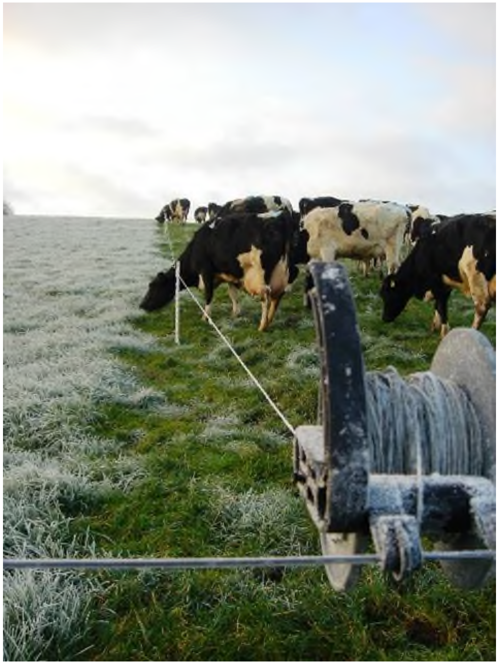
Cow welfare in grass based milk production systems

End of Project Report

Project 5403



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1. Summary

Under this project, aspects of pasture based milk production systems, namely different milking frequency and feeding strategies as well as genetic selection for improved fitness using the Irish Economic Breeding Index (EBI) were evaluated in terms of dairy cow behaviour, health, immune function and reproductive performance. Additionally, a typical Irish pasture based system was compared to one in which cows were kept indoors in cubicles and fed a total mixed ration for the duration of lactation in order to elucidate the perceived benefits of pasture based systems for dairy cow welfare.

The peripartum period is associated with a depression of the immune system response, which can be further impaired by the metabolic stress suffered by high yielding dairy cows. A reduction in the frequency of milking from twice to once-a-day (OAD) is a valid management alternative to lessen the metabolic load during early lactation and is also a labour efficient strategy for milk producers with off-farm employment. However, it is known that the practice causes milk leakage, udder distension and abnormal locomotion in the early to peak lactation period. The objective of the first study was to evaluate the effect of OAD milking on functionality of the immune cells to determine whether the practice results in stress induced immunosuppression. We found that there was reduced phagocytosis and decreased production of reactive oxygen species by polymorphonuclear leukocytes and monocytes from cows milked once-a-day. It is most likely that the stress associated with the physical discomfort caused by the engorgement of the udder from cows on the once-a-day milking strategy may have altered the functionality of immune cells. This suggests that limiting the milk production of high yielding animals during early lactation has an important detrimental effect on immunity. Further research is required to determine the implications of this finding for disease.

In the second study we evaluated the effect of switching milking frequency in mid-lactation on dairy cow welfare. Switching milking frequency offers lifestyle, economic and labour benefits to producers with seasonal calving herds. It was already known that once a day milking from calving had negative health and welfare implications for dairy cows in the early to peak lactation period. However, it was not known whether switching from twice to once a day milking in mid-lactation would elicit the same problems. We compared lying behaviour, milk leakage and udder firmness scores of cows switched from twice to OAD milking at 110 days in milk with those of cows milked twice daily for the entire lactation. We found more milk leakage, disrupted lying patterns and a higher prevalence of udder engorgement around the time of the switchover. However, these effects were transient. Further research is required to elucidate whether these transient welfare problems could elicit immunosuppression as found in cows milked once a day from calving.

In the third experiment an evaluation of the effects of genetic selection for improved survival in two Irish grass based milk production systems on indicators of dairy cow health and welfare was undertaken. We evaluated sub-clinical indicators of disease and health in cows from three genetic strains; two were classified as being of high EBI but had either North American (NA) or New Zealand (NZ) ancestry; and the third was of low EBI with North American ancestry during the peripartum and early lactation period. During this time dairy cows are particularly susceptible to poor welfare caused by stress and disease ultimately leading to reproductive problems. Our studies showed that high EBI NZ cows showed an increased immune response compared to the other two genotypes. The fluctuation in white blood cells observed is thought to be beneficial in disease resistance and recovery from the peripartum period. Nevertheless, disease outcomes were similar for high EBI cows of either NA or NZ ancestry. This suggests that the high EBI NZ cows were simply showing different physiological strategies for coping with the stresses associated with calving. Considering that the ancestors of these cows were selected in different environments (i.e.

