks post calving (mean data for the Low, Medium and High concentrate input system)

a)



b)



Fertility and health characteristics

The effect of cow genotype on fertility performance and health characteristics are presented in Table 4. The Jersey crossbred cows had a significantly lower calving difficulty score (easier calving) than the Holstein cows, with this reflecting the fact that the calves born to the crossbred cows were approximately 4 kg lighter than those born to the Holstein cows.

While there was no difference between genotypes in relation to the percentage of cows showing luteal activity within 42 days of calving, the crossbred cows had a shorter interval to commencement of luteal activity, had a higher conception rate to first service, and to first and second service, and had a higher conception rate after 12 weeks of breeding. The improved reproductive performance of the crossbred cows in the current study is in agreement with the findings of a number of other studies undertaken elsewhere with Jersey crossbred cows (Auldist *et al.*, 2007 Heins *et al.*, 2008). In addition, similar improvements in reproductive performance were observed at Hillsborough when Norwegian crossbred cows were compared with pure Holstein cows (Dale *et al.*, 2006). As there appears to have been little difference between genotypes in terms of energy balance, then hybrid vigour is likely to be one of the main factors contributing to the improved fertility performance with the crossbred cows in Experiment 1. For example, hybrid vigour for fertility traits in dairy cattle can be between 5-10%. Based on the findings of the current study, crossbreeding would appear to provide a clear option by which fertility performance can be improved within a dairy herd.

Although somatic cell counts did not differ between genotypes, the crossbred cows had a significantly lower incidence of mastitis compared to the Holstein cows. However in this study there was no evidence of genotype having an impact on the number of cows treated for lameness. There was, however, a significant increase in the proportion of cows treated for lameness problems as concentrate feed levels increased, with the incidence being 5%, 16% and 25% with the Low, Medium and High concentrate feed levels respectively.

Table 4 Effect of dairy cow genotype on fertility performance and health parameters across a 'Low', 'Medium' and 'High' concentrate input system

	Genotype			
	Holstein	Jersey x Holstein	s.e.d.	Sig.
Calving details				
Calving difficulty score (scale 1-5)[†]	1.5	1.3	0.08	*
Calf birth weight (kg)	41.3	37.6	0.82	***
Fertility performance				
Cows displaying luteal activity within 42 days of calving (%)	80	90	6.3	NS
Interval to CLA (days)	27.0	23.6	1.49	*
Days to 1st observed heat	50.5	41.7	3.71	*
Conception to 1st service (%)	35	58	8.0	**
Conception to 1st and 2nd service (%)	52	81	7.7	***
Pregnancy rate after 12 weeks of breeding (%)	73	89	6.4	*
Health parameters (proportion of cows with at least one case)				
Mastitis	0.29	0.16	0.067	*
Lameness	0.19	0.11	0.057	NS
Displaced abomasum	0.07	0.00	0.031	NS

[†] 1 represents an unassisted calving and 5 a caesarean section

Performance of Jersey crossbred cows within a high input system (Experiment 2)

One of the key findings from Experiment 1 was that Jersey crossbred cows continued to exhibit a similar production response as the Holstein cows to increasing levels of concentrate supplementation. While crossbreeding has normally been assumed to be more suited to lower input systems, such as those within New

Zealand, the findings of Experiment 1 suggest that there may be a role for crossbreeding within higher input systems. To address this issue, a second study was conducted in which Jersey crossbred and Holstein cows were managed on either a low input grazing system or a high input total confinement system for a full lactation. Cows on the low input system were offered approximately 7.0 kg concentrate/day until turnout, and there after 1.0 kg concentrate/cow/day throughout the grazing season. Cows on the total confinement system were confined all year and offered a diet containing 60, 50 and 40% concentrate (DM basis) during days 1-100, 101-200 and 201-250 of lactation respectively. Total concentrate inputs with the low input grazing system and total confinement system were approximately 3.3 and 1.2 t concentrates, respectively.

Milk Production

Food intake was measured continually for the cows within the total confinement system, and in common with the findings of Experiment 1, did not differ between genotype (Table 5). Compared to the Holstein cows, the crossbred cows produced 280 kg (low input grazing system) and 2037 kg (total confinement system) less milk. When the higher fat and protein content of the milk of the Jersey crossbred cows is taken into account, these volume differences were substantially reduced, with yields of fat + protein not being different between genotypes on the low input system. This again supports the findings of Experiment 1, that Jersey crossbred cows can compete well with Holstein cows (in terms of production performance) within lower input systems. Within the total confinement system the Holstein cows had a fat + protein yield approximately 100 kg higher than the crossbred cows. Although part of this difference can be explained by the Holstein cows having a greater number of ‘days in milk’ compared to the crossbred cows (325 vs 303), the finding highlights the potential of the Holstein cows to continue to respond to higher concentrate feed levels than the crossbred cows.

Table 5 Effect of dairy cow genotype and management system on full lactation milk production

	Low input grazing		Total confinement			Significance		
	Holstein	Jersey x Holstein	Holstein	Jersey x Holstein	s.e.d.	Genotype (G)	System (S)	G x S
Days in milk	291	302	325	303	7.36	NS	***	**
Average daily dry matter intake (kg)			18.5	18.5	0.51	NS		
Lactation milk yield (kg)	6056	5778	9467	7430	356.5	***	***	***
Milk composition (g/kg)								
Fat	43.4	46.7	43.5	48.3	1.42	***	NS	NS
Protein	33.5	36.0	34.0	36.8	0.76	***	NS	NS
Lactation fat + protein yield (kg)	465	477	730	631	27.0	*	***	**
SCC (000/ml)	84	176	208	299	94.3	NS	NS	NS
SCC (log^{10})	1.86	2.09	2.01	2.26	0.108	**	*	NS

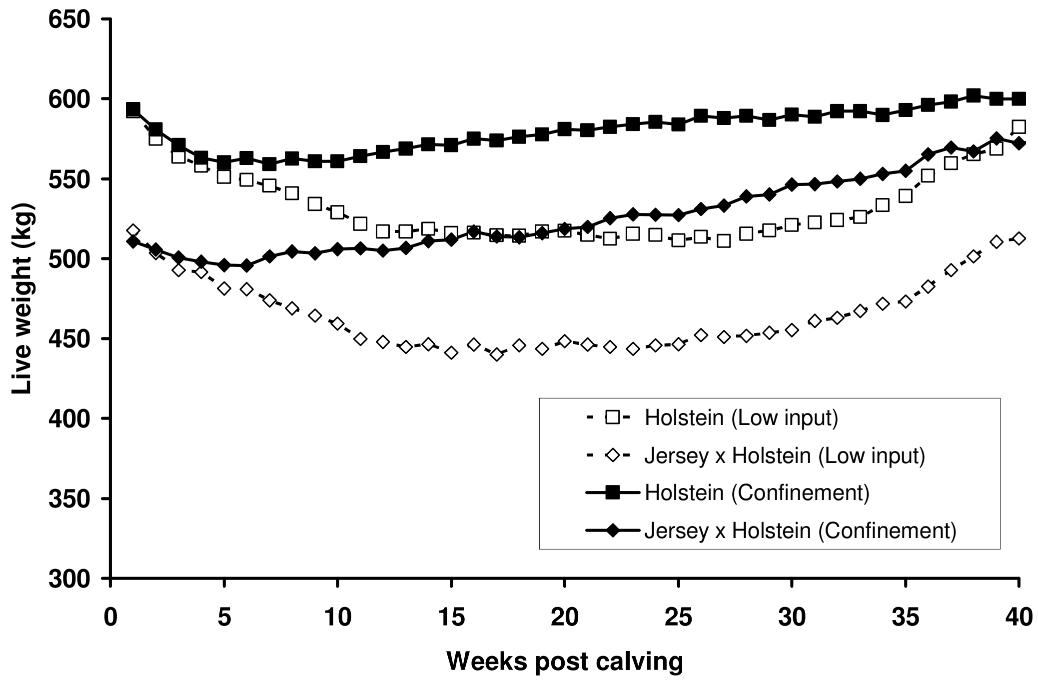
Few other studies have examined the performance of crossbred cows within a high input system. One exception is the study by Heins *et al.* (2006) in which pure bred Holstein cows were compared with crosses of the Montbelliard, Scandinavian and Normande breeds. The results of this study highlighted that the loss in production with the Scandinavian crosses especially was relatively small. In this study the Holstein cows produced 9757 kg milk and 651 kg fat + protein, while the Scandinavian crossbred cows produced 9281 kg milk and 637 kg fat plus protein. Thus crossbreeding may well have a role in high input systems, but careful selection of breeds is necessary to ensure that a loss of production does not result.

Body tissue reserves

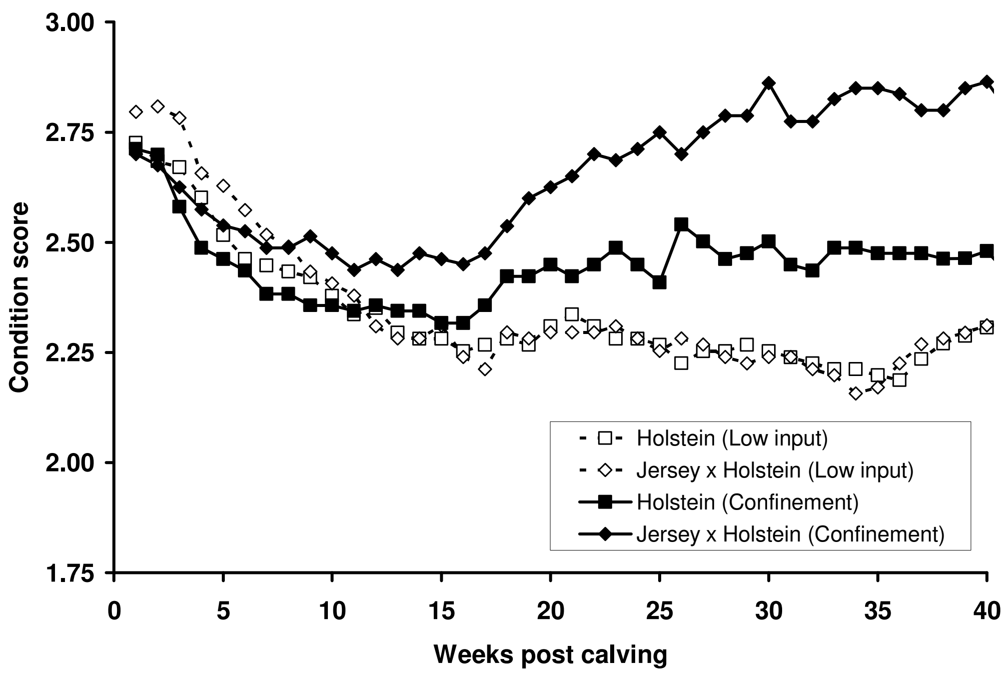
While the crossbred cows in this study were approximately 90 kg lighter than the Holstein cows at calving, both genotypes had similar condition scores at calving (Figure 4). Within the low input grazing system the live weight and condition scores of both genotypes followed a similar pattern, with the delay in condition score gain until approximately week 35 of lactation reflecting the very difficult grazing conditions encountered during 2009. However on the high input system the Jersey crossbred cows began to gain condition from approximately week 20 of lactation onwards, so that by week 35 of lactation the mean condition score of this group was almost 3.0, compared to a score of approximately 2.5 with the Holstein cows. Thus crossbred cows offered a high concentrate feed level began to partition a significant proportion of food consumed to body tissue reserves, commencing mid lactation, and were at risk of becoming over-fat in late lactation. Indeed, to address this issue the level of concentrate in the diet was reduced to 25% (DM basis) during the last 50 days of lactation to prevent individual cows becoming excessively over-conditioned. This difference in nutrient partitioning within the total confinement system provides an explanation as to why the crossbred cows did not respond to the additional concentrate offered to the same extent as the Holstein cows, part of the extra nutrients offered simply being partitioned towards body tissue reserves.

Figure 4 Changes in liveweight (a) and condition score (b) with Holstein cows and Jersey x Holstein crossbred cows during the first 40 weeks of lactation within a low input grazing system and a total confinement system

a)



b)



Fertility and health

Fertility data with the crossbred cows within the current study was less encouraging than within Experiment 1, although the limitation of the numbers of animals involved must be accepted (Table 6). While days to first observed heat and to first service were fewer for the crossbred cows, none of the other fertility measures were affected by either genotype or production system. Indeed the trend was for poorer fertility performance with the Holstein cows on the high input system, compared to the lower input system, while the reverse might have been expected given the information on condition scores presented above.

Within this study detailed hoof measurements were undertaken at approximately 100 and 250 days post calving. A scoring system was adopted which involved scoring each of the claws of the hind feed for sole lesions, heel erosion and white line disease. Mean data across these two periods are summarised in Table 6. For each of the parameters examined, crossbred cows had a lower incidence of hoof health problems than the Holstein cows. It has long been postulated that the black hooves of Jersey crossbred cows make them less susceptible to hoof problems, with previous research having demonstrated that Jersey cows have harder hooves than Holstein cows (Leithbridge and Margerison, 2008). While the DM content of hoof slithers in the current study (a possible measure of hoof hardness) did not differ between genotypes, the improved hoof health characteristics of the crossbred cows were apparent.

Table 6 Effect of dairy cow genotype and management system on fertility performance and hoof health scores

	Low input grazing		Total confinement			Significance		
	Holstein	Jersey x Holstein	Holstein	Jersey x Holstein	s.e.d.	Genotype (G)	System (S)	G x S
Fertility performance								
Days to 1st observed heat	34.2	30.9	40.8	29.0	5.19	*	NS	NS
Days to 1st service	76.1	64.8	79.2	66.0	6.97	*	NS	NS
Conception to 1st and 2nd service (%)	67	70	58	75		NS	NS	NS
Pregnancy rate after 12 weeks of breeding (%)	72	75	74	85		NS	NS	NS
Hoof health scores[†]								
Sole lesions	20.6	6.1	15.7	5.9	3.39	***	NS	NS
Heel erosion	4.8	1.0	0.5	0.5	0.74	***	***	***
White line disease	1.8	0.9	2.3	0.7	0.45	***	NS	NS
Digital dermatitis	1.8	0.2	0	0	0.44	*	**	*

[†] Higher scores indicate poorer hoof health

On-farm study

In addition to the experiments being undertaken at Hillsborough, the performance of Holstein and Jersey crossbred cows is currently being examined in an on-farm study involving 11 Northern Ireland dairy farms. These farms include spring and autumn calving herds with a wide range of concentrate inputs (approximately 0.7–2.2 t/cow/year). On each farm 15–20 pairs of Holstein cows were matched for genetic merit, milk yield and parity, and one cow within each pair bred to a Holstein sire, while the second was bred to a Jersey sire. This was repeated, but reversed during a second year. The resultant heifers from this breeding programme (Holstein and Jersey x Holstein crossbreds) were subsequently monitored within the experiment. One hundred and ninety three Holstein heifers and 188 Jersey crossbred heifers calved and commenced the first lactation.

While this experiment is still ongoing, the production and fertility performance of the cows on the experiment is summarised in Table 7. In each of lactations 1–3, Holstein cows produced significantly more milk than the crossbred cows. However, when the improved compositional performance of the crossbred cows was taken into account, there were no differences between genotypes in terms of fat + protein yield. This is in agreement with the findings of the low input systems examined within the two Hillsborough experiments. There were also no differences between genotypes in terms of somatic cell counts. With regards to fertility performance, while there was a trend for improved conception rates to first service with the crossbred cows during each breeding season, to date the only difference in fertility performance was during Lactation 2. While this study is still ongoing, it is hoped that the study will clarify if differences in survivability exist between the two breeds. At the time of going to press, 54% of the Holstein cows and 48% of the Jersey crossbred cows which started the study have been culled.

