Effect of three different concentrate build-up strategies in early lactation on production performance, health and fertility of high yielding dairy cows

End of Project Report to AgriSearch

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STRUCTURE OF REPORT

This report begins with an Executive Summary which provides the background to the research, details of the work undertaken, key findings, and practical implications.

The main body of the report describes the study.

The report finishes with a summary of technology transfer associated with this work.

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EXECUTIVE SUMMARY

Background

- Intensive genetic selection for milk production within the Holstein breed has resulted in dairy cows with a huge capacity to produce milk. However, during early lactation these cows are unable to consume sufficient food to support milk production and as a result mobilise their own body fat to produce milk. This is reflected in the loss of body condition, and cows are said to be in negative energy balance (NEB).

- Severe and prolonged periods of NEB can predispose the dairy cow to metabolic disorders, immunosuppression, reproductive failure, and behavioural abnormalities, all of which contribute to a decline in the cow's general well-being. Thus it is generally accepted that reducing NEB in early lactation should result in improved cow health and fertility.

- In an attempt to meet the higher nutrient requirement of these high yielding cows, and thus reduce the extent of NEB experienced, concentrate feed levels have increased dramatically in Northern Ireland during the last 10 years. However, higher concentrate levels can further drive milk production and actually make the problem worse. In addition, offering diets containing high levels of concentrates can lead to rumen acidosis, impaired rumen function and reduced intakes, with the latter exacerbating NEB.

- An alternative approach to reduce the extent of NEB in early lactation has been suggested. This involves reducing concentrate feed levels and dietary crude protein content during the post-calving period, thus slowing down the rate of increase in milk yield post-calving. In addition, low concentrate feed levels in early lactation may also have positive effects on rumen health.

- In a previous AgriSearch funded study (D-50-10), concentrates were introduced into the diet of freshly calved cows according to either a rapid build-up (concentrate build-up from day 1-10 of lactation) or a delayed build-up (concentrate build-up from day 28-42 of lactation) strategy. Results from this study showed that forage intake and subsequent rumen function was improved by delaying concentrate build-up in early lactation. Furthermore, the acceleration in milk yield was reduced without having a detrimental effect on 305-day milk yield.

- While the results of this initial study were positive, it was accepted that delaying the inclusion of a significant proportion of the dietary concentrate component until day 28 post-calving would be unacceptable to many producers, especially in situations where forage quality was poorer.

Objective of the current study

- To compare three different strategies by which to introduce concentrates into the diet of dairy cows in early lactation, namely a rapid build-up (RBU), an intermediate build-up (IBU) or a slow build-up (SBU) strategy.

Methodology

- This three treatment study involved 69 winter calving Holstein-Friesian dairy cows.

- From calving onwards, all cows were offered *ad libitum* access to a forage based ration containing 70% grass silage and 30% maize silage (DM basis). In addition, all cows were offered 6.0 kg of concentrate/day via in-parlour feeders. This basal diet supplied 12.3 MJ metabolisable energy (ME)/kg DM, 149 g crude protein (CP)/kg DM and 168 g starch/kg DM.

- In addition to this basal diet, a second concentrate was introduced into the diet of all cows (via out-of-parlour feeders) from calving onwards at one of three incremental rates; 0.19, 0.31 and 0.80 kg/day, representing either a slow, intermediate or rapid build-up strategy, respectively. These build-up strategies continued until a maximum concentrate allocation of 8.0 kg/day was achieved at days 10, 26 and 42 post-calving, respectively. Once full concentrate allocation levels had been achieved the total ration supplied 12.6 MJ ME/kg DM, 178 g CP/kg DM and 205 g starch/kg DM.

- The treatments examined are presented graphically in Figure i.

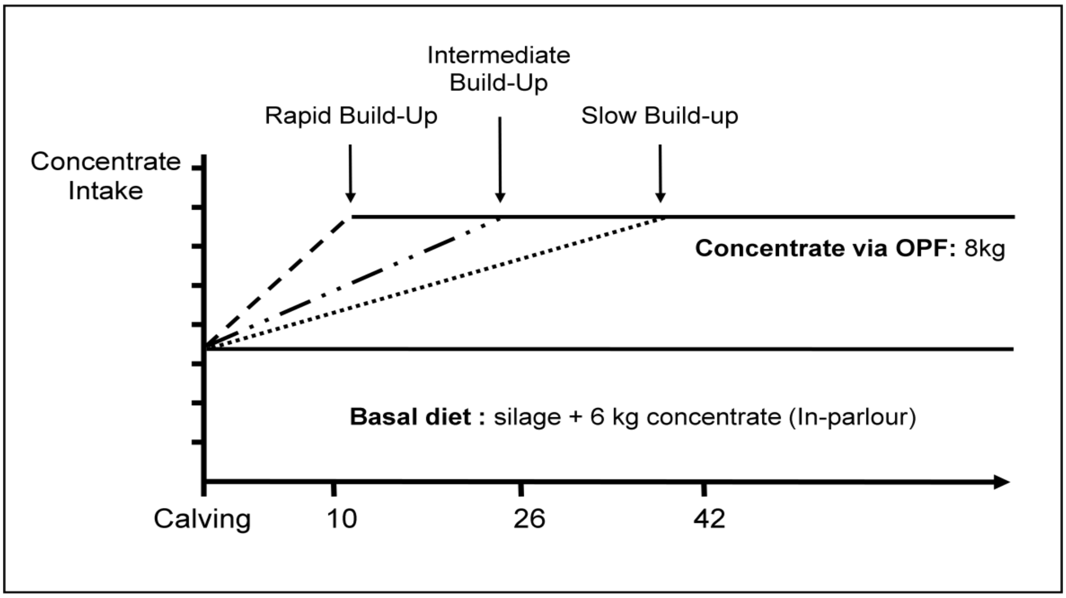

Figure i: Schematic of concentrate build-up strategy within the rapid (RBU), intermediate (IBU) and slow build-up (SBU) treatments.

Outcomes

- Cows on the slow build-up strategy had a higher forage dry matter intake during the first 150 days of lactation than those on the intermediate and rapid build-up strategy (Figure ii). This was largely due to a much higher forage intake during the first few weeks of lactation, a reflection of the lower concentrate intake at this time. Over the first 150 days, there was a concentrate saving effect of 0.5 kg/day (fresh basis) for cows managed on the slow compared to the rapid build-up of concentrates (Table i). There was no effect of concentrate build-up strategy on total dry matter intake.

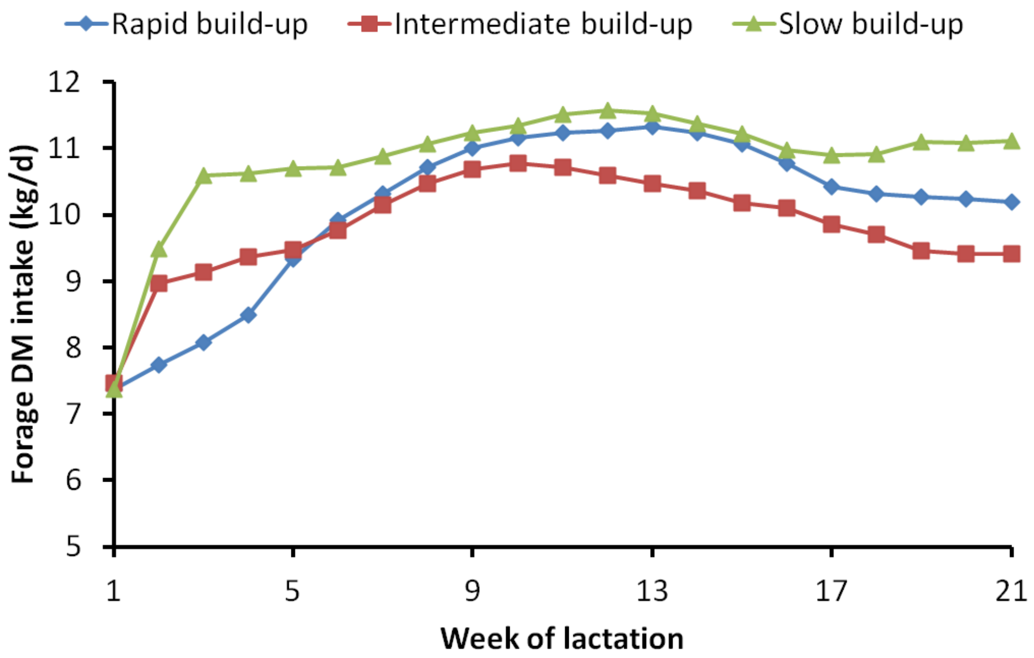

Figure ii: Forage intake (kg DM / cow / day) of animals managed on either a rapid, intermediate or slow concentrate build-up strategy in early lactation.

- Cows on the slow build-up strategy had a lower milk yield during weeks 3-7 of lactation, compared to those on the rapid build-up strategy (Figure iii). However, there was no significant difference in milk yield from week 8 of lactation onwards, the period when all cows were offered the full ration.

- There was no significant effect of concentrate build-up strategy on milk composition in this experiment (Table i).

- Thus, this study demonstrates that a short-term reduction in dietary crude protein content and concentrate levels can slow the rate of increase in milk yield in early lactation with no long term detrimental effect on overall performance.