NZ=pasture vs. NA=confinement) and hence with different breeding goals these differences could reflect inherited peripartum adaptation strategies.

Lameness was also monitored in the three strains under two different grass-based milk production systems for the entire lactation. After mastitis, lameness is the second most important production disease contributing to poor longevity in dairy cows. It is also the major welfare problem of dairy cows because of the pain it causes. We evaluated indicators of lameness namely locomotory ability and hoof disorders as well as cases of clinical lameness and found that irrespective of their ancestry higher EBI cows had equal or improved locomotion ability, less severe hoof disorders especially infectious (i.e. digital dermatitis and white line disease) and traumatic lesions (e.g. sole ulcers) and less clinical lameness than animals of lower genetic potential.

These findings suggest that the outlook for the EBI in terms of improving cow foot health is good which is significant given the importance of the EBI in contributing towards the sustainability of Irish dairying. However, a greater understanding of differences between strains of cows in peripartum adaptation strategies is necessary to avoid any deleterious effects arising from the use of high EBI genetics. Furthermore, selection for high EBI could have an unforeseen impact on other correlated traits that influence cow welfare such as behaviour which was not evaluated in the current project.

We also found that cows in the production system employing a higher stocking rate and concentrate input showed significantly greater odds of having severe digital dermatitis and traumatic hoof lesions such as sole ulcers. Digital dermatitis is an infectious disease that is generally only associated with the housing period where close proximity of cows favours transmission of the disease. This study showed that high stocking densities at pasture can also favour transmission of the disease. Similarly while the link between concentrate feeding and sole ulcers in dairy cows in zero-grazing systems is well established the possible link found in this study between higher levels of concentrate feeding and sole ulcers in cows at grass is novel.

In the fourth experiment a comprehensive range of measurements were monitored to compare a system in which cows were at pasture for the duration of lactation with one in which cows were indoors in cubicles for the duration of lactation. The main aim of this study was to underpin the largely anecdotal evidence that dairy cow welfare is better in pasture based systems compared to those employing zero-grazing. We found that cows at grass had better locomotory ability, improved patterns of lying behaviour and a lower incidence of most hoof disorders and mastitis throughout lactation. However, we also found that sub-clinical acidosis resulting in laminitis and walking on farm roadways are potential risk factors for white line disease in cows at grass. In the early post partum period we found that rumen fill scores of cows outdoors on grass were lower than those of cows indoors on a TMR diet possibly reflecting a lower dry matter intake at grass. Nevertheless, cows at grass appeared to have an earlier onset of uterine involution and luteal activity and this appeared to be associated with better reproductive performance although the limited scale of the study precludes robust inference.

Improved reproductive performance of cows at grass was also related to oestrus behaviour. We found that cows indoors do not show the same peri-oestral increase in mounting behaviour characteristic of cows at grass. The lower libido of the former animals could be attributed to slippery underfoot conditions, more lameness, the stress of confinement and possible nutritional interactions. Furthermore our results have implications for management of oestrus in confinement systems indicating that irrespective of the oestrus detection method employed, significantly less oestrous events will be detected than if cows were given access to pasture.

In general these findings help to strengthen the potential advantage Irish dairy producers will have over their European counterparts if legislation implementing access to pasture comes into force in the future.

