Animal & Grassland Research and Innovation Centre

Moorepark

Moorepark Research Report 2010

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INTRODUCTION

Despite the economic difficulties, 2010 was a very positive year for the Irish agri-food sector resulting in a large increase in exports now worth close to €8bn per annum. The Food Harvest 2020 report proposes a 50% increase in milk output for the Irish dairy industry using smart green technologies. A 50% increase in milk production will require milk deliveries to increase from an average of 5.1 billion litres over the 2007 to 2009 period to 7.66 billion litres by 2020. The expansion in Irish milk production will increase the profitability of Irish dairy farms, create valuable new jobs within the national dairy industry and combined with value add at processing level; will be worth in excess of €1 billion to the Irish agri-economy in the next decade. There is general agreement within the industry that these targets can be achieved. This is made possible with the abolition of EU milk quotas in 2015. The abolition of quotas opens up both an exciting and challenging prospect for the Irish dairy industry. Exciting, because for the first time in 30-years allows us to plan to exploit Ireland competitive advantage in milk production. Challenging, in that we do so in a situation where there is little supply management, resulting in greater price volatility- albeit around a higher average price.

The challenges are in production, processing and marketing. At farm level Irish dairy farmers planning to take advantage of quota removal must act now to develop and plan their farm systems for increased milk production efficiency. In this environment, only those dairy farmers who fully capitalize on the inherent competitive advantages associated with low cost grass-based seasonal milk production system will be successful based on key technologies such as compact calving, higher stocking rates, and increased numbers of high EBI replacements, high quality pasture management and low cost labour efficient farm infrastructures.

Based on the 2010 Teagasc profit monitors completed the top 10% of dairy farmers obtained a net margin of approximately 18 c/l compared to 12.2 c/l for the average. After a deduction of 6 c/l for own labour this is equates to a profit of €30,000 for the top 10% of dairy farmers compared to €15,500 for the average based on a milk quota of 250,000 liters. The top 10% of dairy farmers operated at a higher stocking rate yet produced higher milk yield and milk composition per cow. Similarly the top 10% of dairy farmers achieved the higher profit at lower concentrate, fertilizer and machinery cost per liter. These results indicate that technologies in relation to grassland management in association with high EBI genetics were key into achieving high dairy farm profitability and will be even more important in the future.

This report contains a brief account of all work carried out at the Centre during 2010. A more detailed account is contained in the 140 publications, which were issued during the year, including 26 peer-reviewed papers in international scientific journals. A full list is given in the Publication Section of this report.

The following are the main highlights from the 2010 programme:

Genomic selection within the farm gate
Genomic selection was launched for Irish dairy cattle in spring 2009. The reliability of genomic proofs at that time was 48%. The cost to genomically test an animal was approximately €150 making it prohibitively expensive to exploit routinely at farm level. In 2010 two research targets were set: 1) to increase the reliability of genomic proofs and 2) to reduce the cost of genomic selection. Average reliability of genomically selected young bulls was increased from, on average, 48% to 54%; this was due primarily to the procurement of additional genotype data on bulls. The ability to predict all 54,000 pieces of DNA (i.e., SNP markers) from a selected subsample of 3,000 with 98% accuracy was also proven. This is important because it facilitated a reduction in cost of genomic selection to approximately €50. This makes genomic selection more appealing and feasible to individual farmers. If exploited genomic selection will result in increased genetic gain at farm level through more accurate selection of genetically elite replacement females (and males). On farm genotyping of females also has implications for the long-term accuracy of genomic selection since the genotyped females will contribute to the genomic selection reference population once they have data when lactating; this will result in increase reliability of genomic proofs.

The Effect of Genetic Merit for Fertility on Reproductive Efficiency
Reproductive efficiency has been declining in high yielding dairy cows for the past 50 years. Despite intensive research, the precise mechanisms contributing to this decline in dairy cow fertility remains poorly understood. To elucidate the underlying physiological basis of declining reproductive performance, the phenotypic performance of Holstein cows with divergent genetic merit for fertility traits, but with similar genetic merit for milk production traits was evaluated. The two groups of cows were maintained as one herd throughout the study, thus standardising factors that are known to impact fertility performance (herd management, plane of nutrition, proportion of Holstein genes and genetic merit for milk production traits). Results showed cows with good genetic merit for fertility traits (Fert+) had improved reproductive performance during a 20 week breeding season, maintained a greater body condition score and had greater circulating concentration of insulin-like growth factor and insulin during lactation compared to cows with poor genetic merit for fertility traits (Fert-). During the first 13 d of the oestrous cycle, Fert+ cows developed a corpus luteum that was 16% larger and had 25% greater circulating progesterone concentrations than Fert- cows. Maximum preovulatory follicle diameter was larger in Fert+ compared with Fert- cows, and a greater proportion of Fert- cows ovulated following a silent heat compared with Fert+ cows. The differences in follicular dynamics and steroid concentrations may partially explain the superior fertility performance of the Fert+ cows. Fert+ cows exhibited greater hepatic

expression of insulin-like growth factor-I and reduced hepatic expression of lower molecular mass binding proteins, explaining the elevated circulating concentration of insulin-like growth factor-I. Hence, this study highlighted the large effects that genetic merit for fertility traits has on the physiological controls regulating reproductive performance, which may not necessarily be to the detriment of milk production.

Effect of post-grazing residual on animal performance

Anticipated increases in stocking rate over the coming years will result in an increased demand for grazed grass in early spring. Currently, recommendations are to graze to 4cm during the first two grazing rotations in spring. However, if pastures can be grazed to lower post-grazing heights, without deleterious consequences on animal production performance, it would increase the availability of grazed grass within the system. Throughout the spring of 2010 severe (2.7cm; S) and moderate (3.5cm; M) post-grazing heights were imposed from February 10 to April 18 (Period 1; P1). Following P1, animals were re-randomised on P1 treatment across two post-grazing heights to monitor the carry-over effects. Similar to P1, animals grazed to either severe (3.5cm) or lax (4.5cm) post-grazing heights from 19 April to 30 October (Period 2, P2). The difference in post-grazing height was achieved by ensuring a 3 kg DM/cow/day difference in daily herbage allowance. Mean daily herbage allowances (DHA) during P1 were 6.2 and 9.3 kg DM/cow/day, respectively for the S and M treatments. Decreasing post-grazing sward height in P1 depressed milk yield (- 2.3 kg/day), milk solids yield (- 240 g/day) and protein content (- 1.16 g/kg). The decrease in production reflected a high level of restriction placed upon the S treatment animals indicating they were physically restricted from grazing further into the sward. There was no effect on BW or BCS at the end of P1. P1 treatment had no carry-over effect on milk and milk solids yields throughout P2. However, animals assigned to the M treatment during P1 had a greater fat content (+2.3 g/kg)) than their counterparts on the S treatment during P2. Severe grazing in P1 subsequently increased ($P<0.01$) lactose content (+0.50 g/kg) and yield (+31.8 g/day) in P2. Animals from the S treatment in P1 had a greater BCS at the end of P2 (+0.07). Severe grazing in early spring improved pasture utilisation (+29 %). The results of this study demonstrated that cows grazed to a low post-grazing residual in early lactation (i.e. early spring) will achieve reduced milk production; however there was no carry over .effect to in subsequent lactation if grazed to a higher post-grazing height.

Technologies to reduce greenhouse gas (GHG) emissions

Ireland's agricultural sector emitted 28% of the nation's total greenhouse gas (GHG) emissions in 2009. Approximately 33% of agricultural emissions arise from milk production. As an EU member state Ireland is committed to reduce national GHG emissions to a level 20% below those of 2005 by the year 2020. However, milk production in Ireland is forecast to increase with the abolition of EU milk quotas in 2015. Thus, the dairy industry is currently faced with the challenge of meeting an obligation to reduce GHG emissions, while increasing milk production to satisfy growing demand. Methane is the predominant GHG emission from Irish dairy production. It is produced by cattle when digesting feed and to a lesser extent during slurry storage. The accepted approach to evaluate GHG emissions from the entire dairy production system is life cycle assessment. The approach considers emissions generated both on and off-farm (GHG emissions associated with the production of purchased inputs e.g. concentrate feed) to fully evaluate mitigation strategies. Research has demonstrated that emissions per kg of product can be reduced through full adoption of research technologies in relation to grassland management and genetic merit. Key technologies for improving GHG efficiency in milk production include earlier calving, reduced replacement rate, increased milk solids concentration, increased grazing season length, higher stocking rate, inclusion of white clover cultivars to fix freely available atmospheric nitrogen. These changes will result in increased milk solids per hectare, thus having a positive effect on the financial performance of the sector, and hold the potential to reduce current GHG emissions from 16.06 kg to 13.53 kg CO_2 equivalents per kg MS produced. In the long term, emissions per kg MS could be reduced as much as 40% from the current national average performance based on current research herds.

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ANIMAL RESEARCH PROGRAMME

A comparison of methane emissions by Holstein-Friesian, Jersey and Jersey×Holstein-Friesian dairy cows under varying stocking rates

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Introduction
Ireland has committed to reducing its agricultural greenhouse gas (GHG) emissions by 20% relative to 2005 levels by 2020 (EPA, 2010). Ireland's largest contributor of GHG emissions is the agricultural sector, accounting for 29.1% of total emissions in 2009. Methane (CH_4) from enteric fermentation is the largest single source of GHG arising from Irish milk production systems. The objective to this study was to compare enteric methane emissions of Holstein-Friesian (HF), Jersey (J) and Jersey×Holstein-Friesian (F_1) cows under varying stocking rates.

Materials and Methods
Forty-five cows of each breed were randomly assigned to one of three stocking rate (SR) treatments in spring 2010. The HF and F_1 animals were stocked at 2.5 (LS), 2.75 (MS) and 3.0 (HS) cows/ha while the J animals were stocked 0.25 cows/ha higher in each SR treatment. Each group was balanced for parity. Each treatment group was allocated a fixed farmlet comprising 20 randomly allocated paddocks at the trial site. Paddock sizes varied for each stocking rate (0.3, 0.27 and 0.25 ha for the HF and F_1 low, medium and high SR, respectively and 0.27, 0.25 and 0.23 ha for the J low, medium and high SR, respectively). Paddocks were grazed in a rotational system, groups were moved when a target (HS 3.00-3.50; MS 3.75-4.25; LS 4.75-5.25 cm) post-grazing sward height was measured (Rising Plate Meter, Jenquip, Feilding, New Zealand). Milk yield was recorded daily; milk composition and bodyweight (BW) were determined weekly. Daily enteric CH_4 emissions were measured during mid-late lactation. CH_4 measurement periods 1 and 2 corresponded to 187 and 244 days in milk, respectively. In measurement period 1 cows grazed grass only, while in period 2 grass was supplemented with 1.75 kg grain concentrate DM/d. Each CH_4 measurement using the sulphur hexafluoride (SF_6) tracer gas technique took place for five consecutive days allowing measurement of all 135 cows within a three week period. Mean SF_6 permeation rate was 6.60 mg/d (SD 1.10). Individual CH_4 emissions were calculated using a minimum of three observations. Outliers within each group were defined as daily values more than one interquartile range above or below the 75% and 25% percentile, respectively. On this basis data for three cows during period 2 were excluded from analysis. Overall data analysed comprised four or more observations from 91% of cows. The milk production, BW and CH_4 data were analysed using PROC MIXED (SAS, 2006) and the model: $Y = \mu +$ breed group + stocking rate + measurement period + calving date + e. Cow was included as a random repeated effect. The interaction between breed and stocking rate was not significant and was removed from the model.

Results and Discussion
The mean (SD) pre-grazing sward height for the CH_4 measurement periods were 10.2 (1.52), 10.5 (1.58) and 10.4 (1.25) cm for the HS, MS and LS, respectively (Table 1). The corresponding mean (SD) post-grazing sward heights were 3.3 (0.32), 4.2 (0.26) and 5.0 (0.71) cm. Jersey cows had the lowest milk solids yield ($P<0.01$) and lower CH_4 emissions ($P<0.001$) on a g/day basis compared to the HF and F_1 cows. Methane emissions on a g/kg milk solids basis were not significantly different between breed groups. Stocking rate had a significant effect on milk solids yield and CH_4 emissions (g/day) ($P<0.001$) with cows on the higher SR having lower milk solids yield and CH_4 emissions (g/day). Methane emissions on a g/kg milk solids basis were not significant between stocking rates.

Conclusions
Evidence from the current study indicates that J cows emit less CH_4 compared to HF and F_1 cows. However CH_4 per unit milk solids output was not dissimilar between these breeds. Similarly there was no evidence from the current study that cows managed at different SR differ in CH_4 per unit milk solids output, although cows at high stocking rates grazing to lower post-grazing heights did have lower total CH_4 emissions (g/day) compared to cows at lower stocking rates.

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Environmental protection Agency (2010).
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Acknowledgements
The authors would like to acknowledge the technical assistance of Billy Curtin and the staff at 'Ballydague' farm. Financial support from the Research Stimulus Fund (RSF-07-517) is gratefully acknowledged.

Table 1: Effect of breed of dairy cow on milk production, bodyweight and methane emissions.

	Breed					Stocking rate				
	HF	J	F_1	SEM	Sign.	High	Medium	Low	SEM	Sign.
Milk yield (kg/day)	18.1[a]	13.5[b]	16.3[c]	0.53	***	14.3[a]	16.5[b]	17.1[b]	0.52	***
Fat (g/kg)	44.9[a]	59.3[b]	54.5[c]	0.13	***	53.4	51.9	53.4	0.12	NS
Protein (g/kg)	36.7[a]	42.9[b]	41.0[c]	0.05	***	40.2	40.0	40.4	0.05	NS
Milk solids (kg/day)	1.46[a]	1.36[b]	1.54[a]	0.051	**	1.30[a]	1.50[b]	1.57[b]	0.050	***
BW (kg)	552[a]	406[b]	489[c]	11.8	***	468	490	488	11.7	NS
CH_4 emissions (g/day)	403[a]	356[b]	415[a]	9.8	***	358[a]	399[b]	417[b]	9.6	***
CH_4 emissions (g/kg MS)	282	274	274	9.3	NS	284	271	275	9.3	NS

BW = Bodyweight, MS = Milk solids. * = P<0.05, ** = P<0.01, *** = P<0.001, NS = P>0.05
[a-c]Means with a different superscript within a row are significantly different (P<0.05)

RMIS 5502

A comparison of Holstein-Friesian, Jersey and Jersey×Holstein-Friesian dairy cows under varying stocking rates

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Introduction

With the impending abolition of milk quota there will be a change in emphasis from maximising production per cow to per ha. Milk quota will no longer be the limiting production factor. Ireland is ideally placed to take advantage of these policy reforms with its low cost, grass-based production system. Research from New Zealand demonstrates that profit per ha is optimised at stocking rates higher than those recommended here to fore in Ireland. Previous research has shown that Jersey×Holstein-Friesian genotypes are well suited to Irish production systems and coupled with higher stocking rates may be a very efficient milk production system. The objective of this study is to evaluate the performance of Holstein-Friesian, Jersey and Jersey×Holstein-Friesian dairy cows under varying stocking rates.

Materials and Methods

Forty-five Holstein-Fresian (HF), 45 Jersey (J) and 45 Jersey×Holstein-Friesian (F_1) animals were randomly assigned, within each genetic group, to 1 of 3 stocking rates in a completely randomised design in Spring of 2010. The HF and F_1 animals were stocked at 2.5, 2.75 and 3.0 cows/ha while the J animals were stocked 0.25 cows/ha higher at 2.75, 3.0 and 3.25 cows/ha. Each group was balanced for parity. Nine farmlets were set out for the nine groups of cows with paddock sizes varying for each stocking rate (SR) (0.3, 0.27 and 0.25-ha for the HF and F_1 low, medium and high stocking rates, respectively, and 0.27, 0.25 and 0.23-ha for the J low, medium and high stocking rate, respectively). Each group had 20 paddocks and were grazed in a rotational system. Stocking rates were set to account for total farm production, including conservation of winter forage. Groups were moved to a fresh paddock when the required post grazing sward height was reached 3.00-3.75, 3.75-4.5 and 4.5-5.5cm for the high, medium and low stocking rates, respectively as measured using the Rising Plate Meter (Jenquip, Feilding, New Zealand). Concentrate supplementation averaged 627, 614 and 643 kg per cow for the High, Medium and Low stocking rate groups, respectively. Milk yield was recorded daily; milk composition and bodyweight (BW) was determined weekly and body condition score (BCS) was measured once a month on a scale of 1-5. The mean milk production, BW and BCS data were analysed using PROC GLM of SAS (SAS, 2006). The model in all analysis was similar: $Y = \mu$ + breed group + stocking rate + parity + calving date + e

Results and Discussion

There was no interaction (P>0.05) between breed group and stocking rate for any of the variables measured (Table1). With the exception of lactose percentage and milk solids produced per ha, which were not significant between breed group, breed group had a significant effect on all variables measured (P<0.001). Yield of milk solids per cow was highest for the Medium and Low SR groups. HF and F_1 cows had similar milk solids yields. Milk solids per ha were highest for the medium SR group. BW was highest and BCS was lowest for the HF group. BW and BCS were lowest for the High SR group with the Medium and Low SR groups being similar.

Conclusions

The results suggest that on a per ha basis HF, J and F_1 cows can produce similar yields of milk solids. The results also suggest that optimum performance per ha under Irish grazing conditions is achieved when grazing to approximately 4cm, as measured using the rising plate meter.

Reference

SAS® User's Guide. (2006) Version 9.1: Statistics. SAS Inst., Cary NC, USA

Table 1. Effect of breed of dairy cow and stocking rate on cow and/or per ha performance through lactation.

	Breed					Stocking Rate				
	HF	J	F_1	SEM	Sign.	High	Medium	Low	SEM	Sign.
Milk yield (kg/cow)	5872[a]	4567[b]	5373[c]	107.5	***	4837[a]	5448[b]	5527[b]	107.0	***
Fat (g/kg)	41.0[a]	53.6[b]	48.1[c]	0.09	***	48.0	46.8	47.8	0.09	NS
Protein (g/kg)	34.8[a]	40.1[b]	37.9[c]	0.04	***	37.3	37.8	37.7	0.04	NS
Lactose (g/kg)	46.2	46.5	46.6	0.03	NS	46.3	46.6	46.4	0.03	NS
SCM (kg/cow)	5666[a]	5216[b]	5730[a]	109.7	***	5088[a]	5689[b]	5836[b]	109.2	***
Milk solids (kg/cow)	447[a]	424[b]	460[a]	8.8	***	407[a]	456[b]	468[b]	8.8	***
Milk solids (kg/ha)	1222	1255	1254	24.6	NS	1243[a]	1282[b]	1207[a]	24.5	**
BW (kg)	549[a]	407[b]	482[c]	7.5	***	465[a]	486[b]	487[b]	7.5	**
BCS	2.76[a]	2.92[b]	2.91[b]	0.05	***	2.79[a]	2.88[b]	2.92[b]	0.045	**

BCS range: 1 = extremely thin, 5 extremely fat; SCM = Solids Corrected Milk yield. ** = P<0.01, *** = P<0.001

RMIS 5502

Energy efficiencies of Holstein-Friesian, Jersey and Jersey × Holstein-Friesian cows through lactation

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Introduction

Previously Prendiville *et al.* (2009) reported differences in production efficiencies between Holstein-Friesian (HF), Jersey (J) and Jersey × Holstein-Friesian (F_1) dairy cows at pasture. The aim of this study was to examine differences in energetic efficiencies between these breed groups over the course of lactation.

Materials and Methods

Data were available for 110 cows: 37 HF, 36 J and 37 F_1. Sixteen HF, 10 J and 9 F_1 were first parity animals with the remainder in parity two. Cows were managed as a single herd under a rotational grazing management system. Milk yield was recorded daily and milk composition weekly. Total dry matter intake was determined five times on each cow throughout lactation using the n-alkane technique. Energy related variables were calculated for each cow using the French Net Energy system of Jarrige (1989), where the values were expressed in UFL (Unité Fourragère du Lait). Lactation was subsequently divided into 6 stages; less than 60 days in milk (DIM), 61 to 120 DIM, 121 to 160 DIM, 161 to 190 DIM, 191 to 230 DIM and greater than 230 DIM. Energetic efficiencies examined included the proportion of energy used for milk production having accounted for maintenance (NEL/(NEI-NEM)) and net energy intake per unit milk solids (NEI/MS), indicating the energy required to produce 1 kg MS. Data were analyzed using the MIXED procedure of SAS, (2003). The linear model included the fixed effects of breed group, parity, stage of lactation and the interaction of breed group and stage of lactation. Calving day of year was fitted as a continuous covariate. Cow was included as a random repeated effect.

Results and Discussion

Milk solids production was similar for the HF and F_1 (Figure 1a). The J had comparable yields of MS to the HF with the exception of mid-lactation but lower than the F_1 (P<0.01). The estimated proportion of available energy used for milk production, NEL/(NEI-NEM), was highest (P<0.001) in early lactation and declined steadily until the end of lactation (Figure 1b). In early lactation, J cows had a greater NEL/(NEI-NEM) compared with the HF cows (P<0.01), but similar to the F_1 throughout lactation. The NEL/(NEI-NEM) was similar for the HF and F_1 across all stages of lactation with the exception of stage 5 which was greater for the F_1. The profile for NEI/MS was lowest in early lactation but increased thereafter (Figure 1c; P<0.001). The J had a lower (P<0.01) NEI/MS in early lactation (stages 1 and 2) compared with the HF but similar to the F_1. Net energy intake/MS was similar for the HF and F_1 throughout lactation, with the exception of stage 5 which was lower for the F_1.

(a)

(b)

(c)

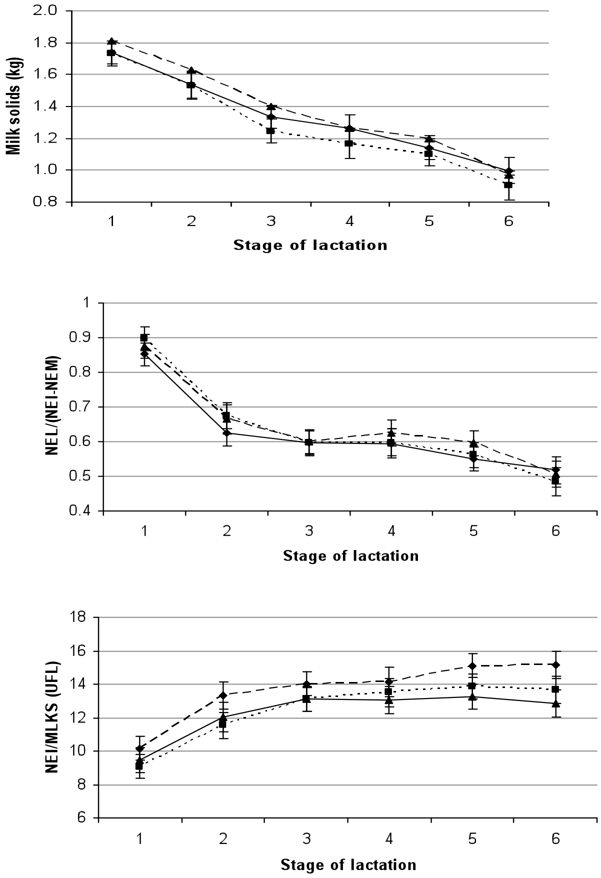

Figure 1: Milk solids production and energetic efficiency measures of Holstein-Friesian (—♦—), Jersey (---■---) and Jersey × Holstein-Friesian (--▲--) cows through lactation.

Conclusions

Efficiency measures follow a similar trend to MS yield, most favourable in early lactation and decline as lactation progresses. Results also show the J is a more efficient converter of feed to MS compared with the HF. This can be attributed to the higher intake capacity and lower maintenance requirement of the J.

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RMIS 5502

Comparative grazing behaviour of Holstein-Friesian, Jersey, Montbeliarde and Norwegian Red cows in grass based production systems

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Introduction

Profitable grazing systems are dependent on dairy cows that can achieve sufficient quantities of herbage and efficiently convert feed to milk solids. Since daily feed intake at pasture is limited compared to levels achievable on total mixed ration diets (Buckley *et al.*, 2005), understanding the interaction between the sward and foraging behaviour of the animal is a significant element to grassland research. The aim of this study, carried out at Ballydague research farm, Teagasc Moorepark in 2007, was to consider differences in grazing behaviour between Holstein-Friesian (HF), Jersey (J), Montbeliarde (MB) and Norwegian Red (NR) cows.

Materials and Methods

Data from 105 animals were available: 37 HF, 34 J, 18 MB and 16 NR cows. Sixteen HF, 10 J, 9 MB and 9 NR were primiparous animals while the remainder were in parity two. Milk yield was recorded daily with milk composition and body weight (BW) determined weekly. Cows were managed as a single herd under a rotational grazing system and received no concentrate supplementation. Average sward height was 106 (s.d. 19.7) mm pre-grazing and 46 (s.d. 6.9) mm post-grazing. Individual grass dry matter intake (GDMI) was estimated four times using the n-alkane technique. Grazing behaviour measurements were determined over a 24 h period on two occasions for each cow during lactation. Data were analysed using PROC MIXED procedure of SAS. The model used was:

$Y = \mu$ + breed group + parity + calving date + stage of lactation + e

Cow was included as a random repeated effect while parity, breed group and stage of lactation were included as fixed effects.

Results and Discussion

Milk solids yield of the J was similar to HF and NR but greater than MB ($P<0.05$). Body weight was greatest with MB, intermediate for the HF and NR and lowest with J ($P<0.01$). Grass DMI was similar for HF and MB but greater than the J and NR ($P<0.01$). Grazing time and number of grazing and ruminating bouts were similar across all breed groups. Grazing mastications were greatest for NR ($P<0.05$). Bite rate and total bites/ day of the NR were similar to the MB but greater than HF and J. Ruminating time of the HF was greater than the J with the MB and NR similar to both ($P<0.05$). Expressed per unit BW and GDMI, grazing time was greater with J compared to the other breed groups. Ruminating time/100 kg BW was greatest ($P<0.05$) with J, lowest with MB and NR, and HF intermediate. Ruminating time/ GDMI was greatest with the NR, lowest with MB with HF and J similar to both.

Table 1: Effect of breed group on grazing behaviour parameters.

	Breed group					
Measurement	HF	J	MB	NR	s.e.	P-value
Milk solids (kg)	1.27^{a}	1.21^{ad}	1.08^{b}	1.16^{cd}	0.35	<0.05
Body weight (kg)	500^{a}	376^{b}	528^{c}	482^{a}	7.1	<0.01
GDMI (kg)	16.6^{a}	14.5^{b}	16.5^{a}	15.3^{b}	0.32	<0.01
Grazing time (min)	648	641	665	613	17.6	NS
Grazing bouts (number)	10.1	9.0	8.5	9.3	1.06	NS
Grazing time/100 kg BW (kg)	130^{a}	170^{b}	128^{a}	130^{a}	4.5	<0.001
Grazing time/ GDMI (kg)	39.8^{a}	44.5^{b}	40.1^{a}	41.4^{a}	1.37	<0.01
Grazing mastications (number/d)	4061^{a}	4720^{a}	4773^{a}	5791^{b}	349.2	<0.05
Total bites (bites/day)	40761^{a}	39322^{a}	38786^{ab}	35528^{b}	1280.0	<0.05
Bite rate (bites/min)	58^{a}	59^{a}	61^{ab}	63^{b}	1.4	<0.05
Ruminating time (min)	422^{a}	369^{b}	381^{ab}	401^{ab}	19.4	<0.05
Ruminating bouts (no)	17.8	14.6	11.2	13.1	4.58	NS
Ruminating time/ 100 kg BW (kg)	86^{a}	99^{b}	69^{c}	82^{ac}	4.5	<0.05
Ruminating time/ grass DMI (kg)	26.0^{ab}	25.5^{ab}	22.2^{a}	27.0^{b}	1.32	<0.05

Conclusions

The results from this study suggest that in grazing environments, significant differences exist between the breed groups for milk solids yield, BW and GDMI. Results also show subtle differences in the grazing behaviour between the breeds.

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Acknowledgements

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RMIS 5502

Effect of cow genotype on the duodenal expression of nutrient transporter genes

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Introduction

Recent studies from our group (Prendiville *et al.*, 2009) and others (Olson *et al.*, 2010) have shown clear differences in feed efficiency between Holstein Friesian, Jersey and their F_1 hybrid. Given its central role in dietary nutrient assimilation, it has been suggested that the activity of intestinal nutrient transporters may influence feed efficiency in mammals. However, there is a dearth of published information on this subject for cattle. The objective of this study was to examine gene transcript abundance for three important classes of nutrient transporters *viz.* nucleoside, sugar and amino acid transporters lipid transporters (Liao *et al.*, 2009) in duodenal tissue of Holstein Friesian and Jersey dairy cows and their F_1 hybrid.

Materials and Methods

From an initial population of 110 animals, consisting of 37 Holstein-Friesian, 36 Jersey and 37 F_1 cows, 10 animals from each genotype were selected randomly for the current study. Following drying off, all animals were offered a grass-silage based diet *ad libitum* for two months and subsequently slaughtered with duodenal epithelial tissue collected and stored at -80°C. Total RNA was extracted using TRIzol reagent, from fragmented frozen duodenal tissue, its quantity determined spectrophotometrically and was reverse transcribed to generate cDNA. Primers were designed to amplify specific fragments of the following 15 genes involved in the absorption of nutrients in the duodenum, namely nucleoside transporters: solute carrier 28 member 1, SLC28A1; SLC28A2; SLC28A3; SLC29A1; amino acid transporters: SLC3A1; SLC3A2; SLC7A1; SLC7A6; SLC7A7; SLC6A14; SLC15A1; sugar transporters: SLC2A2; SLC2A5; SLC5A1; and the lipid transporter ATP-binding cassette, subfamily G (ABCG8). Quantitative real-time RT-PCR reactions were performed to measure the relative expression of these genes. β-actin, Rps9 (40S ribosomal protein S9) and GAPDH (glyceraldehyde 3-phosphate dehydrogenase) were employed as housekeeping genes. GenEx 4.3.5 software was used for efficiency correction of the Ct values for all genes, normalisation to reference genes, calculation of quantities relative to the average and natural log transformation of the expression values. Data were statistically analysed using mixed models ANOVA in SAS with breed included as a fixed effect and parity as a covariate. Orthogonal contrasts were used to test potential heterotic effects. Spearman correlation coefficients were calculated to determine associations amongst gene expression values and production efficiency variables measured during the previous 305 d lactation. Production variables included residual feed intake, total milk solids (kg) and milk solids produced per kg of total dry matter intake.

Results and Discussion

Expression of the following genes could not be detected in any duodenal sample: SLC29A3; SLC29A4; SLC7A9; Glut 4; SLC5A10; SLC29A2; CD36; and ABCG5. In addition, there was no effect of cow genotype or indeed evidence of heterotic effects on the expression of any of the nutrient transport genes measured (P>0.05). Furthermore there was no association between the expression of any gene and the production efficiency variables measured. Interestingly, significant positive correlations were observed between the expression values of some genes involved in common nutrient transporter roles (Table 1).

Table 1. Correlation coefficients between the expression of duodenal genes with common nutrient transport function

	Nucleoside transporters			Amino acid transporters							Sugar transporters		
SLC[1]	28A2	28A3	29A1	3A1	3A2	7A1	7A6	7A7	6A14	15A1	2A2	2A5	5A1
28A1	0.67***	0.22	0.32	0.45	0.64	-0.08	0.67	0.11	0.56	0.78	0.68	0.76	0.32
28A2		0.32	0.48**	0.60	0.56	0.06	0.46	0.20	0.50	0.61	0.76	0.73	0.42
28A3			0.40***	0.70	0.79	-0.32	0.41	0.65	0.56	0.70	0.21	0.14	-0.03
29A1				0.34	0.52	0.24	0.42	0.35	0.33	0.37	0.24	0.39	0.10
3A1					0.75**	-0.14	0.37*	0.62***	0.60***	0.36	0.58	0.49	-0.03
3A2						0.52	0.69***	0.52**	0.69***	0.58	0.44	-0.14	0.15
7A1							-0.10	-0.12	0.03	0.04	-0.06	0.13	-0.02
7A6								0.34	0.65***	0.79***	0.27	0.57	0.35
7A7									0.35	0.18	0.15	0.14	-0.14
6A14										0.72***	0.51	0.58	0.33
15A1											0.53	0.80	0.50
2A2												0.68***	0.46*
2A5													0.49**

*P<0.05; **P<0.01; ***P<0.001. SLC[1]: Solute carrier.

Conclusions

The results of this study suggest that it is unlikely that the documented differences in feed efficiency between the Holstein-Friesian, Jersey and their F_1 hybrid are mediated through differences in the expression of duodenal nutrient transporters. Expression of some genes involved in common nutrient transport roles were positively correlated, suggesting that these may be co-regulated.

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RMIS 5502

Population stratification between eight breeds of cattle commonly used in Ireland

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Introduction

The probability of Type I statistical errors in genome wide associations in cattle populations are greater if population sub-structure has not been properly accounted for in the statistical analyses (Pearson *et al.,* 2008). Similarly, knowledge of the degree of genomic association among breeds is useful in quantifying the potential benefit of across-breed genomic selection. The objective of this study was to assess population stratification across eight purebred cattle breeds (Holstein, Friesian, Hereford, Simmental, Limousin, Angus, Belgian Blue and Charolais) and one crossbreed of Holstein-Friesian.

Materials and Methods

Genotypes on 766 animals (219 Holstein [HO], 53 Friesian [FR], 74 Holstein-Friesian crossbreds [HO-FR], 58 Simmental [SI], 128 Limousin [LM], 39 Angus [AA], 38 Belgian Blue [BB], 117 Charolais [CH] and 40 Hereford [HE]) using the Bovine high-density panel (Illumina, San Diego, CA) were available. A random sample of 7,354 SNPs relatively equally spaced across chromosome 29 were chosen for inclusion in the analysis. Population structure analysis of the animals was carried out using STRUCTURE (Prichard *et al.,* 2000). This programme uses a Bayesian approach by implementing a Markov Chain Monte Carlo (MCMC) which is capable of estimating population structure using multilocus genotypes and a clustering method. Exploratory MCMC runs revealed that a burn-in length of 10,000 chains to minimise the effect of the starting configuration and 10,000 chains for parameter estimates was sufficient. The model assumed correlated allele frequencies and admixture (i.e., that individuals may have mixed ancestry). The average estimated probability membership (q) to each cluster was calculated for each breed with a threshold value of $q \geq 0.8$ being chosen and any value below this was considered admixed. Also the extent of genetic differentiation among subpopulations was also calculated through Fst values produced by STRUCTURE.

Results and Discussion

A model assuming three clusters was optimal. A clear segregation among dairy and beef breeds was evident, with Holstein-Friesian cattle primarily belonging to one cluster, Hereford cattle to another cluster and the remaining beef breeds to the final cluster (Figure 1). Holsteins had little admixture with an estimated membership value to the cluster of 0.830. The Friesians were most related to the Holsteins, which is to be expected as they are both dairy breeds and the Holsteins originated from a cross of the white animals from within the Friesian herd. In comparison, the Limousin, Charolais and the Simmentals had membership values of 0.937, 0.833 and 0.805, respectively to a separate cluster. Both the Limousin and the Charolais originate in central France and the Simmental breed originate in Switzerland suggesting that location of origin is pivotal in determining ancestry. A similar result was reported by Blott *et al.* (1998), upon the construction of a neighbour joining tree, in which the French breeds of Charolais and the Limousin were grouped together with the Simmental being on the periphery of this group. The Belgian Blue breed which originated from crosses between the Shorthorn and the Dutch Black Pied, (similar to the Friesian) was an almost equal admixture of all three clusters. The Friesian was similarly admixed indicating that the Belgian Blue is genetically similar to the Friesian breed. Hereford cattle were assigned to a distinct cluster, with an estimated membership probability value of 0.844. The low level of admixture in the Hereford breed is consistent with the findings of Blott *et al.* (1998), who also reported this breed to be significantly different from six other European breeds. The Fst values for the Hereford, Holstein-Friesian and remaining beef breeds were 0.1989, 0.1935 and 0.1163, respectively. Therefore a high level of genetic differentiation is present among individuals in the Hereford and Holstein-Friesian clusters and only moderate levels in the remaining beef breeds. This is indicative of a greater influence of genetic drift in the Hereford and Holstein-Friesian populations.

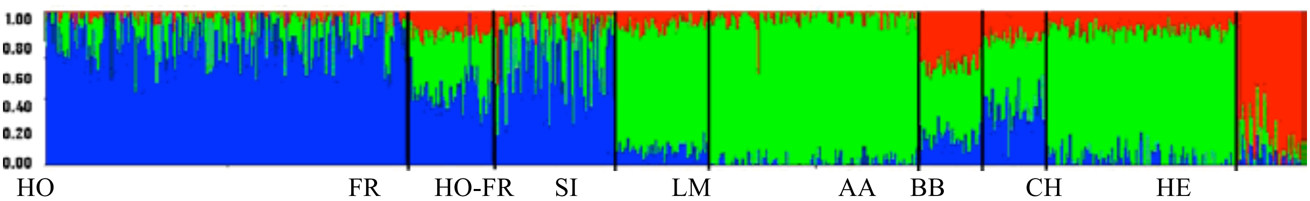

Figure 1. Clustering assignment of each breed. Each animal is represented by a thin line that is divided into segments whose colour and size represents its proportion to each cluster. A thin black line separates each breed.

Conclusions

Across the predominant breeds in Ireland, significant population stratification exists which must be accounted for in genome wide association analyses in order to minimize type I statistical errors.

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RMIS 5665

Imputation of genotypes from low- to high-density genotyping platforms

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Introduction
Genomic selection is increasing in popularity as a method of evaluating the genetic merit of animals. However, the acquisition of high density genotypes on individual females, necessary to obtain direct genomic values (DGVs), is currently prohibitively expensive for most individual farmers. The objective therefore, of this study was to quantify the accuracy of predicting or imputing genotypes from lower density, lower cost marker panels to higher density marker panels.

Materials and Methods
Genotypes on 5,489 Holstein-Friesian AI bulls (n=4,318) and cows (n=1,171) using the Bovine50K marker panel (Illumina, San Diego, CA) were available. Following the removal of single nucleotide polymorphisms (SNPs) on the sex chromosome, of unknown position, and SNPs with >0.5% mendelian inconsistencies between parents-offspring, 51,602 SNPs remained. The commercially available lower density Bovine3K marker panel (Illumina, San Diego, CA) contains 2,900 SNPs. Only SNPs on the autosomes were retained and one SNP, of unknown position was also discarded leaving 2,730 SNPs.