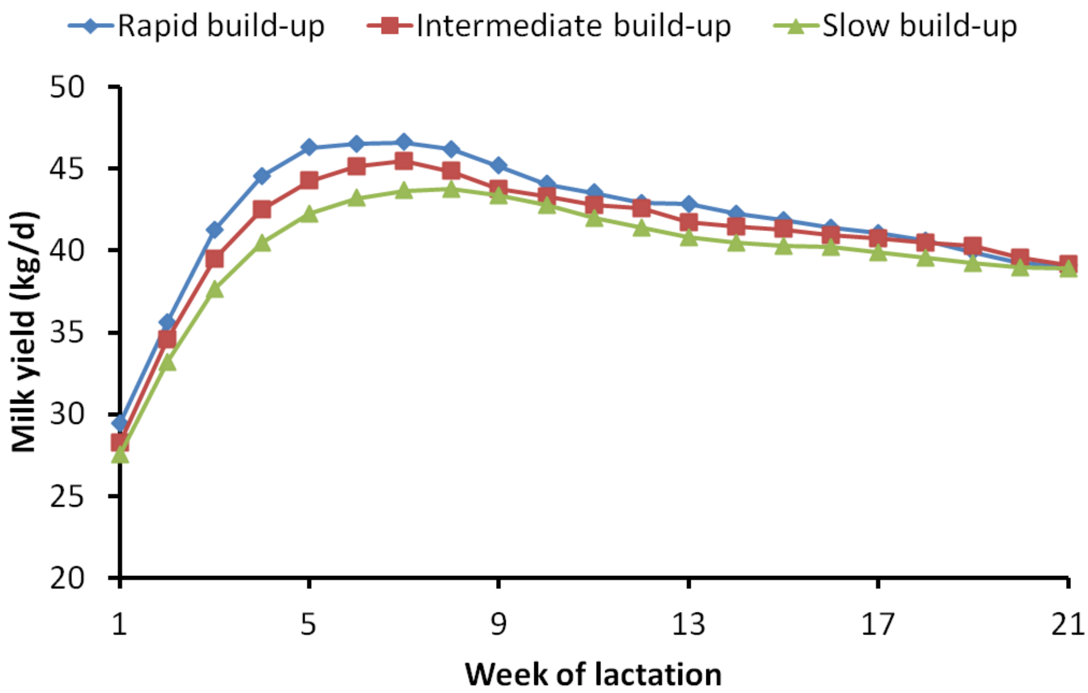

Figure iii: Milk yield (kg/cow/day) of animals managed on either a rapid, intermediate or slow concentrate build-up strategy in early lactation.

- Concentrate build-up strategy had no significant effect on mean live-weight or body condition score during the first 150 days of lactation. However, cows managed on the slow concentrate build-up strategy had a significantly higher daily and cumulative energy balance during the first 150 days of lactation compared to those on the rapid concentrate build-up strategy (Table ii).

Table i The effect of concentrate build-up strategy on dry matter intake and milk production (mean for first 150 days of lactation)

	Concentrate build-up strategy		
	Rapid	**Intermediate**	**Slow**
Dry matter intake (kg/day)			
Total	21.4	21.1	21.6
Forage	10.1	9.9	10.9
Concentrate	11.4	11.3	10.9
Milk yield (kg/cow/day)	42.0	41.2	40.1
Butterfat (%)	4.2	4.3	4.2
Protein (%)	3.4	3.3	3.3

Table ii The effect of concentrate build-up strategy on body condition score, live-weight and energy parameters (mean for first 150 days of lactation)

	Concentrate build-up strategy		
	Rapid	**Intermediate**	**Slow**
Body condition score	2.4	2.4	2.3
Live-weight (kg)	630	626	622
Daily energy balance (MJ/day)	-39.4	-37.9	-23.9
Cumulative energy balance (MJ)	-4288	-3793	-2881

- Cows managed on a slow concentrate build-up strategy had significantly lower plasma urea levels during the first 28 and 84 days of lactation compared to those on a rapid build-up strategy, a reflection of the lower dietary CP levels in early lactation.

- In early lactation, 46% of cows on rapid build-up strategy were treated for a dilated abomasum, compared to 13 and 22% on the intermediate and slow build-up strategies, respectively. In this experiment, the term "dilated abomasum" was used to describe cows that had excess gas in the abomasum, causing movement of the abomasum up the flank, but which did not display any other typical symptoms of a displaced abomasum such as dehydration, diarrhoea, ketosis etc. This finding suggests that cows managed on both the intermediate and slow build-up strategy had improved rumen function.

- Concentrate build-up strategy had no significant effect on the incidence of mastitis.

- Concentrate build-up strategy had no significant effect on conception rate to first insemination, cconception rate to 1st and 2nd inseminations, in-calf rate at day 100 of the breeding period, or in-calf rate at the end of the breeding period (Table iv). An improvement in fertility may have been expected with cows managed on the slow build-up strategy as they returned to positive energy balance before cows on the rapid build-up strategy. However, the relatively small numbers of animals involved in this study meant that it was not possible to robustly assess the effect of treatment on fertility performance.

Table iv The effect of concentrate build-up strategy on fertility

	Concentrate build-up strategy		
	Rapid	**Intermediate**	**Slow**
Conception rate to 1st insemination (%)	50	47	33
Conception rate to 1st and 2nd insemination (%)	72	79	56
Cows pregnant after 100 days of breeding (%)	72	79	72
Cows pregnant at end of breeding (%)	89	100	83

- Cows managed on a slow build-up of concentrates had a significantly lower incidence of metritis at day 21 of lactation than those on either an intermediate or rapid concentrate build-up strategy.

- As the extent of post-calving metritis increased, the 100-day pregnancy rate decreased.

- In the current study, cows with an improved energy balance had a lower incidence of uterine infection.

INTRODUCTION

The high-yielding dairy cow normally achieves peak milk yield at approximately 5–6 weeks post-calving, while peak intake is normally achieved at 7–10 weeks post-calving. Thus, during early lactation high-yielding dairy cows are unable to consume sufficient food to support peak milk production, resulting in severe and prolonged periods of negative energy balance, with this reflected in excessive mobilisation of body tissue reserves. In an attempt to address this issue, farmers normally increase the energy density of the diet by increasing the quantity of purchased concentrate feed being offered. However, while this strategy certainly promotes increased nutrient intakes (Ferris *et al*., 2001), it may not result in a dramatic improvement in energy balance, with cows frequently exhibiting a milk yield response to the additional nutrients offered. Furthermore, feeding high levels of concentrates in early lactation can lead to rumen health problems (acidosis and/or displaced abomasums), which may in turn further exacerbate negative energy balance, and have an adverse effect on health, milk production and reproductive performance. This is reflected in the fact that high-yielding dairy cows suffer a much greater incidence of health problems during the first few weeks post-calving than at any other time during lactation (Ingvarsten, 2006). Indeed, the latter author has demonstrated that the risk of disease is related to the rate of acceleration in milk production during the early lactation period. Thus, this might suggest that if the rate of increase in milk yield during the early lactation period could be reduced, the incidence of health problems could also be reduced.

With this in mind, a novel approach to feeding the high-yielding dairy cow during the first few weeks post-calving has been proposed, the objective of which is to slow the rate of increase in milk production in early lactation so that peak milk yield is achieved later in lactation, closer to the time of maximum dry matter intake. This approach was examined in a previous AgriSearch funded project (D-50-10) and used a combination of lower concentrate feed levels and lower crude protein diets to slow the rate of increase in milk yield in early lactation. In this initial study cows on the Control (‘rapid build-up’) treatment achieved their full concentrate (14 kg/day) allocation and dietary CP content (187 g/kg dry matter (DM)) within 10 days of calving. Cows on a 'delayed build-up' treatment received no additional concentrates (above those in a basal ration) until day 28 post-calving, with these cows not achieving their full diet (concentrate level and dietary CP content) until day 42 post-calving. Results from this study indicated that adopting a delayed concentrate build-up strategy in early lactation improved forage intake throughout the first 120 days of lactation, while having no detrimental effect on milk production. Delaying concentrate build-up also improved rumen function and tended to improve the energy status of the cow, but had no significant effects on fertility performance.

While the results of this initial study were positive, it was accepted that delaying the inclusion of a significant proportion of the dietary concentrate component until day 28 post-calving would be unacceptable to many producers, especially in situations where forage quality was poorer. Thus the current study was conducted to examine if similar positive effects could be achieved by adopting a slow rate of concentrate build-up in the diet from calving as opposed to delaying concentrate build-up until day 28 of lactation. Three treatments were examined, comprising either a rapid, intermediate or slow build-up of concentrates in the diet, with concentrate build-up commencing immediately post-calving. The slow build-up strategy was once again designed to slow the rate of increase in milk production in early lactation using a combination of lower concentrate feed levels and lower dietary crude protein levels.

MATERIALS AND METHODS

Animals and Housing

This experiment involved 69 multiparous Holstein Friesian dairy cows (mean parity, 3.1), calving between 5th September and 30th December 2010 (mean calving date, 16th October). Three weeks prior to calving (close-up dry period), cows were housed as a single group in a free stall house with slatted flooring. Following calving, they were placed in a single lactating cow group and were kept as a single group in a free stall house with concrete and slatted flooring. The cubicle to cow ratio was ≥1:1 at all times, thus meeting the recommendations of FAWC (1997). Cubicles (2.20 m x 1.25 m) were fitted with rubber mats and bedded with sawdust thrice weekly. Concrete passageway floors were scraped a minimum of four times daily by an automated system. Lights were left on in the cow house at all times.

During the close-up dry period cows had *ad libitum* access to grass silage supplemented with pre-calving minerals (150 g per cow per day) and Calcined Magnesite (50 g per cow per day). No additional concentrate was offered during the dry period.