1. Introduction

The production of milk in Ireland, facilitated by the country's mild climate, is based mainly on a grass based system which is more cost effective than the mainly grain/maize silage systems of continental Europe (Dillon et al., 1995). In the majority of EU countries, year round housing, or zero grazing of dairy cows is common. However new stipulations in some countries e.g. Switzerland, require periods of grazing in the summertime due to the increasing importance placed on animal welfare by society (Spörndly and Wredle, 2002). Indeed potential new legislation on dairy cow welfare ensuing from a report currently being compiled by the European Food Safety Authority (EFSA) is likely to place pressure on producers to allow cows access to pasture. Under such circumstances the Irish dairy industry could have an important advantage over its competitors on the continent.

Nevertheless, the belief that grass-based systems have an advantage over other systems because they are more 'natural' and therefore 'welfare friendly' is largely anecdotal. Furthermore, most of the existing research comparing the welfare of dairy cow indoors and at pasture has focused on single welfare (e.g. behaviour, O'Connell, 1991) or health (e.g. mastitis, Washburn et al., 2002) indicators. For the comprehensive evaluation of a production system it is necessary to use a wide range of indicators simultaneously (e.g. Broom et al., 1995). Indeed single indicators are inadequate to measure such a complex issue as animal welfare. To date there have been no comprehensive studies employing a wide range of indicators to directly compare cow welfare in grass based and housed systems over a complete lactation. Hence the main aim of this research was to redress this gap in the knowledge and to underpin the perceived advantages of grass-based systems from an animal welfare perspective. Dairy cow welfare was evaluated using a diverse range of measurements including behaviour, health (including mastitis and lameness), fertility/reproductive performance and measures of immune function.

While Irish dairy producers could potentially have significant advantages over their European counterparts if legislation insisting on access to pasture is enforced, this does not mean that we can be complacent when it comes to dairy cow welfare. Cows in pasture based systems can still suffer from poor welfare. Furthermore, any new EU Directive on the welfare of dairy cows could also constrain the way in which cows are fed and managed and could also restrict aspects of genetic selection. In light of these potential constraints on dairying practices in the future a proactive approach to cow welfare is necessary. Hence another aim of this project was to evaluate aspects of the way in which Irish dairy cows are bred, fed and managed in terms of the indicators mentioned above with particular emphasis on health in the peripartum period. Dairy cows have been genetically bred to maximise the conversion of nutrients to milk thus decreasing the availability of nutrients for other biological functions such as maintenance of body weight, reproduction and health (Hoekstra et al., 1994; Pryce and Veerkamp, 2001). The imbalance is specially exacerbated during the 'Transition Period', taken to be three weeks prior to and three weeks after parturition (Grummer, 1995) and this is when most infectious diseases (e.g. mastitis) (Mallard et al., 1998) and metabolic disorders (e.g. milk fever, ketosis, retained foetal membranes, metritis) occur (Goff and Horst, 1997). Such disorders have obvious negative implications for cow welfare.

3. Experiments

3.1 Experiment 1

Effects of milking frequency on phagocytosis and oxidative respiratory burst activity of bovine polymorphonuclear leukocytes of primiparous and pluriparous dairy cows during early lactation

Introduction

Cows milked once-a-day (OAD) experience udder distension resulting in poorer locomotory ability compared to cows milked twice-a-day (TAD) (Boyle *et al.,* 2005). OAD milking also results in neutrophilia and elevated cortisol levels (Keane, 2004; Gleeson *et al.*, 2007) indicative of stress (Yagi *et al*., 2004). The objective of this study was to investigate the effect of milking frequency (MF) on the phagocytosis and respiratory burst activity of polymorphonuclear leukocytes (PMNL) and monocytes of heifers and cows under two nutritional management regimes.