Animals were separated into two groups: 1) reference group of animals born prior to 2006 (n=4,725), and 2) a test group of animals, >50% Holstein, born from 2006 onwards (n=764). Only the 2,730 SNPs from the Bovine3K (after editing) were retained in the test group of animals with the remaining SNPs on the Bovine50K in these animals to be imputed. Imputation was undertaken for each chromosome separately using the freely available software Beagle Version 3.1.0 (Browning and Browning, 2007). Genotype and allele concordance rate, defined as the average proportion of correctly imputed genotypes and alleles, respectively was used as a measure of accuracy of imputation.

To quantify the impact of imputation on the estimation of DGVs in the imputed animals, genomic prediction was undertaken for all traits in the Economic Breeding Index using the procedures outlined by Berry *et al.* (2009); the posterior probabilities of each imputed allele was used for the imputed animals. Animals included in the estimation of SNP effects were born prior to 2006 and had to have a reliability, less parental contribution, for the respective trait under investigation of ≥60%. A total of 41,609 SNPs with a minor allele frequency >0.02 and in Hardy-Weinberg equilibrium were included in the genomic prediction.

Results and Discussion
Across all chromosomes and animals, the mean (standard deviation in parenthesis) genotype and allele concordance rate was 0.950 (0.044) and 0.974 (0.023), respectively. However, across chromosomes the mean genotype concordance rate varied from 0.930 to 0.959, while the mean allele concordance rate varied from 0.964 to 0.979.

Mean genotype concordance rate per animal varied from 0.843 to 0.994 but was negatively skewed; 98% of animals had a genotype concordance rate of ≥0.90, 57% had a genotype concordance rate of ≥0.95, and 3% had a genotype concordance rate of ≥0.99. Mean allele concordance rate per animal varied from 0.917 to 0.996 and was also negatively skewed; 97.6% had a genotype concordance rate of ≥0.95, and 4.8% had a genotype concordance rate of ≥0.99. The mean (standard deviation in parenthesis) genotype concordance rate per animal, for animals with no parent in the reference population (n=98), only one parent in the reference population (n=632), or both parents in the reference population (n=34) was 0.927 (0.022), 0.952 (0.015) and 0.991 (0.002), respectively; the respective statistics for the allele concordance rate was 0.962 (0.012), 0.975 (0.008) and 0.995 (0.001).

The differences between the DGVs predicted using the real or imputed genotypes were normally distributed for each trait. The standard deviation of the difference between the DGVs predicted using either the real or imputed genotypes varied from 0.13 (progeny carcass fat score) to 0.47 (locomotion) of the standard deviation of the DGVs of the 746 test group animals when estimated using their real genotypes. The regression of the DGVs of the test group of animals estimated using the real genotypes on the DGVs estimated using the imputed genotypes were close to unity and only differed (P<0.05) from unity for perinatal mortality, progeny carcass conformation and fat score, and locomotion. The correlation between the DGVs of the test group animals when their real or imputed genotypes were used varied from 0.92 (locomotion) to 0.99 (cow carcass weight and progeny carcass fat); the average was 0.96. The correlation between the EBI estimated from the weighted sum of the individual trait DGVs predicted using the real or imputed genotypes was 0.98.

Conclusions
The cost of genomic selection can be considerably reduced by genotyping on the Bovine3K and, through the use of imputation algorithms, obtain 'in silico' genotypes on the Bovine50K.

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RMIS 5666

Predicting cow body energy status using mid-infrared spectrometry of milk
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Introduction
Cow body energy status is an important indicator of health and fertility in dairy cows, but is difficult to measure, primarily due to the cost of measuring feed intake. Mid-infrared spectrometry (MIR) is a tool used to routinely measure the fat and protein content of milk. The objective of this study was to attempt to predict the energy status of dairy cows using the MIR spectrum of milk.

Materials and Methods
Performance data collected between 1990 and 2010 on 1,145 research cows stationed at Crichton Royal Farm, Scotland were used. Random regression models were fit, within parity, to routinely collected dry matter intake, milk production, live weight and body condition score records to generate daily solutions for each trait. These solutions were used to calculate body energy status (EB; MJ) for each day of lactations 1 to 4 (Banos and Coffey, 2010).

Monthly between September 2008 and May 2010, three milk samples (representative of morning (AM), mid-day (MD) and evening (PM) milking from each cow were analysed using an MIR spectrometer (Foss Milkoscan FT6000). The resulting MIR spectrum generated for each milk sample contained 1,060 data points representing the absorption of light through the milk sample in the 900cm^{-1} to 5,000cm^{-1} wavelength region. Only spectral data with an actual phenotypic record for all component variables of EB within 7 days of the corresponding milk sample were retained. Spectral data were transformed from transmittance to linear absorbance through a $\log_{10}$ transformation of the reciprocal. A total of 1,883 AM, 1,731 MD and 1,855 PM milk spectra were retained for analysis.

Partial least squares analysis was used to relate the linear absorbance spectrum data to EB. Calibration and validation data sets were generated by randomly splitting the data in a ratio of 75% (calibration) to 25% (validation). This process was iterated 4 times so that 4 calibration data sets were generated to develop prediction equations and 4 validation data sets were developed to test the accuracy of prediction of the equations in independent data. Prediction accuracies were tested using both cross validation within the calibration data set (equations developed were tested on 5% of the calibration data set iteratively until all samples were predicted) and external validation within the validation data sets. Results presented are the average across all four external validation data sets. The maximum number of explanatory variables included in the models to explain EB was determined in response to the changes in accuracy of both cross validation and external validation when the number of factors was altered. Separate prediction equations were developed using AM, MD and PM milk samples. In a separate set of analyses, milk yield was added to the prediction models. The accuracy of predicting EB in early lactation (days in milk <61) was also tested. Finally, to test if the prediction equations developed were more accurate than fat to protein ratio (FPR) as a predictor of EB, the correlation between FPR and EB was also tested.

Results and Discussion
The average EB across the entire data set was -4.3 MJ (SD = 29.6). The correlation between milk FPR and EB was -0.09 across lactation and -0.28 in early lactation, thus FPR was a poor indicator of EB in this study, despite being suggested as a possible indicator (Heuer *et al.*, 2000).

Accuracy of predicting EB across lactation using the MIR spectrum as the sole predictor was 0.72, 0.71 and 0.75 for AM, MD and PM milk samples, respectively, when tested using cross validation. The corresponding accuracy of prediction when tested using external validation on independent data was 0.68, 0.67 and 0.72 for AM, MD and PM milk samples, respectively. The regression coefficient between predicted and actual values of EB was not different from one (P>0.05) indicating that a one unit change in predicted EB was associated with a one unit change in actual value.

When milk was included as an additional explanatory variable in the model, the accuracy of prediction improved. The external validation accuracy of prediction was 0.70, 0.69 and 0.75 for AM, MD and PM milk samples, respectively. Improved accuracies of prediction were expected since milk yield was included in the calculation of EB and hence a statistical part-whole relationship between the two variables exists. A biological part-whole relationship also exists and since data on milk yield will be available at milk recording, its inclusion in the models is justified. Poorer accuracies of prediction were obtained for animals in early lactation. The accuracy of external validation was 0.59, 0.65 and 0.69 for AM, MD and PM milk samples, respectively. The data sets used to develop and test the equations in early lactation were smaller than across lactation and comprised 387, 353 and 384 records for AM, MD and PM samples, respectively.

Conclusions
The use of MIR spectrum data to predict EB shows great promise. Accuracies of prediction using this method were greater than the traditionally used FPR and offer a method of cheap and accurate predictions of cow body energy status through routine milk sampling.

Acknowledgements
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RMIS 5791

Validation of equations to predict milk fatty acids in commercial Irish cows
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Introduction
Milk fat of dairy cows typically contains 70% saturated fatty acids (SAT) and 30% unsaturated fatty acids (UNSAT). Large variation in this 70:30 ratio exists (McParland and Berry, 2010). Because of the prohibitive costs of measuring fatty acids (FA) in milk, routine estimates of the ratio of SAT to UNSAT in commercial cows are not freely available. Recently equations were developed to accurately predict the level of FA in milk from mid-infrared spectroscopy (MIR) using data from commercial cows in Belgium and Luxembourg as well as cows from research herds in Scotland and Moorepark (Soyeurt *et al.*, 2010). The objective of this study was to validate the accuracy of the developed prediction equations on a random sample of commercial cows from the Irish national herd.

Materials and Methods
Milk samples (n=143) were obtained from the Dairygold Cooperative Society Limited during June 2010. Dairygold operate a commercial milk recording service, and the milk samples obtained were from a random selection of cows representative of several herds within the Munster region of Ireland. All milk samples were analysed using a MIR spectrometer (FOSS Milkoscan FT6000). The resulting MIR spectrum obtained for each milk sample represented the absorption of light through the milk sample at 1,060 different wavelengths. Following MIR analysis, FA content of each milk sample was determined using gas chromatography, the gold standard method of determining the FA in milk. Results from the gas chromatography were considered the "true" measure of FA in the milk. The prediction equations developed by Soyeurt *et al.* (2010) were used to predict the level of 15 individual FA and 13 groups of FA (Table 1) in each milk sample. Product moment correlations and the bias between the true value for each FA and corresponding predicted values were undertaken.

Results and Discussion

The mean fat percent across all 143 milk samples was 3.93%, while the mean proportion of SAT and UNSAT in the milk fat was 66% and 34%, respectively. These results are similar to those previously presented from an Irish research herd (Mc Parland and Berry, 2010) and are more favourable than results shown for Dutch Holstein-Friesians (Stoop *et al.*, 2009). Mean proportion of SCFA, MCFA and LCFA in milk fat were 9% 49% and 42%, respectively. All correlations between the true and predicted values of individual FA were moderate to strong and ranged from 0.54 (C18:2*cis*9*cis*12) to 0.97 (C8:0, C10:0) for individual FA. The mean correlation coefficient between true and predicted values of individual FA was 0.82. Correlations between true and predicted values of grouped FA were slightly stronger than the correlations for individual FA, and ranged from 0.63 to 0.99 (Table 1). The mean bias across all FA was -0.01 and ranged from -0.10 where FA were over-predicted (C18:1*cis*9), to 0.05 (SAT), where FA were under-predicted. The more abundant FA in milk generally had stronger correlations between true and predicted values, since the ability of the MIR to predict components in milk increases as the concentration of the component in the milk increases (Soyeurt *et al.*, 2006).

Table 1. Correlation coefficient (r) between true and predicted levels of fatty acids or groups of fatty acids in milk

Fatty Acid	r	Fatty Acid Group	r
C4:0	0.91	C18:1 trans	0.77
C6:0	0.96	C18:1 cis	0.88
C8:0	0.97	C18:2	0.67
C10:0	0.97	Omega-3	0.63
C12:0	0.96	Omega-6	0.69
C14:0	0.96	Saturated	0.99
C14:1	0.72	Monounsaturated	0.95
C16:0	0.95	Polyunsaturated	0.83
C16:1 *c*[1]	0.62	Unsaturated	0.95
C17:0	0.85	Short chain	0.97
C18:0	0.84	Medium chain	0.98
C18:1 *c*9	0.87	Long chain	0.95
C18:2 *c*9, *c*12	0.54	Branched	0.76
C18:3 *c*9, *c*12, *c*15	0.59		
C18:2 *c*9,*t*11[2]	0.59		

[1] *c* = cis; [2] *t* = trans

Conclusions

Strong correlations between true and predicted values of individual FA and groups of FA indicate that the equations developed to predict milk FA are suitable for use on Irish commercial cows. The use of MIR technology to predict FA in milk allows for a quick and inexpensive method of determining the FA in milk at no extra cost over and above routine milk recording.

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RMIS 5791

Relationship between milk fatty acids and body energy status in Holstein dairy cows

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Introduction

Energy balance is the differential between energy intake and expenditure. Negative energy balance is associated with mobilisation of body reserves to make up the short fall of energy required for milk production. The ratio of milk fat to protein is often used as an indicator of energy status (Friggens *et al.*, 2007). Milk, however, contains hundreds of fatty acids (FA) which differ in their origin and can be classified into two broad groups: saturated fats (SAT) and unsaturated fats (UNSAT). These groups can be further divided according to their number of structural carbons (C). The objective of this study was to determine the association between groups of milk FA and the body energy status of Holstein cows.

Materials and Methods

Performance data from 1990 to 2010 from a research herd of Holstein cows stationed at Crichton Royal Farm, Scotland were obtained. Cows were split in two groups and fed either a high concentrate or a low concentrate diet. Random regressions were fit through the records of milk, fat and protein yield, individually recorded dry matter intake, live weight and body condition score to create daily solutions and ultimately compute body energy status (EB; MJ) for each day in milk according to the methodology of Banos and Coffey (2010).

Monthly between September 2008 and May 2010 milk samples from the morning (AM), midday (MD) and evening (PM) milkings of all research cows were analysed using a MIR spectrometer. From the resulting spectrum, the level of milk FA in each milk sample was predicted using the equations developed by Soyeurt *et al.* (2010). Groups of FA predicted included: 1) SAT, 2) UNSAT, 3) short chain FA (SCFA; FA between 4 and 10 C), 4) medium chain FA (MCFA; FA between 12 and 16 C) and 5) long chain FA (LCFA; FA between 17 and 22 C). Accuracy of predicting the groups of fats ranged from 0.91 for the SCFA to 0.98 for SAT (Soyeurt *et al.*, 2010). The weighted average FA content of the AM, MD and PM milk samples was obtained for each day with an associated MIR spectrum.

Product moment correlations between each group of FA and EB were undertaken. The correlations between each group of milk FA and EB were also investigated separately within each feeding treatment.

Results and Discussion

The mean proportion of SAT and UNSAT in the milk fat of the cows in the study was 700 mg/g fat and 300 mg/g fat, respectively. Mean proportion of SCFA, MCFA, and LCFA in milk fat were 90 mg/g fat, 530 mg/g fat and 380 mg/g fat, respectively. Weak to moderate correlations existed between FA groups and EB. The correlation between the milk fat to protein ratio and EB was -0.11. Across both experimental feeding systems, cows in positive EB had a higher proportion of SAT in the milk fat (r = 0.30) and lower levels of UNSAT in the milk fat (r = -0.19). The negative association between UNSAT and EB may be driven by oleic acid, the most abundant UNSAT in milk, as it is released during body fat mobilisation (Rukkwamsuk *et al.,* 2000) and was also negatively associated with EB in the present study (r = -0.21). In addition, the preformed milk fat precursors originating from body fat mobilisation (i.e. negative energy balance) reduce the requirement for *de novo* synthesis, and thus reduce the proportion of SAT in the milk. Positive correlations between both SCFA and MCFA and EB existed (r = 0.18 and 0.35, respectively), yet there was a negative correlation between LCFA and EB (r = -0.24). This negative association between LCFA and EB may be explained by the LCFA stearic acid (r= -0.14), also released during lipolysis (Rukkwamsuk *et al.,* 2000).

Table 1 summarises the differences between the high and low concentrate feeding groups in their relationship between milk FA and EB. The proportion of FA in the milk were similar between the two groups, yet the association between the FA and EB of the group of cows fed low concentrate were stronger than the same associations in the cows fed high concentrates.

Table 1. Mean (standard deviation) of EB (MJ) and proportion of FA group (mg/g fat) and its correlation (r) with EB for the high and low concentrate diet groups

	High Concentrate		Low Concentrate	
	Mean (sd)	r	Mean (sd)	r
EB	-1.1(23.2)	-	-8.0(34.2)	-
SAT	70.2(8.5)	0.15	69.1(8.5)	0.39
UNSAT	29.7(4.8)	-0.13	30.9(4.9)	-0.23
SCFA	9.2(1.4)	-0.04	8.9(1.3)	0.32
MCFA	55.0(7.0)	0.27	52.5(7.2)	0.51
LCFA	36.5(6.1)	-0.20	39.5(6.3)	-0.24

Conclusions

Weak to moderate correlations between milk FA groups and EB were observed. Although no correlation was strong enough to be used exclusively to predict EB, these findings indicate that milk FA are more useful as indicators of EB than the milk fat to protein ratio.

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RMIS 5791

Genome-wide associations for milk production and somatic cell count in Irish Holstein-Friesian cattle

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Introduction
Identification of genomic regions associated with performance may help elucidate the biological pathways underpinning phenotypic differences in performance. The objective of this study was to identify genomic regions associated with milk production and somatic cell count in Irish Holstein-Friesian cattle.

Materials and Methods
A total of 54,001 single nucleotide polymorphisms (SNPs) from the Illumina Bovine50 Beadchip on 1,957 Holstein-Friesian AI sires with daughters in Ireland were available. SNPs were removed in the following order: if the SNP (1) was on the X chromosome or of unknown position, (2) did not conform to Mendelian inheritance patterns between sire and son, (3) had a minor allele frequency ≤5%, (4) had >5% of the genotypes missing, (5) had poor SNP clustering, and (6) had a ratio of heterozygotes >90%. Following editing 37,431 SNPs remained. Daughter yield deviations (DYD) with their respective reliabilities for milk production and average somatic cell score (SCS) (i.e., $\log_e$ SCC) were available on all sires. Only sires with reliability, less parental contributions, for milk of ≥80% or SCS of ≥70% were retained. In total 914 sires met these criteria for inclusion in the analysis of milk, fat and protein yield as well as fat and protein concentration; 776 sires were included for SCS. SNP associations were undertaken using a Bayesian approach which assumed that many of the SNPs will actually have no effect, and the prior distribution of the SNP variances is a mixture of a distribution with zero variance and an inverted chi-squared distribution with 4.012 degrees of freedom. The prior probability of a SNP having a non-zero effect was set at 0.0027. The dependent variable was DYD for milk production and SCS. The Monte Carlo Markov Chain was run for 100,000 cycles with the first 30,000 cycles discarded as burn-in to minimise the influence of starting values provided. The posterior quantitative trait loci (QTL) probability was calculated for each SNP after the burn-in was complete.

Results and Discussion
The posterior QTL probabilities for each SNP for each trait are illustrated in Figure 1. A posterior probability >0.5 indicates that there is a greater chance for a particular trait that a QTL associated with this region actually exists rather than not.

In total 26 SNPs had a posterior probability >0.5 across the 4 traits. SNP with posterior probabilties > 0.5 were in general within well-known QTL regions for these traits (Khatkar *et al.*, 2004). There were 8 SNP with posterior probabilities >0.5 associated with milk yield of which the SNP ARS-BFGL-NGS-18487 located on BTA 16 had the highest probability. Nine SNPs were associated with milk fat percentage, the largest posterior probability was SNP ARS-BFGL-NGS-4939 on BTA 14 which was also the SNP with the highest posterior probability for protein percentage. This SNP was approximately 1.2 Mb upstream of the Diacylglcerol acyltransferase 1 gene which is known to have a large effect of milk production traits (Berry *et al.*, 2010). There were 8 SNP with a posterior probability >0.5 associated with protein percentage while only 4 SNP associated with SCS. The SNP with the greatest posterior probability was ARS-BFGL-NGS-11073 on BTA 26. A number of the SNPs with posterior probabilities >0.5 were situated on BTA 20 within ~2.5Mb from the growth hormone receptor gene which has been linked to milk production traits and somatic cell score (Waters *et al.*, 2010).

Conclusions
Several SNPs were identified that were associated with milk production and SCS.

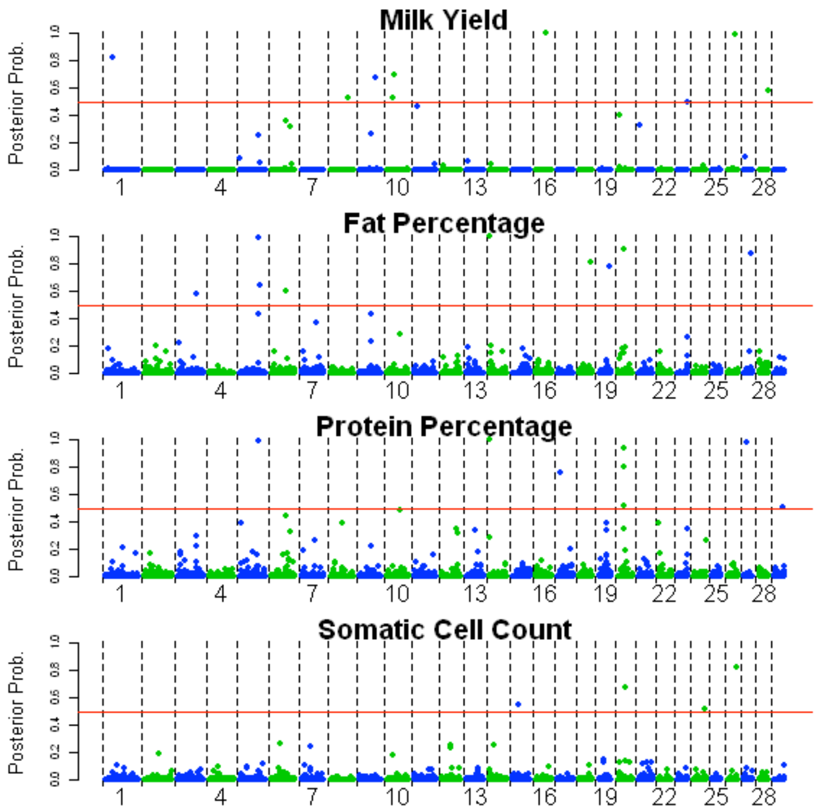

Figure 1. Posterior QTL probabilities for milk production and somatic cell score for each of the autosomes from left (BTA 1) to right (BTA29)

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RMIS 5883

Genome-wide associations for fertility using data from experimental herds in four countries
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Introduction
Genome-wide associations for difficult to measure traits are limited by sample population size with accurate phenotypic data. Fertility phenotypes using information on hormonal profiles are more heritable (Veerkamp *et al.*, 2000) than traditional fertility measures thereby increasing the power of genome-wide association studies. The objective of this study was to use data on primiparous Holstein-Friesian cows from experimental farms in Ireland, the UK, The Netherlands and Sweden to identify genomic regions associated with fertility including a fertility phenotype derived from milk progesterone profiles.

Materials and Methods
Phenotypic data were available on 2,031 primiparous Holstein-Friesian cows from Ireland, 1,018 cows from the UK, 725 cows from The Netherlands, and 225 cows from Sweden. Sampling and determination of milk progesterone concentration have previously been described in detail for the data originating from Ireland (Horan *et al.*, 2005), the UK

(Pollot and Coffey, 2008), The Netherlands (Veerkamp *et al.*, 2000) and Sweden (Petersson *et al.*, 2006). Milk sampling was undertaken two to three times weekly between the years 1991 and 2005. The traditional fertility traits investigated were days from calving to first observed heat (CFH) or first service (CFS), calving interval (CIV), number of services (NS), and pregnancy rate to first service (PRFS). Post-partum interval to the commencement of luteal activity (PPCLA) was defined as the number of days from calving to the first occurrence of two consecutive test-day records with a milk progesterone concentration of ≥3 ng/ml. Genetic and residual (co)variances for the fertility traits were estimated using animal linear mixed models. Fixed effects were country-experimental treatment-year and country-year-season of calving. For PRFS, CFS was also included as a fixed effect.

Following the removal of animals that did not pass parentage verification using the genomic information, as well as the removal of single nucleotide polymorphisms (SNPs) that had a minor allele frequency of <0.01 in each country, deviated from Hardy-Weinberg equilibrium, or there was poor quality in calling the genotypes, a total of 37,590 SNPs from the Illumina Bovine50 Beadchip on 1,570 cows from Ireland (n=319), UK (n=461), The Netherlands (n=583), and Sweden (n=207) remained. The genome-wide association analysis was conducted using a Bayesian Stochastic Search Variable Selection (BSSVS) model that estimates effects for all SNPs simultaneously. All univariate BSSVS models were run for 50,000 cycles, discarding the initial 10,000 cycles for burn-in (i.e., to remove the uncertainty of starting values provided). All bivariate models were run for 100,000 cycles, discarding 20,000 for burn-in.

Results and Discussion

Heritability estimates for the traditional fertility traits varied from 0.03 (PRFS) to 0.16 (CFH). The heritability of PPCLA was 0.13. The interval traits (i.e., CFH, CFS, CIV and PPCLA) were all strongly genetically correlated (0.37 to 0.99) with each other. The posterior QTL probabilities for the traditional fertility traits were all less than 0.021. Posterior probabilities of >0.04 were observed for PPCLA on BTA2 (BTA-49769-no-rs; probability of 0.060) and BTA21 (BTA-12468-no-rs; probability of 0.045). The SNP on BTA2 explained 0.51% of the genetic variance in PPCLA while the SNP on BTA20 explained 0.35% of the genetic variance in PPCLA. The Bayes factors of BTA-49769-no-rs and BTA-12468-no-rs were 24 and 18, respectively. The posterior QTL probability of 0.060 for PPCLA at SNP BTA-49769-no-rs estimated in the univariate analysis increased to 0.094, 0.121, 0.162, 0.662 and 0.162 when included in a bivariate analysis with CFH, CFS, NS, CIV and PRFS, respectively. The posterior probability of 0.045 for PPCLA at SNP BTA-12468-no-rs on BTA20 when estimated in the univariate analysis increased to 0.052, 0.152, 0.072, 0.123 and 0.135 when included in a bivariate analysis with CFH, CFS, NS, CIV and PRFS, respectively

Conclusions

Regions of the genome associated with PPCLA were identified although no obvious region was associated with the traditional fertility measures. This suggests that genome wide associations may be more successful if phenotypes derived from physiological measures, less influenced by management, are used. The inclusion of additional information through bivariate analysis increased the QTL probabilities.

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RMIS 5883

Relationship between stocking rate, herd size and profit on Irish spring calving dairy farms

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Introduction

The relationship between on-farm profit and stocking rate has been evaluated using controlled experiments in Ireland and overseas (McGrath *et al.,* 1998). Little farm-based analysis of the relationship has, however, been undertaken in Ireland. The relationship between on-farm profit and herd size has been evaluated on pasture based dairy systems in New Zealand (Jaforullah and Devlin, 1996), but as of yet not in Ireland. The objective of this study was to quantify the association with farm profit of both farm stocking rate and herd size across a large number of commercial Irish dairy herds.

Materials and Methods

Data were extracted from Profit Monitor, a web based software package administered by Teagasc for the collection and comparison of farm physical and financial performance data. Data from 1,131 Irish spring calving dairy farms with >20 cows for the years 2007 to 2009 inclusive (representing 2,201 farm years), were available. All herds had information on physical and financial performance. Measures of costs and profit were available as cent/litre (c/l), € per cow (€/cow) and € per hectare (€/ha). Overall farm stocking rate was calculated in Profit Monitor by dividing total farm livestock units by the number of forage hectares farmed expressed in livestock units per hectare.

The association between both stocking rate and herd size and measures of profitability was quantified using mixed models where herd (n=1,131) within region of Ireland (n=18) was included as a repeated effect; a compound symmetry covariance structure with heterogeneous variances were assumed among records within herd. Stocking rate and herd size were both forced into the model as continuous variables; where an association existed ($P<0.05$) the quantity of purchased feed was included as a covariate. Non-linear associations with all independent variables were also investigated.

Results and Discussion

Across the three years of the study, herd size averaged 83.8 cows stocked at 2.1 cows/ha producing, on average, 5,165 litres milk per lactation with 39.2 g/kg fat and 34.2 g/kg protein. Total variable and fixed costs averaged 10.0 c/l and 9.4 c/l respectively, while average net margin per litre was 10.9 c/l.

Following adjustment for herd size and quantity of purchased feed, net margin increased with stocking rate but at a declining rate (Table 1). The non-linear association between stocking rate and profit observed here supports international pastoral dairy systems research (McGrath *et al.*, 1998). In the present study, increasing from 2.0 to 2.5 LU/ha increased net profit per hectare by €393/ha. Recommended stocking rates are designed to achieve high overall dairy profitability through a balance between grass utilisation and production per cow and per hectare (Shalloo *et al.*, 2004). Milk production per cow declined linearly while milk price increased linearly with increasing stocking rate (Table 1) suggesting that milk composition improved. Variable and fixed costs per hectare increased as stocking rate increased.

Net margin per cow declined as herd size increased (Table 1) but the association, although statistically significant was biologically small. Neither milk yield nor variable costs per cow were affected by changes in herd size. Milk price (c/l) and fixed costs (€/cow) however increased linearly with increases in herd size.

Table 1. Linear and quadratic regression coefficients (standard errors in parenthesis; $P<0.05$) of herd financial performance on stocking rate and herd size from a multiple regression model.

Variable	Linear	Quad.
Stocking rate		
Milk yield (litres/cow)	-330 (37.2)	
Variable costs (€/ha)	342 (57.0)	-32.6 (13.2)
Fixed costs (€/ha)	290 (20.0)	
Net margin (€/ha)	1459 (182.6)	-149 (41.9)
Milk price (c/l)	0.307(0.0524)	
Herd size		
Milk yield (litres/cow)	NS	
Variable costs (€/cow)	NS	
Fixed costs (€/cow)	0.55 (0.10)	
Net margin (€/cow)	-0.40(0.15)	
Milk price (c/l)	0.0025(0.0006)	

Conclusions

These results confirm the positive association between stocking rate and measures of profitability on spring calving dairy farms. They also suggest that larger herds are delivering comparable production to smaller herds with little negative impact on profit per cow. Finally the results also confirm the roles that higher stocking rates and larger herd size have in increasing dairy farm profitability on Irish spring calving dairy farms.

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RMIS 5889

Relationship between dairy cow genetic merit and profit on Irish spring calving dairy farms

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Introduction

The relationship between the profit-based Economic Breeding Index (EBI) and actual on-farm profit for spring calving herds was last evaluated in 2006 with a limited number (n=315) of spring calving farms (Ramsbottom *et al.*, 2006). The objective of this study was to quantify the association between genetic merit and profitability across 1,131 commercial Irish dairy herds. Particular emphasis was given to the association between the EBI and profitability.

Materials and Methods

Data were extracted from Profit Monitor, a web based software package administered by Teagasc for the collection and comparison of farm physical and financial performance data. Data from 1,606 Irish spring calving dairy farms with >20 cows (representing 3,162 farm years) for the years 2007 to 2009, inclusive were available. All herds had information on physical and financial performance. Net profit was available as cent/litre (c/l) of milk produced. Genetic information on average herd predicted transmitting ability (PTA) of the lactating animals was also available from the September genetic evaluation for each of the relevant years. Data on herd average EBI, as well as its component traits were available. Only herds where genetic data were available on ≥75% of the lactating animals in that year were retained. Data on herd genetic merit for overall conformation, udder conformation and legs conformation were available for 910 of these herds. Following the merging of genetic and performance data, 1,131 herds representing 2,201 herd-years remained for inclusion in the subsequent analysis. The association between herd average genetic merit and herd performance and profitability was quantified using mixed models where herd (n=1,131) within region of Ireland (n=18) was included as a repeated effect; a compound symmetry covariance structure with heterogeneous variances were assumed among years within herd. Confounding factors considered for inclusion as fixed effects in the mixed model were year as well as the continuous variables of stocking rate, herd-size and quantity of feed purchased per animal; non-linear associations with the dependent variable were also considered. The dependent variables, both of which were normally distributed, were net profit per litre and net profit per cow. Partial correlations among herd performance and herd average genetic merit, both adjusted for stocking rate, herd size and quantity of feed purchased were also estimated.

Results and Discussion

The correlations between genetic merit and phenotypic performance of the respective traits for milk yield, fat yield, protein yield, milk fat concentration, milk protein concentration and calving interval varied from 0.26 to 0.61 (Table 1) indicating that herds of greater genetic merit performed phenotypically better. Genetic merit for the milk production subindex was associated ($P<0.001$) with higher yields of milk of greater composition; the milk production subindex was however also positively correlated ($r=0.11$; $P<0.001$) with longer phenotypic calving intervals. Herd genetic merit for the fertility subindex was negatively correlated ($P<0.001$) with phenotypic yield (-0.29 to -0.24) but positively correlated ($P<0.001$) with milk composition (0.17 to 0.23); the fertility subindex was negatively correlated ($P<0.001$) with phenotypic herd average calving interval (-0.31). Genetic merit for overall cow conformation was positively correlated ($P<0.001$) with phenotypic yield and calving interval but negatively correlated with phenotypic milk composition.

The correlation between EBI and net profit per cow was 0.22 (Table 1) suggesting that EBI explained 5% of the variation in net profit per cow. Following adjustment for confounding factors, a positive ($P<0.001$) linear relationship existed between EBI and net profit. Net margin per cow increased ($P<0.001$) by €1.94 (SE=0.42) per unit increase in EBI; this is not different from the expectation of €2 per cow. Net margin per litre of milk produced increased ($P<0.001$) by 0.043 c/l (SE=0.0075c/l) per unit increase in EBI equivalent to €215 per unit increase in average farm EBI per 500,000 litres of milk. The production and fertility subindexes, when both included in the mixed model, were positively associated ($P<0.001$) with net profit per cow of €3.43 (SE=€0.68) and €1.72 (SE=€0.63) per unit increase in the respective index. Overall conformation, after adjusting for differences in genetic merit for the production and fertility subindexes and other confounding factors, was not associated with profit per cow. These results are at variance with a previous study in a smaller dataset which found no association between the milk production subindex and profitability per cow (Ramsbottom *et al.*, 2006) in spring milk herds.

Conclusions

These results confirm the association between EBI and profit on spring calving dairy farms and the strength of the association is in line with expectations. These results also confirm that EBI is an appropriate tool for Irish dairy farmers to use when selecting dairy sires.

Table 1. Correlations (r; P<0.05) among herd average predicted transmitting ability (PTA), EBI and performance

Genetic Trait	Performance measure	r
EBI	Net margin/cow	0.22
PTA milk yield	Milk kg	0.35
PTA fat yield	Fat kg	0.26
PTA protein yield	Protein kg	0.30
PTA fat %	Fat %	0.61
PTA protein %	Protein %	0.61
PTA calving interval	Calving interval	0.31

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RMIS 5889

Life-time genetic profiles for beef and dairy animal's live-weight and price

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Introduction

Animal live-weight and price are measured routinely in Ireland and therefore, at the sire level at least, may be considered longitudinal traits. The appropriateness of including all data in a genetic evaluation with a phenotypic adjustment for differences in age is not clear since genetic (co)variance components for animal live-weight and price across ages are not known. Furthermore, development of statistical models that account for genetic and permanent environmental covariances across a trajectory have several uses in herd management, such as predicting the phenotypic level of the trait under investigation as well as benchmarking herd performance relative to contemporaries, while simultaneously adjusting for other systematic environmental effects and genetic merit of the herd. The objective was to estimate covariance functions for genetic and permanent environmental effects for beef and dairy live-weight and price across an age trajectory.

Materials and Methods

A total of 2,967,791 live-weight and animal price from 2,506,110 beef and dairy animals sold at 71 livestock auctions in Ireland between the years 2000 to 2008 inclusive, were available. A further 875,874 live-weight records from 682,694 commercial animals, aged between 150 and 600 days, collected from 32,089 herds, between the years 2000 to 2008 were also available from commercial herds. Two contemporary groups were defined: auction-date of sale and herd-year-season of sale. Where on-farm data were used, contemporary group was defined as herd-date of weighing. Only records from contemporary groups with at least 4 other records were retained. Animals with a known sire were retained. The fixed effects included in the models used to estimate variance components were contemporary groups, gender, calving ease, whether the animal was born as a singleton or twin, heterosis, recombination loss, and a polynomial on age of the animal in weeks. The sire genetic and animal permanent environmental effect were modelled using random regression Legendre polynomials. Residual variances were estimated separately for ages between two days and twelve weeks of age, six and twelve months and 12 and 36 months, and cows (30 months and or a recorded calving record) two years and three years of age. For live-weight the three aforementioned residual variance blocks were used as calves are not weighed going through the marts. Within block residual variances were assumed homogenous but were allowed to vary between blocks; no residual covariance was assumed between blocks.

Results and Discussion

The most parsimonious model for both live-weight and animal price was a second order random regression on the additive genetic component and a first order regression on the permanent environmental component. The genetic variance for animal live-weight increased from a minimum of 686 kg^2 at 27 weeks of age to 937 kg^2 at 75 weeks of age after which it decreased to 909 kg^2 at 99 weeks of age before increasing thereafter until 156 weeks of age (Figure 1). The heritability varied from 0.12 (99 weeks of age) to 0.28 (156 weeks of age) and was similar to the ranges reported by McHugh *et al.* (2011), (0.24 to 0.38) who used multi-trait models with animals of similar ages grouped together. The abrupt changes in heritability are a function of the differences in residual variances estimated within each of the age groups. Genetic correlations between live-weight at each week of age decreased as the interval between ages compared increased, but was always positive.

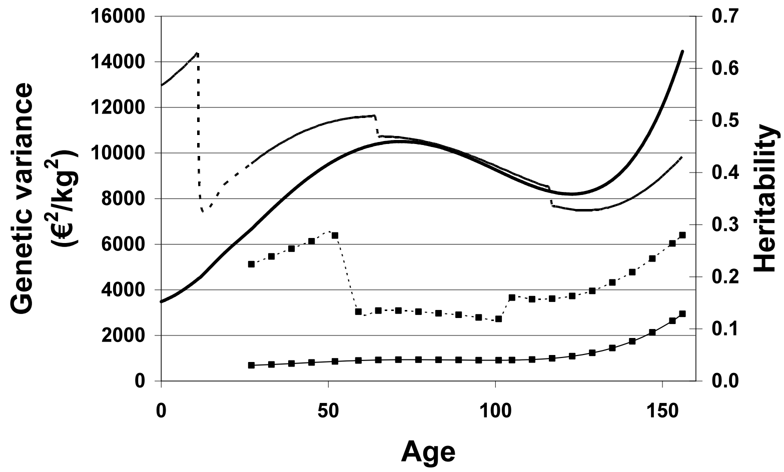

Figure 1. Genetic variance (continuous line) and heritability estimates (broken line) for animal price (no legend) and animal live-weight (squares)

The genetic variance for animal price varied from a minimum of 3,484 euro^2 at 1 week of age to 10,500 euro^2 at 156 weeks of age and followed a similar pattern to the change in genetic variance of live-weight (Figure 1). The heritability for animal price was largest when the animals were <12 weeks of age, and varied across the animal's life-time from 0.33 (125 weeks of age) to 0.63 (11 weeks of age). Although higher than those reported by McHugh *et al.* (2011; 0.09 to 0.34) using multi-trait models with animals of similar ages grouped together, the heritability estimates in the present study followed a similar trend with higher estimates in younger animals. The trend in genetic correlations between animal price at each week of age was similar to that observed for animal live-weight and was always positive.