Table 7 Comparison of milk production and fertility performance of Holstein and Jersey x Holstein crossbred cows on 11 Northern Ireland dairy farms (after Park *et al.*, 2009)

	Genotype			
	Holstein	Jersey x Holstein	s.e.d.	Sig.
Milk Production				
Lactation 1				
Milk yield (kg)	6012	5628	99.9	***
Fat + protein yield (kg)	448	452	7.81	NS
Lactation 2				
Milk yield (kg)	6518	6006	160.8	**
Fat + protein yield (kg)	505	506	13.4	NS
Fertility performance				
Maiden heifers				
Conception to 1st AI (%)	62	72		NS
Conception to 1st and 2nd AI (%)	93	95		NS
Lactation 1				
Conception to 1st AI (%)	48	52		NS
Conception to 1st and 2nd AI (%)	76	75		NS
Lactation 2				
Conception to 1st AI (%)	49	52		NS
Conception to 1st and 2nd AI (%)	63	78		*

Issues to be considered before adopting crossbreeding

The findings of the AFBI studies, together with an increasing body of international evidence (both historic and recent) has clearly demonstrated the potential advantages of crossbred cows in terms of improved health, fertility and longevity. Similarly, within lower input systems crossbred cows have been shown to have the potential to produce similar outputs of milk solids as pure bred cows. So is the 'crossbreeding route' one that all farmers should be actively considering?

On many Northern Ireland farms where appropriate sire selection programmes have been in place in the past, crossbreeding may offer little in terms of an overall improvement in economic performance. However, on other farms crossbreeding may have a very real role, and crossbreeding has of course already been adopted at various levels on many local farms. Nevertheless, the adoption of crossbreeding is not a decision that should be taken lightly. Its impact on a herd, both in the short term and long term needs to be considered, and both the potential positive and negative impacts of crossbreeding need to be examined. The following are some of the key issues that need to be considered before embarking on a crossbreeding programme:

1) Crossbreeding will not solve problems associated with poor management or poor nutrition. Many dairy farmers have adopted crossbreeding in an attempt to solve problems that are largely management related, such as high cell counts and lameness. Many of these problems may remain unresolved with crossbred cows. It has been suggested that a 'bad' pure bred farmer will be an even poorer 'crossbred' farmer. Farmers must clearly identify why they are considering crossbreeding (i.e. what is the problem that they are attempting to solve), and then identify if crossbreeding is likely to provide part of the solution, or if management changes will be equally effective.

2) Crossbreeding does not represent true genetic improvement. True genetic improvement takes place when the top AI sires (for the most economically important traits) are used within that breed. For some genetic problems, the solution may well be found within the parent breed. Selection indexes which have a major emphasis on functional traits now exist for the Holstein breed within many countries, including the UK PLI, as detailed by Carson *et al.* (current publication). Through careful sire selection, bulls which can help to

overcome current herd weaknesses can be chosen. Nevertheless, on many herds it will take quite a few generations to reverse some longstanding problems.

3) Following on from the above, hybrid vigour must be recognised as a ‘bonus’ rather than long term genetic gain. For many traits, for example milk yield, levels of hybrid vigour can be relatively low (average of 4.7%), and in many cases the level of production of the crossbred cow will remain below that of the pure bred parent. Adopting crossbreeding solely to gain the benefits of hybrid vigour is unlikely to be justified, although undoubtedly levels of hybrid vigour for some functional traits can be high. It is critical to remember that hybrid vigour is not passed on to the next generation.

4) While crossbreeding may be advocated as a means of overcoming inbreeding depression, levels of inbreeding within the UK Holstein population are still relatively small. It has been suggested that inbreeding really only becomes problematic when levels are >6.25%. With careful sire selection, high levels of inbreeding can be avoided.

5) Crossbreeding is a long term commitment. For cows that have been bred to a sire of a different breed this spring, it will be 2–3 years before the potential benefits of these animals becomes apparent within the herd, and at that stage these crossbred cows are unlikely to comprise more that 25% of the herd. Similarly, while ‘crossbreeding’ can be introduced into the herd during a single breeding season, it can take many generations to ‘erase’ the impact of a crossbreeding decision if its effects are found to be undesirable.

6) Crossbreeding can complicate management issues, especially in relation to housing and milking facilities. Depending on the breeds used, crossbreeding will often result in smaller cows, and cows with a more diverse range of sizes. While the former may be advantageous within a grazing system,

smaller and mixed sized cows can result in problems in the milking parlour and in cubicle houses.

7) The impact of crossbreeding on the value of cull cows, male calves and surplus breeding stock needs to be considered. The impact may vary depending on the breed chosen. For example, the use of the Montbeliarde breed within a crossbreeding programme may well increase the value of cull cows and male calves, while the reverse is likely to be true when the Jersey is used. In addition, the impact of crossbreeding on the long term value of the herd needs to be considered.

8) The choice of the second (and possibly third) breed for use within a crossbreeding programme is a critical decision. A number of issues need to be considered. Firstly, the breed should be suitable for the milk production system in which its offspring will function (i.e. low input grazing vs high input confinement). In most cases, a breed should be chosen to minimise any loss in milk production, while at the same time maximising the gain to be made in other traits. Evidence from AFBI studies would suggest that Jersey crossbreds are not particularly suited to high input systems, while evidence from the US would suggest that Scandinavian crosses are. In addition, any breed being considered for use within a crossbreeding programme should have an associated breed improvement progeny testing programme, with a significant focus on traits of greatest economic importance. To facilitate this, breeds being considered should have a sufficiently large population size to allow ongoing genetic improvements to be made. When choosing a breed the first step is to identify the key goals of the crossbreeding programme, and to identify a breed which will allow these goals to be achieved.

9) Using a breed that is genetically ‘distanced’ from the parent breed will also impact on the level of heterosis to be gained. For example, while some have advocated the use of Red Holsteins as a ‘breed’ for ‘crossbreeding’, the benefits of these in terms of heterosis are likely to be relatively small,

although they may provide scope for ‘out crossing’ within many Holstein populations.

10) The choice of sire within a breed is perhaps even more critical than the choice of breed itself. The perception is still widespread that a bull of a different breed purchased from a ‘neighbour down the road’ will be suitable for crossbreeding, just because it is of a ‘different breed’. This will only do a great disservice to the concept of crossbreeding. Sires used within crossbreeding programmes should be top sires for PLI from within the breed selected.

11) As already highlighted, crossbreeding is a long term commitment, and one which requires a long term strategy to be in place with regards the next genetic step. By the time that the F_1 crosses have reached breeding age, a clear strategy with regards the next step in the genetic pathway should have been decided upon. A number of options exist:
    a. <u>Two breed rotational crossing</u>: this involves mating the F_1 cross back to one of the two parent breeds, and mating the offspring from that cross back to the other parent breed, with this process being repeated in future generations. This strategy will result in long term achievement of 67% of the heterosis expressed by the F_1 cross (Lopez Villalobos *et al.*, 2000)
    b. <u>Three breed rotational crossing</u>: this involves mating the F_1 cross to a third breed, with the offspring of this cross being bred back to the breed of the original animal. This strategy will result in long term achievement of 86% of the heterosis expressed by the F_1 cross (Lopez Villalobos *et al.*, 2000). This breeding cycle could be modified to involve a fourth breed.
    c. A third possible strategy involves the use of progeny tested crossbred F_1 sires. Semen from Jersey x Holstein F_1 sires is now available within the UK.

Conclusions

Crossbreeding is not for everyone, and on many farms crossbreeding will not overcome problems of poor management. Nevertheless, a well planned and well managed crossbreeding programme can result in robust cows with fewer calving difficulties, fewer health problems, higher levels of fertility, and ultimately improved longevity. While crossbreeding may have a detrimental impact on some economic aspects such as the value of male calves and cull cows, the positive financial impact associated with improvements in functional traits has the potential to improve overall economic performance of the dairy business.

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Bovine information system (BovIS) – the development of a phenotypic database for the Northern Ireland dairy industry

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Introduction

The Bovine Information System (BovIS) is currently under development by AFBI and partners including the College of Agriculture, Food and Rural Enterprise (CAFRE), DARD Veterinary Services, Livestock and Meat Commission (LMC), Irish Cattle Breeding Federation (ICBF) and Scottish Agricultural College (SAC). Applications of BovIS for the beef industry have been presented in a paper by Carson *et al.* (2009), which demonstrated the potential for data from the Animal Health and Public Information System (APHIS), integrated with meat plant data, to be used as a basis to develop benchmarking tools for farmers to evaluate the physical performance of their herds. On-line benchmarking tools have been developed by AFBI and CAFRE for the pig industry (PiGIS; available a www.ruralni.gov.uk). In the South of Ireland, ICBF have developed a range of benchmarking applications for the dairy sector (available at www.icbf.com). AFBI has started work to develop benchmarking tools for BovIS which will be accessible over the internet by beef and dairy producers.

The first component of work for the dairy sector has involved herds in the AFBI/CAFRE heifer study detailed by Carson *et al.* (2010). Herd data stored on the APHIS in relation to births, calvings, deaths and movements on and off farm has been run through an ICBF software application for benchmarking calving performance. It is planned that AFBI and its partners within BovIS in Northern Ireland will work together with ICBF in developing new benchmarking applications including a proposed new tool to evaluate carbon emissions from dairying systems.

The purpose of this paper is to review findings from the benchmarking data of farms involved in the AFBI/CAFRE heifer study to (1) detail the range of management information which can be obtained from the analyses of statutory information stored within APHIS and (2) evaluate performance of dairying systems in Northern Ireland in relation to a range of calving parameters.

Summary calving data

Of the 250 herds involved in the AFBI/CAFRE heifer study, 160 agreed access to their APHIS data. This enabled data from the on-farm questionnaire to be linked for each herd with analysis of performance parameters determined from APHIS. Data from this work is presented in the current paper in the same format as that in the benchmarking reports. Data from all participating herds has been aggregated and the mean, and where appropriate median values, are presented.

Overall, the average number of animals calving per herd over the period from 1 April 2009 to 15 March 2010 was 77.1 with 22 of these being replacement heifers (Table

1). On average, a total of 22.9 cows per herd with a calving record in the database did not calve over the 1-year period. The total number of 'eligible cows' i.e. all females on the farm that are greater than or equal to 22 months was 91.3. Herd size was a little higher than the Northern Ireland average due to the fact that smaller herds (less than 30 cows) were not included in the heifer study.

From the total of 77 animals that calved per herd, 77 calves were born alive, on average, with 73.8 alive at 4 weeks. The average twinning rate was 3.7%.

The average age at calving for the cows was 6 years and for the heifers 2 years 9 months.

Table 1 Summary calving data averaged for 160 dairy farms in the AFBI/CAFRE heifer study (09-10 data)

	Cows plus heifers	Heifers only
Total calvings	77.1	22.8
No. of calves – Live at Birth	77.3	22.1
No. of calves – Dead at Birth	2.7	1.2
No. Male Calves – Live at Birth	37.7	10.4
No. Female calves – Live at Birth	39.5	11.7
No. of cows not calved	22.9	
No. of calves – Live at 28 days	76.8	
All females 22 months plus	91.3	
	Cows	Heifers
Average age at calving	6 yr 0 m	2 yr 9 m

Age at first calving

Rearing dairy herd replacements represents a major investment by dairy producers in the future of the enterprise. As part of a dairy heifer research and development initiative, a blue-print for improved heifer rearing was developed from research at AFBI Hillsborough and put into practice on pilot farms across Northern Ireland in a programme undertaken in partnership with CAFRE and John Thompson and Sons Ltd. The blue-print was based on a target age at first calving of 23-25 months at a live weight of 540-580 kg for Holstein-Friesian heifers.

The key to efficient heifer rearing is to monitor growth for age and on this basis make informed decisions. A calibrated weigh band has been developed by AFBI to make growth monitoring easier and more accurate. The calving reports generated as part of the current study provide the potential for all dairy producers to monitor age at first calving in their herd and enable the impacts of changes in rearing practices to be assessed.

In the survey of herds in Northern Ireland, 39% of producers reported to implement calving at 24 months of age. In line with this, the producer estimate for age at first calving, averaged across herds, was 27.4 months. This is considerably lower than the average of 32.7 months determined from APHIS records. The median value represents the midpoint of the ages at first calving for heifers within a farm. This takes out any outliers which may skew the data and, when working with industry data, probably represents a better parameter for assessing age at first calving on farms. Across the 160 farms, the median value for age at first calving was 30.4 months of age. This is similar to the South of Ireland where the average age at first calving for herds was 31.1 and 29.8 months of age for autumn and split calving milk recorded herds, respectively (ICBF, 2010). In the UK, when all pedigree registered Holstein Friesian heifers were pooled, the median age at first calving over the period 2006-2008 was 28.1 months (CDI, 2008). Comparisons with some of the other main dairy producing countries are interesting. In the Netherlands, the average age at first calving is reported as 26 months (veepro.nl, 2009), in the US 25.2 months (USDA, 2007).

Reducing age at first calving will have a beneficial impact on greenhouse gas emissions through reducing the number of heifers required. Modeling work undertaken by Nottingham University indicated that reducing age at first calving from 27 to 24 months of age will reduce total herd emissions by 6%.

Factors associated with age at first calving (producer estimate)

In the survey, average age at first calving estimated by producers declined as herd size increased ($P<0.01$) and the number of first lactation heifers milking increased. However, based on the APHIS data (Table 2), the decline in age at first calving was not observed until herd size increased above 150. This trend for younger age at first calving with larger herds has also been found in the US (USDA, 2007).

In terms of calf rearing, an association was found between timing of introduction of concentrates and age at first calving. Herds that introduced concentrates at an earlier age reared heifers to calve down at a younger age ($P<0.001$).

Increasing herd milk yield was associated with decreased age at first calving (producer estimate). Likewise, dairy herds that fed higher levels of concentrates reared heifers to calve at an earlier age ($P<0.05$).

Herds that practised more AI tended ($P=0.10$) to rear heifers to calve at an earlier age (1 month difference) compared with herds that used more stock bulls for breeding.

For calving at 24 months of age, breeding needs to commence at 13.5 months of age at a target live weight of 350-370 kg. Producers that placed a higher minimum live weight at service calved heifers at an older age ($P<0.05$).

Producers who participated in a recording scheme such as milk recording, CAFRE dairy herd benchmarking etc. calved heifers at a younger age than those not participating in recording (28.1 versus 27.0 months of age; producer estimate) (P< 0.05).

Table 2 Average age at first calving on 160 farms in the AFBI/CAFRE heifer study

Herd size (no. of cows)	Average age at first calving (months)		
	Farmer estimate	APHIS records	
		Average	Median
30-50	28.5	32.1	30.7
50-100	27.4	32.9	30.8
100-150	27.3	33.6	31.0
150+	26.0	31.5	28.8
Average	**27.4**	**32.7**	**30.4**

Calving interval

Calving interval has a major effect on the physical, financial and environmental performance of dairy herds. In the current study the average calving interval was 431 days with a median value of 402 days. An average milk yield of 6350 litres is assumed (the Northern Ireland average for 2009). This is very close to the reproductive performance reported for similar type herds in the South of Ireland where the median value for calving interval for Holstein-Friesian cows with recorded parentage was 403 days with an average milk yield of 6493 litres (2009 data reported by ICBF, 2010). The value for calving interval recorded in the current study is in line with that (421 days) calculated previously from BovIS for Holstein Friesian cows in Northern Ireland over the period 2005-2009 (Carson *et al.*, 2009).

Within herds in Northern Ireland, on average, half of the cows had a reasonable calving interval (under 400 days) (Table 3). However, a third of the cows had a significantly extended interval (over 435 days) which is likely to be associated with considerable reductions in milk output and increases in the risk of metabolic disorders.