Materials and Methods

Experimental design and treatments

Spring-calving heifers (n=12) and cows (n=12) were assigned randomly at calving to one of 4 treatments in a 2x2 factorial design. Treatments were: OAD and TAD milking at a high (H) or low (L) nutritional level (NL). OAD cows were milked at 0730 and TAD cows were milked at 0730h and 1530h. Cows were housed in cubicles until the 22 March. During this time, H cows received silage *ad libitum* and 7 kg/cow/day of concentrates, while L cows received grass silage *ad libitum* and 4 kg/cow/day of concentrates. Grazing management was based on a rotational grazing system. The first grazing cycle took place between the 22 March and the 17 April. During this period, H cows received 4 kg/day of concentrate and L cows received 1 kg/day of concentrate. During the main grazing period the difference in feeding regimes was dictated by post-grazing height. H cows grazed to a height of 8.3 cm, while L animals grazed to a height of 6.7 cm. Stocking density was based on herbage allowance (kg DM/cow) calculated by taking account of the pre-grazing herbage yield (kg DM/ha), size of paddock (ha) and number of cows. OAD cows were milked at 07:30 h and TAD cows were milked at 07:30 h and 15:30 h.

Measurements

Blood was collected from all cows by coccygeal vessel puncture into lithium heparinised tubes 1-7d prior to calving and at 1-7, 14-21 and 42-49 days post-partum. Phagocytic and oxidative burst activity (determined by stimulation of cells with *E. coli* and phorbol 12-myristate 13-acetate [PMA]) of PMNL and monocytes were analysed by flow cytometry using commercial assays (Phagotest® and Phagoburst®).

Statistical Analysis

Data were analysed statistically using the mixed procedure of SAS® [Statistical Analysis System (SAS) V9.1. Institute Inc., Cary, NC, USA]. The model included fixed effects of parity group (primiparous or pluriparous), milking frequency (TAD or OAD), nutritional levels (H or L) and sampling time (prepartum, 1-7 days, 14-21 days or 42-49 days postpartum), and all possible two-way interactions. The repeated statement was used to take into account repeated measures for each individual animal. Where significant effects were found, Tukey's Test was used to establish pair-wise differences. Statistical differences were considered significant at $P<0.05$. Tendencies towards significance ($0.05<P<0.1$) are also presented. Data are presented as lsmeans ± s.e.

Results and discussion

NL did not effect the variables measured (P>0.10, data not shown). OAD milking reduced the percentage of phagocytic PMNL and the phagocytic index of PMNL (P<0.05, Table 1). OAD also tended to decrease the median fluorescence intensity (MFI) of the oxidative burst positive PMNL (P=0.06) indicating that fewer bacteria were ingested by these cells. The percentage of oxidative burst positive monocytes (P=0.06) and oxidative burst index of monocytes (P=0.09) also tended to be reduced by OAD milking (Table 2). PMNL and monocytes from heifers had higher oxidative burst activity, higher MFI and a higher oxidative burst index than those of cows (Tables 1 and 2). This suggests that heifers have an enhanced immune response relative to cows. Furthermore, a significant parity group by milking frequency interaction showed that PMNL of TAD heifers had the highest MFI (P<0.01, data not shown). This indicates that OAD milking reduced the number of bacteria ingested by PMNL of heifers to levels similar to that of cows. Thus, while the number of trafficking neutrophils may increase in response to OAD milking their functional capabilities are reduced. This indicates that OAD milking causes immune stress possibly linked to physical discomfort arising from udder distension.

Table 1 Effect of parity and milking frequency on % of phagocytic polymorphonuclear leukocytes (PMNL), median fluorescence intensity (MFI), phagocytic index and % of oxidative burst positive PMNL, MFI and oxidative burst index*

PMNL	Heifers	Cows	s.e.	P	OAD	TAD	s.e.	P
% phagocytic cells	43.0	43.7	2.2	NS	39.9	46.9	2.12	0.03
MFI of phagocytic cells	746.1	641.7	46.83	NS	694.2	693.6	44.25	NS
Phagocytic Index	302.7	287.6	20.75	NS	257.5	332.8	19.87	0.01
% oxidative burst positive cells	16.6	11.9	1.97	0.09	14.6	13.9	1.89	NS
MFI of burst positive cells	321.2	261.2	18.11	0.02	*428.3*	*521.3*	*34.99*	*0.06*
Oxidative burst index	67.4	31.8	11.2	0.03	46.6	52.6	10.69	NS