Conclusions

Exploitable genetic variation clearly exists for animal price and live-weight and this can be modelled using random regression models to account for the longitudinal nature of the data. Genetic evaluation for either trait needs to take cognisance of the heterogeneous variances and correlation between different ages less than unity observed in this study.

References

Mc Hugh, N., Evans, R.D., Amer, P.R., Fahey, A.G. and Berry, D.P. (2011) *J. Anim. Sci*., **89:**29-39.

RMIS 5889

Indirect selection for animal price using subjective measures of animal conformation and size

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Introduction

Animal price and live-weight contribute substantially to the overall profitability of beef and dairy production systems and have previously been shown to exhibit significant genetic variation throughout life (Mc Hugh *et al.,* 2011). However, not all animals are sold at livestock marts during their lifetime thereby impacting the accuracy of selection for these traits. No study has attempted to quantify the genetic associations between routinely available type traits and animal price in growing cattle. The aim of this study was to quantify the genetic associations between muscular, skeletal and functional linear type traits and animal price.

Materials and Methods

A total of 2,967,791 live-weight and animal price records from 2,506,110 animals sold at 71 livestock auctions in Ireland between the years 2000 to 2008 inclusive, were available. The data were divided into three distinct maturity categories: calves, weanlings, and post-weanlings. Two contemporary groups were defined: auction-date of sale and herd-year-season of sale. Only records from contemporary groups with at least 4 other records were retained. Linear scoring is routinely carried out in both commercial and pedigree Irish beef herds by trained linear scorers for the Irish Cattle Breeding Federation (ICBF). Linear type traits were available on 40,999 animals, aged between 186 and 364 days, from 2,085 herds. Within the present study 21 linear traits representing the skeletal, muscle and functional characteristics of the animal were investigated. Phenotypic and genetic (co)variance components for linear type traits and animal price, within maturity group, were estimated using linear animal mixed models in ASREML (Gilmour *et al.,* 2008). The fixed effects included in the model for animal price were contemporary groups, gender, age of animal at selling, parity of dam and age of dam centred within parity, breed proportion of the animal, calving ease, whether the animal was a singleton or twin, heterosis, and recombination loss. Fixed effects included in the model for the linear traits included contemporary group, breed proportion of the animal, age at scoring, dam parity, gender, heterosis and recombination loss.

Results and Discussion

The heritability of the type traits ranged from 0.05 (foreleg front view) to 0.32 (hind quarter development); standard errors ranged from 0.02 to 0.04. The coefficient of genetic variation across all traits ranged from 0.07 (chest width) to 0.13 (height at withers). The genetic correlations between the type traits and calf price were generally weak to moderate and ranged from -0.40 to 0.20; standard errors ranged from 0.02 to 0.26. The genetic correlations between the type traits and weanling price were always stronger than the respective correlations with calf price, with the exception of foreleg front view. All correlations between the type traits and weanling price were positive or close to zero (-0.10 and 0.71; s.e. ranged from 0.04 to 0.16). A selection of the genetic correlations is presented in Table 1. The strongest correlations with weanling price were for the muscularity traits (0.52 to 0.71) suggesting greater prices were paid for animals with better developed loins, hind quarters and inner thighs. The genetic correlations between the type traits and post-weanling price ranged from -0.28 (hindleg side view) to 0.94 (development of inner thigh); s.e. ranged from 0.03 to 0.23. Similar to weanling price, stronger correlations were recorded between the muscular type traits and post-weaning price (0.08 to 0.94). The strong correlation between animal price and especially the muscularity traits, even after adjusting for differences in live-weight, is not unexpected since muscularity is likely to play an important role in the eventual carcass conformation and thus market value of the carcass. Four type traits, hind quarter development, length of back, chest width, and thigh development explained 49% of the genetic variation in weanling price. Weanling live-weight, along with the aforementioned type traits explained 68% of the genetic variation. When all 15 type traits with a significant genetic correlation with weanling price were included in the selection index the proportion of genetic variation in weanling price explained was 73%.

Table 1. Genetic correlations[†], between linear type traits and price in calves, weanlings and post-weanlings (Post).

	Calf	***Weanling***	***Post***
Skeletal			
Chest depth	-0.21	0.21	0.26
Chest width	-0.07	0.58	0.68
Width of pelvis	-0.001	0.55	0.65
Muscle			
Loin development	0.05	0.61	0.32
Thigh width	0.19	0.71	0.54
Depth of rump	-0.04	0.52	0.08
Functional			
Foreleg front view	-0.40	-0.03	0.50
Locomotion	-0.10	0.06	-0.08
Hind-leg side view	-0.05	-0.10	-0.28

[†]s.e. of correlation varied from 0.02 to 0.26.

Conclusions

Skeletal and muscular type traits are good predictors of genetic merit for animal price and should therefore be incorporated into the national genetic evaluations to increase the accuracy of selection for animal price.

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RMIS 5889

The effects of genetic merit for fertility traits on body condition score, milk production and hormonal and metabolic profiles

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Introduction

The incorporation of fertility traits into selection indices has allowed identification of animals with similar genetic merit for milk production traits, but divergent genetic merit for fertility traits. Using a high and low cow fertility genetic model established in this manner, we have generated cows with similar phenotypic milk production, but divergent phenotypic fertility performance (Cummins *et al.*, 2009). The aim of this study was to examine indicators of bioenergetic status and production characteristics in cows with divergent genetic merit for fertility traits but similar genetic merit for milk production traits.

Materials and Methods

Cows with high (n=24) and low (n=21) estimated breeding values (EBV) for fertility were identified and used in this study (EBVs are summarised in Table 1). For the duration of the study (-4 to +46 weeks from parturition), animals were maintained as a single herd in a typical grass-based production system. Milk yield was recorded twice daily and milk composition was determined once weekly. Body condition score (BCS: scale 1 to 5) was recorded every 2 weeks. Blood samples were collected once weekly for three weeks prior to parturition, twice weekly during the first 4 weeks of lactation, once weekly from week 5 to 9, and once every two weeks thereafter until the end of lactation. All samples were analysed for IGF-I, glucose, NEFA and BHB.

Table. 1. Mean pedigree index (and SD) for high and low fertility sub-index groups based on expected breeding values for milk production and fertility traits.

	High Fertility	Low Fertility
Milk BV (kg)	228(67.0)	239(72.6)
Calving interval BV (days)	-3.2(0.69)	2.9 (1.44)
Longevity BV	+1.6 (0.39)	-0.1 (0.58)
Production sub-index[1] (€)	47 (17.1)	41 (14.1)
Fertility sub-index[1] (€)	52 (8.2)	-35 (18.5)

[1]Economic Breeding Index

Table 2. Effect of genotype (Geno) on plasma concentrations[1] of insulin-like growth factor-I (IGF-I), non-esterified fatty acid (NEFA), β-hydroxybutyrate (BHB) and glucose in samples collected between weeks -4 and +37 of lactation.

	Genotype		P-values		
	High Fertility	Low Fertility	Geno	Geno × week	Geno × parity
IGF-I (ng/mL)	136.5 (127.8, 145.6)	105.8 (98.6, 113.4)	<0.0001	NS	0.04
NEFA (mmol/L)	0.196 (0.177, 0.216)	0.173 (0.158, 0.19)	0.069	NS	<0.001
BHB (mmol/L)	0.388 (0.363, 0.413)	0.304 (0.284, 0.325)	<0.0001	NS	0.006
Glucose (mmol/L)	2.72 (2.579, 2.859)	2.6 (2.465, 2.729)	0.067	NS	0.03

[1] Geometric mean (95% CI)

Data were analysed using the mixed model procedure in SAS with repeated measures. The model used for milk production, BCS, and blood analytes was: Y = μ + genotype + lactation week + parity + genotype*lactation week + genotype*parity + calving fortnight + e. Cow nested within genotype was included as a random effect.

Results and Discussion

During the 46 week lactation, mean milk yield (17.5 vs. 16.3 kg/day) was higher in the high fertility sub-index group (P < 0.001), but milk fat, protein and lactose concentrations did not differ (all P>0.05). BCS was greater in the high fertility sub-index group throughout lactation (3.1 vs. 2.94; P < 0.0001). A genotype by parity interaction was observed for BCS, whereby 1st parity high fertility cows maintained a higher BCS compared to the 1st parity low fertility cows (3.25 vs. 2.94; P <0.001), but no differences were observed between 2nd parity animals. Mean circulating IGF-I and metabolite concentrations are summarised in Table 2. Mean plasma concentrations of IGF-I and BHB were significantly greater for the high fertility cows, and concentrations of glucose and NEFA also tended to be greater in the high than low fertility cows. Genotype × parity interactions were observed for all blood analytes; differences between high and low fertility cows in parity 1 were greater than the differences in parity 2. The IGF-I profile is illustrated in Figure 1.

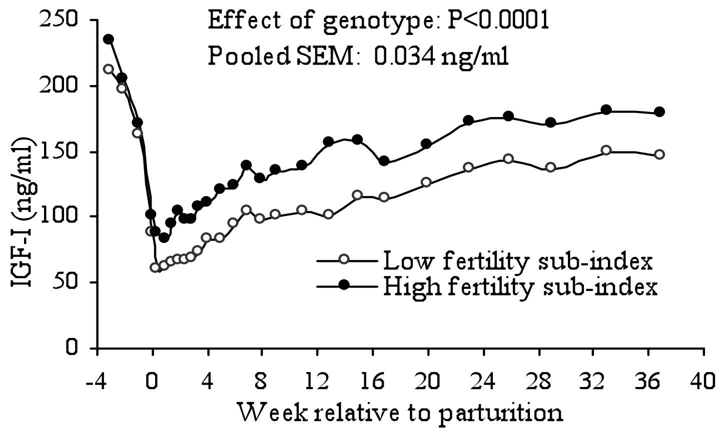

Figure 1. Temporal profile of circulating IGF-I concentrations from weeks -4 to +37 of lactation

Conclusions

Differences in milk yield and circulating indicators of bioenergetic status were observed, demonstrating that the effects of genetic merit for fertility traits may be manifested in alterations of metabolic status. Further work is necessary to characterize the somatotropic axis in this animal model.

Reference

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RMIS 5667

Comparison of Double-Ovsynch vs. Presynch 14-Ovsynch for first postpartum timed AI in lactating dairy cows

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Introduction

Ovulation synchronisation protocols, e.g. Ovsynch, that use timed AI (TAI) ensure that a cow is submitted for AI without the requirement to observe for signs of oestrus. The use of Ovsynch regimens involves (i) synchronising the growth of a new follicular wave; (ii) induced luteal regression; and (iii) synchronisation of ovulation 2 days (d) later. Use of ovulation synchronisation protocols has resulted in acceptable conception rates with maximal submission to AI after the end of the voluntary waiting period. Presynchronisation protocols have been developed to optimise the response to TAI protocols (Moreira *et al.*, 2001, Souza *et al.*, 2008). Souza *et al.* (2008) recently reported that that Double-Ovsynch increased pregnancies per AI (P/AI) compared with Presynch followed by Ovsynch. However, Double-Ovsynch increased P/AI only in primiparous cows and not in multiparous cows. The objective of this study was to test the hypothesis that improved first service conception rates can be achieved in first parity animals through use of Double-Ovsynch compared with Presynch 14-Ovsynch.

Materials and Methods

Lactating Holstein dairy cows (n = 739; 341 primiparous and 398 multiparous) on a commercial dairy farm in Wisconsin, USA, were enrolled in the study from October 2009 through April 2010. Cows were housed in free-stall facilities bedded with sand, equipped with feedline head lockups and with *ad libitum* access to fresh feed and water. Weekly, a cohort of 30-50 cows were randomly assigned to one of two hormonal treatments to facilitate first postpartum TAI: PRESYNCH 14-OVSYNCH (PS) or DOUBLE-OVSYNCH (DO) (Souza *et al.*, 2008). DO utilises an Ovsynch protocol for presynchronisation followed by an Ovsynch protocol for TAI. PS utilises two injections of $PGF_{2\alpha}$ administered 14 d apart for presynchronisation, followed by an Ovsynch protocol for TAI. Animals were assigned to treatment based on animal identification number; odd number cows were assigned to PS and even number cows were assigned to DO. Animals assigned to PS (n = 373) received two injections of $PGF_{2\alpha}$ (35 mg dinoprost tromethamine) at 45 ± 3 DIM (days in milk) and 59 ± 3 DIM, and then began the Ovsynch-56 TAI protocol 12 d later. Animals assigned to DO (n = 366) received GnRH (100 µg of gonadorelin diacetate tetrahydrate) at 54 ± 3 DIM, followed by an injection of $PGF_{2\alpha}$ 7 d later, GnRH 72 h after $PGF_{2\alpha}$, and then began the Ovsynch-56 TAI protocol 7 d later. All cows received the Ovsynch-56 TAI protocol: GnRH1 at 71 ± 3 DIM, $PGF_{2\alpha}$ 7 d later, GnRH2 56 h after $PGF_{2\alpha}$, and TAI 12 to 14 h later at 81 ± 3 DIM. After the first postpartum timed AI, pregnancy was diagnosed by palpation per rectum at 39 d.

Pregnant cows were re-examined by palpation per rectum at 74 d after TAI to determine the late embryo loss rate. Cows re-inseminated before being examined for pregnancy diagnosis were considered not pregnant to the previous timed AI. Cows were evaluated for body condition score using a quarter point scale from 1 to 5 (1 = emaciated and 5 = obese) (Edmonson *et al.*, 1989) at 92 ± 3 DIM coinciding with d 11 after TAI. Cows were classified as LOW (≤ 2.5) or HIGH (> 2.5) BCS at 92 ± 3 DIM. Blood samples to determine plasma concentrations of progesterone (P_4) were collected via coccygeal venipuncture from all cows at 71 ± 3 DIM and 92 ± 3 DIM coinciding with GnRH1 of the Ovsynch-56 TAI protocol and d 11 after TAI, respectively. Cows were classified as having LOW (≤ 0.5 ng/mL) or HIGH (> 0.5 ng/mL) P_4 at both 71 ± 3 DIM and 92 ± 3 DIM. Treatment effects were analysed by logistic regression using the GLIMMIX Procedure of SAS. Explanatory variables in the statistical model included treatment, parity (1, ≥ 2), body condition score (BCS) (LOW ≤ 2.50; HIGH > 2.50), treatment*parity and treatment*BCS interactions.

Results and Discussion

Presynchronisation with DO tended ($P = 0.06$) to improve P/AI (46.6 vs. 41.5%, DO vs. PS, respectively). One-tailed contrasts revealed improved ($P = 0.04$) P/AI for first parity animals treated with DO with no improvement ($P > 0.05$) observed for older animals. There was no effect ($P > 0.05$) of presynchronisation treatment on the incidence of late embryo loss after first service (9.1 vs. 6.1%, DO vs. PS, respectively). No difference ($P > 0.05$) in P/AI to second service was observed (33.1 vs. 34.9, DO vs. PS, respectively). DO increased the proportion of animals with $P_4 > 0.5$ ng/mL at GnRH1 of Ovsynch (0.93 vs. 0.75; $P < 0.001$). A treatment by BCS interaction ($P < 0.05$) was observed for plasma P_4 at GnRH1 of Ovsynch. Low BCS cows assigned to PS had lower P_4 concentrations at GnRH1 of Ovsynch compared with low BCS cows assigned to DO.

Conclusions

Presynchronisation protocols attempt to increase the proportion of cows at the optimum stage of the oestrous cycle at the onset of Ovsynch to optimise ovulatory and luteolytic responses and fertility outcomes following Ovsynch. Presynchronisation with Double-Ovsynch may be used to increase pregnancies per AI in first parity animals and increase the proportion of cows with high progesterone at the first GnRH of the Ovsynch-56 TAI protocol.

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RMIS 5672

The effect of dietary polyunsaturated fatty acids on follicle development, corpus luteum volume and circulating progesterone in lactating dairy cows

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Introduction

It has been suggested that beneficial effects of feeding fat on reproductive performance may be independent of energy status, and instead be due to specific effects on the pituitary gland, ovaries and uterus, mediated by the fatty acid composition of the fat source (Mattos *et al.*, 2000). The aim of this study was to determine the effects of different fat sources on ovarian follicular dynamics and steroid hormone concentrations in lactating dairy cattle.

Materials and Methods

Forty-eight Holstein-Friesian cows were blocked on the basis of parity, calving date and milk yield, and randomly assigned to one of four dietary fat supplements at 38 days in milk (DIM; ± 11 d (SD)): (i) 500 g palmitic acid (Control); (ii) 200 g flaxseed supplement, containing 72 g alpha-linolenic acid (Flax); (iii) 100 g lipid-encapsulated supplement containing 10 g each of trans-10, cis-12 and cis-9, trans-11 conjugated linoleic acid (CLA); or (iv) a fish oil supplement containing 30 g each of EPA and DHA (FO). All lipid supplements were formulated to be isolipidic; palmitic acid was added as necessary to provide a total lipid supplement intake of 500 g/d. All cows received the same basal total mixed ration diet. Cows were synchronised to be in oestrus on day 15 of dietary treatment. All antral follicles were counted, and dominant follicles, subordinate follicles and corpora lutea were measured daily via transrectal ovarian ultrasonography from the day before the synchronized oestrus until the day of ovulation at the subsequent spontaneous oestrus. Blood samples were collected daily by coccygeal venipuncture. Data were analysed using mixed model analysis in SAS with treatment and day of cycle included as fixed effects and block as a random effect. Repeated measures were included where appropriate. A contrast statement was used to compare the two n-3 fat sources (Flax and FO) with the Control or CLA supplements.

Results and Discussion

There was no effect of dietary treatment on oestrous cycle length, ovulatory follicle diameter or time to first or second follicular wave emergence (Table 1). A contrast revealed that the n-3 treated cows had fewer follicles in the first follicular wave than Control cows (P = 0.02). There was a significant effect of dietary fatty acid source on circulating progesterone (P4) concentrations (P = 0.03, Figure 1) and corpus luteum volume (P = 0.03, Table 1). Post-hoc analysis revealed that circulating P4 was greater in CLA-treated cows compared with cows receiving Flax. A contrast revealed that the n-3 treated cows had lower circulating P4 than both Control and CLA cows (P = 0.05 and 0.006, respectively).

Table 1. Effect of dietary fat source on follicle development and corpus luteum volume

	Control	Flax	CLA	FO	S.E.M	P-value
Cycle length (d)	22.3	20.1	22.8	23.1	1.5	0.4
Number of waves	2.4	2.5	2.3	2.5	0.2	0.9
Max. diameter ovulatory follicle (mm)	16.8	16.6	17.6	16.3	0.9	0.6
Day of 1st wave emergence	1.5	1.3	1.5	2.3	0.5	0.1
Day of 2nd wave emergence	9.3	9.5	10.3	11.1	0.8	0.3
Number of follicles in the 1st wave	6.5	5.5	5.9	4.4	0.6	0.09
Corpus luteum volume day 5-15 of cycle (mm^3)	9197[a]	7913[a b]	8982[a b]	7444[b]	662	0.03

[ab] Within row means not sharing a common superscript differ significantly (P<0.05)

Elevated concentrations of P4 may be due to either an increase in steroid synthesis in the corpus luteum or due to a reduced metabolic clearance rate in the liver (Hawkins *et al.*, 1995).

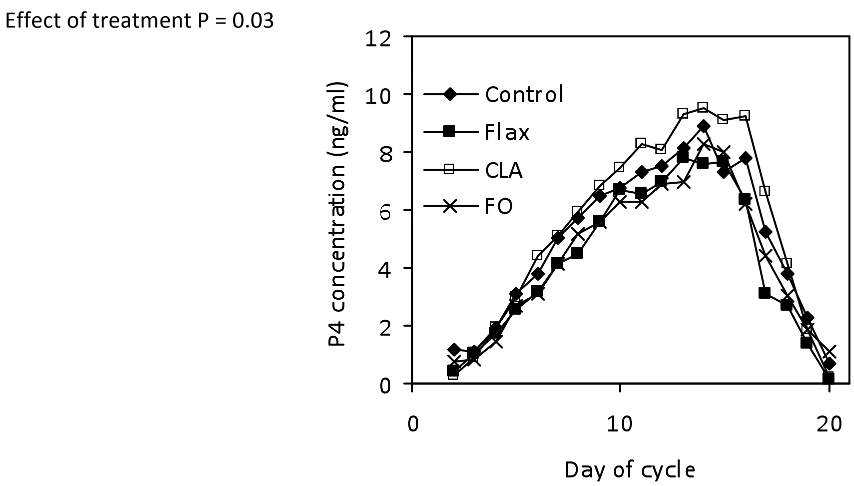

Figure 1: Effect of dietary fat source on circulating progesterone (P4) concentration. The pooled SEM = 0.7 ng/ml

Conclusions

There was little effect of dietary fat source on follicle development, but both circulating P4 and CL volume were altered by dietary fat source.

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RMIS 5890

Animal Health and Well-Being

Dictyocaulus viviparus: a longitudinal study of bulk milk seropositivity in a subset of Irish dairy herds using an ELISA technique

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Introduction

Although a live vaccine and a number of effective anthelmintic drugs are available against *D. viviparus* in adult dairy cows, infections are widely reported in many parts of Western Europe (Esker and Hubert, 2002). Prior to the development of an enzyme-linked immunosorbent assay (ELISA) for the detection of *D. viviparus* in bovines, the Baermann technique was used for diagnosis of patent *D. viviparus* infections. Unlike this technique, the ELISA for detecting antibodies against *D. viviparus* can test bulk milk and individual blood (Schnieder, 1992) instead of faecal material yielding an adaptable easy to use and inexpensive method to determine the seropositivity to *D. viviparus* in dairy herds. The objective of this study was to a) sample a subset of Irish dairy herds over a twelve month period, b) determine bulk milk seropositivity to *D. viviparus* within these herds, c) determine the usefulness of bulk milk analysis as a screening tool in an Irish context.

Materials and methods

Bulk tank milk samples were collected from 22 commercial dairy farms in the Munster region and seven Teagasc dairy farms located throughout Ireland over a 12-month period (March 2009 to March 2010). Milk samples were centrifuged at 20,000g for 1 minute, de-fatted and the supernatant frozen at -80^{o}C until analysed. Testing was carried out using a recently developed ELISA test, which is based on recombinant major sperm protein (Fiedor *et al.,* 2009). The adopted cut-off value between negative and positive ELISA results was 0.493 optical density ratio (ODR) value. To demonstrate the longitudinal seropositivity of these dairy farms, the mean ODR values were calculated and plotted over time with error bars using SPSS. On completion of the trial each study participant was interviewed to determine the clinical histories for each herd during the course of the 2009 lactation.

Results and Discussion

D. viviparus disease outbreaks commonly occur between June and November (Urquhart *et al.*, 1996). This study highlighted two increases in mean ODR values during this time period, namely June and July and later in the season during October to December (Figure 1), which agrees with the expected clinical risk period for lungworm infections in temperate climates. This study shows that infection with *D. viviparus* is common in this sample of dairy herds in Ireland and indicates that vigilance and control measures may be required. In addition, on one of the study farms a severe clinical outbreak of *D. viviparus* occurred in the month of August. Over the two months prior to this disease outbreak the bulk tank milk ELISA showed a rise in ODR value on this farm. With routine screening for *D. viviparus* through bulk milk analysis, this study farm could have been informed of the likelihood of a clinical outbreak, which would have allowed preventative treatment to be instigated. On the basis of this, all study participants continue to be monitored for rises in bulk milk seropositivity and participants have been made aware of the signs of dictyocaulosis clinical infections to allow further associations between bulk milk seropositivity and clinical disease to be recorded.

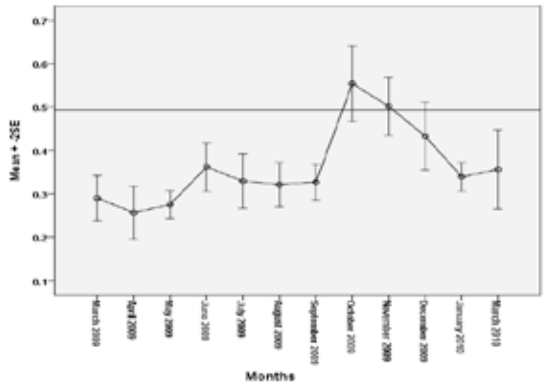

Figure 1. Monthly standard error of mean ODR values across all study farms

Conclusion

Use of a bulk milk ELISA screening technique will provide farmers and veterinarians with an additional diagnostic tool to allow assessment of the potential risk of parasitic bronchitis and to strategically implement appropriate measures. Routine screening for *D. viviparus* in dairy herds using bulk milk samples can now be implemented and would greatly contribute to the reduction of *D. viviparus*.

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RMIS 5900

Calf loss on commercial dairy farms - a problem revisited

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Introduction

Calf loss has always been a significant welfare and economic problem in Irish dairy herds (Greene, 1978). In recent years there has been no research work carried out on this problem as funding has gravitated towards other issues within the animal health sphere. However, following solicitations from commercial dairy farmers in Munster this problem was revisited in 2010 with the commencement of a prospective longitudinal study of the extent, nature and causes of calf loss in the periparturient period. This is a collaborative research project involving the local Cork Regional Veterinary Laboratory, the Central Veterinary Research Laboratory of DAFF, UCD, ICBF, AFBI and SAC.

Materials and methods

Between January and June 2010, 227 necropsy examinations were carried out on calves which died within 48h of calving on 30 spring-calving dairy farms (1-23 calves/farm) with high and low calf mortality. Epidemiological data were collected on carcass submission questionnaire forms and necropsies were carried out at Moorepark Dairy Production Research Centre. Additional laboratory analyses were conducted by the veterinary laboratories of the Department of Agriculture and Food in Cork (microbiological culture, fetal serology for Leptospira hardjo and Neospora caninum-Immunocomb), Limerick (maternal blood selenium) and Backweston (liver copper, cobalt and selenium and kidney selenium analysis and BVDv tissue PCR, and BVDv serum antigen and antibody assays and histopathology slide preparation), the Veterinary Sciences Division of AFBI in Stormont, Northern Ireland (maternal blood plasma inorganic iodine, copper and magnesium) and the Scottish Agricultural Colleges (SAC), Penicuik, Scotland (neonatal hepatic and serum vitamin A and E analyses).

Results and Discussion

Of the 227 calves submitted, 206 (91%) were singletons, 160 (70%) were from pluriparae and 139 (61%) were male. One hundred and five (46%) were unobserved/unassisted at calving and 77 (34%) had difficult (score $\geq$3) calvings. The majority of calves had a history of dead at birth/stillborn (77%). In almost half the calves their lungs were completely atelectatic (49%) with the remainder partially atelectatic (27%) or inflated (24%). The mean death weight of the calves was 34.8kg. These epidemiological and pathological findings are similar to those reported in the pilot study on perinatal mortality conducted in 2009 in a smaller group of herds. In addition to the time and cause of death, the absolute and relative weights of nine internal organs were recorded (n~7,000 records) in each carcass. These data will be used to detect abnormal organometry, to determine baseline values for various categories of calves and to compare with archival datasets of organs weights to determine temporal trends. For example, on average, the absolute and relative thyroid gland weight of this cohort (15.1g and 0.44, respectively) was normal, but goitrous glands (up to 53g and 1.15) were also detected. The five most significant causes of mortality detected were lethal congenital defects, prolonged calvings, premature placental separation, malpresentations and malpostures and anoxia. Of the lethal congenital defects, atresia of the small and large intestines (not the anus) was the most common (Mee and Kenneally, 2010). This finding warrants further research to determine how repeatable these defects are in this cattle population, how widespread these defects are in other Irish cattle populations and whether there is a genetic basis for these defects. Over a quarter (26%) of all calves had a non-lethal, sub-lethal or lethal congenital defect detected. Many of these would normally go undiagnosed without a detailed necropsy examination.

The findings from the initial year of this study in commercial dairy herds have confirmed many of the findings of the pilot study. In addition they have created a large, current dataset of epidemiological and pathological factors associated with both the timing and the causes of calf mortality in the periparturient period; unique internationally. This dataset can be used to refine our current diagnostic criteria (Mee, 2010). Further validation and analysis of these data is required before more comprehensive conclusions can be drawn.

Conclusions

This initial analysis of the data indicates that the majority of perinatal mortality cases on these commercial farms are stillborn, singleton males with partially or completely atelectatic lungs from pluriparae. A surprisingly high proportion of calves had congenital defects some lethal cases of which warrant further research.

Acknowledgements

The authors thank the participating dairy farmers for their collaboration in this research study and the cooperation of colleagues in the Veterinary Laboratory Services of DAFF.

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RMIS 5902

Effect of pre-weaning housing type on calf weight gain and health

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Introduction

With 50% of dairy farmers intending to expand over the coming years (O'Donnell *et al.*, 2009) management systems for larger numbers of calves will become increasingly important. Greater numbers of calves will necessitate the provision of more housing facilities. Therefore, housing options that ensure healthy calves with high levels of weight gain need to be investigated. The objective of this study was i) to compare indoor and outdoor calf rearing systems and ii) to determine the level of shelter necessary with outdoor rearing.

Materials and Methods

One hundred and eight spring born heifer calves from the Teagasc Moorepark spring calving herd were randomly assigned to one of three housing treatments at birth (mean date of birth 18 February 2010; s.d. 18 days) on the basis of breed (Holstein Friesian; Jersey cross or Norwegian Red) and birth weight (37.1, s.d. 5.14 kg). The three treatments were: i) indoors in a conventional straw bedded housing system (I), ii) outdoors provided with a portable roofed steel shelter (SH; Figure 1) or iii) outdoors provided with large straw bales in an 'X' shape (ST; Figure 2). The experiment ran from birth through to 21 July 2010. There were 18 calves per group. Once groups were filled a replicate of each treatment was created. Thus there were 6 groups of calves in total, 2 groups per treatment.

Calves that were assigned to the outdoor treatments were immediately moved to another housing facility away from the main calving shed to ensure no sharing of air space. Here, they were housed in their groups until turnout at approximately three weeks of age.

All calves were given colostrum and removed from their dam within one hour of birth. Whole milk, at a rate of 4.5 litres/calf/day, was offered twice daily for the first three weeks and once daily thereafter until weaning. All calves were offered fresh water, *ad libitum* concentrate and *ad libitum* hay.

Calves were weaned at approximately 11 weeks of age. Following weaning all calves were offered *ad-libitum* grass outdoors and 1.5 kg concentrate/calf/day for 6-weeks. Calves were weighed weekly pre-weaning and every second week post-weaning until the experiment finished. All treatments administered throughout the experiment were recorded as were any incidences of mortality. Data were analysed using analysis of variance and the PROC MIXED statement of SAS, where animal was the experimental unit. The model included replicate, treatment, month and the interaction of group and treatment.

Results and Discussion

No interactions between treatment and replicate were found. Mean weaning date was similar between all treatments (8 May). There was no difference between treatments in the number of days from birth to weaning (81 days). Daily weight gain from birth to weaning was similar for calves in the SH and ST treatments (0.54 kg/calf/day). Calves from both of these treatments had higher ($P<0.05$) daily weight gains pre-weaning than calves from the I treatment (Table 1). Illness and mortality rate was greatest indoors, followed by the ST treatment. Number of veterinary/medical treatments administered was lowest in the SH treatment (1 treatment) with no mortality observed, compared to the I and ST treatments (0.11 and 0.06, respectively).

Rearing calves outdoors compared to indoors tended ($P=0.175$; Table 1) to increase weight gain up to the 21st July (72 days after mean weaning date).

Figure 1. Steel roofed shelter, providing both wind and rain protection

Figure 2. Large straw bales in an 'X' shape to provide shelter

Table 1. Birth weight, pre-weaning weight gain and weight on 21st July 2010

(kg)	IN	SH	ST	SED	Sig
Birth weight	37	38	36	1.76	0.300
Weight gain to weaning	0.48^a	0.55^b	0.53^b	0.032	0.032
Weight 21 July 2010	126	135	131	6.56	0.175

Conclusions

The results from this study show that calves reared outdoors had higher weight gains during the pre-weaning period. They also tended to be heavier 10 weeks post-weaning. Furthermore, when calves were reared outdoors and provided with shelter from wind and rain they were healthier and less incidences of mortality occurred.

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RMIS 6009

Animal facilities, labour, automation and energy efficiency

Cow overmilking in a single operator side-by-side parlour as influenced by parlour size and pre-milking routine
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Introduction
A milk quota policy change coming into effect in 2015 is expected to lead to rapid expansion of dairy herds in Ireland. Efficient milking systems, in terms of labour demand, capital investment and cow udder health are critical to successful expansion. Some Irish farmers managing larger herds that have undergone expansion are reporting issues with milking management, in particular optimizing udder health (minimizing somatic cell count and clinical mastitis) and the length of time it takes to milk the herd (efficiency). In Ireland most parlours are swingover herringbone or side-by-side without automatic cluster removers (ACR). Overmilking is one consequence of milking management that contributes to mastitis risk (Hillerton *et al.*, 2002). Overmilking is defined as the period when teatcups remain attached to teats after the milk flow rate from an individual cow has fallen below an arbitrary 'end-point' of milking e.g. a milk flow rate of 200 mL/minute. The objective of this study was to establish the effect of parlour size (number of clusters) and pre-milking routine (full and minimal) on overmilking of cows in late lactation, in a single operator side-by-side, swingover milking parlour with stanchion bailing.

Materials and Methods
The approach was to simulate milking in a parlour without ACR, using the time between ACR detachment and attachment of that cluster to the next row to calculate overmilking duration. The experiment was conducted at the Moorepark Research Farm milking parlour which had 30 clusters, ACR and data recording software (DairyMaster, Ireland). The ACR were set to activate at a milk flow rate threshold of 200 mL/minute. A 2x5 factorial design was used to study the effects of milking routine and parlour size on overmilking duration. Five combinations of parlour size (14, 18, 22, 26 and 30 clusters) were examined, each with two different pre-milking routines (Full: spray, strip, wipe, attach clusters, and Min: attach clusters) and one milking operator. The cows (up to 120) were randomly assigned to groups (n = 14, 18, 22, 26 or 30) before each milking session. The trial was carried out over 40 milking sessions in total. Row within a milking session was the experimental unit. Four rows of cows were milked at each session giving three data points (cluster changeovers) per session. Each combination of routine and parlour size were tested at four sessions (two AM, two PM) giving a total of 12 values for each combination. The data was analysed as mixed models fitted using REML in GenStat 13.2.

Results and Discussion
A full pre-milking routine (compared to minimum) significantly reduced time to milk letdown, milking time and average flowrate ($P<0.05$) but did not affect milk yield (Table 1). Almost all parlour sizes and routines, cows were overmilked assuming overmilking occurred when milk flowrate was <200ml/min.

Table 1: Mean milking characteristics for late lactation cows, milked using two different pre-milking routines

Stage	Variable	Full	Min	SED	P value
Late lactation	Milk yield (kg/milking)	7.1	7.3	0.19	0.275
	Milking time (min)	4.41	4.78	0.06	<0.001
	Time to milk letdown (min)	0.76	1.05	0.04	<0.001
	Maximum flow (kg/min)	3.25	3.11	0.06	0.029
	Average flow (kg/min)	1.58	1.49	0.03	0<0.05

SED = standard error of difference

As cluster number increased, the duration of overmilking increased at a greater rate with a full compared to minimum routine (Figure 1). Thus, the use of pre-milking preparation decreased milking time per cow but as parlour size increased, milking row times, as well as the proportion of cows that were overmilked, also increased, thereby reducing overall efficiency.

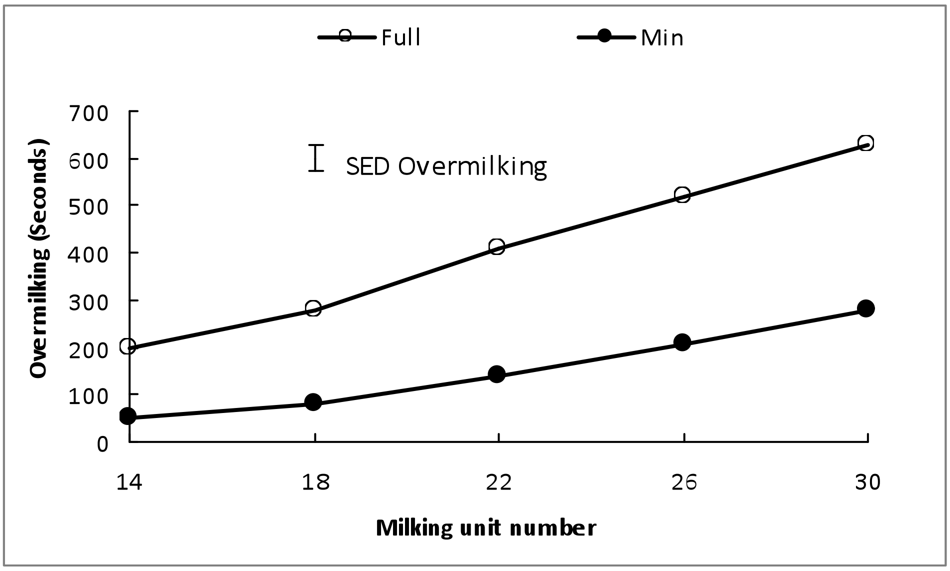

Figure 1. Overmilking time for cows milked in a parlour with 14, 18, 22, 26 or 30 clusters, and two different pre-milking routines (Full and Min), when cows were in late lactation

Conclusions

These results have implications for milking management in late lactation in single operator swingover parlours without ACR. As parlour size increases, a pre-milking routine including fore-stripping reduces milking time per cow but increases the extent of overmilking at a greater rate than a minimum routine. The consequences of overmilking for mastitis risk requires investigation.

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RMIS 5897

Suitability of air-source heat pumps for water heating on Irish dairy farms

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Introduction

Energy audits carried out by Teagasc Moorepark in 2009 identified water heating as one of the major consumers of electricity, accounting for over 30% of total electrical energy used making it the second largest user of electricity on Irish dairy farms. The most common method of providing hot water on dairy farms is electrical water heating. The aim of this study was to determine if air source heat pump water heaters (HPWH) could offer benefit to Irish dairy farmers and provide hot water with lower power consumption than conventional electrical water heaters. A HPWH operates on an electrically driven vapour-compression cycle and pumps energy from the air in its surroundings to water in a storage tank, thus raising the temperature of the water (Hepbasli *et al.,* 2009).