Comparisons with other dairy populations are informative. The average calving interval for Holstein Friesian milk recorded cows in Northern Ireland was 413 days with an average milk yield of 7176 litres for 2009 (CDI, 2007). In GB, the average calving interval was 428 days with an average yield of 8262 litres (CDI, 2008). In the Netherlands, the average calving interval was 417 days with an average yield of 8725 litres for milk recorded cows (veepro.nl). In NZ, the average calving interval was 370 days with an average yield of 3710 litres for milk recorded cows (LIC, 2009). In US the average calving interval was 406 days with an average yield of 9050 litres for milk recorded cows (USDA, 2007).

In the current study, the average number of calves produced per cow per year for herds in Northern Ireland was 0.73 close to the average for herds in the South of Ireland (0.8) (ICBF, 2010).

Reducing calving interval and thereby increasing the number of calves produced per year has a significant impact on the carbon footprint of dairy production. It has been estimated, in approximate terms, that a 1 day reduction in the calving interval for the Northern Ireland dairy herd will reduce greenhouse gas emissions by 5700 tonnes of carbon equivalents (Carson *et al.* unpublished data).

Table 3. Average calving intervals for cows in 160 herds in the AFBI/CAFRE heifer study (09-10 data)

Calving interval	No. calved	% calved
Cows calved <= 365 days	16.9	29.6
Cows calved 366-400 days	11.4	19.3
Cows calved 401-435 days	7.2	12.2
Cows calved >435 days	18.5	37.6

Seasonality of calving

A very significant proportion of the industry in Northern Ireland (41%) has moved away from seasonal calving patterns (Table 4). Only 12% of producers reported to have either an autumn or spring calving pattern with 46% reporting a calving pattern spreading over the winter (taken as September to April).

Table 4 Calving schedules reported by Northern Ireland dairy producers (AFBI/CAFRE heifer study)

Calving schedule	% of producers
Autumn	7
Spring	5
Winter	46
All year	41

Just over 2.5 times the number of cows calve in October compared with July (Table 5). For heifers, seasonality in calving in a little more pronounced with 3.5 times more heifers calving in September compared with June (Table 5). Nonetheless the data shows the fact that a significant proportion of cows and heifers calve in all months of the year.

Table 5 Seasonality of calvings in 160 dairy herds in AFBI/CAFRE heifer study (09-10 data)

Calving period	% cows		% heifers	
	This year	Last year	This year	Last year
April	10.7	8.8	8.0	6.1
May	7.9	7.6	5.4	5.0
June	6.3	5.6	4.8	3.6
July	4.2	4.2	4.2	3.7
August	5.5	4.8	7.2	5.8
September	8.3	8.7	12.0	13.1
October	11.7	10.7	13.4	12.4
November	12.4	9.2	12.7	11.2
December	10.0	10.0	8.8	10.9
January	10.4	9.9	10.3	9.6
February	9.0	8.9	9.9	9.5
March	3.7	11.4	3.3	9.2

Lifespan

Increasing lifespan of cows is a key issue for the Northern Ireland dairy industry. On average within the 160 herds in the current study, 50.8% of cows were first and second calvers (Table 6). Only 19.1 % of cows were 5th calvers or greater.

Increasing the longevity of dairy cows in Northern Ireland, thus reducing replacement rates from current estimate of 27% to 25% has been estimated to lead to a saving of 10,571 tonnes of carbon dioxide equivalents, if livestock numbers remain stable (Carson *et al.*, unpublished data).

Table 6 Average number of calvings per cow in 160 dairy herds in the AFBI/CAFRE heifer study (09-10 data)

Calvings	Number of cows	% of cows
1st calving	3693	29.0
2nd calving	2767	21.8
3-4th calving	3818	30.0
5-7th calving	2075	16.3
>7th calving	361	2.8

Calf mortality

In the current study average mortality within herds was estimated at 6.5% close to the value determined from APHIS data (4%) and that reported for herds in the South of Ireland (4.8%; ICBF, 2010).

Next steps in the programme

This paper outlines some of the simple, but important, management information that can be generated from the use of APHIS data. CAFRE Dairying Development Advisers will feed back copies of the individual reports to all the herds participating in the research programme over the next couple of months. All partners involved in this BovIS programme will monitor progress and work to develop systems to make these calving reports available to the wider industry in the autumn of this year. This will be followed up by additional benchmarking applications which AFBI and its partners within BovIS in Northern Ireland will work together with ICBF to introduce. New benchmarking applications are planned including on-line beef cattle growth and carcass benchmarking and a proposed new on-line tool to evaluate carbon emissions from dairying systems.

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Latest research on calf management for performance

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Introduction

Good husbandry and stockmanship are crucial for successful calf rearing. As herd size increases on dairy farms across Northern Ireland, greater demands are placed on developing successful calf rearing enterprises which can be managed with less labour available. This paper outlines the findings from the AFBI/CAFRE survey of heifer rearing practices on Northern Ireland dairy farms and reviews the latest research on management systems for optimal calf health and performance.

Calf health

Calf ill health and mortality represent a significant cost to the Northern Ireland dairy industry, both in terms of direct veterinary costs associated with treating sick animals and losses associated with poor performance and death of animals. In the AFBI/CAFRE heifer survey, producers estimated an average calf mortality rate of 6.5% for their systems which is similar to that calculated from APHIS and reported for systems in the South of Ireland (ICBF, 2010) and GB (Blowey, 2005). Significant differences occurred in calf mortality between farms (range 0-26%), highlighting the fact that management and/or environment are major factors impacting on calf health.

Survey data from North America (USDA, 2007) has shown that the main causes of neonatal death in dairy systems are enteric diseases and pneumonia (Table 1) and these in turn are affected by housing, colostrum and nutritional management. In the AFBI/CAFRE survey approximately one third of producers indicated that they had a significant problem with calf scour and/or pneumonia. Vaccination can help combat many of the scour and pneumonia pathogens. In the survey 15% of producers reported to vaccinate their cows to provide better immunity to calves against scours. Twenty-one percent of producers vaccinated their calves against pneumonia agents.

Table 1 Percentage of deaths by cause on US dairy farms (USDA, 2007)

	Percent deaths (%)	
Cause of death	Pre-weaned	Post-weaned
Scour	57	13
Pneumonia	23	47
Lameness or injury	2	13
Joint/navel ill	2	1
Other	16	26

When treating sick calves, in particular those with pneumonia, it is important to isolate these calves to reduce the risk of disease transmission. However, less than 25% of producers in the survey adopted this approach. Furthermore, not all producers follow the recommended protocol of administering electrolytes to scouring calves (14% did not use electrolytes). Within the questionnaire, there was evidence to suggest that many farmers withdrew milk/milk replacer from calves suffering from mild scour. Continued milk feeding to calves showing mild to moderate signs of diarrhoea in conjunction with rehydration therapy is generally recommended to maintain calf growth and support the repair of damaged intestinal mucosa (Heath *et al*., 1989; Garthwaite *et al*., 1994)

Producers routinely administer antibiotics to control calf scour (47% of producers use an antibiotic in cases of mild scour). However, Cryptosporidia and Rotavirus, the most common pathogens in cases of calf scour on Northern Ireland farms (Table 2), do not respond to such treatment. Consequently, care needs to be taken to ensure the unnecessary use of antibiotics is avoided.

Table 2 Main pathogens identified in calf faecal samples from Oct 08 – Sept 09 (AFBI VSD)

Pathogen	Samples tested	Number positive	Percentage (%)
Cryptosporidia	1851	743	40
Rotavirus	1753	523	30
Coronavirus	1768	64	4
Escherichia coli K99	900	42	5

Data from the AFBI Hillsborough herd has been analysed to quantify the impact of a case of scour or pneumonia in early life on subsequent performance. Mortality rates were higher in animals which had experienced an episode(s) of scour in the pre-weaning stage (Table 3). In addition, live weight of animals in their first and second year of life was slightly lower in those which had experienced calf scour. However, there was no significant effect on subsequent performance during lactation.

Table 3 Effect of calf scour on animal performance

	Scour in early life (pre-weaning)		
Parameter	Yes	No	Sig.
Live weight (kg)			
3 months	91	91	***
6 months	149	151	***
1 year	287	290	***
1.5 year	420	423	*
Mortality 1 year (%)	7.9	4.8	*
Age at calving (months)	24.3	24.1	NS
1st lactation yield (kg)			
Milk	7190	7000	NS
Fat	280	278	NS
Protein	236	234	NS

The impact of an episode(s) of pneumonia in early life on subsequent performance is shown in Table 4. In contrast to scour, pneumonia had no significant effect on overall mortality rates in the AFBI herd data. However, there was a significant association with lactation performance. Heifers which had experienced pneumonia in early life had lower live weights through to calving and produced 4% less milk. The impact on milk production of an episode(s) of pneumonia in later life (post weaning) was of similar size (6% less milk).

Table 4 Effect of calf pneumonia on animal performance

	Pneumonia in early life (pre-weaning)		Pneumonia in later life (post-weaning)	
Parameter	Yes	No	Yes	No
Live weight (kg)				
3 months	91	93***	87	92***
6 months	149	152***	143	150***
1 year	288	292***	277	290***
1.5 year	421	424**	409	423***
Calving	558	571**	555	566 $^{p=0.10}$
Mortality 1 year	5.8	5.7 ^{ns}	-	-
Age at calving (months)	24.2	24.2 ^{ns}	24.4	24.2 ^{ns}
1st lactation yield (kg)				
Milk	6933	7192 $^{p=0.10}$	6723	7143*
Fat	273	284 $^{p=0.06}$	272	280 ^{ns}
Protein	229	240*	224	237*

Colostrum

Colostrum is a key factor in the prevention of many calf health related problems. Insufficient intake of colostral antibodies during the first 24 hours of life is the main cause of calf health problems in the pre-weaning period. Calves that do not receive adequate antibodies through colostrum are between 2 and 26 times more likely to die as those calves receiving adequate levels of colostrum (Berge *et al.*, 2009). Data from the AFBI Hillsborough herd found that calves with low immunity, during the pre-weaning period were more than twice as likely to experience calf scour or pneumonia as calves with adequate immunity.

Colostrum can vary in quality and this can have an impact on the passive immunity received by calves. No studies of colostrum quality has been undertaken in Northern Ireland dairy systems but American studies have shown that the antibody concentration of colostrum varies from 14 to 100 g/l. This makes it difficult to determine how much colostrum to feed to achieve adequate calf immunity. The data in Table 5 demonstrates how this variation in the concentration of antibodies affects the amount of colostrum a calf weighing 40 kg requires to achieve an adequate level of immunity.

Table 5 The effect of colostrum quality on the volume required to achieve an adequate level of immunity

	Colostrum quality		
	Poor	Average	Excellent
Required antibody intake (g)	120	120	120
Antibody concentration (g/l)	14	41	100
Required amount to feed (l)	8.6	2.9	1.2

Offering more than 8 litres of colostrum to a calf within the first few hours of life is not possible and if all calves only received the common 2 litres within the first few hours, many calves would never achieve an adequate level of immunity. These calves would therefore be more likely to suffer from disease, incur a reduced growth rate and possibly perform less well in the milking herd. An important point to note is that colostrum can only provide immunity to the diseases to which the dam has been exposed to and therefore producing antibodies against. Feeding 3-4 litres of colostrum within the first hours of life should be an adequate compromise, ensuring the majority of calves receive an adequate quantity of antibodies to give them a good start.

Timing of colostrum feeding is critical. The efficiency of absorption of antibodies in colostrum is highest immediately after birth but declines to almost zero by 24 hours of age. Therefore, it is critical that the calf receives colostrum as soon as possible after birth. Although the absorption of antibodies is minimal after 24 hours post-birth, it is recommended that, wherever possible, colostrum should be fed for the first 3-4 days of life since particular types of antibodies within the colostrum attach to the lining of the calf's intestine preventing pathogens from causing disease.

Calves that are fed colostrum either by stomach tube or by bottle within the first hours of life, compared with calves that are left to suckle the mother, are almost 3 times more likely to have adequate immunity to fight off neonatal diseases (Table 6). This is primarily a result of variation in the time taken by calves to suckle successfully (Besser *et al.*, 1991). Slowness to suckle successfully can be pronounced in dairy calves, with the average calf from a dairy cow taking over 4 hours to suckle. Despite clear benefits of stomach tubing each calf with colostrum, only 24% of Northern Ireland dairy farms surveyed conducted this practice (Table 7).

Table 6 Effect of colostrum feeding method on percentage of calves with less than adequate immunity

	Percentage of calves less than adequate immunity	
Reference	Suckle	Bottle
Beam *et al*. (2009)	26	17
Franklin *et al*. (2003)	38	13
Besser *et al*. (1991)	61	11-19
Brignole and Stott (1980)	42	-

In contrast, 59 % of American dairy producers were reported to feed colostrum to every calf via bottle or oesophageal feeder (USDA, 2007) and greater than 50% removed the calf from the dam immediately after birth with a further 22% having removed the calf with 12 hours of birth. Removal of the calf soon after birth reduces the risk of disease transmission such as Cryptosporidium (Trotz-Williams, *et al.*, 2007) but only 34% of Northern Ireland dairy heifer rearers carried out this practice. Reduced exposure to scour causing pathogens and a continued focus on improving passive antibody transfer through controlled colostrum feeding will help to ensure that calves experience less health challenges, increase the effectiveness of scour vaccination programmes and improve calf health and performance.

Table 7 Pre-weaning management techniques for Northern Ireland dairy calves

Item	% of operations
Age separated from dam	
<4 hours	9.4
4-12 hours	24.1
12-24 hours	39.2
24-48 hours	22.0
Restricted access (max 3 days)	1.2
Other	4.1
Colostrum feeding method	
Suckle from dam	73
Hand fed	27

Colostrum is not only important for getting calves off to a good start in life but can have long term effects on animal performance. Data from AFBI Hillsborough have shown that beef calves with less than adequate immunity received a greater number of antibiotic treatments in the pre-weaning period, had 17% lower liveweight gains from birth to 3 months and were on average 17 days older at slaughter (Table 8).

Table 8 Effect of calf immune status on long term animal performance

	Immune status			
Parameter	Low	Medium	High	Reference
Liveweight gain 28 d (kg/day)	0.15	0.24	0.27	Berge *et al.* (2009)
Age at slaughter (mths)	20.1		19.5	Dawson & Moss (2009)
Veterinary costs ($/calf)	24.51		14.77	Faber *et al.* (2005)
1st lactation milk yield (kg)	8952		9907	Faber *et al.* (2005)
2nd lactation milk yield (kg)	9642		11294	Faber *et al.* (2005)
Weight difference @ 205 d (kg)	0	+15	+29	Vann *et al.* (2001)
Milk production	8.5 kg increase in yield per mg Ig/ml			DeNise *et al.* (1989)

Few studies have examined the link between immune status and performance in the dairy herd, those that have report that calves with greater immunity have greater milk production performance. For example calves that received additional colostrum within the first hours of life (4 versus 2 litres) produced more milk over the first two lactations in addition to having reduced veterinary costs (Faber *et al*., 2005).

Colostrum derived immunity is the key base upon which to build an efficient calf rearing enterprise however on occasions when colostrum is unavailable due to shortage or disease prevention policies, alternatives need to be used. Table 9 shows the blood immunoglobulin concentration of calves offered a range of commercial colostrum replacers compared with maternal colostrum. All calves offered the maternal colostrum achieved an IgG concentration greater than 10 mg/ml but many of the colostrum replacer treatments failed to supply calves with an adequate level of immunity. The three key factors quality, quickness and quantity are also critically important when using colostrum replacers. The IgG supply must be sufficient in quantity (150-200 g of IgG intake) and timely if calves are to achieve an adequate level of immunity.