Table 2 Effect of parity and milking frequency on % of oxidative burst positive monocytes, MFI and oxidative burst index*

Monocytes	Heifers	Cows	s.e.	P	OAD	TAD	s.e.	P
% oxidative burst positive cells	7.9	1.7	1.30	0.002	3.1	6.4	1.21	0.058
MFI of burst positive cells	*308.0*	*177.6*	*36.24*	*0.017*	105.6	108.8	13.62	NS
Oxidative burst index	7.2	1.9	1.28	0.007	3.0	6.1	1.23	0.089

OAD=once-a-day; TAD=twice-a-day; NS=non-significant (P>0.10)

*Results are from *E. coli* stimulated cells unless shown in *italics* in which case PMA, *E.coli* results being NS

Conclusions

The peripartum period is associated with a depression of the immune system response, which can be further impaired by the metabolic stress suffered by high yielding dairy cows. The reduction of the frequency of milking to once-a-day is a valid management alternative to lessen the metabolic load during early lactation. However, results from this study showed that once-a-day milking had a negative impact on the functionality of immune cells. This was indicated by the reduced phagocytosis and decreased production of reactive oxygen species by polymorphonuclear leukocytes and monocytes from cows milked once-a-day. It is most likely that the stress associated with the physical discomfort caused by the engorgement of the udder (Gleeson et al. 2007) from cows on the once-a-day milking strategy may have altered the functionality of immune cells. This suggests that limiting the milk production of high yielding animals in order to minimise the metabolic load during early lactation has an important detrimental effect on immunity.

3.2 Experiment 2

Effect of switching milking frequency in mid-lactation on dairy cow behaviour, milk leakage and udder firmness

Introduction

Changing milking frequency (MF) offers lifestyle, economic and labour benefits to producers with seasonal calving herds. The options range from milking cows once instead of the usual twice a day (TAD) from calving for the entire lactation to switching from either once to twice, or from twice to once a day milking at some stage during lactation. Cows milked once a day (OAD) from calving show milk leakage and poorer locomotory ability which is related to udder distension (Gleeson et al., 2007). This could be responsible for the higher plasma cortisol concentrations and immunosuppression also seen in OAD cows (Keane et al., 2006; Llamas Moya et al., 2008). These findings particularly apply to cows in early to peak lactation when milk supply is highest. Typically cows would feed their calf 4 to 5 times/day during this period (Albright and Arave, 1997). Milking cows twice per day during the early to peak milk production period and thereafter switching to once a day milking could overcome many of these problems. Studies where cows were switched from twice to once a day milking during lactation are limited but Tucker et al. (2007) found that cows switched at 153 days in milk (DIM) had firmer udders but showed no difference in behaviour, faecal cortisol metabolite concentration or milk leakage. Our aim was to evaluate if switching MF between OAD and TAD milking at 110 DIM affects lying behaviour, locomotory ability, behaviour in the milking parlour, milk leakage and udder firmness in spring calving Holstein Friesian cows.

Materials and Methods

Experimental design and treatments

Spring calving cows (n=42) were blocked according to calving date (28th Feb. ± 20 days), milk yield and parity and randomly assigned to three treatments from calving: i) twice daily milking for the full lactation (2x); ii) 2x switched to once daily (2x1x) and iii) 1x switched to 2x (1x2x). Cows were at grass full-time from March 17 and TAD cows were milked at 0730h and 1530h. OAD cows were only milked at 0730h. MF was switched on the 21st June 2006 when cows were 110 [19.7 SD] days in milk (Day 0). The mean milk yield of cows in each treatment on this date was: 2x=25.0kg; 2x1x=25.2kg and 1x2x=20.7kg.