Materials and Methods

The heat pump (HP) chosen had a water tank capacity of 300 litre. The HP itself was rated at 1.5kW input power and was capable of heating the tank of water to 55^{0}C. The 1.5kW electrical immersion element was capable of achieving a final water temperature of 80^{0}C, which is required for milking equipment cleaning. A destratification pump was fitted to aid mixing of the water within the tank. A destratification pump is a circulation pump fitted to the hot water storage vessel which circulates the water from top to bottom overcoming the temperature stratification of the stored water. Six treatments were devised (Table 1) and each treatment was replicated five times in order to detect a difference of 0.2 in S.D. with a power of 80% and 6 treatments. Ambient air temperature was kept constant in a temperature controlled room and inlet water temperature and pressure were kept constant in all cases. The water temperature rise in the tank and power consumed by the compressor was recorded. The amount of useable hot water was also recorded using thermocouples and flow meters calibrated to ISO17025. Data was analysed using the PROC GLM statement of SAS. Litres of hot water produced per kWh of electricity consumed was the comparable factor across treatments.

Results and Discussion

Treatment 5 & 6 as described in Table 1 represent the traditional electrical water heating approach. Treatment 1, 2, 3 & 4 offer significantly more hot water per kWh consumed than treatment 5 & 6 ($p<0.001$). This is a direct result of the contribution of the air source HP. Treatments where destratification or mixing was employed offered significantly more hot water per kWh consumed than treatments where destratification was not used ($p<0.001$). The presence of a baffle plate in the tank to direct incoming cold water away from the body of heated water was an important factor in achieving these results. The HP tested requires an ambient air temperature of greater than 8^{0}C. Below this critical temperature the HP will cut out and rely on the immersion element to provide 100% of the heating, likewise when the condenser reaches 55^{0}C. Air temperature in the south of Ireland is below 8^{0}C 25.3% of the time between February and November (Met Eireann weather station, Fermoy, Co. Cork). The HP should operate between the hours of 12 midnight to 9am to avail of night rate electricity which is half the cost of day rate electricity. The temperature in Ireland is below 8^{0}C 37% of the time during night rate hours between February and November.

Table 1. Effect of treatment on heating time, power consumption and hot water production

	Heat Pump Status	Immersion Element Status	Mixed	T	Air In (^{0}C)	Energy Consumed (kWh)	Useable water (l) **	l/kWh	S.D. kWh
1	On from 14 to 55 ^{0}C	On from 55 to 80 ^{0}C	No	13	17.9	11.67	146.6	12.56	.09
2	On from 14 to 55 ^{0}C	On from 55 to 80 ^{0}C	Yes	19	17.7	19.0	287.6	15.12	0.24
3	On from 14 to 55 ^{0}C	On from 14 to 80 ^{0}C	No	7.5	17.8	16.1	164.8	10.26	.04
4	On from 14 to 55 ^{0}C	On from 14 to 80 ^{0}C	Yes	12	17.4	23.9	281.6	11.8	0.05
5	Off	On from 14 to 80 ^{0}C	No	10	N/A	15.6	136.4	8.76	.02
6	Off	On from 14 to 80 ^{0}C	Yes	19	N/A	29.3	282.8	9.66	0.04

** Useable hot water is defined as the amount of water extracted from a cylinder between 60^{0}C and 80^{0}C

Conclusions

The air source HP can offer significant gains in terms of kWh consumption for water heating when tested in laboratory conditions. However the 'Heating Times' shown in Table 1, of up to 19 hours, together with analysis of local climatic conditions makes this particular air-source HP non viable for Irish conditions.

Acknowledgements

We acknowledge the Dairy Levy Fund for financial support.

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RMIS 5899

Conditions affecting the performance of Plate Heat Exchangers in milk cooling

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Introduction

The vast majority of Irish Dairy Farms employ Plate Heat Exchangers (PHE) to pre-cool milk before entry to the bulk refrigeration tank. The operating method of a PHE is to pass milk through the heat exchanger whilst cold water is concurrently pumped through the opposite side. The cold water absorbs a portion of the heat, thus pre-cooling the milk. Milk refrigeration is the largest energy consumer on dairy farms at 37% of total consumption (Upton *et al.,* 2010). Improvements in milk pre-cooling dramatically reduce cooling time and energy usage. Results from PHE audits conducted by Teagasc, Moorepark in 2010 found that performance levels for PHE pre-cooling were substantially lower then expected. On every site audited it was found that improper PHE capacity, water flow rates and milk to water ratios were inhibiting the PHE heat transfer performance (Upton *et al.,* 2010). The aim of this research is to examine how varying milk to water flow ratios and PHE capacity (number of plates) affects milk pre-cooling.

Materials and Methods

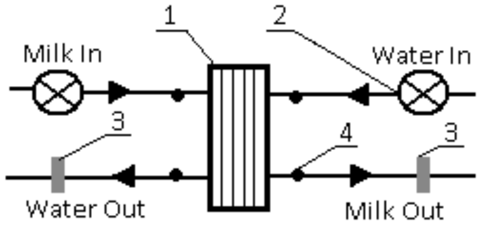

Figure 1: PHE test rig: 1-PHE, 2-Variable Speed Pump, 3- Ultra Sonic Flow Meter, 4- Type K Thermocouple

A single pass PHE was selected for testing. The individual plates were gasket sealed with a chevron angle of 60°. This model of PHE was selected as it is very popular on medium to large dairy farms. The PHE testing consisted of a series of milk to water ratio tests at varying capacities. The milk flow rate chosen was specified by the manufacturer and kept constant during every test. The water flow rate was supplied in multiples of one, two, three and four times the milk flow rate. Initially the PHE test rig (Figure 1) was fitted with the minimum number of plates specified by the manufacturer for this model (25 plates). Four extra plates were added after each test in order to increase the PHE capacity. The milk and water used for each test was maintained at a constant 35°C and 10°C respectively. Once the PHE came into thermal equilibrium at a set ratio the milk exit temperatures were recorded (Figure 2).

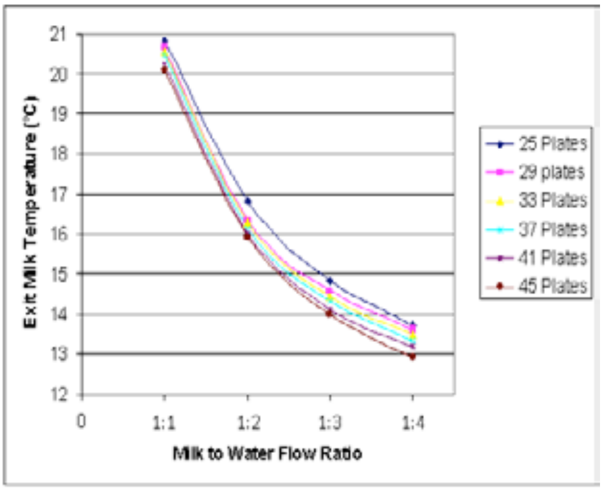

Figure 2: Milk exit temperature for varying ratios and PHE capacities.

Results and Discussion

The most noticeable result from the above test is the reduction in milk temperature corresponding with the increased milk to water ratio. However it takes an ever increasing water flow rate to reduce the milk temperature, as the ratio increases the cooling effect per litre of water is reduced. Another observation from the test is the influence of increased plate capacity on milk temperature. The addition of extra plates improved the performance of the PHE, however the influence of added capacity is very small relative to the impact of increased milk to water ratio. The addition of extra plates to the heat exchanger increases its heat transfer area however this also increases the number of flow channels, thus reducing the milk and water flow velocity at constant flow rates. This reduction in velocity leads to a lesser Reynolds number and Nusselt number causing a decrease in the overall heat transfer coefficient.

Conclusions

A PHE can provide excellent levels of milk pre-cooling under favourable operating conditions. In order to achieve a satisfactory cooling rate a high milk to water flow ratio is critical. Over sizing the capacity is not a viable solution due to the nature in which heat is transferred in a PHE. In recent years variable speed milk pumps have become very popular and are now standard in many milking machine models. Due to the dynamic milk flow rate produced by these machines it is very difficult to size a PHE and select a suitable water flow rate. In such cases a water flow rate control system is required. The development of such a system is a priority in the future research of Teagasc Moorepark.

Acknowledgements

We acknowledge the Dairy Levy Fund for financial support.

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RMIS 5899

A life cycle assessment of seasonal grass-based and confinement total mixed ration dairy farms

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Introduction

In 2015, the EU plan to remove the milk quota system and this is expected to result in an increase in milk output. Within a non-quota environment land availability will be a key constraint facing Irish grass-based milk producers (O'Donnell *et al.*, 2008). In cases where land availability is a major barrier, producers may decide to change from grass-based to confinement total mixed ration (TMR) systems. In conjunction with milk quota abolition, there will be increasing emphasis on sustainable production. Thus, producers in the future will have to comply with limits on greenhouse gas (GHG) emissions and other noxious gaseous emissions e.g. NH_3 and further reduce diffuse pollution of water and soil from N and P (Powers, 2003). Considering these expected policy changes, the aim of this study was to quantify the environmental impacts of a seasonal grass-based and a confinement TMR system using life cycle assessment (LCA; ISO 2006).

Materials and Method

Physical data required to conduct an LCA of each system was obtained from a 1-yr study conducted at Moorepark (Patton et al. unpublished). The grass-based system had an N fertilizer input of 290 kg of N/ha and received 425 kg of dry matter (DM) concentrate per cow in early lactation. The TMR system consisted of (g/kg DM) maize silage (260), grass silage (230), barley straw (80) and concentrate (380). Grass silage was the only home-grown feed in the TMR system. Holstein-Friesian cows in both systems were of similar genetic merit. The length of lactation for each system was 305 days and the number of cows for each system was 90. An LCA model developed using Simapro software was used to evaluate both systems. The biological component of a whole farm model (Shalloo *et al.*, 2004) was incorporated into the LCA model to quantify key biological processes e.g. feed demand. The LCA model was delimited to assess environmental impacts of all processes up until the point milk was sold from the farm. Thus, the environmental impacts from the production of inputs brought onto the farm e.g. manufacture of fertiliser were included. Greenhouse gas emissions, non-renewable energy use (NEU), total land use (TLU), acidification (AP) and eutrophication (EP) were the environmental impacts selected. Each environmental impact was characterised by multiplying emissions or resources by the appropriate factor. For example, GHG emissions CH_4, N_2O and CO_2 were characterised into CO_2 equivalents (eq) by multiplying by the factors 21, 310, and 1 (IPCC, 1996), respectively. Environmental impacts were expressed per kg of fat and protein corrected milk (FPCM), per kg of milk solids and per ha of farmland. Besides producing milk dairy farms also produce meat. Thus, environmental impacts were allocated between these products using a biological allocation approach (Cederberg and Stadig, 2003), where impacts were related to the cow's use of feed to produce milk and meat. Allocation of impacts was also necessary for some concentrate ingredients e.g. palm kernel meal because they are by-products. For these inputs impacts were allocated based on their relative economic value.

Results and Discussion

The results of Table 1 show that the grass-based system required less TLU and NEU than the confinement TMR system. The TMR system also demonstrated poorer environmental performance with greater GHG emissions, AP and EP. In both systems feed was a major consumer of resources and source of emissions. Other important sources of emissions were enteric CH_4 and NH_3 from manure. Resource use and emissions from concentrate production were greater than pasture production. Overall the grass based system had a lower environmental impact when compared to the confinement TMR system.

Table 1. Environmental impacts expressed per kg of fat and protein corrected milk (FPCM), per kg of milk solids and per hectare of farmland for a grass-based (Grass) and a confinement total mixed ration (TMR) dairy farm.

Impact Category	per kg of FPCM		per kg of milk solids		per farm ha	
	Grass	TMR	Grass	TMR	Grass	TMR
GHG (kg CO_2-eq)	0.84	1.01	11.30	13.74	13,006	33,053
AP (kg SO_2-eq)	0.009	0.014	0.121	0.186	136.58	436.00
EP (kg PO_4-eq)	0.003	0.004	0.045	0.060	51.79	141.27
NEU (MJ)	2.80	3.81	37.48	51.69	41,185	119,030
TLU (m^2/year)	0.83	1.02	11.15	14.02	10,000	10,000

Conclusions

This study indicates that grass-based dairy systems require fewer resources and have a lower environmental impact compared to confinement TMR systems. However, further comparisons with a greater number of farming systems are required.

Acknowledgements

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RMIS 5668

Investigation of the relationship between bodyweight and grass dry matter intake in Irish dairy cows

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Introduction

Bodyweight is a variable commonly used in grass dry matter intake (GDMI) prediction of dairy cows due to the relationship between GDMI and bodyweight. A GDMI database was created containing information on animal, grass, supplementary feed and environmental variables recorded during the GDMI measurement periods. Bodyweight is one of the variables included in this database. Due to its importance as a key driver of GDMI, the relationship between bodyweight and GDMI for Irish cows was investigated using the data compiled in the database.

Materials and Methods

A database was created containing information from studies conducted over the period 1988 to 2009 on the research farms of Teagasc, Moorepark. Studies were required to meet the following criteria for inclusion:

1. Animals were offered grazed grass as the main portion of their diet
2. GDMI estimates utilised the n-alkane technique
3. Animals were from spring calving herds
4. Animals had milk production and milk composition data available for the same week that the GDMI was estimated.

Grass DMI was estimated using the n-alkane technique (Mayes *et al.,* 1986) as modified by Dillon and Stakelum (1989) and 184 other variables were included in the GDMI database (60 grass, 48 animal, 29 experimental, 45 supplementation and 2 environmental). For the purpose of this study GDMI data points that had data pertaining to the bodyweight of the animal at the time of the GDMI measurement, to a maximum of 3 weeks pre or 3 weeks post the GDMI measurement period, were selected from the database. Data outside this range were excluded from the study. These data were isolated and analysed in order to ascertain the relationship between GDMI and bodyweight. Bodyweight was recorded electronically using portable weighing scales and the Winweigh software package (Tru-test Limited, Auckland, New Zealand). Regression analysis (PROC REG) was used to determine the relationship between bodyweight and GDMI (SAS, 2006).

Results and Discussion

From the GDMI database 8,727 GDMI measurements had an accompanying bodyweight within 3 weeks pre or 3 weeks post the GDMI measurement period. The relationship between bodyweight and GDMI is shown in Figure 1. There was a significant (P<0.001) relationship between bodyweight and GDMI. Bodyweight explained 27% of the actual GDMI during the measurement period. For each 100 kg increase in bodyweight the GDMI of the cow increased by 2.42 kg. This is similar to the findings of Stakelum and Connolly (1987) who found that for each 100 kg increase in bodyweight GDMI increased by between 1.5 and 2.2 kg and Butler *et al.* (2003) who also found that GDMI increased by between 0.9 and 1.3 kg DM per 100 kg increase in bodyweight. These were calculated using multiple regression equations.

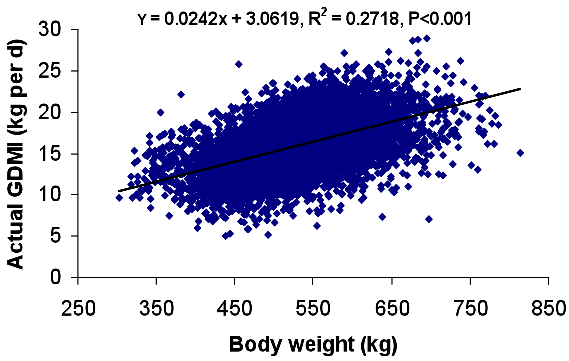

Figure 1. Relationship between bodyweight and actual grass dry matter intake for the 8,727 intakes analysed from the GDMI database.

Conclusions

The results from this study indicate that there is a strong relationship between bodyweight and GDMI. This highlights bodyweight as a useful variable in the development of multiple regression equations or a prediction model to predict GDMI.

Acknowledgements
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RMIS 5793

Variation in perennial ryegrass quality in a national variety evaluation scheme
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Introduction
National variety evaluation schemes have primarily focused on measuring yield and persistency of grass cultivars. Increasing the quality of grass swards can increase the efficiency and profitability of grass-based farming systems and should be reflected in evaluation schemes (O'Donovan *et al.*, 2010). The national variety evaluation system in Ireland has recently been supplemented with estimates of quality traits so as to improve predictions of the animal production value of perennial ryegrass (*Lolium perenne L.*) cultivars (Grogan and Gilliland, 2010). This paper investigates the *in vitro* dry matter digestibility (DMD) and water soluble carbohydrate (WSC) content of perennial ryegrass cultivars and makes comparisons within the ploidy and maturity categories and across the growing season, from four harvest years.

Materials and Methods
Four sowings of 15 perennial ryegrass cultivars (6 intermediate, 9 late; 6 diploid, 9 tetraploid) in replicated national variety evaluation field trials at Backweston, were sampled in four separate years. Trial management and yield analysis were as described by Grogan and Gilliland (2010). A *c.*300 g sub-sample was taken from each plot and analysed using near infra-red spectroscopy (Burns *et al.,* 2011) for DMD and WSC. Data were analysed using ANOVA that included terms for ploidy and maturity blocked by replicates and REML analysis for combined effects and interaction of ploidy and maturity.

Results and Discussion
The only significant interactions were between ploidy and maturity at 'Silage 1', when diploid intermediates had the lowest WSC and DMD values. The highest DMD was in 'Spring' when the swards had a higher leaf to stem ratio. Differences between cultivars were highly significant throughout the growing season, reflecting breeding effort to improve this trait. Significant differences also occurred between ploidies at all seasonal periods. Tetraploids had higher DMD at all periods except 'Silage 2' where diploids had a higher DMD. Differences between maturities were only expressed in the earlier part of the year, with intermediates having a higher DMD in 'Spring' and this trend was reversed for the two silage cuts. The WSC content was highest in spring and decreased through the growing season. Differences between cultivars existed at each seasonal period except 'Silage 2'. No significant difference existed between ploidies at 'Silage 2'. During all other seasonal periods tetraploids had higher WSC contents. The only significant difference between maturities occurred at 'Silage 1' with late heading cultivars having a higher WSC content.

Table 1. Variation of dry matter digestibility and water soluble carbohydrate values in perennial ryegrass

	DMD (g kg^{-1})				WSC in DM(g kg^{-1})			
	Spring^{+}	Sil. 1	Sil. 2	ROY	Spring^{+}	Sil. 1	Sil. 2	ROY
Diploid	835	771	785	789	272	182	156	145
Tetraploid	847	788	793	792	292	201	156	156
Intermediate	845	759.	785	789	281	178	160	154
Late	840	795	793	792	283	202	153	148
S.E.M.[1]	4.19	6.66	5.19	4.30	6.27	7.92	8.10	5.59
Ploidy	***	***	**	***	***	***	NS	***
Within Diploid	NS	**	**	NS	NS	***	NS	NS
Within Tetraploid	*	***	*	NS	***	NS	*	*
Maturity	*	***	***	NS	NS	***	NS	NS
Within Intermediate	**	***	NS	**	***	***	NS	**
Within Late	**	NS	*	**	***	NS	*	*
Ploidy x Maturity	NS	***	NS	NS	NS	***	NS	NS
Cultivar	***	***	***	***	***	***	NS	**

The seasonal periods Spring, Sil. 1 and Sil. 2 and ROY = simulated spring grazing, first and second silage cut, and simulated grazing for remainder of year. $^{+}$ No Spring cut in 2006. *;**;*** and NS represent P < 0.05, P < 0.01, P < 0.001 and P > 0.05 respectively. [1]Standard Error of the mean for all 15 cultivars

Conclusions

The DMD and WSC values of perennial ryegrass cultivars vary throughout the growing season. As significant differences existed within ploidy and maturity other factors had a role in the variation within these quality variables. Although costs and workloads may preclude quality testing at every cut, the national evaluation scheme needs to account for this variation if a true estimate of the relative nutritive value of cultivars is to be attained.

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RMIS 5793

Economic index for ranking perennial ryegrass cultivars

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Introduction

Perennial ryegrass is the dominant forage grass in Ireland, accounting for 95% of all forage grass seed sold (Conaghan *et al.*, 2008). Dairy, beef and sheep grazing systems generally target calving or lambing to coincide with the onset of grass growth, thus maximising the proportion of grazed grass in the animals diet. The important traits in a grass based production systems include spring, mid-season and autumn dry matter (DM) yield, quality, 1st and 2nd cut silage DM yield and persistency. The objective of this study was to calculate the economic value of each trait of importance and rank grass cultivars based on their total economic merit.

Materials and Methods

The Moorepark Dairy Systems Model (Shalloo *et al.*, 2004) was used to simulate a model dairy farm with all herd parameters, nutritional requirements, land use, total inputs and outputs, fixed and variable costs and receipts included for a full calendar year. The model assumed a spring-calving grass-based milk production system with a 365-d calving interval and a mean calving date of 24th February with 40 ha of land, 84 cows and an annual grass DM production of 13 t DM/ha. The economic value for each trait was calculated by simulating a physical change in each trait independently and calculating the effect of the change on the profitability of the system.

Production data was generated from a simulated grazing trial for 12 cultivars across 3 years (2007 to 2009). All DM yield and quality data were analysed using Proc Mixed in SAS. The economic values were then applied to the difference between the average of the 12 cultivars and the actual yield or quality value for each cultivar to determine the economic merit of each cultivar for each trait.

Results and Discussion

The calculated economic values (expressed in €) for a unit change in each trait are shown in Table 1. Table 2 presents the actual DM yield and quality data for each cultivar from the simulated grazing trial. The economic values were applied to the biological data and the results are presented in Table 3 which shows the economic merit for each trait and the total economic merit (sum of each trait) for 12 perennial ryegrass cultivars. The economic values for quality and spring DM yield have a large effect on the total economic merit of a cultivar. No persistency data were available so persistency has been excluded from the results. It is likely however, that the ranking of individual varieties will adjust when persistency data are included.

Table 1. Economic values (€ per ha/year) per unit change in DM yield, quality, persistency and silage yield

Production (€ per kg DM Δ /ha)			Quality (€ per unit decrease in DMD)						€/ % Δ /ha/yr	€/kg DM Δ in silage	
Spring	Summer	Autumn	Apr	May	Jun	Jul	Aug	Sept	Persistency	1st cut	2nd cut
0.15	0.03	0.10	-0.001	-0.008	-0.010	-0.009	-0.008	-0.006	-4.96	0.03	0.02

Table 2. Biological data of individual cultivar performance and the average of the 12 cultivars for yield, silage production and quality

	DM yields (Kg DM/ha)			Quality (DMD g/kg DM)						Silage DM Yield (kg DM/ha)	
Cultivar	Spring	Summer	Autumn	Apr	May	Jun	Jul	Aug	Sept	1st cut	2nd cut
A	1766	6282	3870	849	825	805	826	812	804	5730	3203
B	1718	6459	3853	861	829	808	823	823	809	5393	3691
C	1592	6302	3825	848	825	806	826	794	805	5160	3371
D	2193	6471	3843	844	821	800	810	811	796	5434	3503
E	1590	6396	4171	857	838	811	834	828	818	5015	3480
F	1616	6468	3712	847	832	803	826	818	810	6045	3428
G	1886	6735	4183	853	832	802	824	811	786	5484	3209
H	2075	6763	4174	864	830	815	831	822	809	5042	3203
I	1741	6325	3918	860	828	817	827	813	808	5626	3719
J	1812	6657	3895	855	839	815	821	825	820	5644	3825
K	1610	6384	3942	851	834	811	833	824	839	5339	3532
L	2048	6242	3948	850	817	798	816	802	788	5365	3264
Average	1804	6457	3944	853	829	808	825	815	808	5440	3452

Table 3. Economic values applied to biological data resulting in total economic merit of 12 perennial ryegrass cultivars (values are in €/ha per year)

Cultivar	DM yield	Quality	Silage	Total economic merit	Rank
A	-19	-11	4	-25	9
B	-22	9	4	-9	8
C	-49	-29	-12	-90	12
D	49	-48	1	2	7
E	-11	44	-14	19	3
F	-52	2	21	-29	10
G	46	-26	-4	15	5
H	74	24	-20	78	1
I	-16	11	13	8	6
J	2	35	16	53	2
K	-32	50	-2	17	4
L	31	-62	-7	-38	11

Conclusions

The economic merit index identifies the strengths and weaknesses of individual cultivars on a trait by trait basis. By examining the sub-indices it is possible to select individual cultivars which can contribute to the requirements of a grazing system. This will simplify the selection of a grass mixture to provide the optimum balance of the desired traits to the system. Additional work on the persistency of cultivars is necessary before the economic value for persistency can be included in the total economic merit of a cultivar.

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RMIS 5793

First harvest year productivity of perennial ryegrass mixtures under a silage management

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Introduction

National recommended list trials are used to provide information on the suitability of perennial ryegrass (*Lolium perenne*) cultivars to Irish growing conditions. These trials evaluate cultivars as monocultures, yet in practice the vast majority of seed is sold in mixtures with three or more cultivars. It is known that the cultivar proportions in a mixture usually change after sowing, particularly in the first year, but the implications for sward productivity are complex and not definitively resolved (Gilliland *et al.,* 2010). It is widely believed, however, that mixtures are more adaptable to a diverse range of grassland enterprises. Rhodes (1970) found improved yield with mixtures over their components grown as monocultures, however, Culleton *et al.* (1986) and McBratney (1978) reported no advantage. The objective of this study was to compare the dry matter (DM) yield of monocultures and mixtures under silage management, in the first harvest year after an autumn sowing.

Materials and Methods

Plots (1.5m x 5m) were sown in August 2009 in a three replicate, spilt block design, comprising three perennial ryegrass cultivars, AberMagic (heading date (HD) May 28), Twystar (HD June 15) and Greengold (HD June 2), sown in monoculture and as mixtures. These mixtures were AberMagic/Twystar at 85:15, 70:30, 50:50, 30:70, 15:85; AberMagic/Greengold and Twystar/Greengold at 85:15, 70:30, 50:50, plus one equi-proportional tertiary mixture. At sowing, 32 kg N/ha (CAN) was applied, followed two weeks later by a further compound of 64 kg N/ha, 8.4 kg P/ha and 36 kg K/ha. In 2010, a 2-cut silage regime was imposed with cuts beginning in late March. Five cuts were taken in total across the year. Total fertiliser application for the year was 350 kg N/ha.

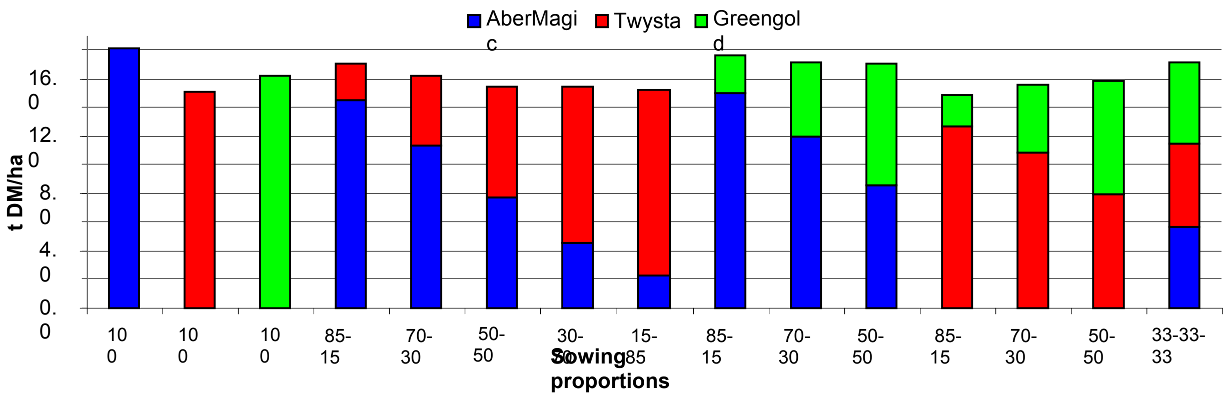

Figure 1. DM yield of monocultures, binary and tertiary mixtures of perennial ryegrass cultivars under a silage management

Plots were harvested with a motorised reciprocating blade (Etesia) and DM content determined on 0.1kg sub-samples dried for 48h at 40°C. Data were analysed using PROC Mixed in SAS (2003) using split plot analysis. Plot and treatment (variety and sown proportion) were included in the model.

Results and Discussion

Total DM production of the mixtures and monocultures for the year is shown in Figure 1. The monoculture AberMagic yielded 18.1 t DM/ha (P<0.01) compared to Greengold at 16.2 t DM/ha and Twystar at 15.2 t DM/ha. The highest producing mixture was sown with a majority content of the highest yielding cultivar (AberMagic/Greengold 85:15) and the lowest yielding mixture was sown with a majority content of the lowest yielding cultivar (Twystar/Greengold 85:15). These two mixtures yielded 17.6 t DM/ha and 14.8 t DM/ha, respectively (P<0.001). Overall, the yield of each binary mixture was intermediate to the yields of the two component cultivars. The yield of the mixtures was a reflection of the sown composition. There was no significant difference between the tertiary mixture and the two highest yielding monocultures but there was a significant yield advantage over Twystar (P<0.01; +2.1 t DM/ha).

Conclusions

In the first full growing season after an autumn sowing, the production of the binary mixtures reflected the production of their components grown as monocultures. This indicated that the performance of a cultivar in a mixture was predictable from its performance in monoculture. There was, however, some evidence of competitive change as the tertiary mixture out yielded two of its components. This suggests that sward composition has changed from what was sown to a situation where the percentage of the most productive cultivar in the sward had increased.

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RMIS 5793

Identifying individual perennial ryegrass cultivars in mixtures using starch gel electrophoresis

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Introduction

The dominant grass species used in agriculture in temperate managed grasslands is perennial ryegrass (*Lolium perenne* L.), particularly so in Ireland where perennial ryegrass accounts for 95% of forage seed sold (Conaghan *et al.,* 2008). There is extensive commercial breeding for new cultivars in this species and this is supported by official government recommended lists. Cultivars are evaluated as monocultures, however, it is normal agricultural practice to sow mixtures of these cultivars. This is perceived as giving greater adaptation to diverse farming enterprises. Previous work (Gilliland, 1995) has shown that cultivars compete once they are sown and the composition of the sward changes over time. The direction and magnitude of these changes is unclear, however, and no information is available on how individual cultivars will perform when sown in mixture. Cultivars of perennial ryegrass are morphologically similar, therefore, no botanical means are available to identify individual cultivars in a grass sward. However, varieties differ genetically; using starch gel electrophoresis, the changes in genotype frequency can be attributed to the changes of individual cultivars within the grass sward. The objective of the paper is to describe the standard starch gel electrophoresis technique used to identify individual grass cultivars in a perennial ryegrass sward and to illustrate how the method can be used to examine variety performance in a seed mixture.

Materials and Methods

The electrophoretic technique is based on isoenzyme banding patterns. Phosphoglucoisomerase (PGI) is a dimeric enzyme for which the bands can easily be translated into genotypes. Perennial ryegrass possesses two loci PGI-1 and PG1-2 and Hayward and McAdam (1977) established a methodology for displaying variety diversity at the PGI-2 locus. Perennial ryegrass has 3 common PGI-2 alleles A, B, C and a rarer D allele. The genotype of diploid cultivars will either be homozygous (AA, BB, CC or DD) or heterozygous (AB, AC, AD, BC, BD or CD). The methodology used in terms of leaf sampling, running starch gel electrophoresis and staining of gels to produce readable banding patterns was described by Kennedy *et al.* (1985). In the example below, the genotype frequency of two commercial diploid cultivars (AberMagic and Twystar) and their binary mixture was determined using this method. In order to give an accurate genotype frequency 200 leaves of each cultivar were sampled. The sample size (n) used to determine mixture frequencies was calculated using the chi squared distances (d) between the cultivars. This was converted to sample number using the formula.

$n = 67/d$ (Kennedy *et al.,* 1985)

Results and Discussion

The genotype frequencies of the two commercial cultivars selected is given in Table 1, in addition the table also contains the frequency of a 50:50 mix of the two cultivars

Table 1. Genotype frequencies of AberMagic and Twystar and a 50:50 mixture of the cultivars

Genotype	AberMagic	Twystar	50:50 mix
AA	0.01	0.22	0.115
AB	0.17	0.48	0.325
BB	0.74	0.19	0.465
AC	0.02	0.06	0.040
BC	0.06	0.05	0.055
CC	0.00	0.00	0.000

Table 2 shows how sample size changes with the distance between the component cultivars. As Chi Squared distances between the cultivars decreases (cultivars are genetically similar) sample size increases.

Table 2. Chi Squared distances and sample numbers

Distance	0.1	0.3	0.5	0.7	0.9
Number	670	223	134	96	74

By using replicated trials of the most distinct cultivars, sample size can be further reduced (e.g to 50 leaves per sample) and still retain the necessary precision level. Therefore the component cultivar selected must be sufficiently genetically different to give a manageable sample size (n) to allow the study of a range of different mixtures and managements. This needs to include sampling of the sward at several time periods across the year to allow changes in sward composition to be detected. Where cultivars show small differences in genotype frequency it may not be practical to examine their mixtures, as large sample sizes (n) would be necessary and moderate changes in sward composition may not be detected. Despite this limitation, a sufficient range of different cultivar types can be studied in mixtures, including comparison of ploidies and heading date to resolve hierarchies in mixture. By monitoring the PGI-2 frequencies in mixed swards during the growing season the effects on variety composition of both biological factors, such as heading date and management factors, such as defoliation frequencies can be evaluated.

Conclusions

Starch gel electrophoresis has a valuable contribution to make to the study of perennial ryegrass varieties in mixture. As this method will allow precise examination of the swards throughout the growing season, it will permit the factors which affect sward composition to be identified and a more scientific basis for mixture design to be devised.

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Effect of dietary iodine and teat disinfection iodine on milk iodine levels

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Introduction

Iodine is an essential trace element for humans and animals. The iodine requirement of humans differs between different scientific groups: 150 µg/day (WHO, 2001; US Dietary Reference Intakes, 2001) to 180-200 µg/day (DACH, 2000). Milk and dairy products are important determinants in human iodine intake. Iodine supplementations at farm level tend to be used in the expectation of increasing cow fertility and health. Iodine is routinely added to feed rations at varying levels of 5-10mg/kg. Teat disinfection with iodine has been shown to reduce mastitis infection rate (Galton *et al.,* 1988) and thus, is used as a routine practice on-farm, post milking and in some instances, pre-milking as well. There is concern that such feed and disinfection practices may result in high milk iodine which could affect dairy product export markets that have specific specifications, including iodine level, such as the infant milk formula ingredients market. The objective of this study was to quantify the effect of iodine supplemented concentrate feed and teat disinfection (with iodine) practices on milk iodine concentrations of dairy cows.

Materials and Methods

Thirty lactating cows were offered 7 kg, 3 kg and 0 kg concentrate (10 mg iodine/kg) during 3 periods of 21 days each. During the first 14 days of each period cows were on dietary iodine treatments only; during days 15-21, 1 of 3 teat disinfection treatments was applied (in addition to the dietary iodine treatments) to each of 3 cow groups (n-=10): non-iodine post-milking; 0.5% iodine post-milking; 0.5% iodine pre- and post-milking. Average cow milk yield was 21.3 kg/day. Cows received 12 and 16kg dry matter (DM) silage/day during the first 2 feeding periods and 18kg DM grass/day during the third feeding period. Cows were selected for the trial based on milk iodine levels during a 14-day pre-experimental period during which cows were offered 7kg concentrate (10 mg iodine/kg) and teat disinfected using a non-iodine product. Individual cow milk samples were taken on days 13, 14 and 20, 21 in each of the 3 periods (360 in total). Milks were analysed for iodine concentration by Inductively Coupled Plasma Mass Spectrometry. Statistical analysis (Students T-test) was undertaken using Microsoft Office Excel (2003).

Results and Discussion

The iodine content of the milks from treated cows reflected iodine supplementation in the feed (Table 1). A daily intake of 300g of milk from cows consuming 3kg concentrate with 10mg iodine/kg would supply an adult human with 185 µg iodine (recommended daily requirement). The iodine content of milk also reflected iodine disinfection practises. Post disinfection and pre and post disinfection contributed 343 and 585 µg/l iodine, respectively (Table 2). As teat preparation (washing of teats and drying with paper towel) was carried out pre-milking, the contribution of post disinfection iodine to milk iodine was probably largely due to absorption through skin. Pre-milking disinfection can pose a substantial risk of iodine transfer to milk, as it is dependent on the degree of removal from the teats prior to cluster attachment. This study indicates the contribution of different iodine supplementations to milk iodine. This is particularly important in winter milk production when both iodine supplemented feed and iodine disinfection are widely used.

Table 1. Effect of dietary iodine supplementation on milk iodine levels (µg/kg milk)

	7 kg concentrate/day 70 mg iodine/day	3 kg concentrate/day 30 mg iodine/day	Control 0 mg iodine/iodine
	733±122 [c]	616±161 [b]	195±71 [a]

Different letters signify significant differences (P<0.01)

Table 2. Effect of iodine teat disinfection on milk iodine levels (µg/kg milk)

Period	Non-iodine disinfection post milking	Iodine disinfection post milking	Iodine disinfection pre and post milking
1	103±34 [a]	400±186 [b]	522±180 [c]
2	51±26 [a]	271±152 [b]	458±177 [c]
3	58±25 [a]	359±132 [b]	522±180 [c]

Different letters in the same row signify significant differences (P<0.001)

Conclusions

Both dietary iodine supplementation and teat disinfection iodine resulted in milk iodine levels exceeding common target values of 250µg/kg. Cow feeding with iodine supplemented concentrate and teat disinfection with iodine products can frequently occur simultaneously on-farm, thus, caution must be exercised in order to maintain acceptable milk iodine levels.

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RMIS 5895

Trichloromethane levels in milk from thirty eight dairy herds

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Introduction

The residue trichloromethane (TCM) develops when chlorine from cleaning and disinfection agents reacts with organic material such as milk (Resch and Guthy, 2000). The legal limit for TCM in food set by the German Verordnung über Höchstmengen an Schadstoffen in Lebensmitteln, (2003) is 0.1 mg/kg. Irish lactic butter holds 13.5% of German market share and has an export value of €175m to Ireland's economy. German dairy manufacturers strive to minimise residual contamination in milk and butter products. To ensure that Irish produced lactic butter contains TCM less than 0.03 mg/kg, milk used for lactic butter production must contain TCM levels below 0.0015 mg/kg. The objective of this study was to monitor TCM levels on thirty eight Irish dairy farms and establish the effect of advice from milk quality personnel in combination with laboratory analysis on reducing TCM residues in milk.