Table 9 Effect of colostrum replacer or maternal colostrum on blood IgG concentration

IgG (mg/mL)	Colostrum replacer	Maternal colostrum	Comment
Godden *et al*. (2009)	9.6 - 19.0	20.7	Two CR levels
Swan *et al*. (2007)	5.8	14.8	On-farm study
Smith and Foster (2007)	7.5 - 9.1	17.6	Two CR levels
Jones *et al*. (2004)	14.7	13.7	Equal Ig intake
Quigley *et al*. (2001)	5.6 - 14.1	18.8	Range of CR levels
Arthington *et al*. (2000)	2.2 - 6.8	12.1	Low IgG intake with CR treatment
Mee *et al*. (1996)	3.0	17.8	Low IgG intake with CR treatment

CR – colostrum replacer

Nutritional supplements

Many non-nutritional scours occur when pathogenic bacteria flourish and grow within the gut often by out-competing the protective and positively productive microflora. Non-antibiotic administration techniques commonly used to help prevent the invasion and growth of these pathogenic bacteria include that of offering competitive bacteria (probiotics) or substances in the milk replacer that prevent the pathogenic bacteria from adhering to the gut wall and therefore prevent scours from occurring. Previous research (e.g. Timmerman *et al.*, 2005) reported positive effects of probiotics on calf health but there is no published data in the literature on the effect of probiotics in a group feeding situation using computer controlled feeders.

Probiotics function through actively out-competing the pathogenic scour causing bacteria but mannan oligosaccharides (MOS), which are a part of the carbohydrate fraction of yeast cell walls (Saccharomyces cerevisiae) (Hill *et al.*, 2009), when added to the diet of growing calves, offer competitive binding sites for certain gram-negative pathogenic bacteria (Spring *et al.*, 2000). Pathogens with the complementary fimbriae adhere to the mannans instead of the intestinal cells of the calf and therefore move through the intestine without colonising (Spring *et al.*, 2000) or potentially causing scours. Heinrichs *et al.* (2003) reported that calves offered MOS had an improved faecal consistency, similar to that of calves offered antibiotic supplemented milk replacer.

Research conducted at AFBI Hillsborough found no major calf performance benefits from including a probiotic or mannan oligosaccharide in the diet of pre-weaned calves (Table 10). However, supplement inclusion did encourage concentrate intake in early life and reduced calf faecal score possibly indicating health benefits.

Table 10 Performance, intake, feed costs and faecal score of calves offered milk replacer containing mannan oligosaccharide and/or S*treptococcus faecium*

	Nutritional Treatment[#]				Sign
	C	MOS	PRO	MOS+PRO	
Proportion of calves initiating autowean[2]	0.63	0.79	0.86	0.62	NS
Wean age (day)	51.7	48.8	49.9	51.9	NS
Total milk replacer intake (kg)	25.57	23.31	25.35	26.45	0.07
Total concentrate intake (kg)	17.71	17.38	18.59	17.47	NS
Total feed cost to weaning (£/calf)	40.05	36.80	39.95	41.23	0.09
Mean faecal score[1]	1.16[b]	1.11[a]	1.11[a]	1.09[a]	*

[#] Control (C), Mannan oligosaccharide (MOS), Probiotic (PRO) and Mannan oligosaccharide plus probiotic (MOS+PRO) [4] 1 = normal consistency; 2 = slightly liquid consistency; 3 = moderately liquid and 4 = primarily liquid consistency

Key calf health messages:

- Calf mortality rates in Northern Ireland systems are similar to those reported in other countries
- Calf scours and pneumonia remain a problem on a significant proportion of farms
- Good colostrum management is fundamental to calf health
- Nutritional supplements can have benefits, but these were found to be relatively small

Calf accommodation

Adequate ventilation and space are key components of any successful calf rearing accommodation. Research has shown that limited ventilation and/or overcrowding can significantly increase the risk of calf scour, pneumonia and mortality (Table 11).

Furthermore, labour requirements can be increased due to inappropriate housing design. All these factors are likely to impact of calf health and performance.

Table 11 Effect of environment on calf health and performance

Factor	Effect on calf health
Overcrowding	+ pneumonia
Infrequent bedding removal	+ scour
Poor ventilation	+ pneumonia
Calves housed in dairy cow housing	+ morbidity
Age when offered forage >20days	+ mortality
Use of detergent when cleaning feeding utensils	- scour
Large group size	+ pneumonia + scour

References: Svensson *et al*. (2003); Losinger and Heinrichs (1997); Hillman *et al*. (1992); Frank and Kaneene (1993); Lago *et al*. (2006); Olsson *et al*. (1994); Fourichon *et al*. (1997); Svensson and Liberg (2006)

On 93% of farms in the AFBI/CAFRE survey, ventilation in the calf accommodation was based on natural airflow. Natural airflow systems are generally built on the principle of thermal buoyancy and forced air exchange. With young calves producing minimal amounts of heat, thermal buoyancy is usually limited, resulting in a stale microclimate at calf level (Lago *et al*., 2006). Forced air exchange, mainly by wind through open sides to the shed, can remove stale air, but care must be taken to avoid draughts at calf level (wind speed >0.25 m/second) and pen design can impede the effectiveness of the ventilation (Lago *et al*., 2006).

As part of the AFBI/CAFRE survey the quality of ventilation within the calf rearing accommodation was assessed on a proportion of the farms. Of the 56 calf rearing houses assessed, ventilation rated as very poor to adequate on 46%. With only 16% of calf rearing houses having excellent ventilation, there is room for improvement to help improve calf health and performance on Northern Ireland dairy farms.

Rearing calves in groups has increased in popularity due to reduced labour demands (Gleeson *et al*., 2003) and although individual pens were common, 67% of Northern Ireland dairy farmers reared calves in groups at some stage during the pre-weaning period. Research studies have shown both positive and negative implications of rearing calves in groups. For example, group housing has been shown to stimulate solid feed intake (Warnick *et al*., 1977), milk intake (Richard *et al*., 1988) and social interaction between calves (Babu *et al*., 2004). Group housing of calves has also been shown to increase social dominance of calves when re-grouped with individually housed calves post-weaning (Warnick *et al*., 1977). In some studies, calf growth was unaffected by housing system (e.g. Hepola *et al*., 2006) but in other studies, calves housed individually significantly outperformed group-housed calves (e.g. Maatje *et al*., 1993). Group housing increases the risk of pneumonia (e.g. Svensson and Liberg, 2006) and cross-suckling between calves (Jensen, 2003). Whatever housing system is adopted, be it individual or group, farm-to-farm variation in calf performance and health can be vast, implying that farm management more so than system is a major factor in determining the success of any calf rearing system.

With increasing herd size there is more pressure on calf and heifer rearing accommodation, particularly later in the calving season. Investment in new or larger calf accommodation is not often financially feasible and as such, alternative approaches have to be considered if both animal health/welfare and dairy herd sizes are to be maintained. This has led to interest in rearing calves outdoors. Over the past two years, research at AFBI Hillsborough has examined the rearing of spring born calves outdoors from 2 weeks of age. In agreement with studies performed in the South of Ireland, outdoor calves performed equally well to those housed indoors and there was evidence of a reduced incidence of scour and pneumonia (Table 12). The provision of a clean, dry, bedded shelter within the grazing paddock is key to this rearing system and the inspection of calves for signs of ill health is paramount.

Table 12 Performance of calves reared at grass or indoors from two weeks of age

	Rearing system	
Item	Indoor	Outdoor
Year 1		
Pre-wean intake (g/day)		
Milk replacer	700	700
Concentrate	473	228
Daily liveweight gain (kg/day)		
Week 1-12	0.50	0.50
Year 2[a]		
Pre-wean intake (g/day)		
Milk replacer	700	700
Concentrate	353	245
Daily liveweight gain (kg/day)		
Week 1-8	0.41	0.43

[a] Preliminary data based on first calves weaned

Calf feeding system

Forty-eight percent of Northern Ireland dairy producers house calves in individual pens. The majority of producers feed calves twice daily (90% of producers) using buckets (>75% of producers). Although such rearing systems are highly effective for rearing dairy heifers, they can be very labour intensive. With labour being expensive and in short supply, options to reduce the labour inputs in calf rearing enterprises require evaluation. Research both at AFBI Hillsborough and Teagasc Moorepark has shown that switching to once per day feeding at 12-15 days of age has no negative impact on calf performance, whilst significantly reducing labour requirements (Table 13).

The manual labour involved in feeding calves can be reduced through the use of computer-controlled milk feeding systems. Calves (over 300 per year) at AFBI Hillsborough have been reared using this equipment since 1999. Although there are significant labour savings with computer-controlled systems, the need for a high level of stockmanship is not removed. Other advantages of the system include: meal sizes can be controlled; milk temperature regulated; gradual weaning is easily facilitated; calves of mixed age can be in one pen; and the system shows health warnings relating to reduced calf appetite. The disadvantages of the system includes: the initial purchase cost, likelihood of a decrease in stockmanship and the factors highlighted previously with group housing of calves.

Table 13 Performance of calves fed once or twice daily

	AFBI Hillsborough*		Teagasc Moorepark[1]	
Parameter	Once	Twice	Once	Twice
Milk replacer intake (kg DM)	14.4	18.6		
Whole milk intake (kg DM)			32.4	32.4
Starter intake (kg DM)	69.7	68.8	68.3	71.1
Liveweight gain (kg/day)	0.4	0.4	0.7	0.6
Relative labour requirement[2]	67	100	75	100

* Calves weaned at 35 and 42 days for the once and twice-a-day treatments respectively – intake and performance data recorded until day 70
[1] Calves weaned at 56 days - intake and performance data recorded until day 70
[2] Labour requirements assessed until weaning in the AFBI study and day 70 in the Teagasc study

Researchers in the US have reported no difference in animal performance with the automated and individual systems, but calculated that rearing calves on the computerised system took <1 min/calf/day compared with 10 min/calf/day with the individual system (Kung *et al*., 1997). This labour saving, when applied to a typical 200-cow herd, rearing 77 female calves means that the cost of the system can be recovered within the first 2-3 years. Gleeson *et al*. (2007) estimated calf rearing took 1.5 min /calf/day based on data collected from commercial farms in the South of Ireland. Using this time requirement would mean the cost of the computerised system, when rearing 77 calves, would only be recovered after 10 years. Therefore the payback period for computerised rearing equipment is highly dependent on the number of calves reared per year and the labour efficiency of the current rearing system.

Low cost group feeding alternatives such as multi-teat feeders have been investigated at Hillsborough. These systems can be highly effective for feeding calves but careful management is required. Our research has found that the performance of calves fed using a 25 teat cafeteria was lower than that with calves fed using individual buckets. The main reason attributed to the poor performance of the group fed calves was a large range in age/weight of calves within the group. Larger, older calves tended to dominant the feeder, highlighting the need to batch by age and weight when using such systems. To minimise the risk of 'greedy' calves stealing other calves' milk allocation, compartmentalised multi-teat feeder have been suggested as a possible solution. However a recent Swedish study reported that calves fed using multi-teat feeders' with separate compartments had similar performance to those fed using non-compartmented feeders (Nielsen *et al*., 2008).

Key calf accommodation and feeding system messages:

- Calf accommodation in Northern Ireland dairy farms is largely based on the reuse of older buildings, which are often not ideally suited to calf rearing – ventilation systems are often less than adequate and should be addressed in order to minimise calf health problems and maximise calf performance
- Labour is a major constraint on many dairy farms. Alternative feeding system options to reduce labour requirements and feed costs exist that are not detrimental to calf performance
- Rearing spring-born calves in sheltered outdoor paddocks can reduce the pressure on calf accommodation, whilst maintaining adequate levels of animal performance
- Good management more so than system, is the major factor in determining the success of any calf rearing system

Calf nutrition

Milk or milk replacer

Milk replacer is used predominantly on 23% of farms, with 77% of producers primarily offering whole milk, of which 58% of producers used milk destined for the bulk milk tank. The widespread use of whole milk in the current study concurs with relatively high utilisation rates of whole milk reported on Swedish farms (e.g. Pettersson *et al*., 2001), where over 40% of producers fed whole milk from birth until weaning. Almost 63% of US producers fed whole milk at some stage during the pre-wean period (USDA, 2007). A significant proportion of the whole milk fed on Northern Ireland farms will have been waste milk, but there was evidence to suggest that saleable milk was routinely fed. Ease of management and availability are likely to be the main reasons for feeding saleable whole milk to calves, although confusion over the cost compared with milk replacer may be a contributing factor.

Whether or not to fed whole milk or milk replacer is an ongoing argument within calf rearers. Numerous research studies have compared the performance of calves offered whole milk and milk replacer. Confusingly many of these studies have often compared calf performance when offering calves the same volume of milk replacer or whole milk. Comparing calf feed types based on energy, protein and fat feed levels would be a better approach. Recent research from Korea indicated that calves offered the same level of fat and protein intake from whole milk as opposed to milk replacer, outperformed calves offered milk replacer (Lee *et al.*, 2009). In contrast, a recent study at Moorepark found that calves offered a restricted level of milk replacer grew faster and more efficiently than calves offered a restricted level of whole milk. It is evident that there is no clear answer to the question "which is best - milk replacer or whole milk for dairy calves?" in terms of calf performance, but with an increased risk of disease transmission, variable supply/quality and an increased cost (saleable whole milk) with the feeding of whole milk, feeding milk replacer to dairy heifer calves should be considered.

Of the producers who used milk replacer and supplied manufacturer and product information (n=40), milk replacer protein and fat content ranged from 20-26% and 18-20% respectively in the AFBI/CAFRE study.

Accelerated growth

Over the last 20 years, recommendations for the pre-weaned calf (up to 8 weeks of age) have been to offer 500-600 g per calf per day of a milk replacer containing 20-23% crude protein, together with access to ad libitum concentrates and water. The aim has been to achieve growth rates from 450 to 600 g/day. This means that a calf consumes approximately 25-30 kg of milk replacer, in total, over the first 6-8 weeks of life. Recently, research from North America has questioned the approach of restricted milk feeding and proposed that higher feeding levels should be adopted in a bid to accelerate growth (up to 1 kg/day) in the pre-weaning period. These higher growth rates can theoretically be achieved by feeding 900 to 1200 g of high protein (up to 30%) milk replacer. Many studies that have attempted to examine accelerated growth have been confounded by complex experimental design with calves often 2-3 weeks of age prior to commencing the studies. Few studies have tracked heifer calf performance into the dairy herd but with one or two studies having shown potential improvements in milk production interest in accelerated calf growth has increased (Table 14). To evaluate the merits of such feeding systems in a controlled manner, a series of collaborative studies were undertaken at AFBI Hillsborough and Teagasc, Grange to compare the performance of dairy-bred calves offered milk replacer containing 23% or 27% crude protein at feeding levels up to 1250 g/day.

Relative to calves offered 500-600 g milk replacer per day, calves offered higher levels of milk replacer per day grew significantly faster during the milk feeding period (birth to 8 weeks) (Table 15). However, differences in live weight and body size recorded at weaning for calves on the higher level of milk replacer disappeared within the first year and there were no beneficial effects on milk production during the first or second lactations. Increasing the protein content of the milk replacer above 23% had no short or long-term effects on performance.