Measurements

Prior to the morning milking on days 108, 109, 111, 112 and 117 DIM five aspects of locomotion were scored from 1 (normal) to 5 (severely abnormal) and milk leakage was recorded as present or absent. In the milking parlour udder firmness was scored from 0=loose to 3=hard. Step/kicking behaviour during cluster attachment was also scored. Lying behaviour of 10 cows/treatment was recorded using Tinytag™ data loggers during 3 periods i) 103 to 109 DIM=pre-switch; ii) 110, 111 and 112 DIM and iii) 115 to 120 DIM (post-switch). The recorders were set to record at 5min intervals as per O'Driscoll et al. (2008).

Statistical analysis

Data were analysed using SAS. Locomotion scores and behaviour were analysed by repeated measures analysis of variance using general linear mixed models. Milk leakage and udder firmness were analysed by logistic regression for repeated measures (Proc Genmod) and chi square tests (Proc Frequency). Step/kick behaviour in the milk parlour was analysed by the non-parametric Kruskal Wallis test (Proc NPar1Way).

Results

On 111DIM, six of 14, 2x1x cows, and no cows in the other treatments were leaking milk (P<0.01). Furthermore, 2x1x cows had higher odds of showing milk leakage (OR 7.5; P=0.024) compared to 2x cows while 1x2x cows showed a tendency for higher odds of milk leakage compared to 2x cows (OR 3.3; P=0.067). More 2x1x cows had udder firmness scores of 3 (2x1x: 5/9; 1x2x: 0/14; 2x: 2/12; P<0.05) at 111DIM. However, treatment had no effect on odds ratios for udder firmness (P>0.05). Treatment had no effect on locomotion scores or on behaviour in the parlour (P>0.05). There was no effect of MF on lying duration prior to switching ([mean/24hr period] 2x: 10.7hrs; 2x1x: 10.4hrs; 1x2x: 11.2hrs, SEM 0.335; P>0.05) (Figure 1). However, 2x1x cows lay less (9.9hrs) on 110 and 111 DIM compared to 1x2x cows (11.5hrs) (SEM 0.457; P<0.01). This difference was still apparent the following week i.e. post switch (8.0 *vs*. 9.3hrs, SEM 0.253; P<0.001).

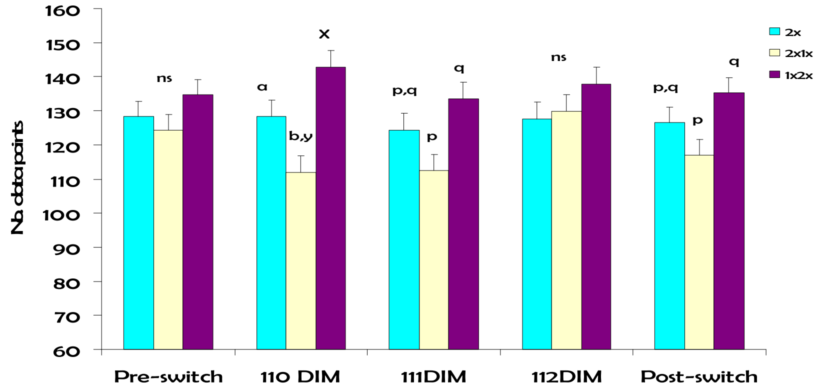


Figure 1 Influence of milking frequency treatment on time spent lying by dairy cows
ns=non-significant; ^{a,b}=P<0.05; ^{p,q}=P<0.01; ^{x,y}=P<0.001