Material and Methods

Bulk milk samples were collected from milk processing outlets at two stages and analysed for TCM. Stage 1 represented the initial milk samples, identifying farms where TCM concentrations were ≥0.0015 mg/kg. Stage 2 represented samples taken after advice was circulated on-farm. At stage 1, thirty eight milk suppliers were identified as having higher than acceptable TCM concentrations (≥0.0015 mg/kg) due to unsatisfactory milking machine cleaning practises (Gleeson and O' Brien, 2010). Advice on correct milking machine cleaning practises and detergent use was distributed to the relevant farm personnel and milk re-sampled at stage 2. Milk samples were analysed for TCM by head-space gas chromatography with an electron capture detector. Data were analysed using a paired Student t-test to identify if any significant reduction in residue levels occurred between sampling stages on each individual farm.

Results and Discussion

The mean concentration of TCM in milk from thirty eight dairy herds decreased with stage of sampling (P<0.001). A reduction of 0.003 mg/kg was observed directly upon provision of advice on the use of cleaning and disinfection agents (P<0.001) (Stage 2). All thirty eight farms had TCM residue levels ≥0.0015 mg/kg at stage 1. However, by stage 2 the proportion of farms with TCM levels <0.0015 mg/kg had increased to forty seven percent. The remaining farms require further investigation in order to achieve the required TCM levels in bulk milk.

Table 1. Trichloromethane concentrations (mg/kg) in milk from thirty eight farms monitored over one year

	Stage 1	Stage 2
Mean TCM (mg/kg)	0.007	0.004
Standard Deviation	0.005	0.007
Range (mg/kg)	0.002-0.028	0.000-0.032
P-value (Stage 1 – 2)	<0.001	

Conclusions

Milk from herds with high TCM concentrations indicate that good management practises, in relation to detergent use and washing procedures, are not being adhered to on-farm. The observed reduction in TCM concentrations on the farms visited showed the positive impact advice had on overall TCM levels.

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RMIS 5895

The effect of hydrated lime (as a bedding material) on the microbial count on cows teats

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Introduction

Mastitis represents a major economic cost to dairy farmers (O'Brien, 2009). Previous studies have shown that some cubicle bedding materials can minimize pathogen growth and can result in lower numbers being transmitted onto cow's teats, thereby reducing the possibility of intramammary infection (Kudi *et al.,* 2009). The aim of this study was to determine if cows bedded in cubicles using hydrated lime would have lower microbial counts on teats compared to cows bedded with the commonly used ground limestone bedding.

Materials and Methods

Non-lactating dairy cows (N=60) were randomly assigned to three cubicle bedding treatments based on expected calving date and lactation number. Treatments included 3 bedding materials; 1=Hydrated lime (red labeled), 2= 50/50 mix of hydrated lime and ground limestone, 3=ground limestone (control). Teats from all cows were swabbed weekly using one sterile swab per cow over a seven week period. Swabs were then placed in individual sterile bottles containing 5mls of Tryptic Soy Broth and frozen (-20^{O}) until plated for the presence of *Staphylococcus* (STA), and *Streptococcus* (STR) using two separate selective agars: Baird parker (STA), and Edwards (STR). Following incubation at 37 ºC for 24 hours, microbial numbers (CFU) for each pathogen type were measured and the results assigned to one of four categories (0= no pathogen present, <10, 11>NS (numerous), NS/IF (numerous/infinite)). Infection levels at calving were recorded using the Californian milk test (CMT). The CMT results were categorized into scores of 1 (somatic cell count $<200x10^3$ cells/ml) or >1(≥ $201x10^3$ cells/ml). Differences in bacterial numbers were measured using Fishers exact test. Where there was an effect of treatment, a Fishers pair-wise comparison was conducted.

Results and Discussion

There were no differences in the levels of bacteria on teats between groups at the trial start date. The hydrated lime bedding had more teats with no STR bacteria present at weeks 3 (P<0.01) and 4 (P<0.001) compared to the ground limestone treatment. Over the seven week period the hydrated lime bedding had more teats with no STR bacteria present compared to the ground limestone (P<0.001). There were no differences in STA bacterial numbers between treatments for categories for 0, <10 or 11>NS. However, the hydrated lime had lower (P<0.05) numbers of cows teats in the NS/IF category compared to the ground limestone (Table 1). There were no differences in infection levels between treatments at calving (Table 2). Both STA and STR bacterial counts on teats reduced over the six week measurement period (Figure 1). This may indicate an effect of improved management for all cubicle beds during the trial period.

Table 1. Staphylococcal (STA) and Streptococcal (STR) bacterial counts on teats with three bedding materials

	Cow numbers			P-value	1 v 2	1 v 3	2 v 3	Sig.
Bedding materials	1	2	3					
Bacterial count CFU				STA				
0	22	12	12	0.123	0.131	0.088	0.829	NS
<10	57	40	48	0.361				NS
11>NS	18	13	12	0.498				NS
NS/IF	23	32	38	0.050	0.077	0.030	0.763	*
				STR				
0	52	34	25	< 0.001	0.056	< 0.001	0.083	***
<10	67	41	60	0.097	0.036	0.370	0.300	*
11>NS	10	21	8	0.006	0.018	0.805	0.004	**
NS/IF	21	21	30	0.307				NS

1= Hydrated lime, 2= 50/50, 3= ground limestone

Table 2. Proportion of quarters with CMT scores of 1 or >1 and number of pathogens in milk

		CMT		Pathogens
Bedding	Quarters	1	>1	
1	53	0.87	0.13	1
2	74	0.91	0.09	1
3	66	0.98	0.02	3

1= Hydrated lime, 2= 50/50, 3= ground limestone

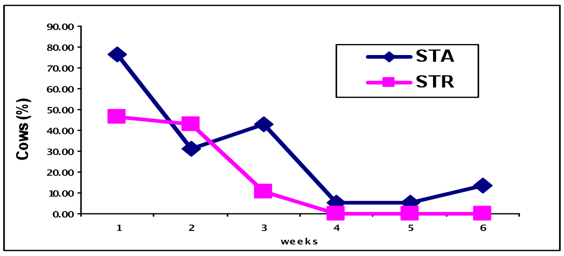

Figure 1. Cows (%) with NS/IF *Staphylococcus* (STA) and *Streptococcus* (STR) bacteria on teats

Conclusions

Lower bacterial numbers were observed on teats with the hydrated lime bedding. Infection levels at calving did not differ between bedding treatments. Further studies are required with lactating cows.

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RMIS 5896

Effect of individual cluster flushing between milkings on the bacterial count on liners

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Introduction

Observations of the microbial count on teats prior to milking have shown the presence of high numbers of both *Staphylococcus* and *Streptococcus* bacteria (Gleeson *et al.,* 2009). Flushing of the milking cluster after each cow milking may reduce the microbial count on the liners thus reducing the potential for bacterial transfer from cow to cow. New technology (Dairymaster, Ireland [Clustercleanse]) has been developed to automatically flush with water each individual cluster after each cluster removal. The objective of this study was to establish the effect of two variables (volume setting and presence of disinfectant) of the 'Clustercleanse' system on the reduction in bacterial numbers on liners.

Materials and Methods

The 'Clustercleanse' system is designed with two water volume settings (Cycle 1 = 0.5 litre or Cycle 2 = 1.0 litre) combined with an air purge, with the option of using a disinfectant solution. The following automatic cluster flushing treatments were evaluated: No cluster flush (NC), cycle 1 (C1) and cycle 2 (C2) and with peracetic acid (0.2%) (C1A and C2A). The five cluster cleaning treatments were randomly applied after cluster removal during two periods of one day per treatment with one group of 15 cows. No teat preparation was carried out prior to cluster application for milking. Four liners from each cluster were swabbed inside the mouthpiece using a separate sterile swab after cluster removal and after cluster flushing. Swabs were then placed in individual sterile bottles containing 5mls Tryptic Soy Broth and frozen (-20^{O}) until plated for the presence of *Staphylococcus* (STA), and *Streptococcus* (STR) bacteria using two separate selective agars: Baird parker (STA), and Edwards (STR). Following incubation at 37 ºC for 24 hours, microbial numbers (CFU) for each pathogen type were manually recorded and assigned to one of four categories depending on the bacterial counts measured (0= no pathogen present, ≤10, 11>NS (numerous), NS/IF (numerous/infinite). The data were analysed using logistic regression using SAS (2004). The main analysis was conducted on binary improvement scores for the swabbing outcomes. If the bacterial count reduced by two categories or equalled 0 after the flush treatment then it was considered a response.

Results and Discussion

There were no differences in the levels of bacteria present on liners after cluster removal for all cows (P>0.05). Flushing clusters with either water or a combination of water and disinfectant resulted in a significant reduction of both STA (P<0.05) and STR (P<0.01) bacteria on milk liners compared to no flushing (Figure 1). The probability of a reduction (P<0.001) in STA (OR=58) and STR (OR=20) bacteria were more likely with C2A, compared to no flushing (Table 1). With no flushing, a large proportion (0.96) of liners had STA bacteria present. The levels of STA observed were reduced with water volume in particular with the addition of disinfectant (Fig 1). Because large numbers of bacteria are removed with the 'Clustercleanse' system, in particular with the setting C2A there is a reduced likelihood of (1) bacterial transfer from cow to cow (2) infection due to build up of bacteria on the liner and (3) spread of infection from a previously milked mastitis cow.

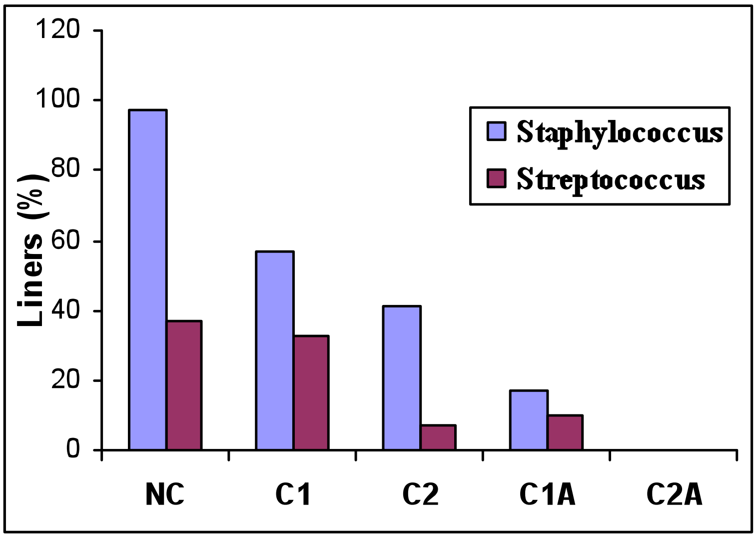

Figure 1. Liners (%) with *Staphylococcus* and *Streptococcus* bacterial numbers of < 10 CFU with different 'clustercleanse' settings (No cluster flush (NC), cycle 1 (C1) and cycle 2 (C2) and with peracetic acid (0.2%) (C1A and C2A)

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Table 1. Estimated odds ratios and their 95% confidence intervals (CI) for the effect of cluster flushing on *Staphylococcus* (STA) and *Streptococcus* (STR) counts on milk liners

	Probability of STA			Probability of STR		
Variable	OR	95%CI	P-value	OR	95%CI	P-value
No Flush	1			1		
0.5 litres water	11.4	0.14 – 0.55	0.05	11.7	0.14 – 0.52	0.01
0.5 litres water + Peracetic acid	13.2	0.12 – 0.48	0.01	11.7	0.14 – 0.52	0.01
1.0 litres water	26.3	0.01 – 0.27	0.01	16.7	0.01 – 0.39	0.001
1.0 litres water + Peracetic acid	58.8	0.00 – 0.16	0.001	20.4	0.01 – 0.34	0.001

Conclusions

Automatic flushing of clusters after each individual milking reduced bacterial numbers on milk liners. The largest reduction in *Staphylococcus* and *Streptococcus* numbers were observed with a setting of 1 litre of water and 0.2% peracetic acid.

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RMIS 5896

GRASSLAND RESEARCH PROGRAMME

Grass Breeding, Establishment and Renovation

The effect of perennial ryegrass (*Lolium perenne*) cultivar on dairy cow rumen function

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Introduction

Nationally, herbage production and utilization on dairy farms is below potential (Shalloo *et al.,* 2010). This could be improved by increasing reseeding levels and harnessing the increased production of high quality pasture with increased stocking rate. Differences exist between perennial ryegrass (*Lolium perenne*) cultivars in terms of fermentation characteristics (Tas *et al.,* 2005), which could give rise to differences in rumen pH. Low rumen pH can impact negatively on milk fat concentration, fibre degradation, nutrient absorption and health and welfare (Kleen *et al.,* 2003). Therefore, information on the effects of perennial ryegrass cultivars on rumen function is important. The objective of the current study was to assess if different perennial ryegrass cultivars give rise to differences in rumen pH.

Materials and Methods

Four rumen-cannulated, and 32 intact, lactating dairy cows were allocated to four grazing groups. Four cultivars were investigated: Astonenery (AE), Bealey (BY), Abermagic (AM) and Spelga (SA). The cultivars were sown as pure monoculture grazing swards. The study began in Apr 2010 and ended in Sep 2010 and was conducted as a 4x4 latin square. A latin square was completed in Apr-Jun (time stage 1 TS1) and another in Jul-Sept (time stage 2 TS2). Each period lasted 17 days, with the first 10 days used for acclimatisation to the treatment and the final 7 days for measurement. Rumen pH was measured on days 15-16 of each period by an indwelling Ionode IJ44 rumen pH probe (Ionode Pty Ltd., Australia). The data were logged at 60-second intervals using a Delta Ohm HD 2105.2 datalogger (Delta Ohm S.r.l., Italy). Average rumen pH across the day was calculated, as was the amount of time spent below certain pH thresholds. At the same time grazing behaviour data were collected by fitting the rumen-cannulated cows with IGER behaviour recorders (Rutter *et al.,* 1997). Total grazing, ruminating and idling times, and the number of prehensions and mastications, were measured. The data were analysed as a 4x4 latin square using the mixed procedure (PROC MIXED) of SAS with cultivar, experimental period, square, cow and their interactions included in the model.

Table 1. The effects of four perennial ryegrass cultivars on dairy cow rumen pH and grazing behaviour (lsmean)

Time Stage	Variable	AE	BY	AM	SA	s.e.	Significance
1	Time spent <pH5.2 (proportion of day)	0.04	0.00	0.00	0.00	0.008	0.02
	Time spent >pH6.2 (proportion of day)	0.46	0.45	0.45	0.66	0.059	0.08
2	Time spent >pH6.0 (proportion of day)	0.84	0.82	0.64	0.92	0.060	0.10
	Time spent ruminating (proportion of day)	0.32	0.31	0.30	0.35	0.012	0.10
	No. ruminating mastications/day	27960	27320	26430	31360	768	0.02

Results and Discussion

The effects of perennial ryegrass cultivar on rumen pH and grazing behaviour are illustrated in Table 1. In TS1 AE cows spent some time at <pH5.2 whereas cows on the other treatments spent no time below this level ($P<0.05$). This agrees with AE being highly digestible (DARD, 2010) and having a high leaf:stem+dead ratio (Wims *et al.,* 2011). Cows offered SA tended to spend more time at >pH6.2 ($P=0.08$) in TS1 and at >pH6.0 in TS2 ($P=0.10$). In TS2 this was reflected in them tending to spend a greater proportion of their time ruminating ($P=0.10$) and performing more ruminating mastications ($P<0.05$) than cows on the other treatments. SA was predicted to be the least digestible cultivar tested (DARD, 2010). In TS1 SA cows produced the lowest milk protein concentration from a sward with the lowest leaf:stem+dead ratio (Wims *et al.,* 2010). In TS2 SA cows produced the lowest milk and milk protein yield (Wims *et al.,* unpublished). Despite some low periods of rumen pH being measured none of the rumen-cannulated cows exhibited depressed milk fat concentration or signs of lameness.

Conclusions

This study demonstrated that perennial ryegrass cultivars with higher digestibility can give rise to longer periods at lower pH than lower digestibility cultivars.

Acknowledgements

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RMIS 5663

Effect of cutting protocol on DM (dry matter) yield of *Lolium perenne* cultivars

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Introduction

Internationally grass cultivar evaluation protocols are widely used to identify the cultivars which are most suitable to conditions within that particular country. Throughout many European countries grass cultivar evaluation programmes incorporate a mixed grazing and conservation based protocol. Such protocols have a reduced number of cuts across the year compared to simulated grazing protocols and generally have between one and three cuts representing silage harvests. The objective of this study was to evaluate the effect of simulated grazing and conservation managements under cutting on the DM yield performance of perennial ryegrass cultivars.

Materials and Methods

One-hundred and eight plots (5 × 1.5 m) were sown with twelve cultivars of perennial ryegrass in autumn 2006 in randomised block design. Four diploid cultivars were used with the following heading dates: Alto (15 May), Arrow (22 May), Portrush (14 June) and Tyrella (8 June) and eight tetraploids were used: Bealey (22 May), Dunloy (8 June), Dunluce (31 May), Glencar (6 June), Greengold (31 May), Lismore (28 May), Malone (22 May) and Navan (9 June). Three cutting managements were imposed on the plots representing simulated grazing (SG); 2-cut silage (2C) and 3-cut silage (3C). Within each management each cultivar was replicated 3 times. The SG consisted of 10 defoliations, beginning on 20th March and then every 3 to 4 weeks until the final harvest in late October. The 2C consisted of 6 defoliations beginning on 1st April, with 2nd and 3rd cuts taken after 7 and 6 week intervals, and the final 3 cuts taken at intervals of 4, 5 and 6 weeks, respectively. The 3C treatment consisted of 5 cuts with the first cut taken on 25th May, the 2nd and 3rd taken after 6 week intervals and the final two cuts on 1st Sept. and 1st Oct. Plots were harvested with a motor Etesia to a height of 4 cm across 3 full growing seasons, 2007 (Y1), 2008 (Y2) and 2009 (Y3). All mown herbage from each plot was collected and weighed; 0.1 kg herbage was dried for 48 h at 40°C to determine the DM content of the samples. The data were analysed by repeated measures analysis with an unstructured covariance matrix using Proc Mixed in SAS. The effects of year, management, cultivar and the interaction between management and cultivar were investigated.

Results and Discussion

There was an effect ($P<0.001$) of year on DM yield, in Y1 average DM yield across all treatments and cultivars was 13.8 t DM/ha compared to 13.5 and 15.9 t DM/ha in Y2 and Y3, respectively. Management had an effect ($P<0.001$) on total DM yield. Average DM yield was lowest for the SG treatment (12.2 t DM/ha) compared to the 2C (15.2 t DM/ha) and 3C (15.8 t DM/ha). There was an interaction between management and cultivar ($P<0.01$) on total DM yield. Table 1 presents the effect of management on total annual DM yield of each of the 12 cultivars. It is clear from this table that the rank of individual cultivars differed between managements. Bealey and Tyrella were the highest yielding cultivars in treatment SG, however, as silage cutting was introduced their performance dropped and they ranked 8th and 10th in the 2C treatment compared to 9th and 10th in the 3C treatments. Malone, ranked 10th overall in the SG treatment compared to 5th and 1st in the 2C and 3C treatments, respectively. This change in rank of cultivars when exposed to simulated grazing or silage managements indicates that the evaluation protocol will significantly affect the performance of a cultivar and results indicate that the protocol in place must closely reflect the conditions under which a cultivar will be grown and utilised.

Conclusions

Management did have a significant effect on the performance of a cultivar, a large number of cultivars re-ranked between simulated grazing and conservation managements. This indicates that some cultivars are suited to a grazing type system while others are more suited to an intensive silage system. In countries where intensive grazing is practiced and silage is used as a source of winter feed, two managements may be necessary within variety evaluation trials to identify the most suitable cultivars for both grazing and mixed grazing/silage systems.

Acknowledgements

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Table 1. Total annual simulated grazing or conservation yields (t DM/ha) with their performance ranking

	Simulated grazing	2-cut silage system	3-cut silage system				
Alto	12.2	14.9	16.4				
Arrow	12.5	15.9	15.7		Significance	*P-value*	SE
Bealey	13.0	15.0	15.4		Year	<0.001	0.07
Dunloy	12.2	14.6	15.2		Management	<0.001	0.09
Dunluce	12.4	16.1	15.4		Cultivar	NS	0.19
Glencar	12.0	15.4	15.5		Management × Cultivar	<0.01	0.32
Greengold	12.0	15.5	15.7				
Lismore	11.8	15.5	15.9				
Malone	11.9	15.4	16.9				
Navan	11.9	15.4	15.6				
Portrush	11.7	14.6	16.4				
Tyrella	12.8	14.9	15.4				

RMIS 6007

Effect of pre grazing herbage mass on grass dry matter production and the milk production performance of spring calving dairy cows

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Introduction

Pre grazing herbage mass (HM) has been shown to influence grass dry matter intake (O'Donovan and Delaby, 2008) and milk production performance (Curran *et al.*, 2010) with a medium HM sward (1500-1700 kg dry matter (DM)/ha) considered favourable over a high HM sward (>2000 kg DM/ha). There is, however, little information available in the literature regarding the effect of continuously grazing pastures with a low pre-grazing HM (<1250 kg DM/ha). Also the effects of HM on grazing management and grass DM production across an entire grazing season have to be documented. The objective of this study was to examine the effect of offering three different levels of pre-grazing HM on milk production and grass DM production within a system study over the entire grazing season.

Materials and Methods

Sixty-nine Holstein-Friesian dairy cows (18 primiparous and 51 multiparous) were selected and blocked using days in milk (DIM) (46; sem 3.1) and lactation number (2.6; sem 1.6) and the appropriate pre-experimental data. Animals were randomly assigned to one of three HM treatments in a randomised block design: 1200 kg DM/ha - Low HM (L), 1500 kg DM/ha – Medium HM (M) or 2000 kg DM/ha - High HM (H). Each treatment was assigned an equal area and this area was managed independently as a farmlet. Herbage mass was calculated above 4 cm. Daily herbage allowance was governed using a post grazing sward height of 4 – 4.5 cm. The level of milk production from cows on each treatment was recorded. The level of grass DM production and level of winter feeding conserved from each treatment was also recorded during this study. Animal variables were analysed using covariate analysis. Treatment, parity and the appropriate pre-experimental variable were included in the model.

Results and Discussion

The levels of HM for each treatment was 1200, 1418 and 1917 kg DM/ha (sem 26.4) for the L, M and H swards, respectively. Herbage mass treatment did not affect milk production performance in this study. Table 1 shows the effect of HM on grass DM production, conserved silage and supplementation level offered during the grazing season. A higher level of total DM production was recorded in the H HM swards (14.1 t DM/ha) which yielded 1.2 and 0.6 t of DM/ha higher than the L and M HM swards, respectively. The H HM farmlet conserved a larger area for silage (8.6 ha) compared to the M or L HM farmlets which conserved 8.1 and 6.5 ha respectively. The lower area conserved for silage coupled with the lower grass DM production meant the L HM farmlet conserved 0.8 ton DM of silage per cow for the winter feeding period, which according to the Moorepark Blueprint for spring milk production leaves a considerable winter feeding deficit. The lower grass DM production was also reflected in the level of silage supplement required during the grazing season. Cows on the L HM treatment required 110 kg DM/cow which was 80 and 65 kg DM/cow higher than what was required on the M and H HM swards respectively. The short rotation lengths during the months of June to July (Table 1), which were required to maintain the L HM swards have being attributed as a reason for the lower grass DM production. Work by Parsons and Penning (1988) and O'Riordan (2000) supports this. These authors agree that maintaining very short regrowth intervals, such as those required to maintain the L HM swards on the current study leads to reduced grass DM production. A review by Fulkerson and Donaghy (2001) suggests that short rotation lengths do not allow the plant to replenish its water soluble carbohydrate reserves and if maintained will lead to reduced grass growth.

Conclusions

This study showed that maintaining a low pre-grazing HM (1200 kg DM/ha) throughout the grazing season does not offer any benefit in terms of milk production over a medium (1418 kg DM/ha) or high (1917 kg DM/ha) HM sward. In fact it showed negative effects of maintaining low HM swards in terms of grass DM production, the level of silage conserved for winter feed and the level of supplement that had to be offered to cows grazing the low HM swards.

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Table 1: Effect of herbage mass treatments on rotation length, grass production and level of supplement offered

Herbage mass (kg DM/ha)	1000	1500	2000
No. Rotations	12	10	9
Average rotation length (days)	18	21	25
April – May	17	18	23
June – July	13	19	25
August – November	24	24	24
Grass production			
Growth (kg of DM/ha/day)	55.5	58.3	60.0
Total grass production (ton DM/ha)	12.9	13.5	14.1
Area conserved (ha)	6.5	8.1	8.6
Silage conserved (tonne DM/cow)	0.81	0.93	1.06
Supplementation during grazing season (April – Nov)			
Silage (kg DM/cow)	110	30	45
Concentrate (kg DM/cow)	200	200	200

RMIS 5664

Effect of re-growth interval on herbage mass, morphology and tiller density of a perennial ryegrass sward

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Introduction

Criteria on when to defoliate perennial ryegrass (PRG; *Lolium perenne* L.) swards must be based on knowledge of the physiology of the plants and their interaction with the environment. Increased frequency of defoliation results in decreasing net herbage accumulation (Brougham, 1959), whereas infrequent defoliation leads to accumulation of dead material and excessive stem elongation, resulting in decreased sward feeding value (Hoogendoorn and Holmes, 1992). The aim of this study was to quantify the effects of three re-growth intervals (two, three and four weeks) on herbage mass (HM), sward morphology and tiller density of a PRG sward under a cutting regime.

Materials and Methods

A three-year old PRG sward was divided into 12 plots (3 m x 5 m) set out in four blocks of three plots. There were three re-growth interval treatments - two, three or four weeks, and the experiment was undertaken from 1 April to 16 September, 2009. Herbage mass (above a 3.5 cm cutting height) was estimated on each plot at the end of the re-growth period by harvesting a 5 m x 1.2 m strip using a reciprocating blade mower. Prior to defoliation, herbage morphological composition was determined for each plot by randomly cutting a 30 g sample to ground level with a scissors. The sample was divided into two portions, above and below 3.5 cm, and subsequently separated into live leaf, live stem and dead material. Perennial ryegrass tiller density was assessed in each plot every four weeks. Three turves (0.10 m x 0.10 m) were randomly selected from each plot, cut to a depth of 3 cm and dissected. The species of each tiller were identified and counted. Analysis of variance was performed with SAS using a mixed model that included the fixed effect of treatment and the random effect of plot.

Results and Discussion

There was a significant effect of re-growth interval on HM (Figure 1). The 2-week re-growth interval treatment had significantly less cumulative HM (6,735 kg DM/ha) than the 3- and 4-week re-growth treatments, 9,103 and 10,385 kg DM/ha, respectively (P<0.001). Above the 3.5 cm horizon, leaf proportion was similar between treatments throughout the experimental period (69.9%). Stem proportion was 5.1 percentage units lower for 2- compared to the 4-week re-growth interval (P<0.001; Table 1). Dead proportions were similar for 2- and 3-week re-growth intervals (13.4%) but lowest for 4-week re-growth interval (9.4%; P<0.01; Table 1). Below the 3.5 cm horizon, stem content was lower for the 2-week re-growth interval by 5.2 percentage units compared with the other two treatments (P<0.01, Table 1). There was no significant treatment effect on PRG tiller density, although there were numerical differences (Table 1). Frequent defoliation over a prolonged period may result in a reduction of energy reserves in the roots due to priority for shoot growth at the expense of root development, with the consequent increase in death rate of plants (Donaghy and Fulkerson, 1998). This may explain the poor performance of the 2-week re-growth treatment plots in terms of herbage production and leaf proportion.

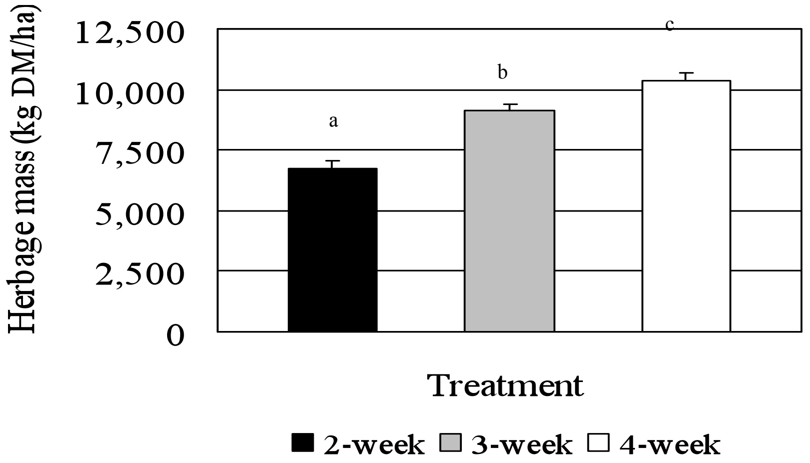

Figure 1. Cumulative herbage mass (kg DM/ha) from 1 April to 16 September on treatments with 2-, 3- and 4-week re-growth intervals. Values with different letters are significantly different at P<0.05.

Table 1. Leaf, stem and dead components (above and below 3.5 cm stubble) and perennial ryegrass (PRG) tiller density (TD; tillers/m^2) on treatments with 2-, 3- and 4-week re-growth intervals. Values within a row with different superscripts are significantly different at P<0.05; SED = standard error of the difference.

	2-wk	3-wk	4-wk	*P* value	SED
(>3.5 cm)					
Leaf %	71.2	70.2	68.2	0.220	1.63
Stem %	14.5[a]	17.4[b]	22.5[c]	<0.001	1.20
Dead %	14.3[a]	12.4[a]	9.4[b]	0.005	1.12
(<3.5 cm)					
Leaf %	5.8	3.8	2.4	0.128	1.48
Stem %	46.8[a]	51.1[b]	52.8[b]	0.002	1.12
Dead %	47.4	45.1	44.8	0.195	1.45
PRG TD	6,668	7,810	7,595	0.172	586.0

Conclusions

Defoliating a PRG sward every two weeks during the April to September period resulted in 35% and 54% less cumulative HM than 3- and 4-week re-growth intervals, respectively. Leaf proportion above a 3.5 cm stubble height was similar across all treatments, and stem proportions were highest and dead proportions lowest on the 4 week cutting interval treatment compared to the other treatments. There was no significant effect of treatment on PRG tiller density.

Acknowledgements

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RMIS 5664

The effect of varying pre-grazing herbage mass on milk production, dry matter intake and grazing behaviour of spring calving dairy cows

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Introduction

Pasture herbage is a mixture of several individual plant components including leaves, stems and seed heads at various stages of maturity from young leafy tissue to senescent and decaying material. The chemical composition and digestibility of these components differ and vary widely with changes in plant age. This influences dietary selection, dry matter intake (DMI), behaviour and performance of grazing animals. Low herbage mass (HM) swards have been shown to increase milk yield, milk fat and milk protein content (Hoogendoorn and Holmes, 1992). The objective of this study was to examine the effect of HM on milk production, DMI and grazing behaviour across the grazing season.

Materials and Methods

Forty five spring calving Holstein-Friesian dairy cows (mean calving date 23 March) were randomised in a complete block design. Animals were offered one of three levels of HM: High HM (H - 2300 kg DM/ha); Medium HM (M - 1500 kg DM/ha) or Low HM (900kg DM/ha). Treatments were imposed from April 18 to October 17, 2010. Each herd grazed their respective farmlets separately throughout the study. Fresh herbage was allocated daily. Dry matter intake was measured using the n-alkane technique across two weekly periods beginning on 15 June (PI) and 16 August (PII). The experimental period was divided in two periods from (April to end of July and end of July to mid October). Grazing behaviour was measured on a subset of animals from each of the 3 treatments during the first intake measurement period. During the study, milk yield was measured daily and milk composition, bodyweight and body condition score were measured weekly. Data was analysed using PROC MIXED in SAS.

Results and Discussion

Mean pre-grazing yields (kg DM/ha) during the study were 2330 (s.d. 420.8), for H HM, 1521 (s.d. 226.9) for M HM and 978 (s.d 253.9) for L HM. Corresponding pre-grazing sward heights (cm) were 11.8 (s.d.1.95), 8.8 (s.d.1.18) and 6.9 (s.d.1.66) for, H, M and L HM treatments, respectively. Post-grazing sward heights were, 4.3 cm (s.d.0.35), 4.2 (s.d. 0.31) and 4.0 (s.d.0.24) for H, M and L HM treatments, respectively. Daily herbage allowance was similar across treatments at 17.0kg DM/cow/day. Daily grazing area per treatment was 1,112 m^2/day for H HM treatment, 1,696 m^2/day for the Med HM and 2643 m^2/day for the Low HM. Table 1 presents the effect of grazing treatment on milk production, grazing behaviour in Period 1 and dry matter intake during both periods. In Period 1, there was no milk production or grass dry matter intake difference between the treatments. The cows grazing the L HM sward grazed for a significantly longer time (P<0.001; + 90 minutes) to achieve a DM intake similar to the other treatments. In period 2, milk solids yield was significantly (P<0.04) higher for the animals grazing the M and L HM treatments. The cows grazing the medium HM treatment tended to have a higher grass dry matter intake.

Table 1. Effect of pre-grazing herbage mass on milk production and intake

Herbage mass (kg DM/ha)	Low	Medium	High	SED	Sig
Period I (18/4 -25/7)					
Milk yield (kg/d)	26.2	25.9	25.0	1.33	0.2478
Milk Solids (kg/day)	1.90	1.83	1.85	0.099	0.6888
Bodyweight (kg)	498	494	503	17.05	0.8180
Grass dry matter intake	15.4	16.0	16.6	0.62	0.2315
Grazing minutes	651	560	558	25.8	0.0014
Grazing bites min	64.9	64.4	63.6	2.59	0.8875
Grazing bouts	10.1	10.7	8.9	1.94	0.7079
Period II (25/7-17/10)					
Milk yield (kg/d)	17.7[a]	17.2[ab]	16.2[b]	0.75	0.1509
Milk Solids (kg/day)	1.34[a]	1.37[a]	1.24[b]	0.059	0.0428
Bodyweight (kg)	509	524	515	16.5	0.6810
Grass dry matter intake	15.2[b]	16.5[a]	15.7[ab]	0.53	0.0902

Conclusions

Little milk production differences took place in April to July period of the study when three different pre grazing herbage masses were offered to grazing dairy cows. During the latter half of the grazing season offering higher HM (>2200) kg DM/ha reduced dairy cow performance. Animals offered lower HM swards (<1000 kg DM/ha) had to graze for 90 minutes longer to achieve 0.95 of the DM intake of the other herds. The grazing area allowed to maintain lower

HM swards was 0.40 higher than Med HM swards and 0.60 higher than H HM swards. Allocating grazing cows swards of approx. 1500 kg DM/ha strikes the correct balance between animal and grazing management efficiency.

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RMIS 5795

Control of *Rumex obtusifolius* L. species as dictated by herbicide application strategy

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Introduction

Low infestations of *Rumex obtusifolius* (dock) in grassland can be tolerated; however population level often increases to a point where they interfere with the general production of the sward. The potential of digital image processing to identify weeds and allow site specific applications of herbicide for their control has been investigated by Gebhardt *et al.* (2006). This type of precision control method would benefit farmers and the environment by reducing the amount of herbicide required to control weed populations relative to the conventional methods. The aim of this study was to compare different methods of herbicide application and quantify effects on quantity of herbicide used, kill efficacy and subsequent dry matter (DM) production.

Materials and Methods

This study was undertaken across two sites i) Moorepark, Co Cork, and ii) Oakpark, Co Carlow over two years 2009 and 2010. The experiment was a randomised design with 6 treatments, each replicated 4 times. Plot size was 15 x 6m ($90m^2$). The study was managed under a three cut silage system at both sites. Conventional (blanket) and precision pasture management (PPM) herbicide application systems were compared. The PPM system (Gramenor) uses image processing technology to identify and specifically target the weed species of choice. The treatments were i) (C) Control – no herbicide applied, ii) (BD) blanket application of fluroxypr/triclopyr (Doxstar), iii) (PD) PPM application of Doxstar, iv) (PR) PPM application of glyphosate (Roundup), v) (BF) blanket application of aminopyralid/fluroxypr (Forefront**),** and vi) (PF) PPM application of Forefront**.** Treatments were applied once, in late June 2009, three weeks after first cut silage, with carryover measurements taken in 2010. Dry matter production (kg DM/ha) above 4cm was estimated prior to each defoliation by cutting a 6m strip across the centre of the plot using a motor Agria machine.A sub-sample (100g) of herbage was dried at $80^{o}C$ for 16 hours to determine DM. Dock population (no of docks/m^2) was assessed prior to applying treatments, 6 weeks after applying treatments and 12 months after applying treatments by counting the number of dock plants within each plot to establish carryover effects. Herbage quality was analysed by NIRS. Data was analysed using GLM procedures of SAS (SAS, 2006).

Results and Discussion

There was no significant effect of treatment on grass DM production pre or post herbicide application in 2009 or 2010. Site had no significant effect on total DM yield in 2009, but did significantly ($P<0.01$) affect DM yield in 2010 with Oakpark producing a higher DM yield (+1290 kg DM/ha) over two silage cuts compared to Moorepark. Figure 1 shows the treatment effect on dock population/m^2 pre and post application. There was no significant difference between dock populations prior to herbicide application (P1). All herbicide treatments significantly reduced the dock population six weeks post treatment (P2, $P<0.001$). All treatments with the exception of the PR treatment continued to significantly reduce the dock population twelve months post treatment (P3, $P<0.05$) compared to the control.

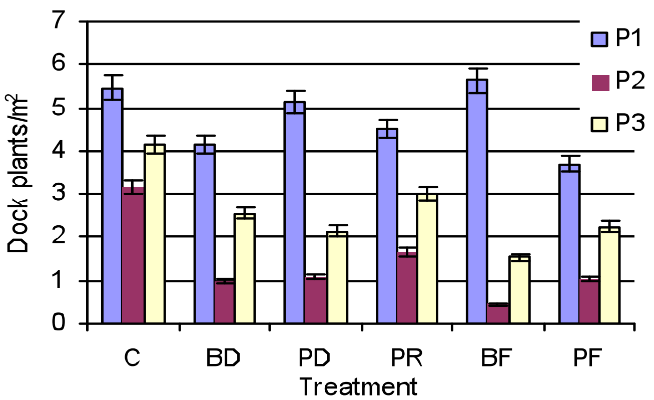

Figure 1. Dock population (plants/m^2) pre and post herbicide application (Treatment averages Moorepark and Oakpark).

P1=Pre treatment, P2= six weeks post treatment, P3= twelve months post treatment, C=Control, BD=blanket Doxstar, PD= PPM Doxstar, PR=PPM Roundup, BF=blanket Forefront**,** PF=PPM Forefront.