Treatments

Cows were allocated to one of three treatments at calving; a rapid build-up (RBU) of concentrates (representing commercial practice), an intermediate build-up (IBU) of concentrates, or a slow build-up (SBU) of concentrates. Animals were assigned to post-calving treatments according to parity, previous lactation milk yield, calving date, calving interval, predicted transmitting ability (PTA) for fat (kg), PTA for protein (kg) and body condition score (BCS) and live-weight at day -21 pre-calving. These treatments were implemented as follows: from calving, all cows were offered a 'basal diet' comprising 6.0 kg of Concentrate A (Table 1) via in-parlour feeders and *ad libitum* access to a forage mix containing 70% grass silage and 30% maize silage (DM basis). In addition, the forage mix also contained 200 g of Alkacarb (sodium bicarbonate) per cow per day. This basal diet was designed to supply 12.2 MJ metabolisable energy (ME)/kg DM, 145 g CP/kg DM and 170 g starch/kg DM.

In addition to this basal diet, a second concentrate (Concentrate B) was introduced into the diet of all cows from calving onwards at one of three incremental rates, namely 0.19, 0.31, and 0.80 kg/day (fresh weight) for treatments SBU, IBU and RBU, respectively. This concentrate was offered through out-of-parlour feeders (OPF), with the build-up rates designed to achieve maximum concentrate intakes of 8.0 kg/cow/day by days 10, 26 and

42 post-calving in treatments RBU, IBU and SBU, respectively (Figure 1). The entire diet (basal diet plus 8.0 kg concentrate through the OPF) was designed to provide 175 g CP/kg DM, 12.2 MJ ME/kg DM and 200 g starch/kg DM. Once full concentrate allocation levels had been achieved, animals remained on these diets until day 150 of lactation.

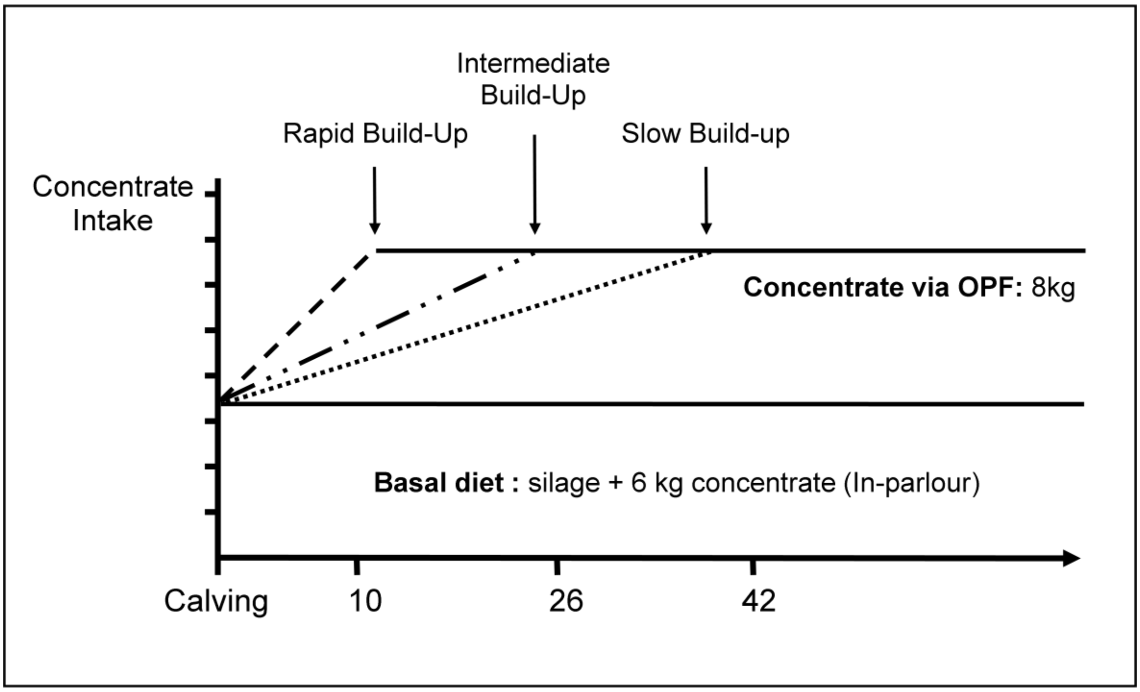

Figure 1: Schematic of concentrate build-up strategy within the rapid (RBU), intermediate (IBU) and slow build-up (SBU) treatments.

Ration preparation and feeding

The forage mix was prepared daily using a mixer wagon and offered between 1000 and 1100 h via feed boxes placed on a computer-linked load cell system. Access to feed boxes was controlled by an electronic identification system (Calan gate; American Calan Inc., Northwood, NH, USA), enabling the DM intake of individual animals to be recorded continuously. Intakes of each individual were checked daily and the health of any animal that had not consumed a minimum of 20.0 kg (fresh weight) of the forage component of the diet during the previous 24-hour period was checked. These animals frequently had excess gas in the abomasum and were treated with an injection of Combivit (Norbrook laboratories, UK) and an oral dose of pro-rumen (Vétoquinol, UK) to improve rumen and abomasal motility.

Food intakes of each individual cow were recorded daily using the feeding system described earlier. Post-calving, diet allocation had a target excess of 7.0% which was removed thrice weekly. Out-of-parlour feeder intakes were checked twice daily; once before 11.00 am and once in late afternoon.

Table 1: Ingredient composition and chemical composition of the concentrate feedstuffs offered post-calving.

Constituent[1]	Inclusion rate (g/kg)	
	Concentrate A	Concentrate B
Barley (milled)	260	170
Maize (milled)	260	170
Citrus pulp	85	120
Soya hulls	85	155
Soya bean meal (Hi-Pro)	120	180
Rape meal	120	140
Megalac[2]	15	15
Dairy cow minerals	25	20
Molaferm[3]	30	30
ME (MJ/kg DM)	13.0	13.0
CP (g/kg DM)	192	226
Starch (g/kg DM)	345	231

[1] ME, metabolisable energy; CP, crude protein
[2] Volac Ltd. Orwell, Hertfordshire, UK
[3] United Molasses, Belfast, NI, UK

Measurements (Feedstuffs)

Daily intakes were used to calculate an average daily intake for each week of lactation.

Grass silage and maize silage samples were analysed daily for oven DM (85^oC), with samples analysed weekly by near infrared reflectance spectroscopy to estimate ME content (Park *et al.,* 1998). Fresh samples of grass silage were also analysed once every 4 weeks for gross energy (Porter, 1992), nitrogen and ammonia-nitrogen (ammonia-N) concentrations (Steen, 1989), lactic acid, VFA's, ethanol, and propanol concentrations (Porter and Murray, 2001) and pH. A daily sub-sample was taken from the oven dry matter residues of grass silage and maize silage and bulked for each 4-week period and analysed for concentrations of NDF (neutral detergent fibre), ADF (acid detergent fibre), and ash as described by Cushnahan and Gordon (1995). Twice-weekly, samples of maize silage were dried at 60^oC and then bulked for each 2-week period and analysed for starch using a Megazyme kit (McCleary *et al*., 1994). Each batch of concentrates produced was sampled, bulked for each 2-week period, with bulked samples analysed for oven dry matter and nitrogen content. One dried sample of each concentrate was bulked every 28 days and analysed for ADF, NDF and ash concentrations as described by Cushnahan and Gordon (1995). A separate concentrate sample was dried at 60^oC and similarly bulked and analysed for starch as detailed above (Table 1). Volatility coefficients (Porter and Murray, 2001) were used with the oven dry matter contents of the grass silage and maize silage to produce volatile-corrected dry matter (VCDM) values.

Measurements (animals)

Cows were milked twice daily, between 0530 and 0700, and 1530 and 1700, through a 50 point rotary parlor. Milk yield was recorded automatically at each milking for each individual animal and a mean daily milk yield calculated for each animal on a weekly basis. Milk samples were taken weekly from each animal during two consecutive milkings and analysed for fat, protein and lactose content, with a.m. and p.m. samples analysed separately using an infrared milk analyser. Each sample had a preservative tablet added (Lactab

Mark III, Thompson and Cooper Ltd, Runcorn, UK) and was stored at 4°C until analysed. A weighted milk composition was subsequently calculated for each weekly sampling occasion.

Live-weight and BCS score were measured weekly from 21 days prior to the predicted calving date until calving. Post-calving, live-weight was measured twice daily and BCS was assessed weekly (on a scale from 1 to 5; Edmonson *et al.,* 1989) until the end of the study.