Table 14 Published studies on accelerated calf growth and its effect on milk production

Reference	Feed level/type per day[1]	DLWG[#] (kg/day)	Milk production (kg/day)	Summary	Comment
Bar-Peled *et al*. (1997)	1.5-3.0 l MR suckled milk	0.56 0.85	30.6 32.1	Increased milk yield	Milk replacer versus suckling, calves housed differently by treatment
Shamay *et al.* (2005)	464 g MR *ad lib* milk	0.59 0.88	28.6 29.8	Increased milk yield	12% fat milk replacer compared with whole milk
Ballard *et al*. (2005)	400-500g MR 1.25-2.25% of BW	0.74 0.81-0.85	20.7 21.0-23.1	No effect	Calves offered accelerated growth plan where 35-40 kg heavier at calving
Davis-Rincker *et al.* (2006)	1.2% of BW 2.1% of BW	0.45 0.68	30.5 30.5	No effect	Fed to achieve growth rate
Drackley *et al*. (2007)	1.25% of birth 2-2.5% of BW	0.30-0.36 0.71	27.8-30.9 34.4-27.3	Increased milk yield	12% ash milk replacer fed to control calves – high loss rate of heifers from accelerated growth treatment
Aikman *et al*. (2007)	400 g MR *ad lib* MR	0.53 1.04	26.6 28.1	No effect	630+kg live weight at calving
Raeth-Knight *et al*. (2009)	570-1002g MR 680-1002g MR	0.6 0.8	42.5 41.9-43.2	No effect	Calves on accelerated growth offered a concentrate with 5% higher CP concentration. Weaning aged differed between treatments
Terre *et al*. (2009)	410 g MR 900 g MR	0.8 0.9	32.4 34.5	No effect	Calves 17 days old prior to commencing the study

[#] DLWG – daily liveweight gain as calves; [1] MR -milk replacer; Birth – birth weight; BW – body weight

Table 15 Performance of Holstein calves offered standard or accelerated milk replacer feeding regimes containing 23% or 27% crude protein (AFBI Hillsborough)

	Milk replacer level (g/day)		Milk replacer protein	
	Standard[a]	Accelerated[b]	23	27
Year 1 study				
8 weeks (weaning)	63[a]	72[b]	68	66
9 months	238	237	241	234
Milk production (1st lactation)				
Milk yield (kg/day)	22.7	22.2	22.4	22.5
Butterfat (%)	3.98	3.79	3.95	3.82
Protein (%)	3.26	3.24	3.26	3.25
Year 2 study				
8 weeks (weaning)	70[a]	75[b]	71	72
9 months	216	232	224	222
Milk production (1st lactation)				
Milk yield (kg/day)	21.4	20.6	20.5	20.6
Butterfat (%)	4.04	4.05	4.07	4.08
Protein (%)	3.29	3.30	3.33	3.29

[a] Standard milk replacer feed levels in years 1 and 2 were 500 and 600g/day respectively

[b] Accelerated milk replacer feed levels in years 1 and 2 were 1200 and 1250 g/day respectively

Solid food intake

The transition from "pseudo-monogastric" digestion to ruminant digestion is a complex process that is influenced by diet (e.g. Morrison *et al.*, 2009). Concentrate intake is a key driver of rumen development. Within the farms surveyed in the AFBI/CAFRE study, calf starter concentrate was made available pre-weaning on 98% of farms, with 88% offering greater than 1 kg/day during the week immediately prior to weaning. Coarse rations were the most popular choice, accounting for 73% of the farms, followed in popularity by pellets (22%) and home mix (5%). In comparison, Pettersson *et al.* (2001) reported that almost 50% of Swedish farmers fed pelleted calf concentrate compared to only 28% offering a coarse ration. The optimum physical form of calf concentrate is subject to debate, but in general, recent research has shown, that type of concentrate has minimal affects on intake and performance (e.g. Bach *et al.*, 2007) provided it is of good compositional quality (Table 16).

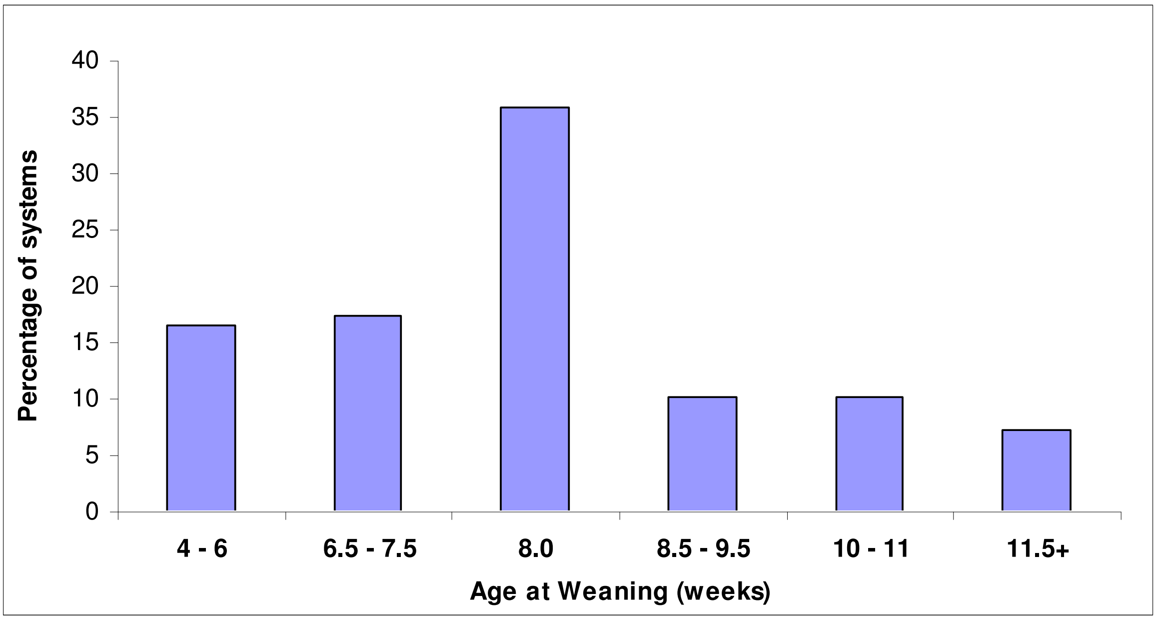
Table 16 Effect of physical form of calf starter concentrate on calf performance (Bach *et al.*, 2007)

	Physical form	
	Coarse	**Pellet**
Starter intake (kg DM)	51.1	45.0
Milk replacer intake (kg DM)	21.7	21.3
Daily liveweight gain (kg/day)	0.78	0.77
Feed conversion efficiency (%)	58.6	61.3

Calves weaned at 57 days or age with daily liveweight gain and feed conversion efficiency calculated at 64 days of age

Forages are less effective at stimulating rumen development than concentrates. However, research from Penn State University (Heinrichs *et al.*, 2005), indicated that forages (or concentrates with large particle size and effective fibre) may assist with rumen development by increasing rumen volume and muscularity, whilst preventing keratinisation of rumen papillae. Care must be taken however, to prevent excessive forage intake at the expense of concentrate intake because rumen development could be impaired. Survey data indicated that calves in US systems received forage at a mean age of 23 days (Heinrichs *et al.*, 1994), whereas almost 70% of Dutch dairy producers offered calves forage within the first 2 weeks of life (Mouritis *et al.*, 2000). From the AFBI/CAFRE survey, forage was offered to calves on 89, 93 and 100% of farms from birth, during the milk feeding stage and at weaning, respectively. Grass silage was introduced at weaning on 25% of farms with the others offering hay or straw.

Figure 1 Estimated age at weaning in calf rearing systems (AFBI/CAFRE heifer survey)



Northern Ireland dairy producers weaned calves at the conventional 8 weeks of age on average, however 28% of producers delayed weaning beyond this target age (Figure 1). Early weaning has been shown by numerous authors, not to be detrimental to calf growth and development (Table 17) but can potentially reduce rearing costs and labour requirements (Gleeson *et al.*, 2007). Only 15% of respondents were able to state an average calf weaning weight (85 kg ±19). In contrast to this lack of monitoring heifer physical development, 89% of farmers rated heifer body size as important or greater when considering when to wean calves. Both physical size and solid food intake were the most important weaning criteria which was in contrast with Dutch (Mouritis *et al.*, 2000) and US calf rearers (Heinrichs *et al.*, 1994) who reported age to be the most important factor.

Table 17 Published studies that have examined the effect of early weaning on calf performance

Reference	Weaning age (days)	Feed level/type per day[1]	DLWG[#] (kg/day)	Effect on calf performance Summary
Jorgensen *et al.* (1970)	21	3.6l milk	0.56	None
	35		0.56	
	42		0.56	
Quigley *et al.* (1991)	28	3.6l milk	0.51	None
	56		0.52	
Hopkins (1997)	28	3.8l milk	0.50	None
	56		0.50	
Greenwood *et al.* (1997)	32	3-3.5l milk	0.45	None
	43		0.43	
	45		0.44	
Kehoe *et al.* (2007)	21	450-500g MR	0.50 - 0.54	None
	28		0.53 - 0.58	
	35		0.55 - 0.69	
	42		0.56 - 0.65	
Gleeson *et al.* (2007)	42	5l milk	0.67	None
	56		0.68	

[#] DLWG – daily liveweight gain as calves; [1] MR -milk replacer

Recognising that solid food intake should be the key driver signalling when to wean calves, a number of studies at Hillsborough have been undertaken recently to examine the concentrate intake threshold to complete the weaning process. Over two autumn calving seasons, 147 calves were assigned to either concentrate dependent weaning or age dependent weaning systems. Calves weaned based on concentrate intake had their milk allocation reduced when they consumed 0.5 kg concentrate/day and weaning was completed when they consumed 1.5 kg concentrate per day (year 2 examined weaning threshold intakes of 0.8/1.0/1.5 kg). Calves weaned based on age were weaned at 8 weeks of age. Results for the first year of the study are shown in Table 18. Weaning based on calf concentrate intake lowered weaning age and milk replacer intake, without adversely affecting the health and performance of Holstein Friesian calves. These savings reduced feed costs to weaning by 20% and in year two, feed costs until weaning were reduced by up to 38%.

Table 18 Intake of dietary components and performance of calves weaned at 8 weeks or weaned based on starter concentrate consumption

	Weaning system			
	Auto	Standard	SED	Sig.
Pre-weaning intake[ab]				
Milk replacer	18.6	23.1	0.53	***
Concentrate	17.0	21.9	1.53	**
Performance at weaning				
Age (days)	47.2	55.0	1.17	***
Live weight (kg)	59.3	66.9	1.31	***
Feed costs (£)				
Cost until weaning	30.07	37.56	0.925	***
Live weight at 40 weeks of age (kg)	226	234	7.7	NS

[a] All means expressed as kg DM/calf [b] total intake recorded until weaning

Key calf nutrition messages:

- Currently, Northern Ireland calf rearing is based on traditional twice daily bucket feeding of whole milk
- Due to the risk of disease transmission, variable supply/quality and an increased cost (saleable whole milk), milk replacer should be considered as the nutrient source for dairy heifers
- No long term performance benefits of feeding calves on an accelerated feeding regimes pre-weaning. Feed approx 1 bag of a 20-23% crude protein milk replacer
- With poor accuracy of live weight prediction and the high degree of importance placed on solid food intake, concentrate intake should be the key criterion used to decide when to wean calves. Calves should be weaned between 6-8 weeks of age
- Good quality forage in the form of hay or straw should be offered to calves from an early age but care must be taken to ensure forage intake does not depress solid food intake and therefore impair optimal rumen development

Overall conclusions

The AFBI/CAFRE survey indicated that calf rearing on Northern Ireland dairy farms is based on traditional rearing systems and techniques. Although these systems, when managed correctly, can achieve adequate level of calf growth whilst minimising calf health problems, labour requirements can be high. AFBI Hillsborough has investigated the relative performance of a range of rearing systems which require less labour and has shown that with good management, adequate levels of calf performance can be achieved. Rearing options such as once-a-day feeding, early weaning and group feeding of calves provide relatively low cost opportunities to save on labour, however, care must be taken to ensure that calf health and welfare standards are maintained. Paramount to the success of any calf rearing enterprise is good colostrum management.

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Overcoming the barriers to research adoption in the Northern Ireland dairy industry

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Background

In order to make real progress in the dairy industry on the feeding and management of heifers, an integrated approach is required in terms of research, development and technology transfer. In view of this, AFBI Hillsborough, CAFRE, and John Thompson and Sons Limited formed a partnership in 2005 with the objective of transferring research on heifer rearing into new rearing regimes on farms to improve the sustainability of dairying.

The key components of the programme were:-

1. Research programmes at AFBI Hillsborough designed to underpin improved rearing regimes funded by DARD and AgriSearch.

2. A major survey of heifer rearing practices on farms across Northern Ireland undertaken by CAFRE Dairying Development Branch and AFBI Hillsborough, This survey involved over 250 dairy producers and set out to evaluate the strengths and weaknesses of heifer rearing systems practised on farms in Northern Ireland and examine a range of aspects of technology transfer.

3. A blue print for improved heifer rearing was developed and put into practice on 8 pilot farms by Thompsons, with support from AFBI. This helped quantify the economic and welfare benefits of adopting improved heifer rearing regimes across a range of milk production systems.

The objective of the current paper is to review some of the findings from the second component of this programme. Particular attention will be given to reviewing the factors which influence the adoption of new scientific developments by producers and, in this context, evaluate some of the linkages between research and dairy producers in Northern Ireland with particular reference to the rearing of dairy herd replacements. The paper will focus on 3 main areas: (1) producer factors affecting the adoption of innovations, (2) models of technology transfer, and (3) creating the right environment for adoption and change.

Producer factors affecting the uptake of research findings

Learning styles

The AFBI/CAFRE study found that most, but not all, producers are keen to learn about new innovations. Overall, 58% of dairy farmers in Northern Ireland described themselves as keen to learn, 28% noted they will examine a new innovation if they have to, 12% indicated they wait and see what others do and 3% reported no interest. The fact that a proportion of farmers wait and see what others do highlights the social pressure element to producer behaviour which needs to be considered, as well as the attitude of the individual producer. However, the data are encouraging in that they highlight the fact that the majority of producers are keen to learn new innovations.

A greater proportion of producers with some form of formal training indicated that they were keen to learn. Overall, 64% of farmers with some formal training indicated that they were keen to learn compared with 36% of those with no formal training.

In the survey, 45% of producers indicated that they had some form of formal training in agriculture. This drops to 32% if short courses are excluded. Formal education attainments have been rising both among farmers and the workforce as a whole. The data from this study and that from elsewhere highlights the fact that this is a crucial factor in increasing the uptake of scientific developments.

Of interest was the fact that most learning is non-specific (66% of producers), i.e. producers tend to browse for general information rather than research particular topics. However, once again level of education was associated with differences in the approach to learning. Producers with some level of formal training were more likely to have a specific objective in mind when learning. Of those producers who indicated their approach to learning was to search out information with a specific objective in mind, 67% had some level of formal training. Matching technology transfer initiatives to specific objectives shared by these producers is likely to increase the speed of new technology adoption (Massey *et al.*, 2004). This suggests that learning should focus on identifying and targeting those individuals who are highly motivated and specific in their learning. However, those individuals who engage in learning without any specific purpose in mind are also important; therefore the key may be assistance with simple interventions to develop learning further such as training on the internet.

In the survey, farmers with formal training were more likely to place less importance on questions such as: 'Is there a need for change?' and 'Do all members of farm agree there is a need for change?' when considering technology adoption and they were more likely to place importance on aspects such as 'Expanding the business', 'Being innovative' and 'Gaining recognition among other farmers' compared with farmers who received no formal training. Thus, increasing the level of training amongst producers is likely to be a continuing key element in reducing barriers to adoption of new scientific developments.

The direct involvement of researchers in agricultural education has real benefits in terms of facilitating current, and future, technology transfer. It establishes direct and strong contact with researchers and their institutes with new entrants to the industry and it ensures that students hear about cutting-edge research first.

Barriers to adoption

Time was identified by dairy producers in Northern Ireland as the main constraint for learning new practices (74% of producers). Other issues identified as the main barrier by producers included 'being happy as they are' (16.3%), costs involved (5.4%) and resource availability (4.6%).

Sources of information

Given the fact that time is a major constraint to learning, and the non specific learning style of many producers, it follows on that press articles are a key source of information (Table 1). Sixty-eight per cent of producers use the agricultural press as a source of information on a weekly basis. Interestingly, producers also reported to gain information from other farmers on a routine basis highlighting the importance of peer-to-peer technology transfer.