Site significantly ($P<0.01$) affected population prior to treatment application with a higher dock population at Moorepark. There was a significant ($P<0.05$) interaction between site and treatment for P2 due to the higher control population at Moorepark. The PR treatment significantly ($P<0.001$) affected the area of bare patches in the sward at P2 ($3.47m^2$ per plot) compared to all other treatments (avg. $0.21m^2$). Herbage quality was not affected by treatment. Treatment application method affected the quantity of herbicide used, with the conventional blanket herbicide application method using 3.1 times more herbicide than the PPM herbicide application system.

Conclusions

All herbicide treatments, with the exception of the PR treatment provided some level of control of dock species up to twelve months; however no treatment eradicated the population completely. The PR treatment also had negative consequences on sward density, significantly increasing the area of bare patches/open space post treatment. The PPM system reduced the quantity of herbicide required, while providing a similar level of control compared to the conventional blanket application method when using dock specific herbicides. Further investigation of the PPM technology is needed to quantify system efficiency.

Acknowledgements

We acknowledge the Department of Agriculture and Food Research Stimulus Fund for financial support.

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RMIS 5795

Evaluation of the GrazeIn model of grass dry matter intake and milk production for Irish grass-based production systems

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Introduction

Grass dry matter intake (GDMI) at grazing is difficult for farmers to estimate accurately due to the dynamic nature of the factors involved (cow, herbage and management factors). The prediction of GDMI and milk production is a useful aid in grazing management decision-making at farm level. As a result it was decided to investigate the prediction of GDMI and milk production for Irish grass-based production systems using the French model GrazeIn (Delagarde *et al.*, 2011). GrazeIn was developed for European grazing systems and uses input variables that are easy for the farmer to obtain. From these variables GDMI and milk production are predicted. The objective of this study was to investigate the precision with which GrazeIn predicts GDMI and milk production for Irish grazing systems.

Materials and Methods

The variables required to run GrazeIn were extracted from the Moorepark GDMI database (O'Neill *et al.*, 2011). They include animal production and herbage variables. The comparison of predicted (P) versus actual (A) herbage intake and milk production was conducted at the herd level (n=522 herds). Individual cow GDMI and milk production was predicted by GrazeIn and then a herd average was calculated. Herd level was used as this reduced the variation between cows and improved prediction accuracy of the model. The actual (A) GDMI and milk production data were regressed on the GDMI and milk production predicted (P) by GrazeIn. The prediction accuracy of GrazeIn was analysed using the mean bias, mean-squared prediction error (MSPE) and the mean relative prediction error (MPE). A positive or negative mean bias (P-A) indicated that the model was over- or under–predicting, respectively, compared to A. The MPE was calculated by dividing the square root of the MSPE by the mean A.

Results and Discussion

The MSPE for GDMI and milk production were 3.71 kg^2/d and 14.28 kg^2/d, respectively. The MPE for GDMI and milk production were 0.12 and 0.17, respectively. This overall accuracy falls within the range reported as acceptable for a successful model by Keady *et al.* (2004). The mean bias was -0.11 kg DM/d for GDMI and +1.60 kg/d for milk production (Table 1). This indicates that GrazeIn underestimates GDMI, but overestimates milk production. The model over predicts GDMI at low intake values and under predicts GDMI at high values (Figure 1). The model is accurate for low milk production but under predicts milk production at high levels (Figure 2.).

Table 1. Prediction accuracy of the GrazeIn model of grass dry matter intake (GDMI) and milk production for Irish grazing dairy cows (n=522 herds)

	Actual (A)	Pred. (P)	Bias (P-A)	MSPE*	MPE†
GDMI (kg/cow/d)	15.95	15.84	-0.11	3.71	0.12
Milk prod (kg/cow/d)	21.90	23.50	1.60	14.28	0.17

*Mean-squared Prediction Error †Mean Prediction Error

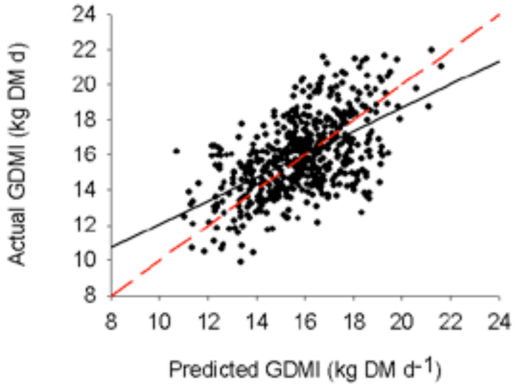

Figure 1. Relationship between actual and predicted grass dry matter intake (GDMI) for 522 Irish grazing dairy cow herds (Red dashed line: Y=X, Black solid line: regression of actual on predicted GDMI)

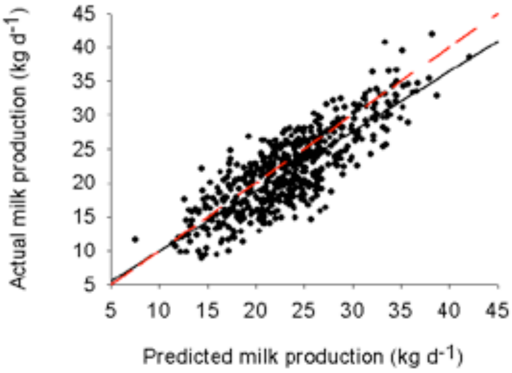

Figure 2. Relationship between actual and predicted milk production for 522 Irish grazing dairy cow herds (Dashed line: Y=X, Black solid line: regression of actual on predicted milk production)

Conclusions

The GrazeIn model satisfactorily predicts GDMI and milk production for Irish grazing systems. However, further work is needed to improve this prediction and to incorporate other scenarios, e.g. restricted access time, intake in early lactation.

Acknowledgements

We acknowledge the Department of Agriculture, Fisheries and Food Research Stimulus Fund for financial support.

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RMIS 5797

Gastrointestinal tract size as a proportion of liveweight in Holstein, Jersey and Jersey-cross cows

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Introduction

A study was previously carried out at the Teagasc Moorepark Ballydague Research Farm in which the production performance of three dairy cow breeds, Holstein Friesian (HF), Jersey (J) and their cross (F1), was investigated (Prendiville *et al.,* 2010). There was a difference in terms of intake capacity and efficiency between the breeds (Prendiville *et al.,* 2009). This may be explained by differences in body composition, particularly the gastrointestinal tract (GIT) (Prendiville *et al.,* 2010; Smith and Baldwin, 1974). The objective of this study was to measure the size of the GIT in the three breeds and to investigate if GIT as a proportion of liveweight (LW) differed between the breeds.

Materials and Methods

In Feb and Dec 2010, on four different days, 47 cows in total from the Teagasc Moorepark Ballydague Research Farm were slaughtered. The group was composed of 18 HF, 18 J and 11 F1 cows. The cows were all dry and not pregnant. All cows were managed identically from dry-off to slaughter and were slaughtered at Dawn Meats, Charleville, Co. Cork. Liveweight before leaving the farm and on arrival at the factory were recorded. At the factory the weights of the following tissues were measured: rumen-reticulum, omasum, abomasum, intestines. The rumen-reticulum was weighed empty. All other organs were weighed as presented. Organs were removed from the animal within 60 min of slaughter. Total GIT was calculated as rumen-reticulum+omasum+abomasum+intestines. For analysis, these tissue weights were expressed as a proportion of LW at the factory and of metabolic LW ($LW^{0.75}$). The data were analysed using general linear models (PROC GLM) in SAS with breed, lactation number, day of slaughter and their interactions included in the model.

Results and Discussion

The breeds all differed from each other in terms of LW (HF 577kg, J 435kg, F1 520kg; P<0.001) as expected (Prendiville *et al.,* 2010). Jersey tissues weighed less than tissues from cows of the other breeds, apart from the omasum, which did not differ in size between breeds (Figure 1a). On a proportion of LW basis HF cows had a smaller rumen-reticulum, abomasum and total GIT than both J and F1 cows (Figure 1b). The results on a proportion of metabolic LW basis were similar (Figure 1c). These findings echo the results of Smith and Baldwin (1974) and Nagel and Piatkowski (1988) who found that J cows had a proportionally greater rumen-reticulum weight and volume and GIT weight than HF cows. The proportionally greater weight of GIT, and thus greater digestive capacity, helps explain the higher intake capacity and efficiency of J and F1 cows (Prendiville *et al.,* 2009).

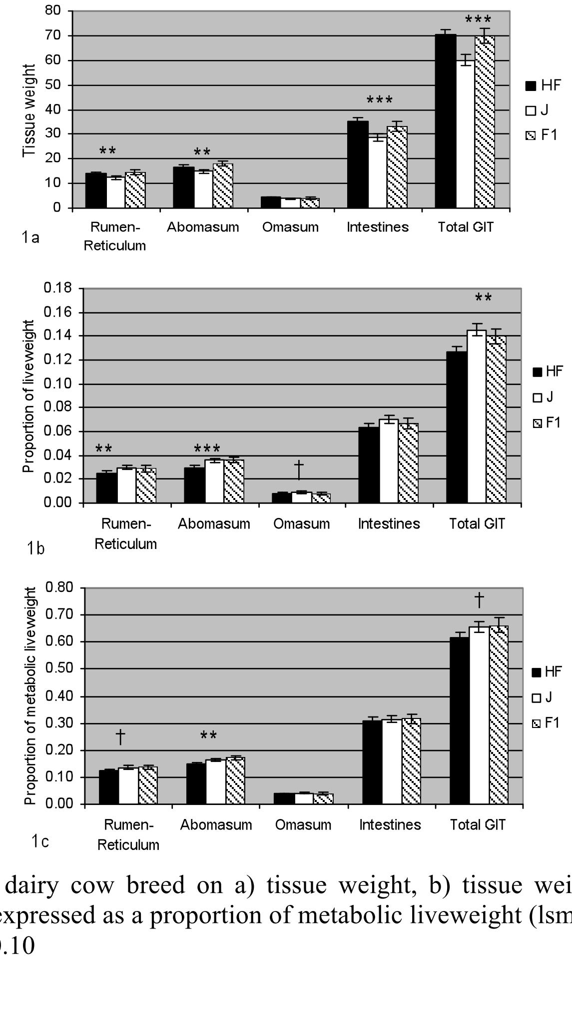

Figure 1a, b, c. The effect of dairy cow breed on a) tissue weight, b) tissue weight expressed as a proportion of liveweight and c) tissue weight expressed as a proportion of metabolic liveweight (lsmean)
** P<0.01   *** P<0.001   † P<0.10

Conclusions
This study illustrates that a significant difference exists between different dairy cow breeds in GIT size. The relatively greater GIT found in J and F1 cows helps explain their greater intake capacity and efficiency.

Acknowledgements
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RMIS 5893

Effects of perennial ryegrass (*Lolium perenne*) cultivars on the milk production performance of Holstein Friesian dairy cows

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Introduction
Selecting the correct grass cultivar is of major importance due to its potential influence on both animal and sward productivity (Gowen *et al.,* 2003). Worldwide, the majority of grass cultivar evaluation protocols test the performance of monocultures under either simulated grazing or conservation based protocols. This provides little indication on how a cultivar will influence animal performance. The objective of this study was to examine the effects of four perennial ryegrass (*Lolium perenne*) cultivars on the milk production performance of spring calving Holstein Friesian dairy cows during the early summer period.

Materials and Methods
A grazing experiment was set up to examine the effects of grass cultivars on the milk production performance of spring calving dairy cows. Four grass cultivars were employed; Bealey - intermediate tetraploid, Astonenergy - intermediate tetraploid, Spelga - intermediate diploid and Abermagic - intermediate diploid. During the grazing experiment, spring calving dairy cows were assigned to each cultivar for a period of 17 days in a 4 X 4 latin square design. Within the period of 17 days, the first 10 days were used for acclimatisation and the remaining 7 days were used to measure daily milk yield and milk composition. Cows were offered a daily herbage allowance of 17 kg DM/cow/day. Herbage mass was measured twice weekly. Pre and post-grazing sward heights were measured daily. The leaf, stem and dead proportion of the swards were measured during the experimental period. Animal variables were analysed using a mixed model in SAS (SAS, 2005). Treatment and period were included in the model. Animal was classified as a random effect.

Results and Discussion
The effect of grass cultivar on milk production performance is shown in Table 1. Grass cultivar had a significant influence ($P<0.05$) on the milk production performance variables measured with the exception of milk fat concentration. Cows grazing Abermagic had a lower milk yield and a lower milk solids yield.

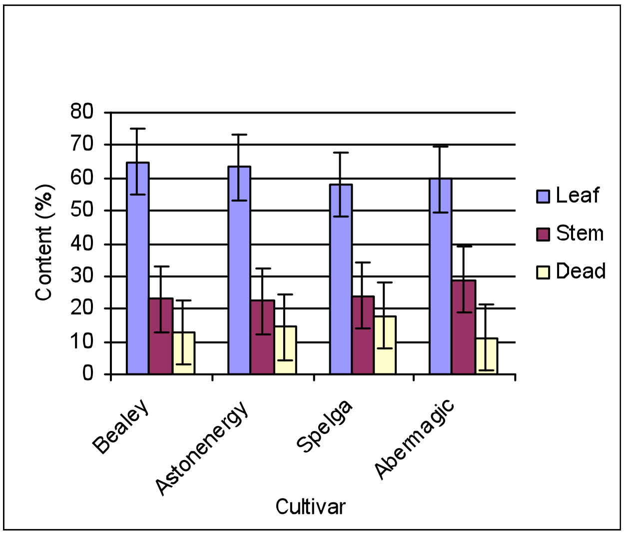
Grass cultivar did not affect pre grazing sward height (mean 9.9 cm, sem 0.26) or pre grazing herbage mass (mean 1531 kg DM/ha, sem 47.0) Grass cultivar did affect post grazing sward height ($P<0.05$) with Spelga having the greatest post grazing height (4.14 cm, sem 0.036) which was 0.1 cm greater than Bealey and Astonenergy but similar to Abermagic. The leaf, stem and dead proportions of the swards investigated showed Abermagic having a significantly ($P<0.01$, 0.29) higher proportion of stem in its sward which was proportionally 0.06, 0.07 and 0.05 higher than Bealey, Astonenergy and Spelga, respectively (Figure 1). Cows grazing the Abermagic swards were offered a sward with a higher stem mass ($P<0.001$, 467 kg DM/ha). This was 136, 129 and 80 kg DM/ha higher than the Bealey, Astonenergy and Spelga swards respectively. Stakelum and O'Donovan (1998) reported that offering swards with an increased proportion of stem reduces the digestibility of the sward and leads to a reduction in daily milk yields.

Table 1: Effect of grass cultivar on the milk production of spring calving Holstein Friesian dairy cows during the early summer period

Treat	Bealey	Astonenergy	Spelga	Abermagic	P Value Treat	P Value Period	sed
Milk yield, kg/day	27.0[a]	26.8[a]	26.9[a]	25.4[b]	***	***	0.31
Milk fat, g/kg	40.8	40.5	40.9	40.1	NS	NS	0.83
Milk protein, g/kg	34.2[ab]	34.5[a]	33.8[b]	34.3[a]	*	***	0.22
Milk lactose, g/kg	47.0[ab]	47.0[ab]	47.3[a]	46.7[b]	***	***	0.17
Milk solids, g/day	2017[a]	2006[a]	1999[a]	1879[b]	***	***	30.0

Signifiance; *** = P<0.001; **=P<0.01 ; * = P<0.05; Ns = Non -signifiant

Figure 1: Effect of cultivar on the leaf, stem and dead proportion of the sward



Conclusions

It can be concluded from the milk output levels achieved in this study that cultivars which maintain a high stem content negatively affect milk production performance.

References

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RMIS 5893

An economic comparison of white clover-based and N-fertilised grassland-based dairy systems under moist temperate climatic conditions

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Introduction

For the last ten years, the farm-gate cost of fertiliser N has been increasing relative to milk price (CSO, 2010), negatively impacting on the profitability of grassland-based dairy production. Biological N fixation (BNF) in association with white clover can replace fertiliser N in grassland. This paper reports on an evaluation of the profitability of white clover-based (WC) and N fertilised grass-based (NF) systems of dairy production. Details of these systems were taken from two system scale experiments conducted at Solohead Research Farm (52˚51'N, 08˚21'W), with a range of stocking densities and N fertilisation rates. The first was conducted between 2000 and 2002 with 18 cows per system (Humphreys *et al.*, 2008) and the second between 2003 and 2006 with 23 cows per system (Humphreys *et al.*, 2009). The economic viability of the contrasting systems of milk production was also evaluated for changing price scenarios.

Materials and Methods

In the first experiment described by Humphreys *et al.* (2008) there were three NF with stocking densities between 2.1 and 2.5 cows ha^{-1} and one WC stocked at 1.75 cows ha^{-1} in 2001 and repeated in 2002. Fertiliser N input ranged between 80 and 361 kg ha^{-1}. In the second experiment (Humphreys *et al.*, 2009) there was one NF and one WC each year for four years (2003 to 2006 incl.). The stocking density was 2 cows ha^{-1} in 2003 and 2.2 cows ha^{-1} in each of the following years for both NF and WC. In this experiment fertiliser N input was of 90 kg ha^{-1} for WC and 226 kg ha^{-1} for NF. Hence, production data from the 10 NF and 6 WC described above were used in this study. For the economic evaluation, the production data were compared on the basis of a farm of 50 ha. The net margin per hectare was calculated using a spreadsheet model developed in Excel. The production data were evaluated using: €0.828 kg N^{-1} urea (0.460 g N g^{-1}), €0.982 kg N^{-1} Calcium Ammonium Nitrate (CAN; 0.275 g N g^{-1}), €0.288 litre^{-1} milk sold, €0.262 kg^{-1} dairy meal (CSO, 2010), €120 head^{-1} for calves, and €350 head^{-1} for culled cows. The overhead costs (e.g. veterinarian fees, artificial insemination, contractor charges) were based on 2008 prices (Anon., 2008). For investigating economic viability of WC under changing price conditions, all the systems were subjected to nine price scenarios by using what-if analysis in Excel. The values above were the medium prices for fertiliser N and milk used for the baseline scenario. Additionally, a low (€0.684 kg N^{-1} for urea and €0.856 kg N^{-1} for CAN) and high (€0.945 kg N^{-1} for urea and €1.347 kg N^{-1} for CAN) price for fertiliser N were investigated. Similarly, a low (€0.233 litre^{-1}) and a high (€0.338 litre^{-1}) price for milk were assessed. No statistical analysis was undertaken.

Results and Discussion

There was a lot of inter-annual variation in net margins (Figure 1) particularly for three NF in 2002. In 2002, high rainfall and poor grass growth response to fertiliser N entailed high average concentrate (€361 (s.d. 35) ha^{-1}) cost for NF, contributing to relatively low net margins per hectare. At similar stocking density of 2.2 cows ha^{-1} on both WC and NF the average net margin was €1423 (s.d. 86) ha^{-1} for WC and €1356 (s.d. 108) ha^{-1} for NF. This was due to a lower fertiliser N cost (€75 (s.d. 6) ha^{-1}) for WC compared with NF (€206 (s.d. 10) ha^{-1}). At a higher stocking density (2.5 cows ha^{-1}), NF attained a net margin of €1360 (s.d. 142) ha^{-1}, similar to the WC stocked at 2.2 cows ha^{-1}, even if NF were associated with higher fixed costs (€931 (s.d. 41) ha^{-1}) than WC (€848 (s.d. 16) ha^{-1}). The WC were more profitable than NF in the scenarios combining medium to high fertiliser N price and medium to low milk price due to higher cost efficiency of WC. On the other hand, the NF were more profitable than WC when low fertiliser N price was associated with high milk price due to higher milk sales for NF.

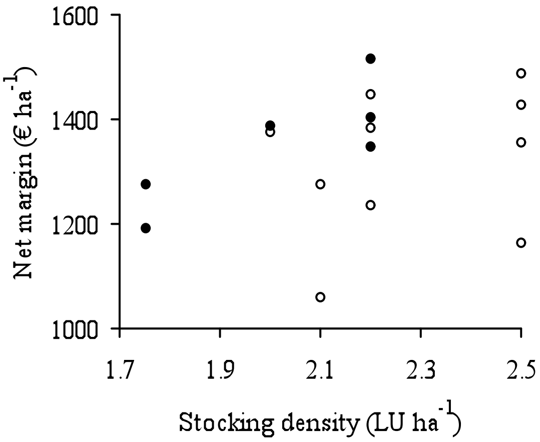

Figure 1. Net margin on WC (●) and NF

Conclusions

The WC were generally more profitable than the NF. The price scenarios showed that WC were more economically viable than NF in the conditions of higher fertiliser N price. This is of importance in future, when further increases in fertiliser N prices and greater instability in milk price are expected.

Acknowledgements

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RMIS 5676

Investigation into the effect of post-grazing height on early lactation dairy cow performance and subsequent carry-over effects on animal performance

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Introduction

Grass-based spring calving systems of milk production predominate in Ireland. In the context of the Food Harvest 2020 report, which targets a 50% increase in milk production by 2020, Irish dairy farmers who expand must adopt new strategies to increase production efficiency and reduce cost. As grazed grass is the cheapest feed source (Shalloo *et al.*, 2004) it is clear that a higher proportion of grass in the diet during early spring and late autumn would significantly reduce feed costs. Utilising more grass may be possible if swards are grazed to low post-grazing sward heights (PGSH). Therefore, the current target of grazing to 40 mm in spring may need to be revised for farmers expanding their enterprises and increasing stocking rates. The objective of this study was to ascertain the effect of PGSH on early lactation animal performance and subsequent carry-over effects during the lactation.

Materials and Methods

Seventy-two (32 primiparous and 40 multiparous) spring calving Holstein-Friesian dairy cows were balanced on calving date (12 February; s.d. 14.8 days), lactation number (1.8; s.d. 1.1), previous lactation milk yield (4744; s.d. 1426.9 kg), bodyweight (BW; 538, s.d. 36.1 kg) and body condition score (BCS; 3.39, s.d. 0.34) in a randomised block design with a 2×2 factorial arrangement of treatments. Animals were randomly assigned pre-calving across two PGSH treatments (n=36): severe (3 cm - S) or lax (4 cm – L) from February 10 to April 18 (period 1; P1). Following P1, animals were re-randomised within P1 treatment across two PGSH to monitor the carry-over effects. Similar to P1, animals grazed to either severe (3.5cm) or lax (4.5cm) PGSH from 19 April to 30 October (Period 2, P2). The difference in PGSH was achieved by ensuring a 3 kg DM/cow/day difference in daily herbage allowance (DHA). Fresh herbage was allocated daily. Herbage mass was calculated twice weekly by cutting two strips per grazing treatment. Pre and post-grazing heights were measured daily. Pasture utilisation was calculated for each grazing rotation from the pre-grazing yield relative to the post-grazing yield. Milk yield was recorded daily; milk composition, BW and BCS were measured weekly. Animal variables were analysed using PROC MIXED in SAS. Terms for parity, P1 and P2 treatments, the interaction of treatment and parity and the interaction of P1 and P2 treatments were included in the model. Pre-experimental values were used as covariates.

Results and Discussion

During P1, mean PGSH were 2.7cm and 3.5cm, for the S and L treatments, respectively. Mean DHA were 6.2 and 9.3 kg DM/cow/day for the S and L treatments, respectively. Mean concentrate supplementation during P1 was 4.5 kg/day for all animals. Decreasing PGSH in P1 depressed ($P<0.001$) milk yield (- 2.3 kg/day), milk solids yield (- 240 g/day) and protein content (- 1.16 g/kg), as shown in Table 1. The decrease in production reflected a high level of restriction placed upon the S treatment animals indicating they were physically restricted from grazing further into the sward. Treatment had no significant effect on BW or BCS at the end of P1. When cows were re-randomised across P2 treatments similar levels of production were observed after 3 weeks indicating a very limited carryover effect. When P2 production was analysed P1 treatment had no carry-over effect on milk and milk solids yields. Animals on the L treatment of P1 had a greater fat content (+2.3 g/kg) than their counterparts on the S treatment during P2. Severe grazing in P1 subsequently increased ($P<0.01$) lactose content (+0.50 g/kg) and yield (+31.8 g/day) in P2. Animals from the S treatment in P1 had a greater BCS at the end of P2 (+0.07). Severe grazing in early spring improved pasture utilisation (+29 %; $P<0.01$).

Table 1. Immediate and carry-over effect of post-grazing height on the animal performance of spring calving dairy cows

	Period 1*		Period 2**		Significance P1		Significance P2	
	S	L	S	L	sed	P Value	sed	P Value
Milk yield, kg/cow	20.3	22.7	17.6	17.1	0.53	0.001	0.29	NS
Milk fat content, g/kg	42.7	44.7	40.8	43.1	1.07	NS	0.66	0.001
Milk protein content,	31.4	32.5	34.5	35.0	0.34	0.001	0.35	NS
Milk lactose content,	46.5	46.9	46.0	45.5	0.20	NS	0.18	0.006
Milk solids yield, g/day	1500	1741	1320	1339	39.0	0.001	22.9	NS
End body weight, kg	446	469	517	511	7.9	NS	2.8	NS
End body condition score	2.89	2.86	2.88	2.81	0.03	NS	0.026	0.033

*Performance in P1 of animals on treatment S, 3cm or L, 4cm. **Performance in P2 of animals on S or L treatment in P1

Conclusions

Severe grazing in early lactation results in milk production losses. There was no carry-over effect of P1 treatment on P2 milk and milk solids production. The results of this study have positive repercussions for farmers with high stocking rates as PGSH can be lowered in early spring in the knowledge that once DHA is increased, when grass supply becomes more plentiful from April onwards, cows will respond. However, the milk production lost in early spring will not be recovered.

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RMIS 5798

Effect of post-grazing sward height on total lactation dairy cow performance

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Introduction

The focus of grass based systems has changed to increase milk production per hectare rather than milk production per cow. Dairy farmers that expand their enterprises by increasing stocking rate may need to graze pastures to lower post-grazing sward heights (PGSH) to maximise the profit from grazed grass. Lee *et al.* (2008) found that pastures can be grazed to a low post-grazing height (4.1 cm) during the spring without adversely affecting milk production. However, there is little knowledge available on the effect of PGSH imposed during a full lactation on dairy cow performance. The objective of this study was to investigate the effect of post-grazing height on total lactation dairy cow production performance, under Irish conditions.

Materials and Methods

This study was part of a larger experiment (Ganche *et al.*, 2010) that investigated the effects of PGSH on dairy cow performance and sward characteristics. The present study reports the production performance of 36 Holstein-Friesian dairy cows (mean calving date, 13 February; s.d. 16.3 days) that remained on the same PGSH treatments up to 30 October. The treatments were: i) grazing to a low PGSH (3.5 cm; L) or ii) grazing to a higher PGSH (4.5 cm; H) for the full lactation. The difference in PGSH was achieved by ensuring a 3 kg DM/cow/day difference in daily herbage allowance (DHA). Fresh herbage was allocated daily. Herbage mass was calculated twice weekly. Pre and post-grazing heights were measured daily. Milk yield was recorded daily; milk composition, bodyweight (BW) and body condition score (BCS) were measured weekly. Animal variables were analysed using covariate analysis and the PROC MIXED statement of SAS with terms for parity, treatment and the interaction of parity and treatment. Pre-experimental values were used as covariates in the model.

Results and Discussion

Throughout the lactation the L treatment animals grazed to 3.4cm while the H treatment animals grazed to 4.5cm. The mean DHA offered to each treatment were 11.0 and 13.7 kg DM/cow/day for the L and H animals, respectively. Total concentrate input was similar for treatments, 517 kg/lactation/cow. Pasture utilisation was 12% greater for the L treatment (82%). There was no significant effect of PGSH on cumulative milk yield (4,552 kg milk/cow; Table 1). Imposing a severe PGSH for the full lactation decreased total fat (-25.8 kg/cow; P<0.01), and protein (-14.8 kg/cow; P<0.05) yield, when compared to the more lax grazing treatment (201.9 and 159.6 kg/cow, respectively). Figure 1 shows the weekly milk solids (MS) yield of both treatments. Severe grazing for the entire lactation depressed (P<0.01) total MS yield by 40.7 kg/cow when compared to the laxer treatment (Table 1). Nadir BW was 24 kg lower (P<0.05) for the L treatment cows when compared to their counterparts on the H treatment (448 kg) whereas nadir BCS was similar across treatments (2.65).

Table 1. Effect of post-grazing height on the total lactation performance of spring calving dairy cows

	Treatment		Significance	
	L	**H**	**sed**	**P Value**
Milk yield (kg/cow)	4409	4694	135.1	0.148
Milk fat content (g/kg)	40.1	43.2	0.66	0.003
Milk protein content (g/kg)	32.9	34.1	0.36	0.031
Milk lactose content (g/kg)	45.6	45.6	0.31	0.939
Milk solids yield (kg/cow)	321	362	9.9	0.007
End BW (kg)	522	525	8.6	0.837
End BCS	2.83	2.77	0.033	0.196

L=3.5cm, grazing height H= 4.5cm grazing height (10 Feb. to 30 Oct.)

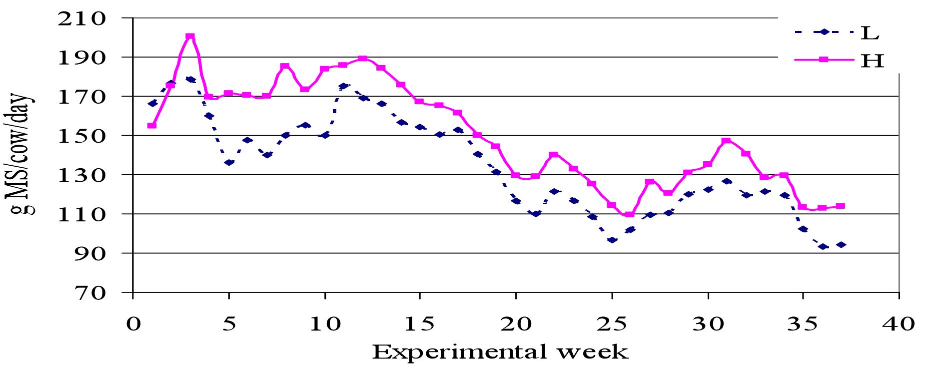

Figure 1. Effect of post-grazing height on milk solids production during the lactation

Conclusions

Although grazing to a low PGSH results in greater pasture utilisation and no significant difference in milk production when compared to animals grazing to a less severe PGSH, milk solids yield per cow is decreased by over 40 kg / lactation. These results indicate that grazing to lower PGSH for a full lactation should only be practiced on farms that are highly stocked and can tolerate losses in per cow production.

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RMIS 5798

The effect of stocking rate and calving date on the reproductive capacity of Holstein-Friesian dairy cows

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Introduction

The imminent removal of milk quotas will have a major influence on the Irish dairy industry, with a large increase in milk production anticipated. To achieve this increase, producers will be required to develop low cost, labour efficient production systems by maximising milk production from grazed grass (Dillon *et al.* 2008). Stocking rate (SR), traditionally expressed as cows per hectare (ha), is acknowledged as the main driver of milk productivity from pasture-based production systems. However, whilst numerous studies have shown that as SR increases, milk production per cow decreases and milk production per ha increases (Macdonald *et al.* 2008), the effect of SR on reproductive performance has not been widely investigated. Therefore, the objective of this study was to evaluate the impact of SR and calving date on the reproductive capacity of Holstein-Friesian (HF) dairy cows over a two year period.

Materials and Methods

Two hundred and seventy six HF dairy cows (138 in both 2009 and 2010, respectively), with an average Economic Breeding Index of €116 and fertility sub-index of €55, were randomly assigned to one of two mean calving date treatments each year, to establish two groups of dairy cows: Early calving (mean calving date: 12th of February) and Late calving (mean calving date: 25th of February). Each year a total of 69 animals from within each calving date were randomly allocated to one of three SR treatments, Low (2.51 cows/ha), Medium (2.92 cows/ha) and High (3.28 cows/ha). The cows used in the experiment comprised of two genotypes of HF; North American (NA) and New Zealand (NZ). Cows were turned out to pasture in early February with SR treatments managed separately and calving date treatments within each SR managed similarly. Different grazing intensities were imposed on each SR, with target post-grazing residual heights of 4.5-5.0, 4.0-4.5, and 3.5-4.0 for the low, medium and high SR, respectively. Concentrate supplementation and artificial fertiliser application was the same for each SR, however late calving treatments received less concentrate. Bodyweight (BW) was measured weekly and body condition score (BCS) every three weeks. Reproductive data were analysed using a logistic regression model (Proc Logistic; SAS) that included the effects of parity, genotype, calving date, SR treatment and covariates. Bodyweight and BCS were analysed using general linear models (Proc GLM; SAS) which also included the effects of parity, genotype, calving date, SR treatment and covariates.

Results and Discussion

Reproductive performance was unaffected by stocking rate or calving date (Table 1) with the exception of embryo mortality which was greater in the low SR compared to the medium and high SR. No significant SR by calving date interactions were found. Animals of NA origin had a tendency for a reduced submission rate ($P = 0.069$), pregnancy rate at 42 days of breeding ($P = 0.103$) and a tendency towards a higher overall infertility rate (24% for NA compared to 15% for NZ). The low SR treatment had a greater ($P <0.05$) nadir BW (460 kg) than the medium and high SR (446 and 445 kg, respectively) and a greater nadir BCS than the high SR (2.77 compared to 2.67 BCS). As SR increased, BW at mating start date, AI and BW and BCS at the end of lactation were also reduced.

Table 1. Effect of stocking rate and calving date on reproductive performance

	Stocking rate (SR)			Calving date (CD)		P-values		
	Low	Med.	High	Early	Late	s.e.[1]	SR	CD
Mean calving date (dd-mm)	19-2	19-2	18-2	12-2	25-2	3.18	0.889	<.001
Calving to service interval (days)	82	84	86	85	83	5.21	0.576	0.501
Calving to conception interval (days)	97	101	100	100	99	3.53	0.630	0.768
24-day submission rate (%)	85	80	77	81	80		0.553	0.943
Pregnancy rate to 1st service (%)	48.9	46.2	47.8	50.7	44.5		0.807	0.265
Pregnancy rate at 42 days of AI (%)	64.1	57.1	57.6	59.4	59.9		0.658	0.863
Overall pregnancy rate (%)	82.6	78.0	80.4	80.4	80.3		0.448	0.939
Embryo mortality (%)	9.8	4.4	1.1	3.6	6.6		0.043	0.254

[1]s.e. – standard error

Conclusions

The results suggest that where appropriate genotypes are selected, increased SR can be achieved without adverse effects on reproductive performance.

Acknowledgments

We acknowledge the Dairy Levy Research Fund for financial support.

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RMIS 5891

Effects of diet during the first winter on replacement heifer weight gain and body condition score

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Introduction

Attaining target weights, particularly at the start of the breeding season, is a critical component of any replacement heifer rearing system. Winter diet has previously been shown to affect weight gain over this critical period (Kennedy *et al.*, 2010). However, cattle often exhibit compensatory growth following nutritional restriction (Ryan *et al.*, 1993). The two objectives of this study were to i) investigate five contrasting winter feeding regimes on heifer bodyweight (BW) gain and body condition score (BCS) and ii) determine if compensatory growth can be relied upon in replacement heifer rearing systems.

Materials and Methods

One hundred and fifty spring born weanling replacement dairy heifer calves were balanced on the basis of breed (Holstein Friesian; 79% of herd, Jersey × Holstein; 13% of herd, Montbelliarde × Holstein; 9% of herd), age (284 ± 20.3 days), BW (213 ± 26.1 kg) and BCS (2.98 ± 0.215) in a randomised block design. They were then randomly assigned to one of five winter feeding treatments from 23 November 2009 to 25 February 2010 (94 days). The five feeding treatments were: i) indoors offered *ad libitum* grass silage and 1.5 kg DM concentrate (IC); ii) indoors offered *ad libitum* grass silage only (SO); iii) outdoors on an out-wintering pad offered *ad libitum* grass silage and 1.5 kg DM concentrate (OWP); iv) outdoors offered 70% kale and 30% grass silage (70K); v) outdoors offered 100% kale (100K). The IC, SO and OWP treatments were all offered the same silage. The 70K animals were offered baled silage. The forage kale was grazed *in situ*. Prior to the commencement of the experiment all animals received one Tracesure® I bolus to provide iodine, selenium and cobalt supplementation, they had previously been supplemented with Cu. The 100K treatment animals were offered straw for the first week of the study to adjust them to the 100% kale diet. It was intended to offer no further fibre source after the first week, however due to continuous frost 3 bales of silage were offered 5 weeks into the experiment. All animals were offered fresh feed daily; the refusals of the IC, SO and OWP animals were removed and weighed daily, the outdoor animals were offered a fresh allocation of kale each morning by moving a temporary electric fence. Animals were grouped by treatment. During the experimental period all animals were weighed weekly and condition scored every three weeks. All animals were turned out to pasture on 25 February and offered *ad libitum* grazed grass. All animals were then weighed weekly to the start of the breeding season (15 April) and monthly thereafter; BCS was recorded monthly from turnout. All data were analysed using PROC MIXED in SAS. Animal was used as the experimental unit. Pre-experimental values were used as a co-variate in the model. The data are reported in three periods, PI: the 94 day experimental period, PII: the period of time from turnout to the start of the breeding season and PIII: from after the commencement of the breeding season to 6 September 2010.

Results and Discussion

The dry matter digestibility (DMD) of the pit silage was 0.70 units (±0.20), dry matter (DM) was 0.29 units (±0.249) and crude protein (CP) was 0.11 units (±0.007). The DMD of the baled silage was 0.70 units (±0.25), DM was 0.34 units (±0.669) and CP was 0.156 units (±0.066). The BW gain during the period when treatments were imposed (PI) was similar for the IC, OWP, 70K and 100K treatments (0.48 kg/day; Table 1). The SO treatment gained less BW during PI ($P<0.01$) than all other treatments. There was no significant difference between treatments in BW gain throughout PII and PIII (0.75 and 0.83 kg/day, respectively), clearly indicating that no compensatory growth was achieved by the SO treatment post turnout. During PI BCS was lowest ($P<0.01$) for the 100K animals (Table 1) which was probably a consequence of prevailing weather conditions during the experiment. Mean air temperatures during the experimental period were 2.9°C, 3.6°C and 2.8°C lower than the 10-year average in December (6.1°C), January (5.8°C) and February (5.8°C), respectively. Due to a risk of ill-health frosted brassicas should not be offered for consumption. The BCS of the animals from 100K treatments may have suffered due to feed restriction during extreme periods of cold weather. However, during PII and PIII there was no effect of winter treatment on average BCS indicating that the 100K animals compensated.