From calving, all animals were blood sampled weekly until week six of lactation and fortnightly thereafter until week 12 of lactation. Blood was taken from the coccygeal vein (before the allocation of fresh food) into uncoated, heparin-coated, and fluoride oxalate coated tubes (BD, Oxford, UK). Plasma was recovered by centrifugation from fluoride oxalate tubes for analysis of glucose and non-esterified fatty acids (NEFA), and from heparinised tubes for analysis of total protein, albumin, urea, and β-hydroxybutyrate (BHB). All analyses were carried out on a clinical analyser (AU640, Olympus UK Ltd, Middlesex, UK). Plasma concentrations of total protein, albumin, glucose, and urea were determined using Olympus kits (Olympus Life Science Research Euorpa, Munich, Germany). Reagents for total protein, albumin, glucose, and urea were ready for use and placed appropriately into the analyser. In the analysis of total protein, cupric ions in an alkaline solution react with proteins and polypeptides containing at least two peptide bonds to produce violet coloured complex. The absorbance of the complex at 540/660 nm is directly proportional to the concentration of protein in the sample (Young, 2000). For albumin, a coloured complex is formed when bromocresol green (BCG) reacts with albumin. The absorbance of the albumin-BCG complex is measured bichromatically (600/800 nm) and is proportional to the concentration of albumin in the sample (Young, 2000). Glucose is phosphorylated by hexokinase in the presence of ATP and Mg^{2+} to produce glucose-6-phosphate and ADP. Glucose-6-phosphate dehydrogenase specifically oxidizes glucose-6-phosphate to gluconate-6-phosphate with the concurrent reduction of NAD^+ to NADH. The increase in absorbance at 340 nm is proportional to the glucose concentration in the sample (Young, 2000). Urea is hydrolysed in the presence of water and urease to produce ammonia and carbon dioxide. The ammonia produced in the first reaction combines with 2-oxoglutarate and NADH in the presence of glutamate-byhydrogenase to yield glutamate and NAD^+. The decrease in NADH absorbance per unit time is proportional to the concentration of urea (Young, 2000). NEFA concentrations were determined using a standard Wako reagent kit NEFA-HR(2) (Wako Chemicals GmbH, Neuss, Germany). Reagents were prepared according to Kreb *et al*. (2000). NEFA is converted to Acyl-CoA, AMP, and pyrophosphoric acid by the action of Acyl-CoA synthetase, under coexistence with coenzyme A and adenosine 5-triphosphate disodium salt (ATP). Obtained Acyl-CoA is oxidized and yields 2, 3-trans-Enoyl-CoA and hydrogen peroxide by the action of Acyl-CoA oxidase (ACOD). In the presence of peroxidase, the hydrogen peroxide formed yields a blue purple pigment by quantitative oxidation condensation with 3-Methyl-N-Ethyl-N-(β-Hydroxyethyl)-Aniline (MEHA) and 4-aminoantipyrine (4-AA). Non-esterified fatty acids (NEFA) concentration is obtained by measuring absorbance of the blue purple colour. β-hydroxybutyrate concentration of plasma was determined according to McMurray *et al.* (1984).

A clinical examination of vagina mucus was performed and scored (Williams *et al*., 2005) on day 14, 21 and 28 of lactation (±3 days). Briefly, the cow's vulva was thoroughly cleaned with a disinfected towel and then dried using a paper towel. A clean lubricated gloved hand was then inserted through the vulva into the vaginal area. In each cow the lateral, dorsal and ventral walls of the vagina and the external cervical os were palpated, and the mucus contents of the vagina withdrawn manually for examination. The vaginal mucus was assessed by a single operator throughout the course of the study for colour, proportion and volume of pus, and a character score assigned as follows: (0) clear or translucent mucus; (1) mucus containing flecks of white or off-white pus; (2) <50 ml exudate containing ≤50% white or off-white mucopurulent material; and (3) >50 ml exudate containing purulent material, usually white or yellow, but occasionally sanguineous. The vaginal mucus was also assessed by odour, and given a score 0 for normal odour or a score of 1 if a fetid odour was detected. To aid the analysis of vaginal mucous score data, the scores were translated into one integer; 0 = 0 (character), 0 (odour); 1 = 1, 0; 2 = 2, 0; 3 = 3, 0; 4 = 2, 1; 5 = 3, 1. If a vaginal mucous score was ≥3, antibiotics were administered through the vagina and cervical canal into the lumen of the uterus, guided by palpation per rectum (Metricure, Intervet/Schering-Plough Animal Health, Walton Manor, Walton, Milton Keynes, MK7 7AJ).

Faecal scores were assessed on days 10, 30, and 50 post-calving for each cow according to the scoring system described by (Zaaijer and Noordhuizen, 2003). All additional animal health measurements were recorded and compiled in a database.

Pregnancy was confirmed via an ultrasound scan carried out by a veterinarian at approximately day 30 post insemination and again at day 60 post insemination. All inseminations were carried out approximately 12 h after an observed estrus by a trained technician following the commencement of breeding (30th November) and a 42-day voluntary waiting period. All fertility events were recorded.

For more detailed fertility measurements, milk samples for progesterone analysis were collected on Mondays, Wednesdays and Fridays (all a.m.) from parturition until day 100 post-calving. Milk samples were taken aseptically, a preservative tablet added (Lactab Mark III, Thompson and Cooper Ltd, Runcorn, UK), and stored at 4ºC until analysis. Milk progesterone concentration was determined using a competitive enzyme–linked immuno-sorbent assay (ELISA) kit (Ridgeway Science Ltd, Gloucestershire, UK), with the assay based on the method of Sauer *et al*. (1986).

The methodology used to interpret data describing milk progesterone was described in full by McCoy *et al*. (2006). Briefly, the onset of luteal activity (OLA) is indicated by the first of at least two consecutive progesterone concentrations ≥3 ng/ml in whole milk. However, when using this definition of OLA the sampling routine introduces an overestimate of 1.17 day (on average), and this was subtracted from the calculated value. The luteal phase (LP) of an individual oestrous cycle is defined as the interval between the first progesterone concentration ≥3 ng/ml and the last consecutive milk progesterone concentration ≥3 ng/ml in whole milk. The sampling routine adopted underestimates the interval by an average of 2.33 day (i.e. 1.17 + 1.17), and as such, the corrected interval was reported as calculated interval +2.33 day. The inter-ovulatory interval (IOI) is defined as the period between the first progesterone rise (above 3 ng/ml) of one cycle to the first progesterone rise (above 3 ng/ml) in the next cycle. No inherent sampling bias exists with this parameter. The inter-luteal interval (ILI) is defined as the period between the demise of one corpus luteum and the rise of the next, and is the interval from the first milk progesterone concentration <3 ng/ml to the last consecutive milk progesterone <3 ng/ml in whole milk. No inherent sampling bias exists with this parameter.

Abnormal progesterone profiles were classified as described by Lamming and Darwash (1998). A delayed ovulation type I (DOV I) was defined as progesterone concentration <3 ng/ml in whole milk for ≥45 days (prolonged ovulation) and a delayed ovulation type II (DOV II) was defined as progesterone concentrations <3 ng/ml in whole milk for ≥12 days after the OLA (prolonged inter-luteal interval). A persistent corpus luteum type I (PCL I) was defined as progesterone concentrations ≥3 ng/ml for ≥19 days on the first luteal phase (delayed luteolysis of the corpus luteum during the first oestrous cycle) and a persistent corpus luteum type II (PCL II) was defined as progesterone concentrations ≥3 ng/ml for ≥19 days on subsequent luteal phases (delayed luteolysis of the corpus luteum during subsequent oestrous cycles).

Calculation of Energy Balance

The average daily energy balance (DEB) for each animal was calculated for each week of lactation using the equations described by Thomas (2004) (DEB = ME intake – ME requirement $[-10 + (ME_{preg} + ME_{maintmilk} * BW^{0.75})] + [(0.0013*BW)/K_m)]$; K_m, efficiency of energy use for maintenance (0.35 x ME/GE + 0.503)). Milk yields, dry matter intake, milk compositions, live-weight, and feed composition data were all used in the calculations. Missing values (less than 2% of all values) were estimated from data for the week prior to, and the week following, the week during which observations were missing.

Statistical Analysis

Data were analysed by a repeated measures approach using the Residual Maximum Likelihood (REML) procedure in GenStat (Payne *et al*. 2007). The model fitted the following fixed effects: concentrate build-up strategy, parity and week of lactation for each parameter. Average live-weight and condition score for week -1 and 1 of lactation were used as covariates. The model included all 2-way and 3-way interactions among these variables.

In addition, the shape of the lactation curve was estimated for individual cows using the Wood's function: $Y_t = At^B \exp(-tC) + \varepsilon_t$ (Wood, 1967), where Y is the average daily milk yield in lactation week t and ε is the error term. Parameter A is a general scaling factor for the average daily milk yield at the start of lactation. Parameters B and C describe the lactation curve to peak and the decrease in milk yield through lactation respectively. Analysis of variance was then used to identify treatment effects on each of the parameters A, B and C.

A logistic regression model evaluating treatment and vaginal mucous score effects was used to analyse the following data; pregnancy rate to first insemination, pregnancy rate to first and second insemination, 100 day in calf rate, intervention, delayed ovulation types I and II, persistent corpus luteum types I and II and whether or not there was more than one abnormal progesterone profile observed.

Linear regression analysis was undertaken to analyse the effect of vaginal mucous score on a range of fertility parameters.

RESULTS

Chemical Composition of the Silages, Concentrates and Diets

The grass silage offered post-calving was well preserved having a pH and concentrations of ammonia-N and butyrate of 3.7, 97 g/kg total nitrogen, and 0.12 g/kg of DM, respectively (Table 2). The maize silage offered post-calving had a dry matter content of 299 g/kg, a CP concentration of 83 g/kg DM, and a starch concentration of 307 g/kg DM (Table 2). The basal ration had a ME, CP and starch content of 12.3 MJ/kg DM, 149 g/kg DM and 168 g/kg DM, respectively. At maximum concentrate allocation, the entire diet had a ME, CP and starch content of 12.6 MJ/kg DM, 178 g/kg DM and 205 g/kg DM respectively.

Table 2: Chemical composition of grass silage and maize silage offered during the experiment.