Table 1 Sources of information used by dairy producers (AFBI/CAFRE survey)

(%)	Weekly	Monthly-yearly	Never
Top-down transfer			
Popular press	68.0	29.1	2.9
Farmer meetings	0.4	80.2	19.4
Participatory bottom-up			
Discussion groups	0	55.2	44.8
Focus farms	0	46.7	53.4
One-to-one advice			
Development adviser	8.8	91.3	0
Veterinary surgeon	1.7	92.0	6.3
Other farmers	10.9	74.8	14.3
Agri Business	1.7	80.4	18.0

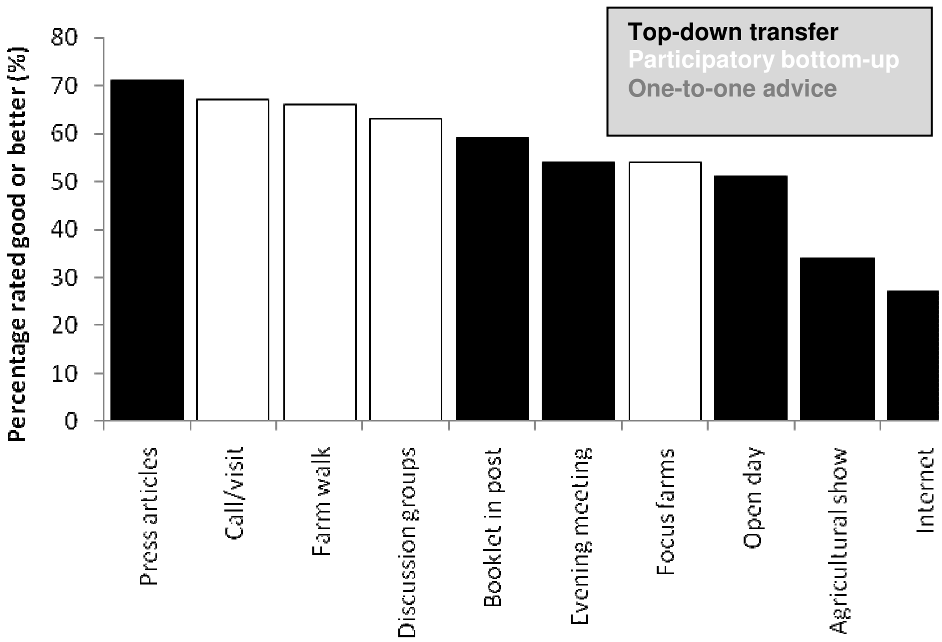
Farmer attendance at a range of different types of technology transfer initiatives is presented in Table 2 (Morrison *et al.*, 2009). Evening meetings were the most commonly attended technology transfer event but despite their popularity, ranked sixth regarding their effectiveness as a method of technology transfer, with popular press articles being the most highly rated (Figure 1).

Table 2 Average attendance (events per year) by dairy producers at a range of technology transfer events (AFBI/CAFRE survey)

Type of event	Average attendance
Farm walks	0.85
Open days	0.31
Evening meeting	2.29
Agricultural show	1.51
Seminar/conference	0.28

Overall, most technology transfer methods rated highly, although the rating for the internet as a good means of transferring information was lower. Whilst still relatively low, usage of the internet by producers is growing. Currently, in the region of 30% of cattle birth registrations are now undertaken on-line. Although there is undoubted potential for wider use of the internet than at present in technology transfer, it would be a mistake to regard it as a panacea for overcoming barriers to technology adoption.

Figure 1 Ratings (good or better) of a range of methods for technology transfer (AFBI/CAFRE survey)



Producer decision making

Much work has gone into understanding and modelling farmer decision-making (e.g. Edwards-Jones., 2006; Garforth *et al*., 2004). The most important issues dairy producers in Northern Ireland considered when deciding on the adoption of research findings were financial and labour/time considerations (Table 3). Whilst other factors were an issue, finance and labour/time must be the main factors considered in planning technology transfer.

Table 3 Factors considered by producers when adopting new technology (AFBI/CAFRE survey)

	Mean rating[a]
What are the financial rewards of change?	1.6[a]
What is the cost of adopting the change?	2.0[b]
What labour/time/energy is required to change?	2.0[b]
Is there a need for change?	2.2[c]
Who and where research for change was done?	2.3[c]
What are the non-financial rewards of change?	2.3[c]
What is the time frame for benefits to be seen?	2.5[d]
Does everyone on farm agree on need for change?	2.7[e]
What will neighbouring farmer's opinion be?	4.4[f]

[a] Mean of producer ratings from 1 = extremely important to 5 = unimportant

Non-financial variables associated with the uptake of technology include: farmer characteristics (age, level of education, gender); household characteristics (stage in family cycle, level of off-farm working, work patterns of spouse); farm business structure (farm type and size, fragmentation, land quality and debt to asset ratio); the wider social environment (level of technology transfer activities, information flows, local culture, social capital, attitude of friends, the policy environment); characteristic of the innovation to be adopted (divisibility, visibility, compatibility, similarity with existing technology) and the farmer's psychological make-up (farmer attitudes and beliefs). For example, technology adoption happens quicker when the individual is younger or less experienced, better educated, receptive to new ideas, self confident and in a position to access economic resources and make decisions; the farm system is large, profitable and linked to other businesses and knowledge networks; the innovation system is linked or in contact with farmers and more involved in management-intensive technology than in capital-intensive technology (Massey, 2004). Understanding these factors, and their interactions, is crucial in developing appropriate technology transfer programmes.

Models of technology transfer

Technology transfer models can be grouped largely into one of five major strategies or communication methods: (i) linear 'top-down' transfer of technology from scientific experts to farmers, (ii) participatory 'bottom-up' and group based approaches, (iii) one-to-one advice or information exchange (whether from farmer to farmer or from professional adviser to farmer and vice versa), (iv) formal or structured education and training and (v) new information technologies (particularly internet). It is recognised that no single model or strategy is likely to be sufficient by itself and in practice combining a number of the strategies often represents the best option. In the next section of this paper the relative merits of the first 3 strategies will briefly be discussed.

Linear top-down approach

In the past, the dominant model of agricultural extension was based on the assumption that new agricultural technologies and knowledge are best developed and validated by research scientists and that the task of the extension agencies is to promote the adoption of these technologies by producers, thereby increasing agricultural productivity. Although various means of communication have been used, the conventional model of extension focussed on the farmers thought to be early adopters, the so called 'progressive farmer strategy'. The expectation being that once progressive farmers embrace the new technology, their example will be followed by others. Whilst this diffusion approach worked for some technologies there are some concerns on equality issues and its use for more complex integrated suites of practices. It has been also argued that the knowledge, skills and adaptive abilities of farmers themselves are devalued in extension strategies based on the notion of top-down transfer of technology from scientific experts to farmers.

Nonetheless it must be recognised that a significant proportion of producers prefer to have direct contact with researchers for their information, as can be seen from the data in Table 3 and also that this type of contact enables flow of information from producers to researchers. The limitations of the linear model can be further addressed by integrating the extension worker into the research and development process itself. In addition, the research agenda is now largely set by government policy makers and industry stakeholders. If anything the risk going forward in a customer-contractor research environment is that the research scientist will not have sufficient consideration in setting future research agendas.

Table 3. Preferences of dairy producers for delivery of technical advice (AFBI/CAFRE survey)

	Milk replacer information	***Sire choice***	***Nutritional management***	***Transition management***
Sales rep	36.1	52.5	16.3	8.4
Vet	2.7	2.5	13.3	41.4
Develop. adviser	18.3	19.1	35.6	30.4
Researcher	24.2	9.3	27.0	11.9
Farmer to farmer	18.7	16.5	7.7	7.9

2. Bottom-up participatory approach

Criticisms of the notion of extension as top-down transfer of technology led to formulation of a range of alternative participatory bottom-up approaches.

In the South of Ireland, and to some extent in Northern Ireland, local discussion groups are a major feature of the industry. These are groups of farmers that meet regularly to discuss technical issues, share information and problem solve. In the

South, Teagasc operates over 500 dairy discussion groups. Such participatory approaches recognise, and draw upon, the accumulated knowledge and experience of producers. Discussion groups encourage producer ownership of problems and solutions and can provide an environment that allows complex problems to be understood and recommendations to be implemented a farm level.

Nonetheless there are limitations to participatory bottom-up approaches which need to be recognised. Reliance on famers' local knowledge to solve new problems is unlikely to be successful – there is a need for outside expertise. Trained facilitators and contact with researchers is essential. Successful discussion groups in the South of Ireland routinely visit research centres and involve researchers at meetings with the provision of trained facilitators by Teagasc. However, it must be noted that farmers vary in their propensity to participate in group-based learning activities. In that their impact is unevenly distributed, participatory strategies have some similarities to top-down strategies.

Focus Farms have been established to promote good practice by example and monitor farms selected to provide a focus for farmer-driven discussion groups. Focus Farms have been developed from Monitor Farms (New Zealand) and Demonstration Farms (Wales). The objectives of Focus Farms are to facilitate farmer-led knowledge transfer from businesses which are able to promote the adoption of best practice. This should lead to improvements in farm performance through peer learning and the provision of farmer to farmer mentoring service. In addition, Focus Farms should encourage a culture of continuous improvement and life-long learning and greater co-operation/collaboration within the Northern Ireland farming community. However for these objectives to be met there is a definite need for linkages to research, ensuring new cutting-edge information made available and for quality control of information.

The final bottom-up participatory approach that has successfully been implemented on Northern Ireland dairy farms is large scale applied research programmes undertaken on commercial farms linked to more basic research programmes carried out within research institutes at AFBI. This type of model embeds technology transfer into research programmes and ensures the 2-way flow of information between the industry and research.

Key features of on-farm research programmes are:-

- Farmers are involved in setting the research agenda. AgriSearch, a farmer levy, co-fund the programmes and their committee structure enables stakeholders to be involved in setting the research agenda.
- The research is undertaken on farm and the producers involved are part of the research team and are co-researchers with the team at Hillsborough. The research programmes are built into the farm structure, thus the impact of the work can be evaluated at systems level.
- A structured recruitment process and formal contract for undertaking the research is established.
- Technology transfer is formally embedded into the programme from day 1 with farm walks being a major vehicle for knowledge exchange. The producers have a major input into the planning and operation of the farm events.
- The research being undertaken links to more basic research carried out at Institutes where more detailed recordings can be undertaken.

As science develops along more fundamental routes, it is crucial that there are linkages to resources where this research can be developed and tested at system level. AgriSearch and AFBI have submitted a major new research proposal to DARD to underpin further developments in on-farm research for the dairy sector.

3. One-to-one advice

DARD, through CAFRE, provides a business development service for farmers and growers providing one-to-one advice which is widely relied on by producers (Table 3). This support to the industry is packaged through benchmarking, technology adoption and training. However, there is also a significant role being played by agribusiness, private consultants and other non-government bodies in providing information and advice to farmers.

Undoubtedly as the research environment and knowledge exchange network broadens out to address all aspects of sustainable agriculture, there is a danger of fragmentation between research organisations and advisory services, between different government departments concerned with agriculture, and between public and private business. This is where high level industry strategies and implementation roadmaps are crucial in setting future direction and helping to co-ordinate the work of all agencies. Northern Ireland is a small place which facilitates the development and implementation of co-ordinated industry strategies. There is an urgent need to develop an overall industry strategy to direct the production sector of the industry in a co-ordinated manner.

Creating the right environment for adoption and change

To be effective, technology transfer programmes need to create the right environment for change to occur. Five key factors have been highlighted as essential to create the right environment for change and adoption on the ground (Devenish, 2006):

1. Extensive knowledge of the problem,
2. Working with farmers to identify and overcome barriers to adoption
3. Involvement of a credible researcher, specialist or extension practitioner
4. Experience in various communication methods and
5. Funding to support research and development activities

Success might still be achieved if one key factor or process is missing, but if 2 or 3 factors are ignored or missing the programme is likely to fail as an effective means of promoting adoption and change.

Obtaining good management information to enable an extensive knowledge of the problem can be difficult at individual farm level. The AFBI/CAFRE survey found that management information with respect to heifer rearing was poor in the Northern Ireland dairy industry. Only 36% of producers in the survey milk recorded giving lactational performance of their replacements. Just over 21% benchmarked the financial and physical performance of their dairy herd, whilst only 2% of producers benchmarked the performance of their dairy replacement enterprise. Research at

AFBI Hillsborough has developed appropriate live weight targets for calving at the economic optimum age of 2-years. However, the survey indicated that only 8% of producers recorded live weights. In addition the survey indicated there were significant discrepancies between producers' estimate of live weight and actual live weight and also between producers' estimate of their average age at first calving and that recorded within APHIS. So undoubtedly lack of management information is a key barrier to the uptake of scientific developments from 2 perspectives. Firstly, it can be difficult to identify the major issues or problems which need to be addressed without the proper information. Secondly, with no methods of monitoring, the benefits of adopting the technology, if undertaken, are not always recognised.

To help understand, and overcome, the barriers to adoption of new rearing regimes the initiative involved work with 8 pilot farms, putting into practice a blueprint for improved heifer rearing. In this work a calibrated weigh band was developed enabling accurate assessment of live weight of heifers. This was followed by the development of a tracking system to monitor growth rates and adjust feed accordingly – the key to success. Working with pilot farms enabled the practical barriers to adoption to be observed at first hand, many of which lay around confidence in assessment of body size and we were able to pilot new ideas. Finally, the new applications of industry databases (Carson *et al.*, 2010) will provide important management information for all producers, and their advisers, on which to base decisions.

The integrated approach of research and technology transfer that was adopted involved researchers, CAFRE technologists and technical staff from Thompsons. The inclusion of researchers in technology transfer has been questioned by some. Also the argument has been put forward that the industry here does not need more research, just better implementation of what we already know. In this integrated approach it was felt essential to include researchers at the heart of the programme due to the first-hand knowledge of the research that was being translated, also the expertise in being able to evaluate research from elsewhere and its applicability. Also the researchers were used to analyse data collected as part of the programme on which to base improved technology transfer programmes.

In line with the findings of the AFBI/CAFRE survey, that highlighted the importance of financial considerations when producers consider adopting new technology, the economic effect of the improved heifer rearing regime was the focal point of the heifer technology transfer initiative. To communicate this main message, which was implementing the heifer rearing blue-print will reduce your costs of production by 1 penny per litre, a range of communication methods were employed:-

- Focus group meetings were held with the pilot farmers giving instant feedback and involvement in the development of the project.
- Open meetings were held for producers. These were undertaken on commercial farms and involved the pilot farmers themselves.
- A booklet was produced and a series of press articles produced.

Although the main components of the study may be complete it is critical that the impact of the initiative is assessed and there is continued reinforcement of the message from all links in the technology transfer process. Only through this continued effort by all parties promoting the same message will improved adoption on-farm be realised.

Conclusions

The effective adoption of scientific developments is a key determinant of the economic return achieved from investment in research, as well as being fundamental to the sustainable development of the agri-food sector. Central to its success is the inclusion of researchers at all stages of the process to help overcome the barriers in an integrated approach.

Acknowledgements

The input of the technical staff of John Thompson and Sons Limited in the dairy heifer research and development initiative is gratefully acknowledged.

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Latest findings on management of dairy youngstock

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Introduction

Rearing dairy replacements represents a major investment by dairy producers. These animals determine the future genetics, production potential and efficiency of the dairy herd. Effective management is therefore crucial to ensure that the best breeding decisions are made and that heifers are reared cost effectively to calve at an age and body size which will maximise lifetime performance. The aim of this paper is to outline the findings of the AFBI/CAFRE heifer survey in relation to youngstock (3 months of age to calving) rearing practices on Northern Ireland dairy farms and review the latest research from AFBI, and elsewhere, on management systems for optimal heifer performance.