Table 1. Effects of winter feeding treatment on bodyweight (BW) and body condition score (BCS)

	IC	SO	OWP	70K	100K	SED	Sig
BW gain PI	0.41[a]	0.29[b]	0.52[a]	0.47[a]	0.51[a]	0.037	0.011
BW gain PII	0.68	0.82	0.73	0.78	0.72	0.054	0.536
BW gain PIII	0.80	0.93	0.81	0.82	0.80	0.027	0.111
Average BCS PI	3.10[ab]	3.07[ab]	3.13[b]	3.05[a]	2.97[c]	0.023	0.009
Average BCS PII	3.15	3.16	3.15	3.22	3.18	0.041	0.757
Average BCS PIII	3.05	3.12	3.10	3.09	3.07	0.031	0.6832

[abc] values in the same row not sharing a common superscript are significantly different

Conclusions

The concept of 'compensatory growth' can not be relied upon when trying to get replacement heifers to attain target weight at breeding start date. The results of the study also clearly show that kale can be used as a winter feed and BW gains similar to a silage and concentrate based diet can be achieved from it.

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RMIS 5892

Body weight of Holstein-Friesian maiden heifers at mating start date and implications for pubertal rate, subsequent cow performance and profitability.

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Introduction

An efficient heifer rearing system is crucial to the future income and sustainability of a dairy enterprise. Calving replacement dairy heifers at 24 months of age is a necessity in order to obtain maximum lifetime productivity, particularly in seasonal calving pasture based systems. Heifer rearing guidelines generally recommend a BW target of 60-65% of mature bodyweight at mating start date (MSD), however, few demonstrate the implications of under or over developed heifers. The objective of this study was to evaluate the effect of body weight (BW) at MSD on pubertal rate in maiden heifers and the impact on subsequent dairy cow performance and profitability.

Materials and Methods

Data were available from 871 Holstein-Friesian (HF) dairy heifers from 48 commercial dairy farms. Herds were visited once, on average 9 (SD 5.2) days prior to MSD; 23 April 2005 (SD 12.6) as maiden heifers. Heifers were weighed using a portable weighing scales (Trutest ltd, Auckland, New Zealand), body condition scored (BCS; 1-5), blood sampled for plasma progesterone concentration analysis and scanned. As cows they were weighed once during May/June 2006 to 2008. Heifers were deemed to be pubertal or non-pubertal as defined by Archbold (2011). Milk production and survival data (lactations 1 to 3) were obtained from the Irish Cattle Breeding Federation. All biological outcomes (305 day milk production, BW and survival) were analysed using Proc GLM in SAS with the fixed effects of herd, age, BCS and BW (quartiles) category in the model. The Moorepark dairy systems model (Shalloo *et al.*, 2004), was used to simulate a 40 ha farm integrating biological data from the current study, with respect to the MSD BW categories.

Results and Discussion

Heifer BW at MSD had a significant effect on the proportion of heifers pubertal (Table 1). Heavier heifers tended to have earlier calving dates in first lactation compared to lighter heifers. Larger heifers (≥ 343 kg) produced 30 kg more MS per lactation compared to the lightest heifers (≤ 290 kg). Heifers that were heavier at MSD were heavier as lactating cows; BW differences increased with time. Body weight at MSD had a significant effect on the longevity from MSD to lactation 1 and lactation 2, with a tendency towards significance with regard to survival in lactation 3 ($P<0.09$). In line with Carson *et al.* (2002) largest heifers had poorer survival. Farm profit was highest for the 317-342 kg BW category.

Table 1. Implications of body weight (BW) at mating start date (MSD) for percentage pubertal as heifers and subsequent calving date (CD), milk solids (MS) production, survival (SUV), BW over three lactations and farm profit.

	Body weight at MSD (kg)					
	≤290	291-316	317-342	≥343	S.E.M.	Sig.
Pubertal rate (%)	55[a]	75[b]	77[b,c]	81[c]	3.2	***
CD (Parity 1)	15-Mar[a]	05-Mar[b]	01-Mar[b]	27-Feb[b]	3.9	*
MS (kg) (Parity 1)	383[a]	394[b]	404[c]	417[d]	4.3	*
MS (kg) (Parity 1)	448[a]	462[b]	467[b]	478[c]	5.4	*
MS (kg) (Parity 3)	474[a]	487[a,b]	496[b,c]	503[c]	7.4	*
SUV (%) (MSD to parity 1)	82[a]	88[b]	92[b]	93[b]	2.9	*
SUV (%) (MSD to parity 2)	62[a]	68[a]	78[b]	76[b]	4.0	*
SUV (%) (MSD to parity 3)	47	52	62	56	4.4	0.09
BW (kg) (Parity 1)	427[a]	455[b]	474[c]	499[d]	5.3	***
BW (kg) (Parity 2)	477[a]	501[b]	521[c]	545[d]	5.3	***
BW (kg) (Parity 3)	498[a]	519[b]	552[c]	579[d]	5.7	***
Farm profit (€)	36649	39010	43343	35689		

[a–d] Means within a row with different superscripts differ ($P < 0.05$).

Conclusions

Pubertal rate in maiden heifers pre-breeding is affected by BW at MSD. Larger heifers are more productive. However, lower survival with heifers grown to in excess of 343 kg at MSD means that heifers reared to approximately 330 kg at MSD are deemed optimal. This corresponds to a mature cow BW of approximately 550kg.

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RMIS 5892

Milk production performance of autumn-calving Holstein Friesian cows managed under grass silage or total mixed ration feeding systems

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Introduction

Increasing the proportion of grazed pasture in the diet reduces milk production costs across a range of scenarios (Dillon, *et al.,* 2002). However, winter milk production systems must achieve this while incorporating a significant quantity of supplements during the indoor feeding period. One potential strategy is to use total mixed ration (TMR) feeding in combination with grazing (Kolver, 1998). The objective was to investigate the milk production and feed budget requirements of autumn-calving dairy cows managed under TMR or grass-silage based systems.

Materials and Methods

Forty-eight autumn-calving Holstein Friesian cows were blocked pre-partum according to parity, genetic merit and body condition score (BCS), and assigned to one of two postpartum treatments; GRASS (stocking rate 2.75 cows/ha, concentrate supplement) or TMR (stocking rate 4.0 cows/ha, total mixed ration supplement). Median calving date was 8th October. Treatments were managed as independent farmlets, having separate decision rules for grazing, forage conservation and feed supplementation. During the winter housing period, the GRASS group were offered *ad-libitum* grass silage harvested from the farmlet area, plus 7kg dry matter of concentrate fed at a flat rate in the milking parlour. The TMR group were offered a total diet consisting of maize silage, grass silage, straw, wheat distillers by-product, plus coarse blend concentrate. Turnout to pasture for both groups in spring was managed such that the entire farmlet was grazed in increasing weekly area allocations, from February 10th until early April. Feed demand was balanced by offering a proportion of the winter diet. Supplements were removed when pasture availability permitted. Average farmlet cover was recorded weekly to facilitate decision-making. Pre- and post-grazing sward heights were measured (platemeter) for each grazing. Approximately 0.52 of GRASS area was removed for silage in late May and July, with further area removed as baled silage to control pasture surpluses. Approximately 0.13 of TMR area was closed for silage in late May, with pasture surpluses removed as per GRASS. Remaining winter forage requirements of TMR were imported on a commercial basis. Forage utilised was estimated by difference, from milk yield, bodyweight and supplement data. Milk yield was recorded daily while milk composition was determined weekly. Data were analysed as repeated measures using the MIXED procedure of SAS, with treatment, time and treatment by time interaction included in the model. An autoregressive covariance structure was used with cow included as a random effect nested within treatment.

Results and Discussion

The TMR group had greater total lactation milk and milk solids yield per cow compared to GRASS (Table 1; $P<0.05$). This was primarily the result of greater milk yield ($P <0.01$) during the winter period (Oct-Feb), as milk production performance during the grazing period did not differ between the groups ($P > 0.05$). Thus, increased nutrient intake improved production for TMR during the indoor feeding period, but there was little evidence of any residual effect during the grazing period. The greater milk yield per cow, combined with a higher stocking rate resulted in a large increase in milk output per ha for TMR. However, there was a considerable attendant rise in requirement for imported feed. Estimated utilisation of forage on each farmlet was similar, indicating that differences in forage substitution due to supplement feeding were minimal.

Table 1: Milk production performance of autumn-calving cows managed under grass silage or TMR feeding systems

	GRASS	TMR	s.e.d	sig.
Winter Period (Oct-Feb)				
Milk Yield (kg/day)	24.3	27.0	1.03	0.01
Milk fat content (g/kg)	40.0	41.4	0.12	0.26
Milk protein content (g/kg)	33.2	33.9	0.06	0.30
Grazing Period (Mar-Sep)				
Milk yield (kg/d)	22.5	23.4	1.04	0.41
Milk fat content	39.5	41.0	0.12	0.21
Milk protein content (g/kg)	34.5	35.2	0.07	0.34
Total lactation milk yield (kg/cow)	6792	7368	276.1	0.04
Total milk solids yield (kg/cow)	494	557	16.9	<0.01
Milk Output (kg/ha grazing platform)	18,678	29,472	-	-
Feed supplement (t DM/ha)	4.1	11.9	-	-
Est. Forage utilised (t DM grazing platform)	12.1	11.7	-	-

Conclusions

This study demonstrates that forage utilisation can be maintained and milk output improved, when using TMR in conjunction with grazed pasture for autumn-calving cows. The relative economic merit of the production systems compared requires evaluation across a range of milk pricing and feed cost scenarios.

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RMIS 5901

A comparison of alternative intensive Irish pasture based systems of spring milk production on a wetland drumlin soil in the Border Midlands West Region of Ireland.

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Introduction

The abolition of EU milk quotas is anticipated to result in lower and more volatile milk prices to producers (Breen and Hennessy, 2003) while allowing milk production within Europe to move to areas of increased competitive advantage such as Ireland. In order to capitalise on this opportunity to expand milk production, Irish dairy farmers will have to increase productivity from pasture through improved growth and utilisation of grazed pasture. The objective of this study was to compare the economic and biological efficiencies of two likely future pasture-based systems of spring milk production on a wetland drumlin soil.

Materials and Methods

Physical performance data were obtained from a 3 year systems comparison at Ballyhaise College, Co. Cavan. In 2005, 2006 and 2007, the college dairy herd (n=68, 2005; n=81, 2006; n=91, 2007) was randomly allocated to one of two feed systems based on calving date, genetic potential (Economic Breeding Index; EBI) and parity. The two systems were: a high grass (HG) system (578 kg concentrate/cow at 2.45 livestock units (LU)/ha) and a high intensity (HI) system (1,365 kg concentrate/cow at 2.92 LU/ha). Cows were inseminated, using artificial insemination (AI), over a 13-week period, starting in late April and ultrasonographic examination was used to determine pregnancy rates. Milk yield was recorded daily during the study with concentrations of fat, protein and lactose determined in one successive evening and morning sample of milk each week. Animal production data for the measurement period were analysed using Proc

MIXED of SAS (SAS, 2006). Feed system, year and parity were included as fixed effects in the final model. Chi-square analyses were used to identify differences in pregnancy rates.The Moorepark Dairy Systems Model, a stochastic budgetary simulation model, (Shalloo *et al.*, 2004) was used to simulate a model farm integrating biological data from each feed system. Both feed systems were compared across three future milk prices of 22, 27 and 33 cents per l, assuming 33.0 g/kg protein and 36.0 g/kg fat with a relative price ratio of 1:2 for fat: protein. Two economic scenarios were investigated within the model, scenario 1 (S1) assumed fixed cow numbers (n=55 cows) and scenario 2 (S2) assumed fixed land area (n= 40 ha). For each scenario, farm profit was estimated using the actual milk production, feed imported and fertility data from the experiment.

Results and Discussion

Feed system had a significant effect on all the yield variables with higher yields of milk and fat plus protein in the HI system (Table 1). Milk fat, protein and lactose content were unaffected by production system. The combination of increased supplementation per cow and increased cow numbers per hectare resulted in a response of 1.53 kg of milk and 0.11 kg of fat plus protein per 1 kg of additional supplement fed in the HI system. There was no significant influence of production system on reproductive performance.

Table 1. Effect of system on milk production

System of Production	HG	HI	se	P. value
Yield (kg/cow)				
Milk	5,606	6,049	165.8	**
Milk solids	427	458	13.1	*
Fertility performance				
Preg. to 1st serve (%)	42	46		NS
42day calving rate (%)	41	45		NS
Empty rate (%)	27	27		NS

*=P≤0.05, **= P≤0.01, se = standard error

The optimum system of production varied depending on milk price (Table 2). At a milk price of 27 c/l, profit per hectare was similar for HG and HI in S1 and higher for HI in S2. At a lower milk price of 22 c/l, all systems were unprofitable, with increased losses observed in the HI system in both S1 and S2. In contrast, at a milk price of 33 c/l, profit per hectare is higher in the HI system with a higher profit realised in S2.

Table 2. Effect of system of production on farm profit

Scenario	S1		S2
System of Production	HG	HI	HI
Farm size (Hectares)	40	40	40
Number of cows calving	100	100	117
Purchased feed cost (€)	11.968	28,323	33,138
Replacement costs (€)	47.967	47,967	56,122
Total costs (€)	166,070	179,457	207,878
Farm Profit/hectare			
@ 20c/l (€)	-314	-416	-435
@ 27c/l (€)	753	734	911
@ 33c/l (€)	1,668	1,720	2,064

Conclusions

The results of this study show that while pasture based systems of milk production in the northern region of Ireland are capable of delivering high profits per hectare at a milk price of greater than 22 c/l, the optimum system of production will depend on milk price.

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RMIS 6015

ENVIRONMENT

The fertiliser potential of dairy soiled water in temperate grasslands

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Introduction

Dairy soiled water (DSW) is produced on dairy farms from the washing of milking plant and cow holding areas during the milking process. It typically consists of a relatively dilute mixture of cow faeces, urine, spilt milk and detergents, and therefore contains plant nutrients. Despite its nutrient content, DSW is typically perceived to be of little nutrient value and is generally managed as a farm waste. The objective of this study was to determine the nitrogen fertiliser replacement value of DSW in a plot experiment on two contrasting grassland soils in SW Ireland.

Material and Methods

An experiment with a randomised complete block design was established at two sites. Treatments consisted of 4 nitrogen (N) rates x 2 fertiliser types x 2 sites x 4 replicates x 9 application timings. The two soil types used were a well-drained sandy loam acid brown earth at Moorepark (MP) and a poorly drained silt loam gley soil at Killbeheny (KB). Treatments were applied every six weeks from 23 July 2008 to 16 September 2009. The four rates of N were 0, 15, 22, and 30 kg N ha^{-1}. The two fertiliser types were DSW and inorganic fertiliser N (calcium ammonium nitrate; CAN). Dairy soiled water was applied at 22,000, 33,000, and 45,000 l ha^{-1} (DSW1, DSW2 and DSW3, respectively) and inorganic fertiliser N at 3 equivalent N rates (IF1, IF2 and IF3, respectively), to achieve N rates of 15, 22, and 30 kg N ha^{-1}. Fresh DSW was collected analysed and diluted to achieve a total nitrogen concentration of 660 mg l^{-1}. Phosphorus and K levels at both sites were maintained at index 4 levels using a maintenance rate of 33 kg ha^{-1} of 24-2.5-10 NPK fertiliser 12 weeks prior to the application of treatments. Plots were 1 m x 5 m in size. Yield (herbage mass in kg DM ha^{-1}) was measured at 4 weeks and 8 weeks after application by cutting a 0.65 m strip down the centre of the plot, using an Agria mowing machine (Agria-Werke GmbH, Mockmuhl, Germany). Factors influencing yield were determined using ANOVA, with N rate, fertiliser type, site and timing as independent variables. Yield response to N application was calculated for SW and IF treatments as the treatment yield minus the C yield. The nitrogen fertiliser replacement value (NFRV) of DSW at each N rate was calculated as the SW yield response divided by the IF yield response, expressed as a percentage.

Results and Discussion

Dairy soiled water application lead to significant herbage growth response (Figure 1). During peak grass growth in July, DSW application increased herbage yield by 668, 2514 and 2217 kg DM ha^{-1} for DSW1, DSW2 and DSW3, respectively. Therefore, DSW has potential as an organic fertiliser and may help replace some inorganic fertiliser use on-farm. Mean NFRV was 72, 78 and 90% for SW1, SW2 and SW3, respectively. Herbage yield increased significantly ($P < 0.001$) with N rate, from 1487 to 1700 kg DM ha^{-1} with an increase in N rate from 15 to 30 kg N ha^{-1}. There was a significant effect of timing ($P < 0.001$) on DM yield (Figure 1). Mean yield, across all treatments, increased from 91 kg DM ha^{-1} in December to a maximum of 3822 kg DM ha^{-1} in July. The application of fertiliser (organic or inorganic) from September to early February resulted in a poor yield response compared to application from March to July (Figure 1).

Table 1. Significant main effects and interactions from ANOVA

Factor/Interaction	***P value***
Timing	<0.001
Type	<0.001
N rate	<0.001
Site	<0.001
Type x Timing	<0.001
Timing x Site	<0.001
N rate x Timing	<0.001
Type x N rate x Timing	<0.001

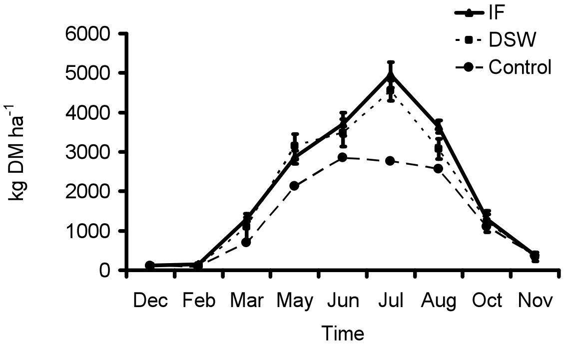

Figure 1. Mean yield for 3 DSW and 3 IF treatments (including error bars).

Conclusions

Results indicate that there is potential to use DSW to increase grass herbage production during the growing season. Mean NFRVs of 72 to 90 % indicate that DSW has the potential to substitute for inorganic fertiliser N, offering cost savings to farmers and decreasing farm N surpluses and their associated environmental impacts. Poor yield responses to DSW application in winter suggests that there may be a greater risk of N loss from DSW through leaching during this period.

Acknowledgements

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RMIS 5796

Nitrous oxide emissions from land application of dairy soiled water

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Introduction

Dairy soiled water (DSW) is produced through the washing-down of milking parlours and holding areas. It contains significant quantities of nutrients that can be applied to grassland as an organic fertiliser. However, some of the N in DSW can be lost as nitrous oxide (N_2O), a powerful greenhouse gas (GHG), following application. The objective of this study was to quantify the seasonal effect of DSW application on N_2O emissions.

Materials and methods

Thirty two undisturbed soil monoliths (30 cm diameter and 70 cm depth) were collected from two sites with established pasture and contrasting soils; a well-drained sandy loam acid brown earth at Moorepark (MP) and a poorly drained silt loam gley soil at Kilbeheny (KB). Four treatments were applied, consisting of a control (C) and DSW applied at 3 time periods: May-August, September-December and January-April (SW1, SW2 and SW3, respectively), (Table 1). All lysimeters received 198 kg N ha^{-1} over the year. The C received inorganic fertiliser (IF) (calcium ammonium nitrate) only. DSW was substituted for IF in the nutrient management plan on an equivalent total N basis.

Table 1. Experimental treatments, showing dates and rates of application (kg N ha^{-1})

Timing	C		SW1		SW2		SW3
21-May	33		33*		33		33
02-Jul	33		33*		0		33
13-Aug	33		33*		33		0
24-Sep	33		33		33*		33
05-Nov	0		0		33*		0
17-Dec	0		0		33*		0
28-Jan	0		0		0		33*
11-Mar	33		33		0		33*
22-Apr	33		33		33		33*
Total	198		198		198		198

*Dairy soiled water application

DSW was applied at the legal maximum rate of 50,000 l ha^{-1} every 6 weeks. N_2O fluxes were measured on each lysimeter at 0, 1, 4, 7, 14, 21 and 28 days post application using the static chamber technique. Atmospheric samples were collected at the start of the sampling period to provide a background concentration, the lysimeters were capped, and gas from the headspace was sampled after 30 minutes. Gas samples were analysed using gas chromatography. Total N_2O flux for 0-28 days was determined using linear interpolation between time-points. Emissions were summed over the year to give an annual total emission. Annual emissions data were analysed using ANOVA with soil type and treatment as the two fixed effects. An average emission factor (EF) for DSW was calculated for each of the three application periods using emissions from lysimeters receiving DSW and from lysimeters receiving none.

Results and Discussion

There was no effect of soil type on total N losses (P > 0.001). Loss of N as N_2O varied from 3.97 to 7.96 kg N $ha^{-1}year^{-1}$, or 2 – 4 % of applied N. Emissions from SW1 and SW3 were significantly lower (3.97 and 3.89 kg N ha^{-1}, respectively) than C and SW2 (6.36 and 7.96 kg N ha^{-1}, respectively) (P < 0.001). Therefore, substituting DSW for IF N in spring and summer can reduce N_2O emissions from grassland (Figure 1). Emissions tended to be highest immediately following N application (Figure 1 and 2), gradually returning to background levels. The emission factors for DSW integrated treatments were 1.62, 0.97, and 2.53 %, for January-April, May-August and September-December, respectively. This indicates that application of DSW during the grass growing season can minimise N_2O losses.

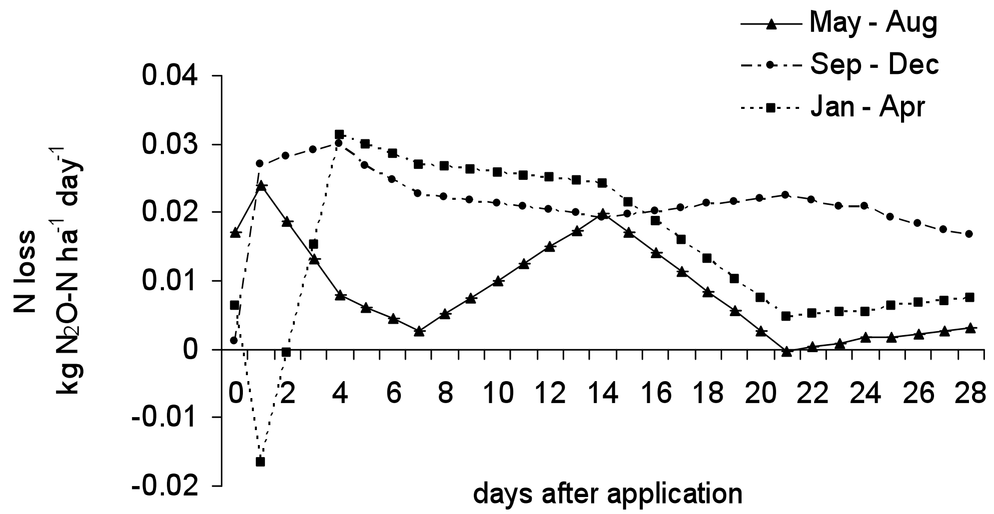

Figure 1: Mean N_2O emissions for lysimeters receiving dairy soiled water (DSW) for May to Aug, Sep-Dec and Jan-Apr.

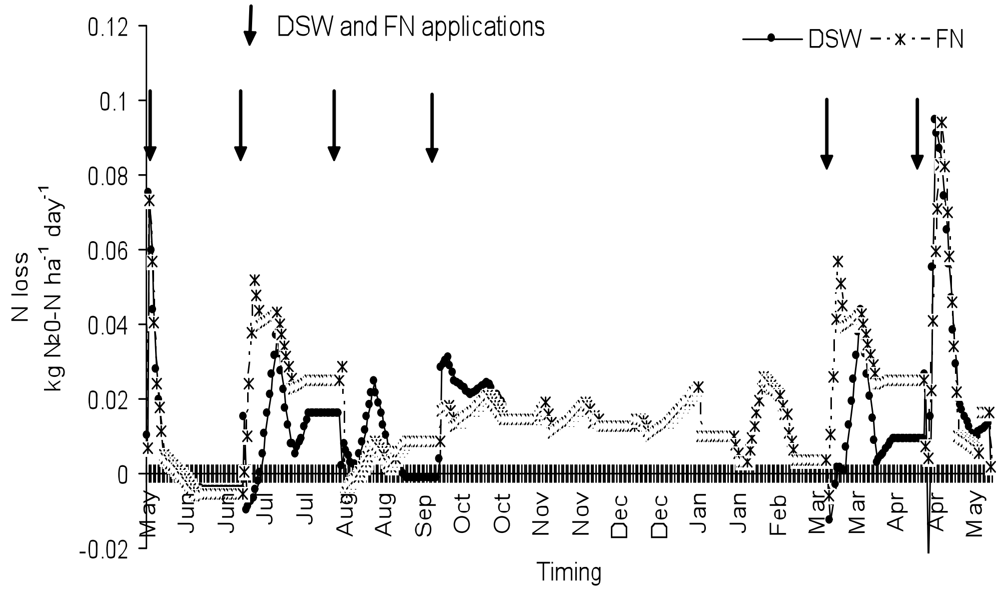

Figure 2: Seasonal patterns of N_2O fluxes (arrow indicates DSW application in tandem with FN)

Conclusions

Application of DSW caused N_2O emissions. However, substituting DSW for IF in spring and summer may reduce overall N_2O emissions from grassland, as losses from IF were typically higher. Emission factors for DSW ranged from 0.97 to 2.53 %, which is higher than the IPCC EF for slurry (1 %).

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RMIS 5796

The effect of dicyandiamide (DCD) application in late summer and autumn on annual herbage production on two soil types

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Introduction

Nitrogen (N) is an effective stimulant to grass growth as it directly increases leaf production and photosynthesis (Parsons and Chapman, 2000). Animal excreta are a valuable source of N for plants in grazed swards. Typically over 70% (range 50 to 90%) of N in fresh urine is present as urea (Haynes and Williams, 1993). Urinary N has a high potential for N losses because of the large N loading on a small area - a single application of urine can provide up to 1000 kg N/ha. Nitrification inhibitors such as dicyandiamide (DCD) have been shown to reduce nitrate (NO_3^-) leaching and nitrous oxide (N_2O) emissions (Moir *et al.*, 2007) from urine applied to grassland by slowing the conversion of ammonium (NH_4^+) to NO_3^- in the soil. Moir *et al.* (2007) also reported a 36% increase in annual herbage production from urine patches increases of up to 25% from non-urine areas following DCD application. The objective of this experiment was to investigate the effect of DCD application at three different times in late summer and early autumn on annual herbage production on two soil types.

Materials and Methods

This experiment was undertaken at the Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork (MPK) and at the Environment Research Department, Crops, Environment and Land Use Programme, Teagasc, Johnstown Castle, Co. Wexford (JC) on two contrasting soil types. The soils were (1) free-draining acid brown earth of sandy loam texture at MPK and (2) a poorly drained gley loam soil at JC. The experimental area consisted of simulated grazed plots (5m x 1.5m at MPK and 5m x 1m at JC). The experiment was a 4 x 2 x 2 factorial arrangement with 3 controls, set out in a complete randomised block design with three replicates at each site. Urine was applied in July, August or September or not applied. Artificial urine (urea and water mix) was applied at a rate of 0 or 1000 kg N/ha. Dicyandiamide was applied at rate of 0 or 10 kg/ha as a single application using a walk behind sprayer (Kestrel Spray-Master), within 24 hours of urine application. Fertilizer N was applied to all plots at a rate of 350 kg N/ha/year. Plots were harvested every 4 weeks from July to November (2009) and February to June (2010) using an Agria motor scythe. Fresh herbage was weighed and a sub-sample dried at 40^0C for 48 hours to determine dry matter (DM) yield. Data were analysed using PROC GLM in SAS. The main factors used in the model were; urine, DCD rate and DCD application date. Data for each site were analysed separately.

Results and Discussion

There was no significant effect of urine application on herbage production at either site. At both sites, urine application caused a scorching effect on the plots, resulting in reduced herbage production for a period (1 to 6 months) after application. As well as the scorching effect the application of urine and fertiliser N may have provided excessive N to the growing sward, thereby inhibiting herbage production (Middelkoop and Deenan, 1990). Annual herbage production (from July 2009 to June 2010) was significantly ($P<0.01$) increased at MPK when DCD was applied with urine in August and September (1,859 and 1,247kg DM/ha^{-1}, respectively) compared to the urine only treatments for these dates (Figure 1). There was no significant effect of DCD application to urine patches on herbage production at JC. The application of DCD to urine patches slows the conversion of NH_4^+ to NO_3^- (Di and Cameron, 2005; Moir *et al.,* 2007) making more N available for grass growth and this is the likely reason for increased grass growth at MPK in August and September. High grass growth rates in July reduced the effect of the increased N availability for grass growth. At JC, soils were very wet in 2009 and water logging may have reduced grass growth, resulting in no effect of DCD or urine application.

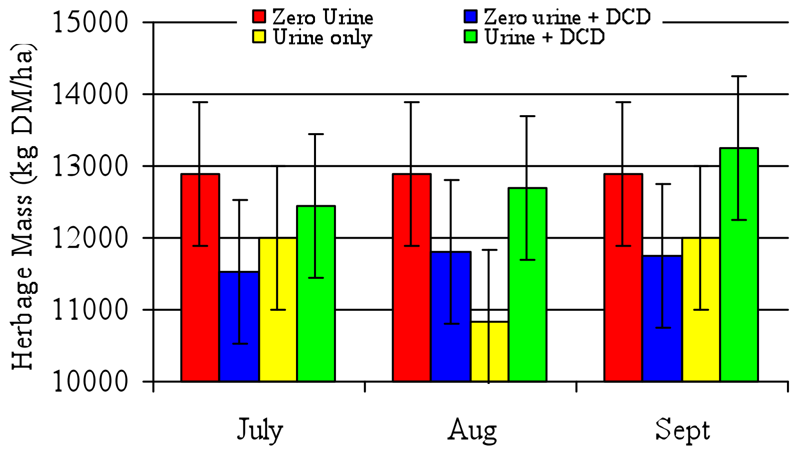

Figure 1. Average annual herbage mass production (kg DM/ha) between July 2009 and June 2010 on plots receiving zero urine, urine in July, August or September with and without DCD in MPK.

Conclusions

The application of DCD with urine in August and September at MPK increased annual herbage production compared to when no DCD was applied. There was no effect of DCD at JC. There was no significant effect of urine application on herbage production at either site due to scorching.

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RMIS 5903

Predicting grass growth: accuracy of three models

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Introduction

Grazed grass is the lowest cost feed for beef and milk production in Ireland. Due to climatic factors grass growth varies within and between years, making feed budgeting at farm level difficult. Models can provide a means to predict grass growth. The aim of this study was to compare the accuracy of prediction of three grass growth models using climatic and measured grass growth data from Teagasc Moorepark (MPK) over a five year period.

Material and Methods

Three models, developed for perennial ryegrass (*Lolium perenne* L.) swards in temperate climates, were selected for evaluation. The first model, developed by Johnson and Thornley (1983) (J&T), was mechanistic, incorporating leaf area expansion and senescence, with above-ground dry matter (DM) divided into four compartments described by structural weight and leaf area index. The second model, developed by Jouven *et al.* (2006) (J), was also mechanistic and was designed to respond to various defoliation regimes. It subdivides the sward into four compartments taking into account biomass, age and digestibility. The third model was empirical and was developed by Brereton *et al.* (1996) (B) and modified by R. Schulte (unpublished) to gain an understanding of the dynamics of a grazing management system subject to a variable herbage supply. The J&T and J models use a daily time step, the B model hourly. The inputs to all models were meteorological data collected at MPK (2005-2009). Modelled data were compared to grass growth measured at MPK using the methods described by Corral and Fenlon (1978). Predicted and observed data were compared using mean square prediction error (MSPE) and mean prediction error (MPrE) for three periods during the grass growing season: spring (weeks 6-13), mid-season (weeks 14-30) and autumn (weeks 31-45).

Results and Discussion

Period 1 - spring (weeks 6 - 13)

Average spring herbage production at MPK was 864 kg DM/ha. On average the J&T model over predicted grass growth by 22 kg DM/ha/day (Figure 1, Table 1), possibly due to the lack of partitioning of energy to reproductive growth in late spring. The J model under-predicted by a mean of 10 kg DM/ha/day, in part due to a large under-prediction in the first four weeks of the spring period (Figure 1, Table 1). The B model over-predicted spring grass growth by a mean of 10 kg DM/ha/day (Table 1).

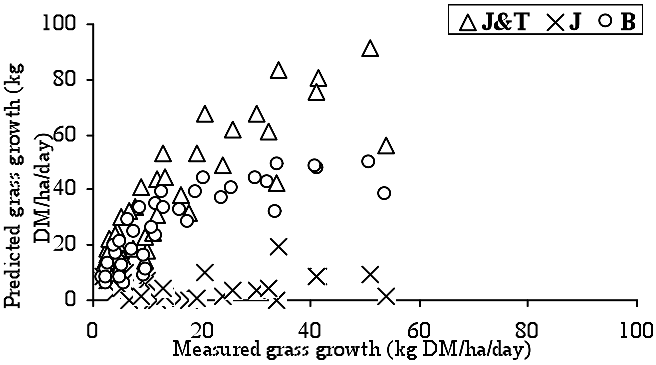

Figure 1. Daily grass growth (kg DM/ha/day) measured (X-axis) and predicted (Y-axis) for spring for years 2005-2009 at Moorepark. Grass growth was predicted using the J&T, J and B models

Table 1. Precision of prediction of grass growth by the Johnson and Thornley (J&T), the Jouven (J) and the Brereton (B) models, evaluated using mean square prediction error (MSPE) and mean prediction error (MPrE) for spring, mid-season and autumn

	Spring		Mid-season		Autumn	
	MSPE	MPrE	MSPE	MPrE	MSPE	MPrE
J&T	598	1.59	17529	1.73	7010	2.09
J	319	1.16	735	0.35	230	0.38
B	175	0.86	401	0.26	312	0.44

Period 2 - mid-season (weeks 14 - 30)

Average mid-season herbage production at MPK was 9,135 kg DM/ha. The J&T model over-predicted grass growth by an average of 129 kg DM/ha/day (MSPE = 17529; Table 1). There is no reproductive component in this model and so all energy is directed to vegetative growth resulting in increased leaf and tiller production. The J model under-predicted grass growth in mid-season by 19 kg DM/ha/day. This would likely be reduced if a soil moisture deficit (SMD) sub-model was incorporated and spring grass growth was more accurately predicted. The B model over predicted by just 2 kg DM/ha/day (MPrE = 0.26; Table 1). The incorporation of a SMD sub-model allows the B model to account for SMD in summer.

Period 3 - autumn (weeks 31 - 45)

Average herbage production for the autumn period observed at Moorepark was 4,088 kg DM/ha. The J&T model over-predicted by an average of 79 kg DM/ha/day, possibly due to high tiller density carried over from the summer period (calculations based on herbage mass and tiller densities from other experiments, data not shown). The J model under-predicted by a mean of just 9 kg DM/ha/day and so had the lowest MSPE of the three models. The B model over-predicted grass growth by 14 kg DM/ha/day.

Conclusions

The B model best predicted weekly grass growth in spring and mid-season while the J model had the best prediction in autumn. To accurately predict grass growth components of both models need to be modified.

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RMIS 5903

Gas sampling error in the ERUCT technique: effect of sample cross-contamination

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Introduction

The methane emissions from ruminants using a calibrated tracer (ERUCT) technique (Johnson *et al.*, 1994) is widely used. The technique enables estimation of the dilution of expired and eructated CH_4 in gases sampled from free ranging animals. To obtain samples representative of daily CH_4 and tracer gas emissions gases are continuously collected from near the mouth and nostrils of individual animals for a 24 h period, typically replicated for 5 d *via* reuse of collection canisters (Johnson *et al.*, 2007). It is assumed that the emission of sulphur hexafluoride (SF_6) tracer gas, arising from a calibrated slow release device in the rumen exactly simulates CH_4 emission and that the subsequent dilution of these gases with ambient air is identical (Johnson *et al.*, 1994). The daily emission of CH_4 is determined from the relative sample concentration of CH_4 and SF_6 and the release rate of SF_6 from the slow release device. We hypothesise that cross-contamination of gas samples may arise if residual gas is not completely removed from sample canisters prior to their reuse.

Materials and Methods

The cross-contamination of collected gas samples was assessed using 180 samples collected for 24 h at a constant rate (~0.5 ml/min) from 45 grazing cows. Prior to collection, residual gas was removed from the PVC sample canisters via repeated evacuation and pressurisation with ultra pure nitrogen (N, 99.995%, Air Products PLC, Cheshire, UK) and canisters were evacuated to 900 mbar below atmospheric pressure. The measurement was replicated on 4 consecutive days. Post-collection retained vacuum was measured and canisters were pressurised to 700 mbar with N in preparation for analysis. The initial concentration of SF_6 and CH_4 gas was determined simultaneously using a dual detector Varian 3800 gas chromatograph. Following analysis, sample gas was discharged and canisters evacuated to -900 mbar. To assess residual gas concentration, canisters were pressurised with N to 700 mbar and then re-analysed. The association between initial and residual gas concentrations were analysed using PROC REG (SAS, 2006).

Results and Discussion

Data from 130 canisters with detectable residual gas were analysed. Residual gas concentration was highly correlated ($P<0.001$) with initial sample concentration (Figure 1) CH_4 $r^2 = 0.98$, SF_6 $r^2 = 0.97$ and explained by the following linear relationships:

i. $[CH_4]_{residual} = 0.0118 + 0.0768\ [CH_4]_{sample}$
ii. $[SF_6]_{residual} = -0.1875 + 0.0794\ [SF_6]_{sample}$

Using these relationships the CH_4:SF_6 ratio of residual gases within each canister decreased by 3.37% (SD 4.75) compared to the ratio of the initial gas sample. These results support the hypothesis that residual gas can remain in canisters between uses.