	Grass silage	Maize silage
Oven DM (g/kg)	197	299
VCDM[1] (g/kg)	204	305
pH	3.7	-
Composition of VCDM (g/kg)		
Crude protein	151	83
Ammonia nitrogen (g/kg total N)	97	-
Ethanol	3.9	-
Propanol	1.3	-
Lactic acid	26	-
Acetic acid	7.3	-
Propionic acid	0.48	-
n-butyric acid	0.12	-
Acid detergent fibre	317	240
Neutral detergent fibre	536	435
Ash	81	34
Starch	-	307
Gross energy (MJ/kg DM)	20.3	-

[1] VCDM, volatile corrected dry matter

Effect of Concentrate Build-Up Strategy on Intake and Production Parameters (1-150 days)

During the post-calving period (1-150 days), cows on SBU had a higher forage intake (P=0.007) and a lower concentrate intake (P=0.002) than those on IBU or RBU (Table 3). Concentrate build-up strategy had no significant (P>0.05) effect on total dry matter intake (Figure 2), milk yield, milk energy, concentrations of fat, protein and lactose, or yields of fat, protein and fat plus protein.

There was a significant treatment by week of lactation interaction for forage intake (P<0.001; Figure 3; SED, 0.57), concentrate intake (P<0.001), milk protein concentration (P=0.003) and milk protein yield (P=0.035).

Figure 4 describes milk production of cows managed on the three treatments. There was no significant treatment by week of lactation interaction for milk yield (P=0.703; SED, 1.58).

Table 3: Effects of concentrate build-up strategy on dry matter intake, milk yield, milk constituents and constituent yields (fat and protein) during the first 150 days of lactation (1 to 150 days)

	Concentrate Build-Up Strategy				P-value		
	Rapid Build-Up	Intermediate Build-Up	Slow Build-Up	SED	Treatment	Time	Interaction
Dry matter intake (kg/day)							
Total	21.4	21.1	21.6	0.35	0.249	<0.001	0.622
Forage	10.1	9.9	10.9	0.32	0.007	<0.001	<0.001
Concentrate	11.4	11.3	10.9	0.13	0.002	<0.001	<0.001
Milk yield (kg/day)	42.0	41.2	40.1	1.42	0.411	<0.001	0.703
Milk constituents (g/kg)							
Fat	42.2	42.6	42.4	1.37	0.956	<0.001	0.274
Protein	33.5	32.9	33.3	0.59	0.528	<0.001	0.003
Lactose	45.5	45.8	45.7	0.32	0.652	<0.001	0.632
Milk constituent yield (kg/day)							
Fat	1.76	1.74	1.68	0.069	0.533	<0.001	0.236
Protein	1.40	1.34	1.31	0.041	0.129	<0.001	0.035
Fat + protein	3.16	3.08	3.00	0.103	0.322	<0.001	0.281
Milk energy output (MJ/day)	134	132	128	4.4	0.374	<0.001	0.391

[1] SED, standard error of the difference;

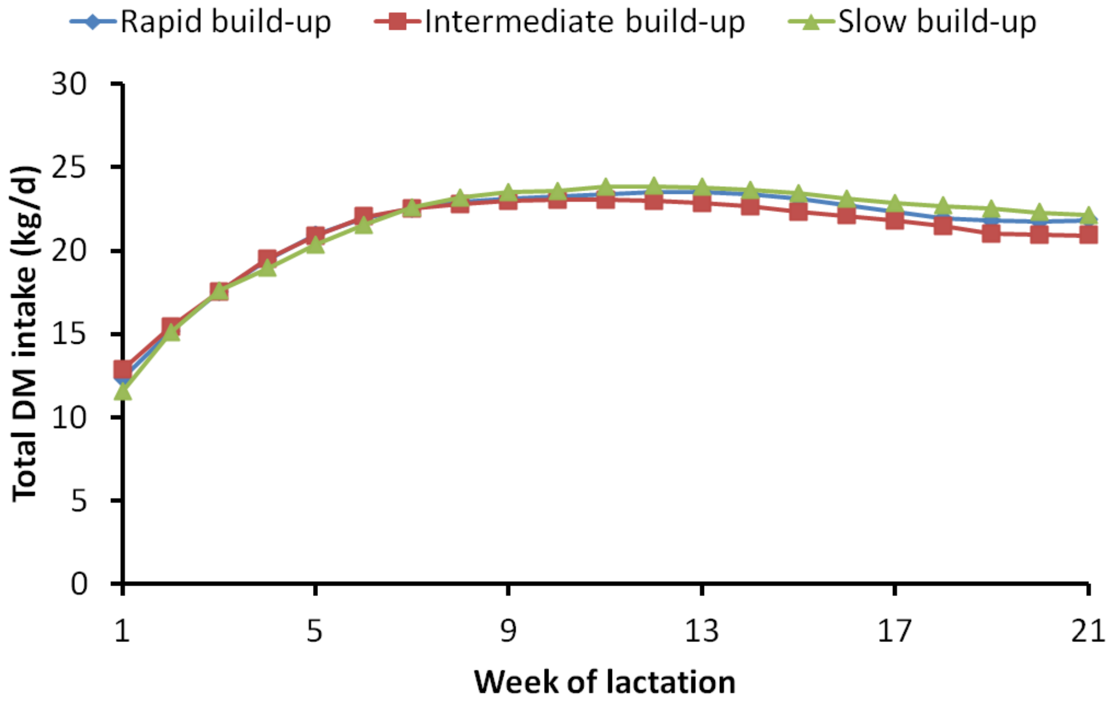

Figure 2: Total dry matter intake (kg / day) of animals managed on one of three concentrate build-up strategies (Rapid vs. Intermediate vs. Slow) in early lactation.

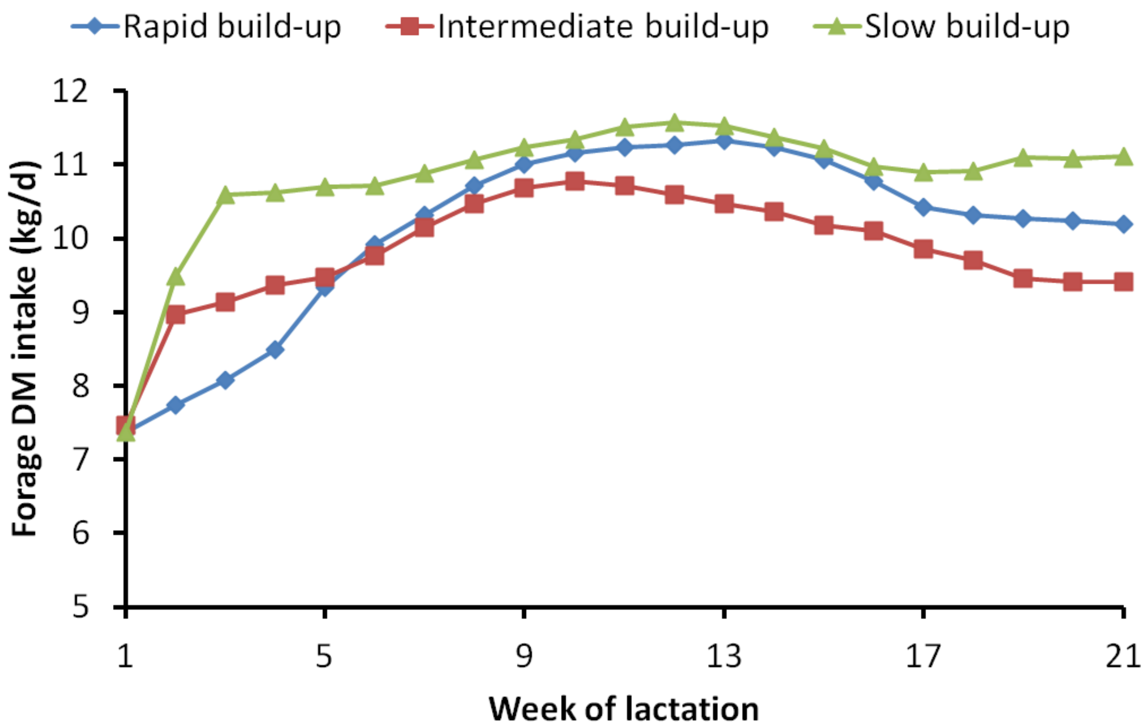

Figure 3: Total forage intake (kg DM / day) of animals managed on one of three concentrate build-up strategies (Rapid vs. Intermediate vs. Slow) in early lactation.