Grazing management

Achieving target weights for age at grass is a key component of efficient heifer rearing systems. In terms of grazing systems, continuous grazing was found to dominate (96% of producers operated continuous grazing in the AFBI/CAFRE heifer study). Only 1-2% of farms surveyed operated a leader-follower system with either the dairy cows or older heifers.

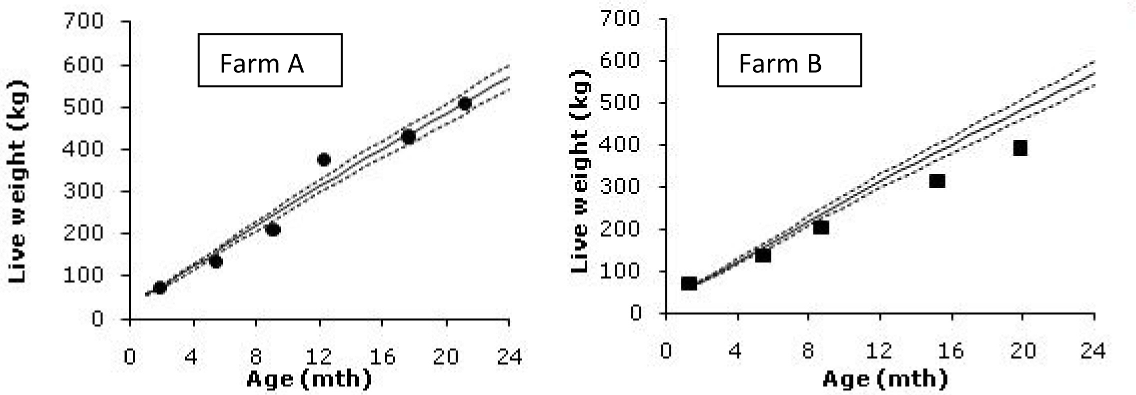
During the grazing period, the majority of producers (59%) offered heifers during their first summer at grass 1 kg of concentrate per day with supplementation removed during the second year at grass on 76% of farms. Of those farmers who purchased concentrates, 81% offered concentrates specifically formulated for rearing dairy replacements. Although variation existed between locations, grazing commenced between mid April and late May and ceased in mid to late October. Assuming an average date of birth for autumn and spring born calves of 15 October and 15 February respectively, dairy herd replacements required on average between 464 (spring born) and 473 (autumn born) days of housing during the rearing period. These housing requirements would be reduced by between 58 (spring born) and 107 days (autumn born) if the average age at first calving in the industry moved to 24 months of age.

Monitoring performance at grass is important to manage heifers effectively. As part of the implementation of a heifer rearing blue-print, staff from John Thompson and Sons Ltd routinely monitored heifer performance on 8 pilot farms. This study demonstrated the range in performance at grass which can occur and the benefits of tracking performance to adjust feeding strategies. Two real examples are given below.

- On farm A, autumn born calves were housed until approximately eight months of age before being turned out to grass. What is clear, during the early housed period these calves did not reach target weight but once they went out to grass they surpassed their growth target. With nutritional advice regarding grazing pressure and concentrate supplementation these heifers returned to the target growth curve for the remainder of the rearing period.

- On farm B the autumn born calves performed poorly at grass and never recovered during the second winter housed period.

Figure 1 Heifer development in relation to target growth on two Northern Ireland farm**s**



Rotational grazing systems enable more flexibility however perceived increases in management and setup costs appear to discourage producers from adopting these systems. There are few recent research studies on grazing systems for dairy youngstock but studies performed in 1970s and 1980s found that animal performance may be marginally improved under rotational grazing (e.g. Ernst *et al.*, 1980). However, instances where rotational grazing has been shown to be superior to continuous grazing have been at high stocking rates (McMeekan and Walshe, 1963). The stocking rate, on the grazing platform, of the calf/heifer rearing enterprise on Northern Ireland dairy farms was estimated from the survey at 2.51 CE/ha, almost half that of the dairying enterprise (4.8 CE/ha.

The leader-follower system adopted at AFBI Hillsborough enables calves to graze rotationally in paddocks ahead of the older cattle therefore getting preferential access to the best quality grazing. This approach has been used widely in New Zealand for many years and was originally investigated under UK conditions in the 1970s (Leaver, 1970). The system enables high levels of calf performance (Table 1) but care must be taken to ensure performance of the follower group does not suffer as reported by Keane (2002).

Table 1 Effect of leader-follower versus separate grazing systems on the performance of calves and heifers

	Grazing system		
Live weight gain (kg/day)	Leader-follower	Separate grazing	Mixed
Leaver (1970)			
Calves (7 - 12 months)	0.81	0.60	-
Heifers (19 - 24 months)	0.78	0.84	-
Keane (2002)			
Calves	0.96	0.57	0.69
Yearling	0.89	1.08	0.95

Young spring-born calves can be difficult to manage at grass and the AFBI/CAFRE survey found that it is now common for turnout of these types of heifers to be delayed until after first cut silage. Research at Hillsborough has investigated the effect on calf performance of earlier turnout. In the first set of experiments calves were turned out in late-April, late-May and late June. Prior to turnout, heifers were offered high quality grass silage and 2 kg of concentrates per day. At pasture all groups grazed together as a leader group in a leader-follower system with zero concentrates. Whilst performance varied through the summer, it was found that by the end of the grazing season, the group put to pasture early had a similar mean live weight to the 2 groups which had been retained indoors for longer (Table 2).

Table 2 Effect of turnout date on the performance of spring-born calves

	Turnout date		
Date to pasture	Late April	Late May	Late June
Live weight (kg)			
Late April	**96**	96	97
Late May	114	**124**	124
Late June	130	131	**153**
October (housing)	228	233	220

Live weights at turnout are highlighted in bold

In a further study the effect of turnout date and supplementation strategy was investigated. Spring born calves were either turned out after first cut silage or in April-May when at least 10 weeks of age. Early turnout groups received either zero or up to 2 kg concentrates per day early and late in the season. When the late turnout group were at pasture they were also offered concentrates at the start and end of the grazing season. Heifers in all groups were housed when performance fell below 0.4 kg/day.

At the end of December, live weights in each of the groups were similar (Table 3). Feeding concentrates in late summer/autumn extended the grazing season by about a month. Early turnout had no detrimental effect on performance.

Table 3 Effect of turnout date and concentrate supplementation strategy on the performance of spring born calves (Preliminary data)

	Housed	Early grazing	Early grazing +conc
Average turnout date	3 Jun	29 Apr	29 Apr
Live weight at turnout (kg)	107	83	81
Housing date	20 Nov	24 Oct	20 Nov
Live weight at housing	216	189	207
Live weight at end of 2008 (kg)	253	250	241
Concentrate offered (kg)			
Post wean to turnout	156	101	100
At grass (first summer)	66	0	148
Indoors (second winter)	48	150	48
Total	270	251	296

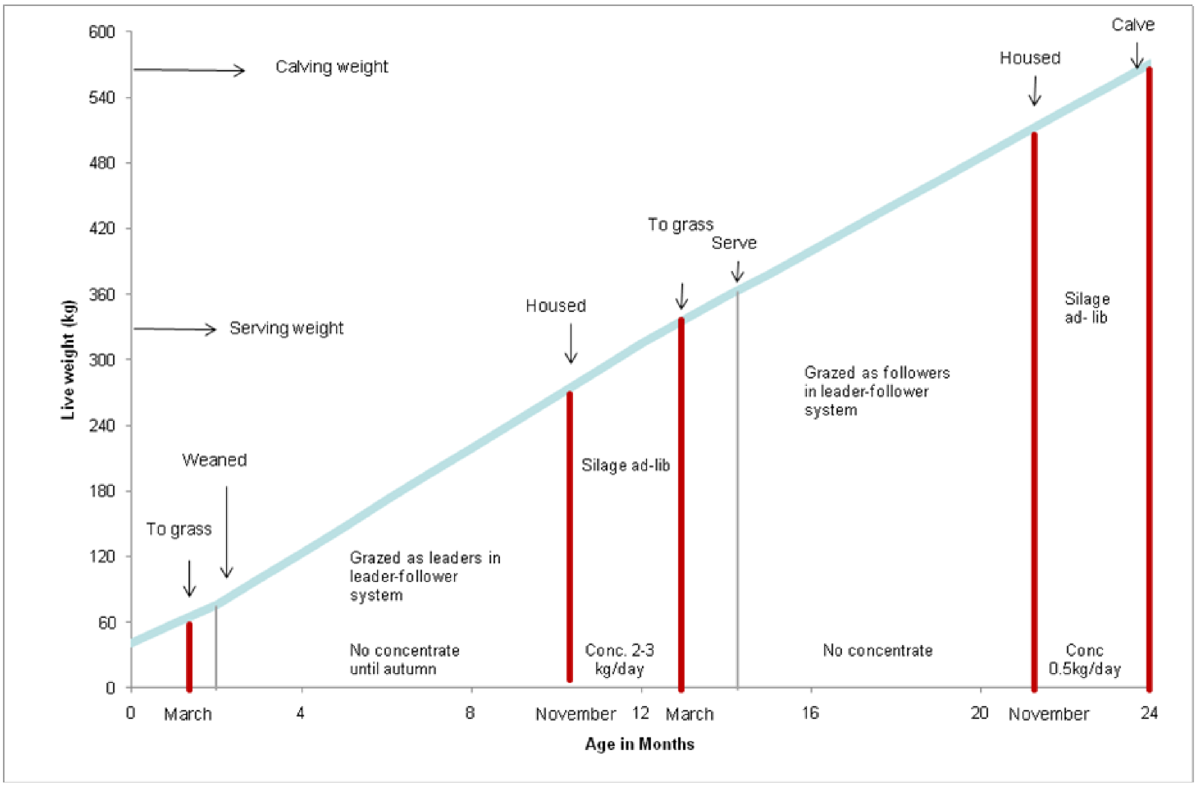
Similarly, research performed at the Institute in the late 1970s (Gordon, 1979) found that when targeting a 320+ kg live weight at 15 months of age, no improvement in performance was achieved when spring-born calves received a greater proportion of their concentrate allowance at pasture, rather than when housed during the winter (Table 4).

By moving to 24 months of age at first calving and adopting improved grazing practices the number of days housing for heifers could be reduced by 40% of that which current systems require. However, it is recognised that increased grazing days is dependent on the soil type, climatic conditions and grazing area available on each farm. Figure 3 illustrates a rearing blueprint for spring-born calves that maximises the number of grazing days.

Table 4 Effect of feeding concentrates to spring-born calves during their first year at pasture

Total concentrates given up to 15 months of age (kg)	386	383	379	375
Concentrates given at pasture (%)	0	15	36	57
Live weight (kg)				
Initial	78	79	77	78
End of grazing period	210	206	213	223
End of winter period	341	333	324	333

Figure 3 Rearing blueprint to maximise grazing days and achieve optimum live weight at calving (spring born calf)



The effective control of parasites is an important component of heifer rearing systems. The AFBI/CAFRE survey found that approximately 20% of producers used worming products pre-turn out with anthelmintics generally administered to heifers whilst out at grass and when re-housed during the autumn/winter . In terms of product selection, the key criteria were past performance, method of application and duration of action (Table 5). Increased concern regarding worm resistance to anthelmintics has led to the recommendation to rotate worm drench type periodically. Forty percent of producers reported to adopt such a practice.

Table 5 Selection criteria used by producers for anthelmintics (AFBI/CAFRE heifer study)

Criteria	Percentage rated as important or greater
Past performance	90
Method of application	86
Duration of action	84
Veterinary advice	66
Price	58
Product specification	49
Brand	44

Key messages youngstock nutrition

- With youngstock rearing primarily based on grazed grass, systems must be designed to maximise grass utilisation and grazing days whilst sustaining adequate animal performance.
- On-farm research demonstrated the variability on heifer performance achieved at grass and the importance of tracking heifer development to enable informed management decisions.
- Parasite control is paramount to any grazing system with a combination of anthelmintics and grazing management the optimal approach.

Breeding dairy heifers

When to breed?

It is well established that feeding and management of Holstein-Friesian heifers should be geared around achieving a live weight at first calving of 540-580 kg at 24 months of age. To achieve this target, nutritional management must begin early to ensure heifers reach target live weights for breeding at 13.5-15 months of age.

As part of the AFBI/CAFRE heifer survey, heifer live weight was assessed on a proportion of the farms. On these representative farms, heifers were on average achieving adequate live weights at the key stages in rearing to achieve a live weight at first calving of 540-580 kg at 24 months of age (Table 6).

Table 6 Live weights of heifers on Northern Ireland dairy farms (farmer estimate and actual) (AFBI/CAFRE heifer survey)

Development stage	Target weight for age (kg)	Farmer estimated live weight (kg)	Actual live weight (kg)	Percentage difference (%)
Weaning	92	85	96	-7.1
Breeding	433	378	438	-11.2
Calving	580[#]	555	585	-3.8

[#] Target weight for calving at 24 months of age but average age of heifers was 27 months with projected calving age of 29 months

Despite the obvious benefits of monitoring heifer growth, at breeding only 4.1, 6.6 and 10.7% of farmers in the AFBI/CAFRE study assessed heifer live weight, body size or body condition score, respectively. Indeed only 35% of producers visually assessed heifer development at breeding. In spite of the lack of monitoring, body size/shape still rated as the most important criterion used by producers when deciding to breed heifers ($P<0.05$; Table 7). Of those surveyed, 37% were able to estimate a minimum weight at breeding.

The heifer survey found that farmers, on average, underestimate the weight of heifers, particularly at the breeding stage (Table 6). Accurate monitoring of size against age is key to making informed decisions in relation to breeding. Consequently, AFBI developed a calibrated weigh band (Morrison *et al.*, 2008) to help producers monitor the progress of heifers against targets, facilitating a cost effective rearing regime. With over 21,000 animal recordings used to construct the prediction model and 850 recordings used for validation, the weigh band gives a robust and reliable indication of the weight of Holstein-Friesian heifers. Live weights recently recorded by the weight band and weigh bridge of recently bred heifers at AFBI Hillsborough are shown in Table 8.

Table 7 Criteria used by producers when deciding when to breed heifers (AFBI/CAFRE heifer survey)

Criteria for breeding	Mean rating	Percentage rated as important or greater
Body size/shape	0.56	94.2
Weight	1.11**	80.2
Age	1.17 ns	78.1
Date	1.66**	59.3
No. of oestrus events	2.91**	15.0
Other	3.44 ns	6.3

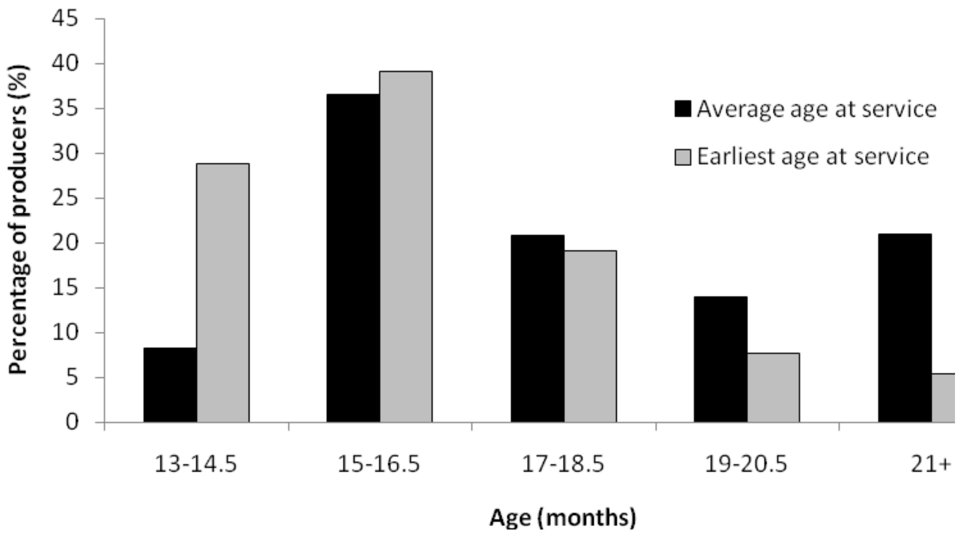
[a] 0 Very important to 4 unimportant
[b] The significance level comparing the mean rating of the item with the next most important mean rating item * P<0.05, ** P <0.01, ns Not significant

Table 8 Live weights of 16-month old heifers recorded by a weigh bridge compared with weigh band

No. of heifers	Average age (mths)	Average weighbridge weight (kg)	Average weighband weight (kg)	Percentage of predictions within 7% of actual weight
38	16	390	395	95

In the survey, the earliest and average ages of heifers at first service reported by producers were 16.0 and 17.9 months respectively. However, there was considerable variation in age at first service reported by producers (12.5-30 months), with 59% of producers quoting an average age at first service greater than 16 months (Figure 4).