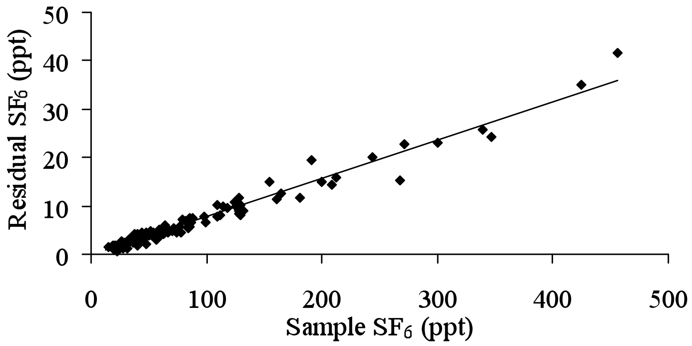

Figure 1. Correlation of sample vs. residual [SF6]

Residual gas will increase the measured concentration of gases within the subsequent sample collected into the same canister and potentially increase or decrease the resulting CH_4:SF_6 ratio. This error will occur when the initial sample collected has a higher concentration and the CH_4:SF_6 ratio differs from the true ratio of the subsequently collected sample. This scenario was simulated (10 random iterations) using the daily [CH_4] and [SF_6] data of 130 cows from Thackaberry *et al.* (2011). The resulting error as a percentage of the correct daily methane emission was normally distributed with mean 0.1% (SD 5.03%). The potential error ranged from +34% to -41% for individual cows. On average 20% of samples were affected by an error of > ±4%, 11% by > ±6% and 7% by > ± 8%.

Conclusions

Cross-contamination between samples contributes to daily variation in CH_4 emissions determined *via* ERUCT where residual gas has not been removed from canisters between uses. However the impact upon large group means is trivial due to the averaging effect of both elevated and suppressed values. The increased variation caused is most likely to impact comparisons between individual animals. Effect upon group means may occur when compounded by small group size, low measurement replication, large treatment differences and systematic affects such as the pattern of canister allocation (whether canisters are used across treatment groups) and where gas sampling error affects sample CH_4:SF_6. To ensure daily measurements are independent it is essential to remove residual gas from sample canisters *via* repeated flushing with N prior to their reuse.

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RMIS5781

Gas sampling error in the ERUCT technique: effect of gas collection apparatus

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Introduction

The methane emissions from ruminants using a calibrated tracer (ERUCT) technique (Johnson *et al.*, 1994) is widely used to determine enteric CH_4 production of free ranging ruminants. The CH_4 emission rate is determined *via* the calculation:

$$CH_4 \text{ emission} = \text{tracer emission} \times ([CH_4] / [\text{tracer}])$$

Gases are collected into canisters under vacuum pressure for 24 h periods. A constant sampling rate is maintained to prevent bias created by diurnal fluctuations in CH_4 emission. Sampling is replicated on consecutive days to enable calculation of average gas emissions. A sampling apparatus draws gases from near the nostrils and regulates flow rate into an evacuated canister. We hypothesise that erroneously high CH_4 emission values arise when undetected faults occur in the sampling apparatus due to wear. This study compares the daily enteric CH_4 emissions of cows determined *via* the ERUCT technique using both used traditional (TRAD) and new modified (MOD) gas sampling apparatus.

Materials and Methods

Forty five cows split between three breeds and three stocking rates (SR) grazed ryegrass swards in a rotational system. CH_4 emissions were determined in two periods, May (P1) and August (P2) at 93, and 179 days in milk respectively. Sulphur hexafluoride (SF_6) tracer gas was used with a mean permeation rate of 6.64 mg/d (SD 1.081). In both periods 2.14 L PVC gas collection canisters were mounted on the cow's backs. Gas samples were collected for 24 h with 4 replicates. Initial canister vacuum was 900 mbar below atmospheric pressure. Sampling rate was maintained *via* a stainless steel (SS) capillary tube (12.7 µm ID, Valco Instruments Co. USA) crimped and calibrated to achieve a constant flow rate of ~0.5 ml/min. During P1 a TRAD apparatus, similar to the widely used design of Johnson *et al.*, (2007) was used. The exposed stainless steel (SS) capillary tube was 50 mm in length, and the filter/capillary assembly comprised 6 brass Swagelok joins. During P2 a MOD apparatus was used, this design consisted of a 15 mm capillary tube housed within the Swagelok SS filter, one end of the capillary was secured inside the sample collection tube (1.65 mm ID) *via* a compression ferrule. This assembly comprised 2 Swagelok SS joins. The sampling tube terminated at the cows nose in a 6mm SS tube stub. Both designs attached directly to the canister *via* a SS quick connect fitting and included a Speedfit Y connection at the terminus of the sampling tube. Tubes (4mm ID) were fitted to extend to the nostrils. Post collection residual canister vacuum was measured and canisters were pressurised to 700 mbar with nitrogen (99.995% purity). Concentrations of CH_4 and SF_6 were determined simultaneously using a dual detector Varian 3800 gas chromatograph. Gas collection failure occurred for 3.3% of P1 collections and 1 cow was removed from P2 due to sampling failure. The CH_4 data were analysed using PROC MIXED (SAS, 2006) and the model $Y = \mu + \text{breed} + SR + \text{period} + e$. Cow was included as a random repeated effect.

Results and Discussion

Performance of the gas collection apparatus had a significant effect upon mean CH_4 emission ($P<0.001$). Average daily emission fell by 110 g/d when the used TRAD apparatus was replaced with the MOD apparatus (Table 1). The mean P1 emission was influenced by 40% of cows that returned CH_4 > 500 g/d, in contrast to P2 where only 1 cow attained such levels. Erroneously high values were associated with individual sampling apparatus, independent of sample canister, breed or SR. The lower emission calculated during P2 was accompanied by a 23% decrease in the mean CH_4:SF_6 ratio. The coefficient of variation (CV) about CH_4/kg body weight also reduced from 27% in P1 to 16% in P2. Error due to apparatus performance may be compounded by the low sampling rate (0.5 ml/min), trace gas concentrations (CH_4, ~80 ppm; SF_6 ~240 ppt) and the difference in molecular weight (g/mol) between gases (CH_4, 16; SF_6, 146). Given the magnitude of the resulting error amongst used TRAD apparatus in the present study and the wide adoption of the TRAD design this error may be a contributing factor to the unexplained between-animal variation in CH_4 emissions determined *via* the ERUCT technique.

Table 2. Effect of apparatus upon CH_4 emission result

	Design			
	TRAD	MOD	SEM	Sign.
CH_4 (g/day)	475	365	14.6	***
CH_4 (g/kg BW)	1.11	0.81	0.042	***

BW = Bodyweight; Sign.: *** = P < 0.001

Conclusions

Mean CH_4 emissions decreased by 23% to biologically realistic levels when used TRAD apparatus were replaced with a new MOD design. Furthermore the CV around CH_4/kg bodyweight decreased by 41%. A confounding effect of time is acknowledged. However the only material difference between P1 and P2 was replacement of apparatus. These results support the hypothesis that faulty gas sampling apparatus used for the ERUCT technique can increase the CH_4:SF_6 ratio in sampled gases. Further research is required to elucidate the cause of this fault, thought to be small or intermittent leaks in the sampling apparatus. However the MOD design described is expected to provide an effective solution.

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RMIS 5781

Effect of cow breed and feed allowance upon enteric methane intensity of milk solids production

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Introduction

Methane (CH_4) from ruminant digestion is the largest source of greenhouse gas (GHG) from Irish milk production systems. O'Brien *et al.* (2010) estimate that enteric CH_4 accounts for 68% of total on-farm emissions on a CO_2 equivalent basis. Ireland is committed to reducing the national emission of GHG's by 14% on 2005 levels by the year 2020. With the potential for further reduction targets as the country pursues a low carbon economy there is a growing desire to reduce the carbon intensity of dairy production at farm level. The objective of this study was to compare the enteric CH_4 emission intensity of milk solids produced by Holstein-Friesian (HF), Jersey (J) and Jersey×Holstein-Friesian (F_1) cows at two levels of feed allocation in order to access the potential for breed mediated mitigation strategies.

Material and Methods

Sixteen HF, 16 J and 16 F_1 mixed age cows from a season length grazing study were housed in individual stalls during mid lactation (mean 197 days in milk, SD 27). The experiment was conducted in four consecutive 14 d blocks balanced for treatment. Cows were randomly selected from two stocking rate (SR) treatments. HF and F_1 cows were from farmlets grazed at 3.0 or 2.5 cows/ha, while J cows were from SR of 3.25 or 2.75 cows/ha. Cows were offered fresh cut ryegrass twice daily to achieve intakes similar to their SR treatment in the grazing study (Thackaberry *et al.*, 2011). HF and F_1 cows from a low SR were fed 20 kgDM/d (high allowance), those from a high SR were fed 16 kgDM/d (low allowance). J cows were offered either 17 or 14 kgDM/d for cows from the low and high SR, respectively. Measurements commenced following 7 d acclimatisation. Individual CH_4 emissions were determined daily for five consecutive days *via* the emissions from ruminants using a calibrated tracer (ERUCT) technique. Permeation tubes were filled with ~3.0 g of SF_6 and release rate was calculated at 39°C using an eight point regression ($r^2 > 0.999$). Tubes were blocked by emission rate (mean 6.40 mg/d, SD 1.112) to treatment within breed and randomly allocated to cow within treatment. Tubes were dosed 114 days prior to this study. The milk production, BW and CH_4 data were analysed using PROC GLM (SAS, 2006) and the model: $Y = \mu$ + breed + feed allowance + block + parity + e. The interaction between breed and feed allowance was not significant and was removed from the model.

Results and Discussion

Grass was harvested at a mean sward height of 11.9 cm (SD 2.78) to a cutting height of 4.7 cm (SD 0.66). Mean dry matter intake (DMI), enteric methane emission and milk solids yield of J cows was lower than either HF or F_1 cows ($P < 0.01$), while HF and F_1 cows did not differ. Milk produced by J cows had a higher concentration of fat and protein than the HF and F1 cows ($P < 0.01$). Despite differences in scale of intake and production between breeds, CH_4 emissions relative to DMI and milk solids yield did not differ (Table 1).

Table 1. Effect of breed and feed allowance on intake, milk production and enteric CH_4 emissions

	Breed					Feed allowance			
	HF	J	F_1	SEM	Sign.	Low	High	SEM	Sign.
Body weight (kg)	572^a	434^b	503^c	8.8	***	488	517	6.9	**
DMI (kg/d)	16.6^a	14.0^b	15.9^a	0.21	***	14.6	16.4	0.17	***
Milk yield (kg/d)	18.0^a	12.8^b	16.1^c	0.45	***	14.5	16.8	0.36	***
Fat (g/kg)	56.8^a	74.1^b	63.9^c	1.89	***	65.0	64.9	1.50	NS
Protein (g/kg)	35.1^a	39.2^b	36.6^a	0.62	***	36.9	37.0	0.49	NS
MS (kg/d)	1.79^a	1.50^b	1.71^a	0.022	***	1.58	1.76	0.018	***
CH_4 emission (g/d)	408^a	351^b	389^a	8.2	***	360	405	6.6	***
CH_4 emission (g/kg DMI)	24.7	25.1	24.7	0.47	ns	24.8	24.9	0.38	NS
CH_4 emission (g/kg MS)	242	237	233	5.2	ns	240	235	4.2	NS

DMI = dry matter intake; MS = milk solids yield; Sign.: ** = $P < 0.01$, *** = $P < 0.001$, ns = $P > 0.05$

[a-c]Means with a different superscript within a row are significantly different ($P < 0.01$)

Conclusions

Cows of the smaller J breed emitted less enteric CH_4 per day, while emissions per unit of ryegrass DMI were similar from all three breeds. At the mid lactation point investigated, the HF, J and F_1 breeds produced milk solids with a similar CH_4 emission intensity. Further work is required to determine the relative lifetime CH_4 efficiency of these breeds at a farm system level.

Acknowledgements

Assistance of B. Curtain, staff of Teagasc Ballydague and Department of Agriculture, Forestry and Food funding (RSF 07-517) is gratefully acknowledged.

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RMIS 5781

Changes in soil organic C in a clay-loam soil under permanent and cultivated grassland

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Introduction

The United Framework Convention on Climate Change obliges countries, through ratification of the Kyoto Protocol, to reduce their GHG emissions by 5% during the first commitment period (2008–2012) compared with 1990 levels. Under article 3.4, countries are allowed to include C sequestered in 'sinks' in attempts to meet emission targets. The aim of this study was to investigate in permanent grassland (i) C sequestration in the soil profile over an 8 year period and (ii) changes in soil organic C (SOC) following cultivation.

Material and Methods

A long term study was carried out on a permanent grass-clover grassland (PG) at Solohead Research Farm (52˚51'N, 08˚21'W), on a poorly drained Gleys (90%) and Grey Brown Podzolics (10%) with a clay loam texture. The experimental area (22 ha) was divided into 4 blocks. Each block consisted of 4 paddocks. The blocks were under typical grassland management mainly used for grazing, and to a lesser extent harvested for silage. In 2001, the swards were between 6 and 16 years since being reseeded.

Soil sampling was carried out in 2001 and 2004 from the permanent grassland (PG). At each sampling date, 15 cores per paddock were taken to a depth of 90 cm using a hydraulic auger. Each core was subdivided into 3 depths: 0-30, 30-60 and 60-90 cm and samples were bulked to one composite sample at each depth within each block. In June 2008 one paddock in each block was ploughed (to a depth of 20 cm) and reseeded; the cultivated grassland treatment (CG). Both the PG and CG were sampled as above on three occasions during 2008 and 2009 (Figure 1). The soil cores were oven dried at 40°C, crushed, sieved (2 mm) and analysed by loss on ignition (LOI) at 850°C for 30 minutes and LOI values were converted to SOC using a standard equation (Ball, 1964). The soil bulk density was measured under PG in November 2001 and under PG and CG in August 2008.

The quantities of SOC in each depth section (t ha^{-1}) were determined using soil bulk density. A one-way ANOVA (proc mixed; SAS) was used to examine the changes in SOC under the PG over time. Linear regression (proc reg; SAS) was used to estimate the annual change in SOC (0-90 cm) (t ha^{-1}). The SOC under PG and CG were subjected to ANOVA with two factors, treatment x sampling date, with sampling date included as repeated measures (proc mixed; SAS).

Results and Discussion

The quantity of SOC in the soil increased linearly ($P<0.05$) between 2001 and 2009 at an annual rate of 5.74 t ha^{-1} (2.83 %). This is an equivalent to the annual sequestration of 21 t CO_2 ha^{-1}.

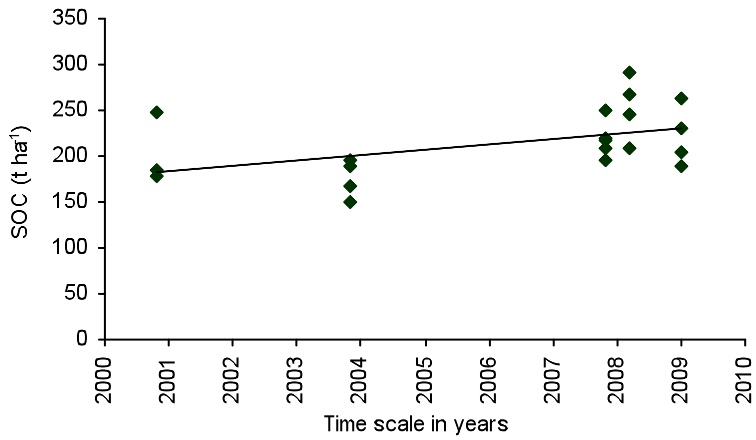

Figure 1. Soil organic C accumulation under permanent grassland between 2001 and 2009; the line was fitted using the regression equation: SOC = 5.74 (year) + 184; $R^2 = 0.219$; $P < 0.05$; where 2001 was year = 0 and 2009 was year = 8.

When the effect of cultivation to a depth of 90 cm was examined, the difference in SOC content between PG and CG was 42.91 t C ha^{-1} ($P<0.05$), recorded 18 months after cultivation (Figure 2). Despite the shallow depth of ploughing (<20 cm), cultivation had an effect ($P<0.05$) on SOC content in the deeper layers, which could be partly caused by increased SOC leaching and changes in the soil moisture status after surface disruption. Assuming that respiration was responsible for the loss, the quantities of CO_2 lost in this study corresponded to emissions of 156.99 t ha^{-1} in the 18 months after cultivation.

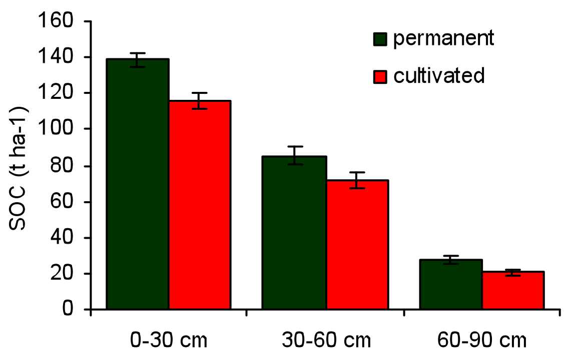

Figure 2. Soil organic C content under PG and CG at 3 soil depths; all the differences are significant at $P<0.05$ level; error bars are ± SEM

Conclusions

Carbon was sequestered in the soil profile under PG at an annual rate of 5.74 t ha^{-1}. Permanent grassland at this site represented a strong C sink. The cultivation of PG decreased SOC content down to 90 cm. The differences were more pronounced in the topsoil. Further research to better understand the mechanism of C accumulation, mineralization and depth redistribution in the soil at this site is needed.

Acknowledgements
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RMIS 5783

Effect of seasonal grazing system on productivity of a grass-clover sward

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Introduction

Irish grassland-based dairy production is dependent on N-fertiliser, the cost of which has been increasing relative to milk price for the last ten years (CSO, 2010). Alternatives are needed and biological N fixation (BNF) *via* white clover is both profitable and environmentally beneficial (Humphreys *et al.*, 2008). However, correct management of white clover is essential. Low N-fertiliser use and winter grazing can increase clover content (Laidlaw *et al.*, 1992) and therefore have the potential to improve BNF and herbage yield. The aim of this experiment was to examine the herbage productivity of three clover-based dairy systems, incorporating the separate effects of N-fertiliser use and extended winter grazing.

Materials and Methods

The experimental area (Solohead research farm (52˚51'N, 08˚21'W)) had three grazing systems in 2008 and 2009: Early spring calving with N-fertiliser (ES+N), early spring calving without N-fertiliser (ES-N) and late spring calving without N-fertiliser (LS-N) (Table 1).

Table 1. Outline of the experimental grazing systems

Grazing system	N-fertiliser (kg ha^{-1})	Stocking rate (cows ha^{-1})	Grazing season
ES+N	90	2.1	Feb-Nov
ES-N	0	1.6	Feb-Nov
LS-N	0	1.6	Apr-Jan

Each system had six paddocks rotationally grazed by 18 Holstein-Friesian cows to a post-grazing sward height of 50 mm. Herbage production in each paddock was measured using pre-grazing lawnmower cuts: four strips (5 m × 0.55 m) were cut to height of 50 mm. Samples were then bulked, weighed and a sub-sample dried for 16 hrs at 100 ºC for dry-matter (DM) content. The proportion of grass and clover in herbage DM was measured in April, June, August and November: strips of herbage (10 cm × 30 cm) were cut from 30 random locations in each paddock and components were separated and dried for DM. Clover stolon mass was measured in February, May, August and November: sods (10 cm × 10 cm) were cut out of the soil to a depth of 80 mm from 30 random locations in each paddock and stolons were washed and dried for DM mass. BNF was calculated using the methodology of Humphreys *et al.* (2008). All results were analysed by ANOVA using PROC MIXED (SAS, 2006) with two factors (system × year) and six replications (paddocks) with month as an additional factor (repeated measures) for stolon mass and clover content.

Results and Discussion

Herbage yields were affected by interactions between grazing system and year (P<0.05; Table 2): ES+N produced more herbage than the other two in 2008 but not in 2009, when LS-N produced as much as ES+N. Grass yield was consistently higher in ES+N in both years (P<0.001). There was no difference in clover yield in 2008 but significant differences between all three systems in 2009, with LS-N producing the most and ES+N producing the least (P<0.001). Therefore the high herbage yield in LS-N in 2009 was due to the higher clover production and associated BNF (Table 2). This also explained clover stolon mass in 2009, which was affected by an interaction between system and sampling date (P<0.05, Figure 2). The two systems without N-fertiliser had higher stolon masses than ES+N in May, but only the LS-N maintained this difference into August.

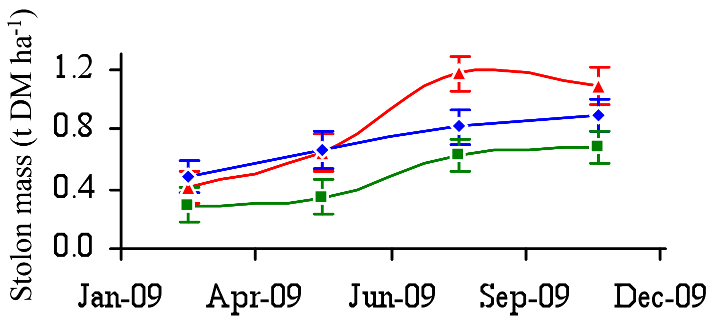

Figure 1. Interaction between date and grazing system (ES+N (■), ES-N (◆) and LS-N (▲)) for white clover stolon mass. Error bars are ± sem, P <0.05

Table 2. The effect of grazing system on herbage yields (t DM ha^{-1}), clover content of herbage DM (g kg^{-1}) and BNF (kg ha^{-1}) at Solohead research farm in 2008 and 2009.

	2008			2009			*P* value			sem
	ES+N	ES-N	LS-N	ES+N	ES-N	LS-N	System	Year	System ×	
Herbage yield	10.2	8.6	9.4	9.1	8.2	9.3	< 0.05	< 0.001	< 0.05	0.26
Grass yield	8.3	6.3	7.4	7.5	5.8	6.1	< 0.001	< 0.001	NS	0.31†
Clover yield	1.9	2.2	2.0	1.6	2.4	3.2	< 0.05	< 0.05	< 0.001	0.27
Clover Content	188	258	213	173	273	326	< 0.01	< 0.05	< 0.01	20.9
BNF	62	100	90	55	106	143	< 0.001	< 0.05	< 0.01	10.1

† = System sem, all other sems are for system × year interactions, sem = standard error of the mean, NS = not significant

Conclusions

Applying fertiliser N in spring (ES+N) increased herbage production relative to the ES-N system but had a negative impact on white clover and BNF. Extended winter grazing (LS-N) substantially increased white clover, BNF and herbage production.

Acknowledgements

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RMIS 5783

The impact of dairy cow grazing on physical indicators of soil compaction

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Introduction

Animal trampling in grassland ecosystems is known to affect soil and vegetation properties, which can influence agricultural system productivity. The main objective of this study was to establish the impact of dairy cattle treading on a range of soil physical properties indicative of soil compaction under four soil moisture deficits (SMD) targets - 0, 5, 10 and 20 mm for two contrasting soils. The second objective was to investigate the relationship between soil physical properties and SMD and to assess the soil recovery 10 weeks post trampling.

Materials and Methods

The experiment was undertaken at Teagasc Moorepark (MK), Fermoy, Co. Cork (50°07 N; 8°16 W; 46 m asl) on a well drained acid brown earth (haplic cambisol) of sandy loam texture, and at Teagasc Johnstown Castle (JC), Co. Wexford (52°292 N; 6°5 W; 49 m asl) on a moderately drained acid brown earth (Gleyic stagnosol) soil with a sandy loam texture. There were four treatments in the experiment - target SMD of 0, 5, 10 and 20 mm. The experiment was conducted as a randomised block design, with four replicates per treatment plus 4 control plots. Each plot at each site was 5 m × 2 m. Soil moisture deficit was calculated using archived and forecasted meteorological data supplied by Met Eireann and a SMD model developed by Schulte *et al.* (2005). Soil moisture deficit was monitored daily and when the target SMD was forecast, two cows of the same weight (545 kg) were walked up and down the designated treatment plots five times in each direction. Each plot was trampled on only one SMD occasion. Bulk density (BD), total porosity (TP), gravimetric (θg) and volumetric (θv) water content, penetration resistance (PR) and soil shear strength (SSS) were measured, using standard methods, pre and post trampling. Actual SMD was recorded on the day of trampling. Soil measurements were repeated 10 weeks post trampling. Data were analysed using the Generalized Linear Model (Proc GLM) statement of SAS. Soil properties were the response variables (y), and soil type, SMD and the trampling event were the predictors (x). The least square means (LSMEANS) was used in the procedure to compare the difference between the two soil types. Data for each site and for the 10 weeks post trampling measurements were analysed separately.

Results and Discussion

Actual SMD's on day of sampling were 0, 4, 9.3 and 21 mm at Johnstown Castle, and 0, 11, 14 and 29 mm at Moorepark. This study showed that SMD significantly affected indicators of soil compaction in the absence of animals (P<0.001 for all indicators). Prior to trampling, SMD was the main factor affecting differences in soil BD, SSS, PR, TP, and soil water content. Trampling significantly affected BD, SSS, and soil water content (P<0.001); BD and SSS increased following trampling, and decreases in soil water content were observed immediately post trampling. There was a significant interaction (P<0.001) between trampling and SMD, as soil was more susceptible to trampling damage at low SMD than at high SMD, on both soil type. Ten weeks post trampling soil physical properties had not recovered to pre-trampling conditions, partially explained by higher SMD on these sampling dates (data not shown). This suggests that while SMD could be used to predict potential damage from trampling by dairy cows, the seasonal context of the SMD value must be taken into account. The difference in soil type between the two soils was significant (P<0.001) for BD, PR and θg (Table 1), but no significant difference was found for TP (most likely due to small number of samples) and SSS.

Table 1. The effect of soil type on a range of soil physical properties at Johnstown Castle (JC) and at Moorepark (MK)

*** P<0.001; ** P<0.01; N.S. = not significant; s.e. = standard error.

Soil physical properties	Soil sites			
	JC	MK	s.e.	*P*value
BD (g cm^{-3})	0.88	0.91	0.003	***
TP (%)	0.63	0.63	0.004.	N.S
PR (MPa)	96.1	107.5	0.66	***
SSS (kPa)	51.6	51.3	0.31	N.S.
θg (g g^{-1})	0.56	0.53	0.003	***
θv (cm^3 cm^{-3}(	0.48	0.47	0.002	**

Conclusions
Trampling had an immediate and significant impact on BD, SSS and θg. The differences between the soil types used in this experiment had varying effects on soil physical properties, even though the sandy loam soil, with the lowest proportion of clay (haplic cambisol at Moorepark) tended to be more sensitive to compaction. The SMD could be used to predict potential damage from trampling by dairy cows, but the seasonal context of the SMD value must be taken into account.

Acknowledgements
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RMIS 5498

ECONOMICS AND RUAL RESEARCH PROGRAMME

The Impact of seasonality on Dairy Industry returns

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Introduction

Milk production from grass based systems in Ireland is seasonal in nature with the milk production profile following the grass growth profile. Nationally, the Irish dairy industry is working off a capacity utilisation of 62%. The Food Harvest 2020 report predicts that milk production will increase by 50% within the next 10 years. If this increase is pro-rata on the existing seasonal milk supply, the capacity to process this additional milk will be severely constrained at the peaks thus highlighting the need for additional capacity. In addition, the volatility of the world dairy markets will be a constant challenge to the industry as market supports are removed and the world dairy market opens up. The dairy industry needs to appraise the current milk supply profile taking cognisance of farm production costs, milk transport, milk processing costs and product portfolio. The objective of this paper is to examine the effect of seasonal milk supply on milk price, component milk values and product yield.

Materials and Methods

The Moorepark Processing Sector Model (MPSM) (Geary *et al.*, 2010) simulates the manufacture of dairy products in an annual time step. The model was further developed to capture the effect of season on milk component values from January through to December. This is a mass balance model accounting for all inputs, outputs and losses. The production of cheese, butter, whole milk powder (WMP), skim milk powder (SMP), fluid milk, and casein were simulated in the model. Final product specifications were met through separation of milk into cream and skim milk. Excess cream or skim milk from the processes were used in the manufacture of other products and/or were sold directly. The volume and composition of milk intake, product portfolio and its composition, product market values and processing costs were used in the model simulations. The processing costs captured in the analysis included collection, assembly, standardisation, processing, packaging, storage, distribution, effluent, interest and fixed costs. Total processing costs, net milk value (NMV), individual component values (€/kg fat and protein) and milk price were calculated. The milk plant examined in this analysis was assumed to process 681 million litres per annum which was representative of a large Irish dairy processor. The intake capacity of the cheese plant was capped at 25 million litres per month. The cheese capacity was filled first with the remainder of the milk pool being apportioned 53%, 24% and 23% to butter, WMP and SMP, respectively. Cheese was not manufactured in December and January due to the processing quality of milk in these months. Milk was apportioned 43%, 43% and 14% to butter, SMP and WMP, respectively, in January and December. The product market values were: cheese €3,291, butter €2,766, WMP €2,453, SMP €2,017, whey €538 and buttermilk powder (BMP) was assumed equivalent to WMP at €2,453 per tonne of dairy product taken from the Deutsch official quotation (www.prodzuivel.nl) and were representative of a 3-yr average (2008–2010).

Results and Discussion

The volumes of products that can be produced throughout the year changed as the volume of milk and the associated milk composition changed (Table 1). The highest net milk value was generated in the peak months when the volume of milk being processed was at its highest resulting in the lowest fixed costs per unit of product. The milk price throughout the year reflected the change in the volume of milk being processed and the volume of product that can be produced with the available milk pool. The lowest milk price was paid in January and December with the highest price being paid in October.

Table 1. Volumes of product produced, net milk value and value per litre of milk

Model outputs	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cheese, tonnes	-	2,364	2,585	2,674	2,713	2,741	2,771	2,815	2,981	3,153	3,103	-
Butter, tonnes	373	-	1,115	1,719	2,386	2,481	2,120	2,157	1,587	982	104	607
WMP, tonnes	165	-	985	1,560	2,356	2,375	1,953	1,983	1,452	908	82	271
SMP, tonnes	613	-	1,846	3,093	4,470	4,496	3,717	3,682	2,579	1,516	153	939
BMP, tonnes	367	-	1,093	1,687	2,346	2,439	2,085	2,123	1,567	972	103	599
Whey, tonnes	-	1,297	1,459	1,391	1,302	1,329	1,376	1,363	1,373	1,377	1,432	-
NMV, € m	2.2	6.5	17.0	23.3	30.1	30.7	27.2	27.5	22.7	17.7	9.6	4.0
Milk price (cent/ltr)	24.7	29.7	31.2	31.0	31.1	31.5	31.9	32.5	33.9	35.6	35.2	29.5

Conclusions

This analysis highlights the impact a seasonal milk supply profile, in terms of volume and composition, has on industry returns ranging from a low of €2.2m in January to a high of €30.7m in June. The model output of cheese was constrained from March to October based on capacity. This analysis provides a platform for the optimal milk supply profile to be determined taking into account processing capacity constraints and the inclusion of investment cost information required to complete the analysis.

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RMIS 5794

An application of Data Envelopment Analysis to measure technical efficiency on a sample of Irish dairy farms

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Introduction

European Union (EU) policy reform between now and 2015 will create significant opportunities for Irish dairy farmers. This will be facilitated by the allocation of additional EU milk quota paving the way for its eventual removal by 2015. Unlimited expansion will be possible for the first time since EU milk quotas were introduced. Under the Common Agricultural Policy (CAP) regime, milk price supports through import tariffs and export subsidies stabilized prices in the EU. However, a potential World Trade Organisation (WTO) agreement is likely to result in reduced EU milk price, through lower domestic support, tariff cuts and a reduction in export refunds (Dillon *et al.*, 2008). Business success in an environment of low and volatile milk prices requires producers to become more focused on maximizing efficiency of milk production. The objectives of this study were to determine the levels of technical efficiency on a sample of Irish dairy farms and to identify key factors that differ significantly between efficient and inefficient producers using Data Envelopment Analysis (DEA).

Materials and Methods

This study uses data from a sample of 190 specialist dairy farms in the 2008 National Farm Survey (NFS). Specialist dairy farms are defined as generating over 66% of their total gross output from the dairy enterprise. The inputs used in the DEA model comprised land in hectares (ha), cow numbers, labour units in fulltime equivalents (FTE), kg of purchased concentrate, kg of fertilizer and other costs (€). These represent all of the important inputs on specialist Irish dairy farms. Efficiency scores were generated using DEA which is a non parametric method of efficiency analysis that employs linear programming to estimate the 'best practice' production frontier. The estimated frontier envelopes the input/output data of the most efficient decision making units (DMU) for each farm in the analysis. Consequently, those DMU lying on the frontier are referred to as technically efficient, with a score of 1, while those below the frontier are regarded as inefficient, with a score of less than 1. All efficiency scores in DEA range between 0 and 1. Technical efficiency scores were generated under the assumption of constant returns to scale (CRS) assuming that for every increase in input the producers will get a proportional increase in output. Frontier Software developed by Zhu and Cook, (2008) was used to estimate DEA efficiency scores. Analysis to determine differences between efficient and inefficient producers was carried out using SAS (Proc GLM).

Results and Discussion

The average level of technical efficiency on Irish dairy farms was 0.763 in 2008. Table 1 shows the characteristics of the technically efficient and inefficient producers. Mean technical efficiency was 0.743 for the technically inefficient producers (n=159) compared to a mean score of 1.000 for the technically efficient producers (n=31). Efficient producers recorded 33% more kg of milk solids relative to the inefficient producers and had significantly higher levels of total output ($P<.001$). Milk solids produced per cow and per hectare were also significantly different among producers with efficient producers generating 24% and 27% extra milk solids per cow and per hectare, respectively (P<0.001). Milk solid yield of both fat and protein were both significantly higher for the efficient producers producing on average almost 5,000kg more fat and protein (P<0.001). Milk quality differences were evident with efficient producers gaining on average €1,500 higher milk bonuses (P<0.01). The grazing season length was significantly longer for the efficient producers by 10 days (P<0.05). For the other variables tested such as stocking rates, breeding season length, quota quantity and milk recording there were no statistically significant differences between the groups.

Table 1: Efficient versus Inefficient Producers

Variable	TE[1]=1	TE>1	
Input	Mean	Mean	Sig[3]
TE	1.000	0.743	<0.0001
MS[2] (kg)	28,319	18,939	0.0003
MS/cow (kg/cow)	401	305	<0.0001
MS/ha (kg/ha)	460	338	<0.0001
Fat (Kg)	15,064	10,132	0.0004
Protein (Kg)	13,255	8,807	0.0002
Milk Bonus (€)	2,665	1,139	0.0084
Milk Penalties (€)	257	553	0.2090
Grazing Days	232	222	0.0775

[1]Technical efficiency score; Milk Solids; Significance -Proc GLM test between means, *** <0.001, **0.001-0.01, *0.01-0.05, +0.05-0.1, NS>0.1

Conclusions
There are a number of key variables that help explain the differences between technically efficient and inefficient producers. The results suggest that efficient producers had longer grazing season length, greater milk quality and greater production per cow, and per hectare.

Acknowledgements
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RMIS 5799

The effect of key management factors on technical, allocative and economic efficiency of Irish dairy farms

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Introduction
Milk quota will no longer restrict the Irish Dairy industry after 2015 creating significant opportunities for dairy farmers to expand their businesses. However receding supports from the EU as quota is removed will mean that milk price volatility will become more of a feature of the production system. Such changes will require farmers to produce milk at the lowest cost possible, therefore becoming more technically and economically efficient. The key to reducing overall costs of production is to use the least amount of inputs possible, therefore becoming more efficient. Economic efficiency or overall efficiency can be defined as the product of allocative and technical efficiency (Farrell, 1957). In that study Farrell defined technical efficiency as the maximizing of output per unit of input and allocative efficiency as the ability to consider inputs based on the market value that they hold. Differences in efficiency have been attributed to poor management (Hanson and Öhlmér 2008). The aim of this study

was to measure technical, allocative and economic efficiency and secondly to investigate the effect of key management factors on efficiency at farm level.

Materials and Methods

Data Envelopment Analysis (DEA) which is a non parametric method of efficiency analysis employing linear programming techniques was used to generate the efficiency scores on a sample of 190 specialist dairy farms using 2008 National Farm Survey (NFS) data. The inputs used in the DEA model comprised physical and financial values of land, cow numbers, labour, concentrate, fertilizer and other costs. An input orientated DEA model was estimated under the assumption of variable returns to scale (VRS). This assumes that every increase in input will not result in a proportional increase in output, so as to account for differences in scale (Banker *et al.*, 1984). DEA Frontier Software developed by Zhu and Cook (2008) was used to estimate the efficiency scores. The effect of a number of key management factors on the efficiency scores was calculated using Tobit Regression (PROC LifeReg; SAS) with the efficiency scores as dependent variables. Tobit regression is the most suitable regression to use in a DEA study, as it is a censored regression technique and DEA generates efficiency scores that are censored towards the upper boundaries of 1 with a positive probability (Hoff, 2007).

Results and Discussion

Table 1 contains the results of the Tobit regression analysis. A shorter breeding season resulted in increased technical, allocative and economic efficiency. This suggests that a shorter breeding season will lead to more compact calving and therefore increasing technical and economic performance. Both allocative and economic efficiency were increased with increased number of calves born in the month of February only ($P<0.001$), highlighting lower production costs associated with early Spring calving. Producers that used a diet feeder also had greater allocative and economic efficiency suggesting a more efficient use of feed. The length of the grazing season had a significant effect on technical and economic efficiency ($P<0.1$) showing that a greater proportion of grass in the diet reduced costs. Milk recording and being a member of a discussion group positively affected allocative efficiency ($P<0.05$) only. All other factors tested in the tobit regression such as other births per month and stocking rates were insignificant.

Table 1: Effect of managerial explanatory variables on efficiency scores

Variable	TE[1]	Sign[2]	AE[3]	Sign	EE[4]	Sign
Feb[5] Births	0.0011	0.1155	0.0037	0.0003	0.0046	0.0009
Disc[6] Group	-0.0147	0.4921	0.0598	0.0365	0.0469	0.2745
Milk Recording	-0.0306	0.1412	0.0481	0.0832	0.0133	0.7502
Diet Feeder	-0.0086	0.7527	0.1561	<.0001	0.1598	0.0038
Grazing days	0.0007	0.0281	0.0002	0.7182	0.0011	0.0935
Breeding days	-0.0005	<0.0001	-0.0003	0.0127	-0.0008	0.0036

[1]Technical Efficiency Tobit Regression Parameter, [2]Significance -Proc LifeReg SAS (2006), *** <0.001, **0.001-0.01, *0.01-0.05, +0.05-0.1, NS>0.[3]Allocative Efficiency Tobit Regression Parameter, [4]Economic Efficiency Tobit Regression Parameter, [5]February, [6]Discussion

Conclusions

Overall the results show that key management factors affecting technical, allocative and economic efficiency included grazing season length, length of breeding season and calving date. It was also shown that producers engaging in milk recording and who were a member of a discussion group positively affected efficiency.

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RMIS 5799

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