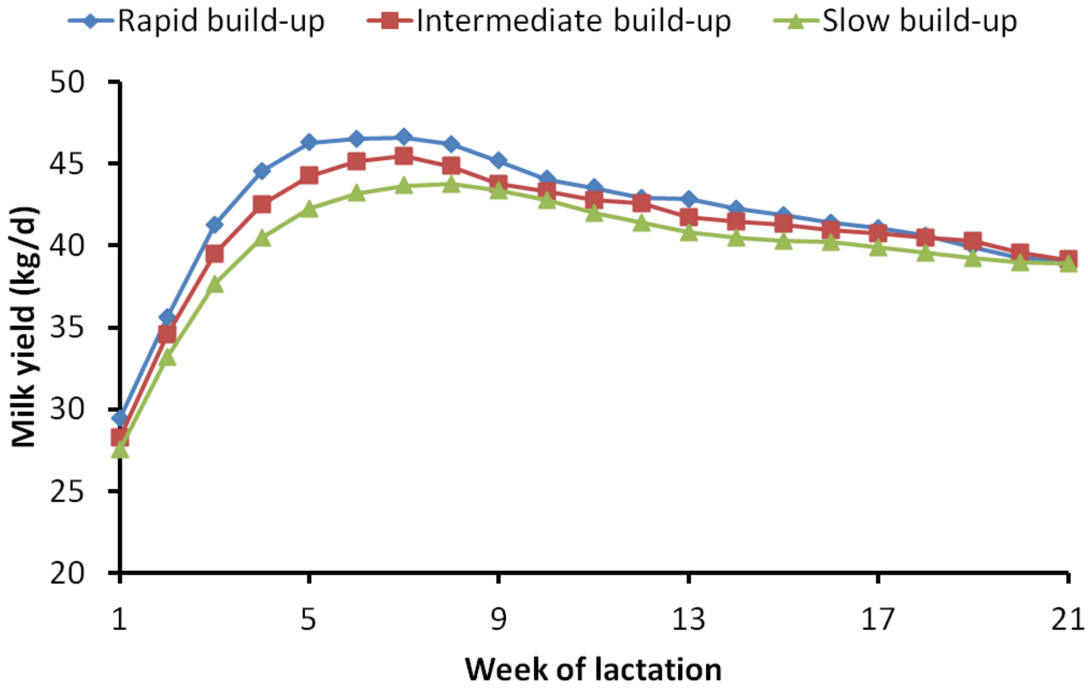

Figure 4: Milk yield (kg / day) of animals managed on one of three concentrate build-up strategies (Rapid vs. Intermediate vs. Slow) in early lactation.

The Wood's equation was used to estimate the shape of the lactation curve for each animal on the trial. It was found that treatment had no significant (P>0.05) effect on parameter *A* (P=0.314; r^2=0.04; RBU, 30.9 vs. IBU, 29.9 vs. SBU, 28.1), describing the starting milk yield of the lactation curve; parameter *B* (P=0.909; r^2=0.003; RBU, 0.345 vs. IBU, 0.332, SBU, 0.349), describing the slope and peak of the curve; or parameter *C* (P=0.711; r^2=0.011; RBU, 0.043 vs. IBU, 0.039 vs. SBU, 0.039), describing the persistency of lactation.

Effect of Concentrate Build-Up Strategy on Live-weight, Body Condition Score and Energy status (1-150 day)

During the first 150 days of lactation, concentrate build-up strategy had no significant effect (P>0.05) on mean live-weight, BCS, ME requirement or ME intake (Table 4). Cows on SBU had a significantly higher DEB (P=0.048) compared to those on RBU and IBU treatments (Figure 5; SED, 11.37). Cows on SBU had significantly higher cumulative energy balance (P=0.045) than those on RBU but not IBU (Table 4).

All the above parameters were significantly (P < 0.001) affected by week of lactation. There was a significant treatment by week of lactation interaction for ME intake (P = 0.016) and cumulative energy balance (P < 0.001; Figure 6; SED, 569).

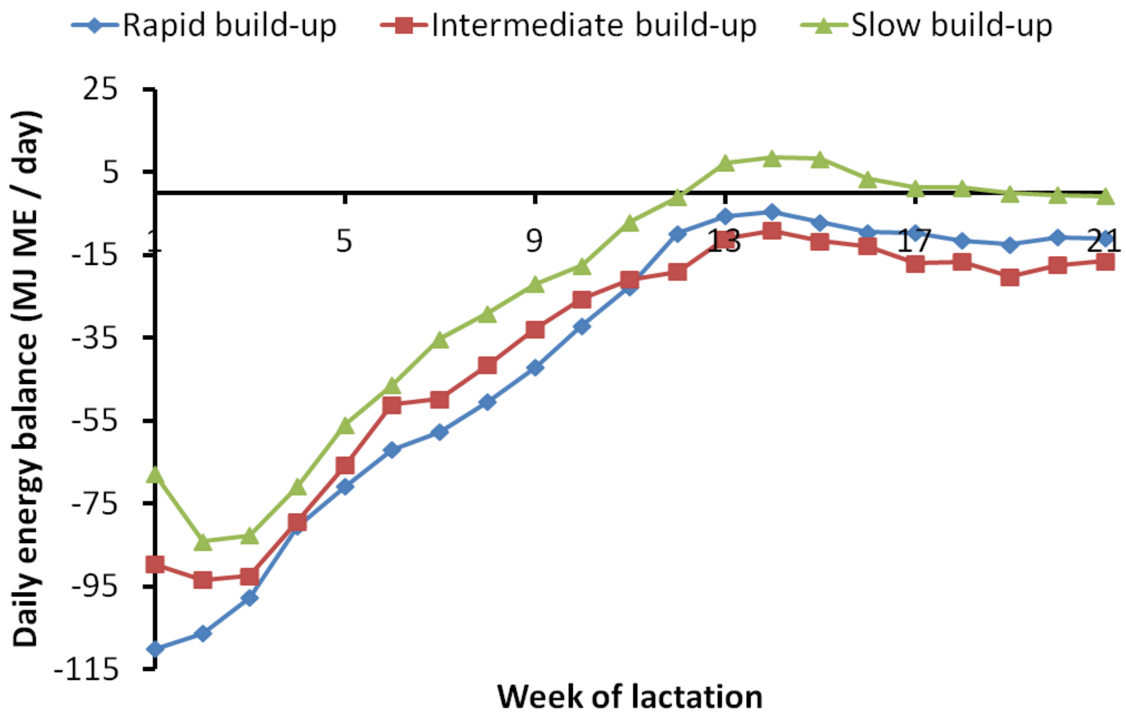

Figure 5: Daily energy balance (MJ ME/day) of animals managed on one of three concentrate build-up strategies (Rapid vs. Intermediate vs. Slow) in early lactation.

Table 4: Effects of concentrate build-up strategy on mean live-weight, body condition score and a number of energy parameters of animals during the first 150 days of lactation

	Concentrate Build-Up Strategy				P-value		
	Rapid Build-Up	Intermediate Build-Up	Slow Build-Up	SED[2]	Treatment	Time	Interaction
Live-weight (kg)	630	626	622	9.8	0.718	<0.001	0.999
BCS[1]	240	245	234	6.3	0.159	<0.001	0.678
ME requirement (MJ/day)[1]	299	294	286	8.1	0.327	<0.001	0.331
ME intake (MJ/day)[2]	259	256	262	4.0	0.260	<0.001	0.016
Daily energy balance (MJ/day)	-39.4	-37.9	-23.9	6.64	0.048	<0.001	0.581
Cumulative energy balance (MJ)	-4288	-3793	-2881	569	0.045	<0.001	<0.001

[1] BCS, body condition score; ME, metabolisable energy

[2] SED, standard error of the difference;

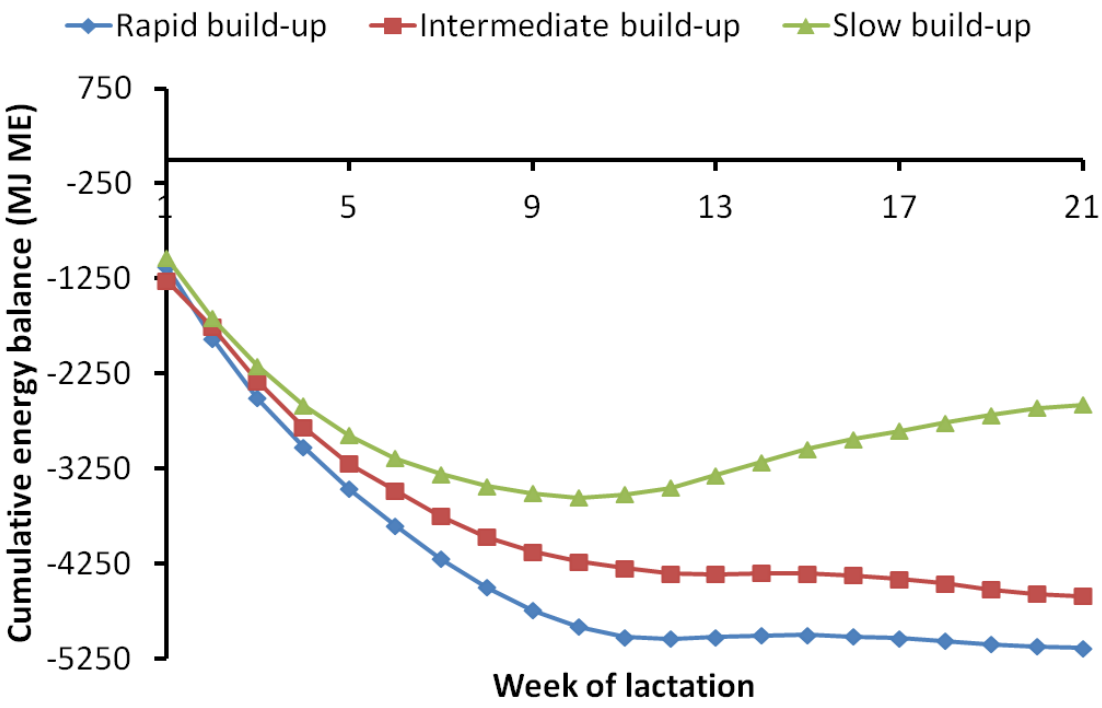

Figure 6: Cumulative energy balance (MJ ME) of animals managed on one of three concentrate build-up strategies (Rapid vs. Intermediate vs. Slow) in early lactation.