Figure 4 Earliest and average age at first service for heifers



What to breed?

Through artificial insemination (AI) more rapid genetic progress can be made using superior bulls to those generally kept as stock bulls. Almost 75% of New Zealand dairy cows (Livestock Improvement Commission, 2009) and 92% of Dutch dairy cows (Veepro Holland, 2009) are bred by AI. In Northern Ireland, 62% and 69% of dairy producers use AI on greater than 50% of heifers and greater than 50% of cows, respectively. Of the farmers able to state the number of AI inseminations performed on each heifer (88%), two or less services were required per pregnancy on 97% of farms.

Oestrus detection is an integral component of heifer breeding programmes. Almost 57% of producers surveyed spent 5-10 minutes per oestrus check with 40% checking heifers twice per day. Duration of oestrus check was significantly associated with age at first calving, with producers that spent between 10-20 minutes per oestrus check calving heifers at an earlier age compared with those that spent less than 10 minutes per check. The importance of adequate resources being allocated to oestrus detection was highlighted by Mayne *et al.* (2002) when examining dairy cow herds. Farms where oestrus checks were performed more frequently had an increased oestrus detection rate which was associated with a reduced calving interval (Mayne *et al.*, 2002) which impacted directly on the financial performance of the farm. Coupled with frequent oestrus checks it is important that accurate records are kept. In the current study almost 25% of producers maintained no heifer heat or service records and this was associated with a greater age at first calving.

As would be expected when selecting sires for breeding heifers, ease of calving rated highly among farmers, with 88% rating it as important or greater (Table 9). Least important of the criteria listed was Profitable Lifetime index (PLI), with only 35% of farmers having rated it as important or greater when selecting bulls. Selection indexes are the best way to combine information on the large number of traits now available for sires, These traits are weighted based on their economic importance and therefore provide an overall value for the sire. Increased emphasis on PLI values when selecting bulls will help direct more balanced breeding in the industry.

Table 9 Relative importance of factors considered for selecting sires to breed heifers

Bull choice criterion	Mean rating[1]	Percentage rated as important or greater
Ease of calving	0.66	87.8
Milk composition	0.95	83.3
Other	1.16	64.0
Milk yield	1.30	75.7
Type traits	1.39	68.6
Cost	2.15	37.3
PLI value	2.21	34.8

[1] 0 Very important to 4 unimportant

<u>Key messages relating breeding age heifers</u>

- Replacements on Northern Ireland dairy farms were found to be generally reared at growth rates which enable adequate weights to be reached for calving at 24 months of age.
- The commonplace delay in breeding heifers until >16 months of age was in part due to under prediction of heifer live weight.

- Monitoring heifer weight for age is the key to success.
- Use of a weighbridge or the AFBI weigh band provides confidence to serve heifers early at the optimum age and weight to ensure calving at 24 months of age at 540-580 kg.
- Increased adoption of the PLI breeding index as the main sire selection criteria will improve the sustainability of the dairy industry.

Management of in-calf heifers on Northern Ireland dairy farms

Age at first calving

In the AFBI/CAFRE survey the average and median ages of heifers at first calving was 32.7 and 30.4 months, respectively (Carson *et al.*, 2010). The association between age at first calving and subsequent performance can be seen from analyses by AFBI of data from herds of the Irish Holstein-Friesian Association (Table 10). Moving from 24 to 36 months of age, first lactation milk yield increased by 791 litres. However, reproductive performance was poorer, and by the 3rd calver stage differences in cumulative milk solids yield from first calving had disappeared. Whilst this analysis could not determine longevity, work in GB has shown fewer problems around calving and increased herd life (+0.2 lactations) with heifers calving at 24 compared with 36 months of age (Wathes *et al.*, 2008).

Table 10 Association between age at first calving and performance of Holstein-Friesian replacements (data from Irish Holstein-Friesian Association herds)

Age at first calving (months)	First lactation milk yield (305 days)	Average calving interval (days) (1-5 calvings)	Average milk solids yield (kg/day) from 1st calving for 3rd calvers
23-25	5,888	394	1.53
26-28	5,960	402	1.53
29-31	6,340	414	1.53
31-34	6,696	408	1.54
35-37	6,679	405	1.55

Age at first calving has a considerable impact on the number of replacements carried on a dairy farm. Compared with calving at 24 months, 3-year old calving increases the number of replacement stock on a 100-cow dairy farm by 30 heifers. This will increase farm stocking rate by 0.4 cow equivalents per hectare and by 25 kg of organic manure N per hectare. To maintain the same organic manure loading as a farm calving heifers at 24 months, an additional 10 hectares of land would be required for a 100-cow dairy herd. Calving at older ages also places greater demands on housing facilities, labour inputs and other overhead costs.

The main barriers to the adoption of 24 month age at first calving on Northern Ireland farms were 1) the perception of farmers that smaller heifers cannot compete within the dairy herd, 2) the belief that there is increased management required to calve heifers at 24 months of age and 3) the opinion that heifers are too small to serve at 13.5 months onward to achieve a 24 month age at first calving (Table 11).

Table 11 Perceived barriers to adopting a 24 month age at first calving policy on NI dairy farms

Barrier	Percentage rated as important or greater
Too small to serve	79
Smaller heifer cannot compete in the dairy	77
Increased management for 24 month calving	72
Increased 1st lactation milk yield with older bigger heifer	53
Sell heifers	31
Low confidence in when serve	22

Target live weight at first calving

Body size targets for Holstein-Friesian dairy herd replacements have been developed from a range of research studies carried out at AFBI Hillsborough over recent years on the feeding and management of dairy heifers. The main findings of this work are summarised as follows:

- Milk production. Heifers reared to calve at heavier (620 kg) compared with moderate weights (540 kg) produced 800 litres more milk in their first lactation. However the effects did not extend into subsequent lactations (Table 12).

- The additional milk produced by rearing heavier heifers (620 compared with 540 kg) resulted from increased body tissue mobilisation in early lactation, resulting in poorer reproductive performance. In addition, foot claw condition was poorer with heavier heifers (20% more heifers with heel erosion during rearing period) and was associated with increased lameness (50% higher (poorer) locomotion scores).
- Increasing growth during the first year of life (above 0.7-0.8 kg/day) increased skeletal size. However, very high planes of nutrition can have detrimental effects on udder development, particularly with strains/breeds of lower mature weight.
- Increasing growth during the second year of life (above 0.8 kg/day) has been found to increase body condition score at calving, reducing dry matter intake in early lactation.
- Stair-step growth patterns (restricted followed by *ad libitum* feeding) exploit compensatory growth and have enabled heavier heifers to be reared with less excessive body condition. However, this type of strategy complicates management and has not resulted in performance benefits.
- Forage type fed during the rearing period has been found to have only small effects on subsequent performance in the milking herd.

Table 12 Summary of research studies on the effect of live weight at first calving on subsequent milk yield

	Moderate heifers	Large heifers	Milk yield (moderate v heavier heifers)	Others
Carson *et al.* (2000)	570 kg	620 kg	No difference	Larger heifers lost more body condition after calving
Carson *et al.* (2002)	540 kg	620 kg	1st lactation: 11% lower (800 litres) 2nd lactation +: no difference Overall: No difference	Shorter calving interval (30 days+) and lower incidence of lameness in moderate heifers
Woods (2005)	540 kg	620 kg	1st lactation: Peak yields lower 2 kg/day, but no overall difference 2nd lactation+: no difference Overall: No difference	Larger heifers lost more body reserves after calving
Woods (2005)	550 kg	600 kg	1st lactation: Peak yields lower 3 kg/day, but no overall difference 2nd lactation+: no difference Overall: No difference	Shorter calving interval (40 days+) and lower incidence of lameness with moderate heifers

Implementation of heifer rearing blue-print

Quantifying the benefits of implementing a rearing blue-print was the objective of a recently completed component of the heifer initiative involving AFBI and John Thompson and Sons Ltd. This part of the project involved the adoption of a blueprint on 8 dairy farms across Northern Ireland. Through informed management decisions based on monitoring heifer growth, age at 1st calving, on average, was reduced from 28 to 25 months.

On the 4 farms with detailed milk records, first and second lactation milk yields were shown to be largely unaffected by adopting the rearing blueprint however reproductive performance (calving interval) was significantly improved (Table 13). The observed benefits on fertility follow very closely those of the research studies reported previously (Table 12).

Table 13 Average age at calving and milk production of heifers born before and after the blueprint#

	Pre-blueprint	Post-blue print
Age at 1st calving	26.4	25.1
1st lactation		
Milk yield (kg)	7658	7564
Fat + Protein yield (kg)	551	565
Calving interval (d)	408	386
2nd lactation		
Milk yield (kg)	9161	9074
Fat + Protein yield (kg)	658	686

Milk production data available from 4 farms

Transition into the dairy herd

During the period around first calving, dairy herd replacements are exposed to many changes which, if not managed, can result in nutritional, physiological and social stress. These types of stressors can have long-term effects on subsequent milk production, fertility, health and welfare.

Training heifers to the parlour

Training heifers prior to calving is commonplace with 58% of producers adopting this practice. Research at AFBI Hillsborough has identified the main effects of training heifers to the parlour – these are summarised below in Table 14. Overall, training heifers had a significant impact on milk production, and somatic cell count, but the effects were relatively short-lived with no longer term effects evident (Wicks *et al.*, 2004). The behaviour of heifers in the milking parlour is altered by training, but again these effects were short-lived with untrained heifers following the same behavioural patterns over time as they became accustomed to the parlour. In terms of fertility there were no beneficial effects, in fact the opposite was observed where the additional early lactation milk yield was not supported by additional feed intake.

Table 14 The effects of training heifers to the parlour for 3-weeks pre-calving on subsequent milk production over the 1st 100 days of lactation

	Control	Pre-conditioned
Milk Yield (kg/day)	25.4	26.7
Fat (%)	3.99	3.87
Protein (%)	3.30	3.31
Somatic cell count ('000)	156	95
Interval calving-conception (days)	83	102

Introducing heifers into the herd

The majority of producers introduce dairy heifers straight into the dairy herd after first calving (Table 15). However, some producers form small groups of calved heifers (or heifers/mature cows) and introduce these groups into the milking herd together. This approach is likely to be beneficial, based on the findings of recent research at AFBI Hillsborough. This work found that heifers introduced to the milking herd as pairs rather than individually had higher milk yields in early lactation (2 kg/day during the first month of lactation) without detrimental effects on fertility (O'Connell *et al.*, 2008).

Table 15 Methods of integrating heifers into milking herds (AFBI/CAFRE heifer survey)

Method of integration	% of NI dairy herds
Straight into milking herd as individuals	74
Group of heifers formed and then introduced	11
Grouped with small batch of cows and then introduced	7
Separate heifer group maintained post-calving	0.5
Other	7

Behavioural observations indicated the paired heifers were less fearful than those introduced into the milking herd as individuals. Delaying the introduction of heifers (as singles) into the herd from day 1 to day 7 post-calving had no benefits on performance or behaviour.

Recent research at AFBI Hillsborough has indicated that heifers find it easier to integrate if they are introduced into the milking herd after the evening, rather than the morning milking. Cows are less socially active in the evening thus heifers have time to settle into the pecking order more easily. However, there did not appear to be any long term effects of treatment on behaviour or performance (Table 16).

Table 16 Effect of timing of introduction on heifer behaviour during day 1, and on performance during the first month post calving

	Time of introduction		Significance
	AM	PM	
Behaviour (frequency/minute)			
Receive threat	0.01	0.00	*
Receive shoulder	0.02	0.01	NS
Receive butt	0.16	0.05	***
Receive chase	0.01	0.00	NS
Receive nosing	0.05	0.06	NS
Social cohesive	0.01	0.04	*
Performance (kg/day)			
Milk yield	25.2	25.9	NS
Fat plus protein yield	2.02	2.06	NS

Key messages relating to in-calf heifers

- Despite research having demonstrated the benefits of 24 month age at first calving the majority of Northern Ireland producers calve heifers at greater than 26 months of age.

- In-calf heifers on Northern Ireland dairy farms are generally at target weight for their age but with calving delayed until almost 28 months of age, live weight at calving will be in excess of 600 kg on many farms.
- The benefits and ease of adopting a 24 month age at first calving policy were clearly demonstrated in the integrated AFBI/CAFRE/Thompsons project, hopefully assisting other farmers in overcoming barriers to adoption.
- The majority of producers have a protocol in place to smooth heifer transition into the dairy herd. Key management options to reduce stress during this period include grouping pairs of heifers, parlour training and introducing heifers after the PM milking.

Overall conclusions

Northern Ireland dairy producers generally rear heifers well during the post-weaning period but there is considerable room for gains in efficiency. The number of grazing days can be increased and concentrate feeding used more strategically.

Research has clearly demonstrated the benefits of calving heifers at 24 months of age at moderate body weights. Increased monitoring of heifer development, particularly at breeding age, will facilitate the widespread adoption of improved heifer rearing.

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ACKNOWLEDGEMENTS

Thanks are extended to:

AgriSearch and the Department of Agriculture and Rural Development for providing funding for projects presented in this seminar

AgriSearch Dairy Committee – Mr John Thompson (Chairman), Mr Harper Doupe, Mr Albert Foster, Mr Jonathan Moore, Mr Gary McHenry, Mr Drew McConnell, Mr Peter Conway, Mr David Stewart and Mr Alan McIlmoyle. The huge contribution made by past members of the AgriSearch Dairy Committee is also acknowledged, especially recent past Chairs, Mr James Brown and Mr Ramsey Stewart

The Dairy and Heifer Research teams (past and present) at AFBI Hillsborough – Dr Hannah Wicks, Mr Andrew Brown, Mr Bernard Lagan, Mr John Madine, Mr John Ward, Mrs Jennifer Meeke, Mrs Barbara Waters, Ms Gillian Scoley, Mr Mike Davies and his team of technical staff and stock persons, and Mrs Rachael Park and Mr Brian Hunter

Dr Sinclair Mayne (Head of Agriculture Branch until January 2009)

AFBI Hillsborough Laboratory staff for chemical analysis of feedstuffs

United Dairy Farmers (past and present) Mr Brian Hunter, Mr Gary Watson and Mr Howard Nicholl

Technical staff at John Thompson and Sons Ltd (past and present) – Prof Fred Gordon, Gordon Donaldson, Richard Moore, Lyle Hamilton and Hugh McCluggage

Farmers who participated in the on-farm heifer project and who continue to participate in the on-farm crossbreeding project

The dairy development advisers and technologist at CAFRE - Martin Mulholland, Mark Scott, David Mackey, Nigel Murphy, Michael Verner, Alan Agnew, William McCulloch, David Alexander, Aidan Cushnahan, Irene Downey, Gary Haslem, Conail Keown, Kenny White, Alan Hopps, Richard Henning, Albert Johnston, Michael Garvey, Olwen Gormley, Alan Warnock, Janes Sayers and Trevor Alcorn