Effect of Concentrate Build-Up Strategy on Blood Parameters (1-28 days, 1-84 days)

During the first 28 days of lactation, cows on the SBU treatment had lower plasma urea (P=0.030) concentrations than those on RBU but not IBU (Table 5). Concentrate build-up strategy had no significant effect (P>0.05) on plasma concentrations of total protein, albumin, globulin, BHB, NEFA or glucose.

During the first 84 days of lactation, concentrate build-up strategy had a significant effect on plasma urea (P=0.042). Animals allocated to the SBU strategy had lower plasma urea concentrations than animals allocated to RBU but not the IBU treatment (Table 5).

Table 5: Effect of concentrate build-up strategy on blood metabolites of animals during day 1 to 28 and 1 to 84 of lactation

Blood parameter	Concentrate Build-Up Strategy: Rapid Build-Up	Intermediate Build-Up	Slow Build-Up	SED	P-value: Treatment	Time	Interaction
Day 1 – 28 of lactation							
Urea (mmol/l)	3.07	2.79	2.63	0.163	0.030	0.363	0.644
Total protein (g/l)	61.6	60.4	60.5	1.94	0.814	<0.001	0.801
Albumin (g/l)	26.5	25.2	24.6	0.95	0.141	<0.001	0.796
Globulin (g/l)	35.1	35.1	35.7	1.64	0.843	<0.001	0.778
NEFA (meq/l)[1]	0.58	0.55	0.53	0.052	0.539	<0.001	0.463
BHB (mmol/l)[1]	0.70	0.76	0.85	0.063	0.077	0.008	0.691
Glucose (mmol/l)	2.95	2.91	2.87	0.079	0.640	0.019	0.958
Day 1 – 84 of lactation							
Urea (mmol/l)	3.31	3.11	3.00	0.132	0.042	<0.001	0.855
Total protein (g/l)	63.0	63.3	64.3	1.80	0.943	<0.001	0.946
Albumin (g/l)	26.9	26.1	26.6	0.75	0.312	<0.001	0.722
Globulin (g/l)	36.3	37.0	37.7	1.53	0.823	<0.001	0.972
NEFA (meq/l)[1]	0.43	0.38	0.39	0.037	0.116	<0.001	0.869
BHB (mmol/l)[1]	0.62	0.65	0.66	0.043	0.488	<0.001	0.555
Glucose (mmol/l)	3.03	3.05	2.98	0.055	0.538	<0.001	0.909

[1] NEFA, non-esterified fatty acid; BHB, β-hydroxybutyrate

There was a significant (P<0.001) effect of week of lactation on all parameters except plasma urea concentrations during the first 28 days of lactation. There was no significant (P>0.05) treatment by stage of lactation interaction for any of the blood parameters during the two time periods.

Effect of Concentrate Build-Up Strategy on Uterine and Rumen Health, and Mastitis Incidence

Concentrate build-up strategy had a significant (P=0.041) effect on the proportion of cows that were treated for a right dilated abomasum. In animals allocated to the RBU strategy, 45.5% were treated for a right dilated abomasum compared to 13.0 and 21.7% on the IBU and SBU treatments, respectively (Table 6). Furthermore, cows allocated to the SBU treatment had a significantly (P=0.044) lower incidence of uterine infection at day 21 of lactation than those on the IBU and RBU treatments. Concentrate build-up strategy had no significant (P>0.05) effect on the incidence of mastitis, vaginal mucous score at days 14, 21, and 28 of lactation, or faecal score at days 10, 30 or 50 of lactation.

The average DEB during the first 150 days of lactation was significantly associated (negative relationship) with the incidence of uterine infection at day 21 of lactation (r^2=0.098; P=0.037). The fitted equation of this correlation was Y=-3.20 -0.0334 (Average DEB).

Effect of Concentrate Build-Up Strategy on Fertility Parameters

Concentrate build-up strategy had no significant (P<0.05) effect on days to 1st insemination, conception rate to 1st insemination, conception rate to 1st and 2nd insemination, 100 days in-calf rate, in-calf rate at the end of a 6 month breeding period, or the interval from calving to conception (Table 7).

Table 6: Effect of concentrate build-up strategy on the incidence of right dilated abomasums, mastitis, uterine infection and faecal score

	Concentrate Build-Up Strategy			SED[1]	P-value
	Rapid Build-Up	Intermediate Build-Up	Slow Build-Up		
Cows with at least one incidence of right dilated abomasum during the first 90 days post-calving (%)	45.5	13.0	21.7	8.71	0.041
Cows with at least one incidence of mastitis during the first 90 days post-calving (%)	31.8	17.4	30.4	9.13	0.460
Uterine infection at day 21 post-calving (% of cows)[2]	18.2	13.6	0.0	5.19	0.044
Mucous score at day 14 post-calving[3]	2.7	1.9	2.3	0.43	0.244
Mucous score at day 21 post-calving[3]	1.4	1.4	1.0	0.35	0.359
Mucous score at day 28 post-calving[3]	0.6	0.7	0.4	0.29	0.489
Faecal score at day 10 post-calving[4]	2.4	2.6	2.6	0.21	0.765
Faecal score at day 30 post-calving[4]	2.6	2.5	2.6	0.23	0.898
Faecal score at day 50 post-calving[4]	2.3	2.6	2.5	0.19	0.475

[1] SED, standard error of the difference;
[2] Animals with a mucus score of 2,1 or 3,1
[3] Mucous score converted to 0-5 to aid the analysis of the data (0 = 0,0; 1 = 1,0; 2 = 2,0; 3 = 3,0; 4 = 2,1; 5 = 3,1)
[4] Faecal score range 1(watery) to 5(firm)

Table 7: Effect of concentrate build-up strategy on fertility performance

	Concentrate Build-Up Strategy			SED[1]	P-value
	Rapid Build-Up	Intermediate Build-Up	Slow Build-Up		
Days to first insemination	80.3	79.3	78.1	7.4	0.958
Conception rate to 1st insemination (%)	50.0	47.4	33.3	11.4	0.549
Conception rate to 1st and 2nd inseminations (%)	72.2	78.9	55.5	9.6	0.292
In-calf rate at 100d of the breeding period (%)	72.2	78.9	72.2	10.1	0.860
In-calf rate at the end of the breeding period (%)	88.9	100.0	83.3	9.1	0.094
Interval from calving to conception (day)	120.7	97.7	112.0	14.8	0.286

[1] SED, standard error of the difference;

Concentrate build-up strategy had no significant (P>0.05) effect on the interval to the onset of luteal activity, the average luteal phase, average inter-ovulatory interval or on the inter-luteal interval (Table 8). Furthermore, concentrate build-up strategy had no significant (P>0.05) effect on the occurrence of abnormal cyclic activity; delayed ovulation types I and II or persistent corpus luteum types I and II (Table 8). A relatively low percentage of animals (26.2%) had more than 1 atypical ovarian cycle post-calving; however, there was no significant (P>0.05) effect of concentrate build-up strategy on the occurrence of this.

Effect of Energy Balance Mucous Score on Fertility Parameters

The average DEB during the first 42 or 150 days of lactation had no significant effect on any of the fertility parameters analysed.

The average mucous score (assessed on days 14, 21 and 28 of lactation) was associated (negative relationship) with the proportion of cows in-calf 100 days after the commencement of breeding (r^2=0.10; P=0.012). The fitted equation of this correlation was Y=2.202 -0.965 (Average mucous score).

Table 8: Effect of concentrate build-up strategy on ovarian luteal activity based on 3x weekly analysis of milk progesterone (day 1-100).

	Concentrate Build-Up Strategy			SED	P-value
	Rapid Build-Up	Intermediate Build-Up	Slow Build-Up		
Onset of luteal activity (day)	31.8	29.5	32.5	4.36	0.758
Average luteal phase (day)	17.9	21.3	15.5	4.08	0.338
Average inter-ovulatory interval (day)	27.4	30.9	26.0	3.91	0.423
Average inter-luteal interval (day)	16.2	14.9	14.9	1.43	0.615
Delayed ovulation type I[1] (% of cycles)	12.8	15.3	13.7	7.5	0.665
Delayed ovulation type II[1] (% of cycles)	63.0	63.5	59.8	9.52	0.958
Persistent corpus luteum type I[1] (% of cycles)	19.2	19.8	12.2	7.6	0.169
Persistent corpus luteum type II[1] (% of cycles)	6.7	0.0	11.3	3.6	0.090
Animals with 1 or > atypical cycles (%)	33.2	18.2	26.9	9.32	0.687

[1] SED, standard error of the difference;

DISCUSSION

Effect of Concentrate Build-Up Strategy on Intake and Production Parameters

As expected, adopting a slower concentrate build-up strategy in early lactation resulted in a significant increase in forage intake during this period, a result of a lower concentrate level in the diet. However, after maximum concentrate allocation had been achieved in all treatments (day 42 post-calving) there was no significant difference in forage intake between animals on any of the concentrate build-up strategies. This was in contrast to the findings of a previous study (Law *et al*, 2011), in which an improved forage intake was sustained until 11 weeks after cows on a delayed build-up treatment achieved their full concentrate allowance. These authors suggested that offering a diet containing relatively low concentrate proportions in early lactation conditioned the rumen thus enabling higher forage intakes in later lactation. The reasons for the different forage intake responses between the two studies are unclear. However, in the current study, cows on the rapid build-up of concentrates had higher forage intakes compared to those on the same treatment in the previous study (10.1 vs. 9.0 kg DM/day) and this may have been due to a slight improvement in forage quality. There was no significant effect of nutritional treatment on total dry matter intake throughout lactation (Figure 2). This would suggest that the substitution rate (the change in forage DM intake per unit of additional concentrate) was close to 1.0 during this early lactation period resulting in a dramatic depression in forage intake.

In the current experiment, reducing the rate of increase in concentrates, and subsequently the overall dietary CP content, reduced the acceleration in milk yield in early lactation (Figure 4). Milk production was significantly lower in cows on the SBU treatment during weeks 3, 4, 5, 6 and 7 of lactation compared to those allocated to the RBU treatment. After week eight, dietary protein levels were approximately 18% on all treatments and from this point onwards there was no significant difference in milk yields between these two treatments. Thus, over the first 150 days of lactation the effect of the lower milk yield in early lactation was diluted as there was no overall significant difference between treatments during this period. Dietary CP supply is a key driver of milk production as the cow has a limited capacity to rely on body protein resources to maintain a high level of milk production (Oldham, 1984). The results of the current study illustrate that cows responded in terms of milk production when the dietary CP content was increased from 149 to 178 g/kg DM. This is in agreement with previous research conducted by this group where it was found that reducing dietary protein levels can be used as a short-term tool to slow down milk production and subsequent increases in dietary protein can reverse this effect with no long term negative effects (Gilmore *et al.,* 2010).

Effect of Concentrate Build-Up Strategy on Energy Parameters

In the current study, cows managed on a slow build-up of concentrates had an improved daily and cumulative energy status compared to those on a rapid build-up of concentrates. This was due to a reduction in milk production in early lactation in cows managed on the slow build-up of concentrates compared to those managed on the rapid build-up of concentrates. There was no significant difference in energy status between cows on slow and intermediate build-up strategies. In contrast, no significant effect of treatment on energy status was identified in the previous study. This may be due to a greater difference in milk yield between cows managed on rapid and slow concentrate build-up strategies in the current study compared to the previous study (1.9 kg/d vs. 1.0 kg/d). This difference between studies may be due to a difference in the dietary CP concentration of the basal ration between experiments. In the previous study the average CP content of the basal ration was 161 g/kg DM, while in the current study it was 148 g/kg DM. Higher dietary CP levels will support higher levels of milk production. Despite a significant effect of treatment on energy status, no effect on BCS or live-weight was found.

Effect of Concentrate Build-Up Strategy on Blood Parameters

As build-up strategy had a significant effect on energy balance parameters, the same response may have been expected in plasma NEFA concentrations. An energy deficit initiates an increase in mobilisation of body reserves (lipolysis), where adipose tissue is hydrolysed to non-esterified fatty acids (NEF). Therefore, during periods of body reserve mobilisation, plasma NEFA concentrations would be expected to increase. However, in the current study there was no significant effect of build-up strategy on plasma NEFA concentrations. The same result was found in the previous study.

During the first 28 and 84 days of lactation, animals allocated to the RBU treatment had significantly higher plasma urea concentrations compared to those on SBU treatment, indicating increased levels of ammonia detoxification. Irrespective of dietary CP concentration, the balance between effective rumen degradable protein (eRDP) and fermentable carbohydrates is important in dictating the quantity of ammonia that is utilised for microbial growth (Kenny *et al.*, 2001). Diets with high dietary CP concentrations increase the risk of rumen imbalance between eRDP and fermentable carbohydrate, which will decrease the proportion of ammonia utilised for microbial growth and increase detoxification to urea in the liver.

Effect of Concentrate Build-Up Strategy on Health

In early lactation, 45.5% of animals on a rapid build-up of concentrates, compared to 13.0% and 21.7% on an intermediate and slow build-up of concentrates respectively, were treated for a right dilated abomasum. These results are comparable with those recorded in the previous study where the incidence of a right dilated abomasum in cows on a rapid and delayed build-up of concentrates was 44.8 and 17.9%, respectively. The abomasum is normally positioned at the ventral end, or floor of the abdomen. However, if the abomasum stops contracting (as a result of a drop in pH) an accumulation of gas (abomasal fermentation) can cause the abomasum to move up the abdominal flank towards the dorsal end, eventually causing a displacement. The term "dilated abomasum" was used in this experiment because the animals didn't display other typical symptoms of a displaced abomasum such as dehydration, diarrhoea, ketosis etc. Animals that didn't consume 20 kg (fresh) of the forage component of the diet in the previous 24-hour period were automatically identified and checked for ill health. Frequently, these animals had excess gas in the abomasum and were treated accordingly to improve rumen and abomasal motility. It is possible that had these animals not been treated at this stage, a proportion would have developed a displaced abomasum. Interestingly, the intermediate build-up strategy was just as effective at reducing the occurrence of abomasal dilation as the slow build-up strategy. This suggests that there may be a threshold at which the rumen stabilises and that the rate of concentrate build-up implemented in the slow and intermediate build-up strategies facilitated stable rumen conditions which resulted in a lower incidence of dilated abomasum.

Animals managed on the slow concentrate build-up strategy had a significantly lower incidence of uterine infection at day 21 of lactation compared to those on an intermediate or rapid build-up of concentrates. At calving, the uterus becomes exposed to a wide range of bacteria following the opening of the cervix. It is estimated that 80-100% of animals experience bacterial contamination of the uterus during the first two weeks post-calving. Despite an immune response and subsequent uterine clearance, recontamination is highly likely. Furthermore, even when there is an absence of clinical signs of metritis, subclinical metritis may be present in up to 50% of cows 40-60 days calved (Sheldon *et al.*, 2008), and this will reduce conception rates. Periparturient immunosuppression is associated with poor recovery from uterine bacterial contamination of the uterus. The duration of this immunosuppressive period is highly dependent on metabolic load or negative energy balance. There is evidence to link severe negative energy balance with the incidence of infectious diseases (Ingvarsten *et al.,* 2003). In concurrence, the average DEB in the current study was negatively associated with the incidence of uterine infection.

Effect of Concentrate Build-Up Strategy on Fertility

Concentrate build-up strategy had no significant effect on reproductive outcomes, including conception rate to 1^{st} insemination, conception rate to 1^{st} and 2^{nd} inseminations, in-calf rate at 100 days of the breeding period, which is in agreement with the outcomes of the previous study. Nevertheless, an improvement in fertility might have been expected with cows managed on the slow and delayed build-up strategies in view of their earlier return to positive energy balance compared to cows on the rapid build-up strategy. However, because of the relatively small numbers of animals involved in these two studies, a robust analysis of the effect of treatment on fertility was not possible. Overall, the average conception rate to first insemination in the current experiment (43.5%) is an improvement on values obtained in the previous study (38.6%) and values quoted in the literature (37.1, Mayne *et al.* (2002); 39.7, Royal *et al.* (2000)).

There was also no significant effect of concentrate build-up strategy on the inter-ovulatory interval (IOI). Interestingly, Royal *et al*. (2000) stated that an IOI outside the range 19-23 days was indicative of reduced reproductive function. In the current study the duration of the IOI was 28.1 days. In the previous experiment, the IOI was significantly lower in animals on the delayed, compared to the rapid build-up strategy (22.0 vs. 31.6 days).

The analysis of thrice weekly progesterone concentrations highlighted that the incidence of a delayed ovulation type II (DOV II, 40.1%) was lower than the previous study (82.0%) but still greater than previously published values. For example, Lamming and Darwash (1998) presented a DOV II of 13% and Royal *et al*. (2000) quoted a value of 16%. Delayed ovulation may be caused by a delay to, or failure of, the surge in circulating concentrations of luteinizing hormone (LH) which causes thinning and subsequent rupture of the follicle wall, leading to ovulation. It may also occur if there is incomplete luteolysis of the corpus luteum from the previous cycle (Sartori *et al*., 2004).

CONCLUSIONS

Adopting a slow or intermediate concentrate build-up strategy in early lactation improved forage intake in early lactation and had no detrimental effect on overall production performance. Furthermore, adopting a slow or intermediate build-up strategy also improved rumen health as evidenced by the significantly lower proportion of animals treated for a “dilated abomasum” compared to animals on a rapid build-up of concentrates. However, no effect of concentrate build-up strategy on fertility was identified in the current trial.

Future research incorporating higher animal numbers may allow fertility trends to be identified.

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TECHNOLOGY TRANSFER ASSOCIATED WITH PROJECT

Visitors to Hillsborough

1. Presentations to industry

▪ AgriSearch Dairy Committee	28th March 2011
▪ REDNEX, Slovakia	11th May 2011
▪ AB Vista, Birmingham	25th May 2011
▪ United dairy farmers	21st June 2011
▪ Fane Valley Feeds	4th August 2011
▪ McLarnons Feeds	11th August 2011
▪ Kevin McDonald, Dairy NZ	31st August 2011
▪ Richard Dewhurst and Christine McCartney	1st September 2011
▪ Joe Jacobs and Chris Korte, AU	1st September 2011
▪ Strabane Dairy discussion group (evening meeting)	6th December 2011
▪ AgriSearch Dairy Committee	16th December 2011
▪ Nuffield Scholars	1st May 2012
▪ Pfizer Visit	15th May 2012

2. Presentations to farmer groups at Hillsborough

▪ Cookstown Dairy Farmers	9th March 2011
▪ Narberth Grassland Society	6th June 2011
▪ Student field group, University of Kiel, Germany	13th June 2011
▪ North Wales dairy farmers	20th June 2011
▪ Meath dairy farmers	16th August 2011
▪ Waterford dairy discussion group	13th December 2011
▪ Kildalton Dairy Students	15th February 2012