Discussion

In previous studies cows milked OAD from calving showed poorer locomotion scores in early lactation compared to cows milked TAD (Gleeson et al., 2007). This disturbance to locomotory ability was brought about by the distended udder associated with high milk yields. In contrast switching from twice to OAD milking on 110 DIM had no effect on locomotion scores. This is probably because the cows had lower milk yields at this stage than cows in early lactation. There was evidence of transient udder distension in cows switched from twice to OAD milking which is not surprising considering the switch resulted in a 15% reduction in milk yield. This also explains why milk leakage was also seen in these animals. While the implications of milk leakage for cows at pasture are not well known udder distension causes discomfort to dairy cows. This is supported by the finding that cows switched from twice to OAD milking also showed disturbances in their lying patterns compared to cows milked TAD for the full lactation and particularly compared to cows switched from once to TAD milking. This disturbance was sustained during the following week suggesting that some degree of discomfort may have persisted. Alternatively the cows may have simply been adapting to the greater disturbance to daily behaviour patterns associated with TAD milking. Further research is required to elucidate whether the transient welfare problems associated with switching from twice to OAD milking elicited immunosuppression (Llamas Moya et al., 2008). The tendency for OAD cows to lie more prior to switching to TAD milking was sustained after the switch but there were no changes indicative of welfare problems for these animals relative to animals milked twice a day for the entire lactation.

Conclusions

Switching from TAD to OAD milking at 110 DIM had transient negative welfare implications for dairy cows. Switching from OAD to TAD milking at 110 DIM had no implications for dairy cow welfare under the conditions of this study.

3.3 Experiment 3

3.3.1. Effect of Holstein-Friesian genetic group on peripartum and early lactation immune function and health

Introduction

The peripartum period is a critical time for dairy cow productivity, fertility, health and welfare. Genetic factors affect the innate immune system homeostasis thus affecting peripartum outcomes (Mallard et al., 1998). Little is known about the periparturient immune function and health consequences of selection on the Irish dairy cattle economic breeding index (EBI). The objective of this study was to investigate the effects of genotype of Holstein-Friesian selected divergently on EBI, on immune function and health in the periparturient period.

Materials and Methods

Experimental design and treatments

In 2006, three genotypes (n=126) of Holstein-Friesian dairy cattle were compared based on the EBI. The three genotypes were: national average genetic potential of North American Ancestry (LowNA), North American high genetic potential (HighNA), and New Zealand high genetic potential (HighNZ). The average EBI (s.d.) values of these genotypes were €30 (13.6), €70 (9.7) and €80 (18.67), respectively. The parity structure of each group was the same with 25, 25 and 50% of first, second and third or greater parity animals, respectively.

Measurements

Blood samples were collected at -24, +3 and +35 days relative to calving and the concentrations of two main acute phase proteins (APP; haptoglobin and serum amyloid A) and complete haematology was determined. Daily rectal temperature (RT) for the first 10 days in milk (DIM) was determined at each morning milking. Degree of calving difficulty (scale 1 to 5) and stillbirth was recorded for all animals. Resumption of oestrus cyclicity (yes/no) and presence of metritis (yes/no) was determined using trans-rectal ultrasound imaging at approximately 35 DIM (range 28 to 42 DIM).

Statistical analysis

Box-Cox methodology was used to define the most appropriate transformation to normalise the data where necessary. The effect of genotype on the continuous variables was determined using mixed models, with time relative to calving included as a repeated effect. Preliminary analyses of calving difficulty indicated that the odds across different thresholds were proportional across genotypes and were therefore analysed using ordinal regression. The logit of the probability of a positive outcome for the binary variables was evaluated using logistic regression. In both analyses, genotype and parity were included as factors in the model and calving date was included as a covariate.

Results and discussion

Genotype of HF affected ($P<0.05$) RT. Mean RT for the HighNZ cows (38.4ºC; s.e.=0.038) was lower ($P<0.05$) than that of the LowNA (38.5ºC; s.e.=0.037) and HighNA (38.5ºC; s.e.=0.037) cows. Monitoring the increase of RT is useful in identifying cows at greater risk of disease (Smith and Rico, 2005). LowNA cows had the earliest highest peak of RT (Figure 1). This could suggest that the health of LowNA cows is at greater risk in the early post-partum period compared to the other 2 genotypes.

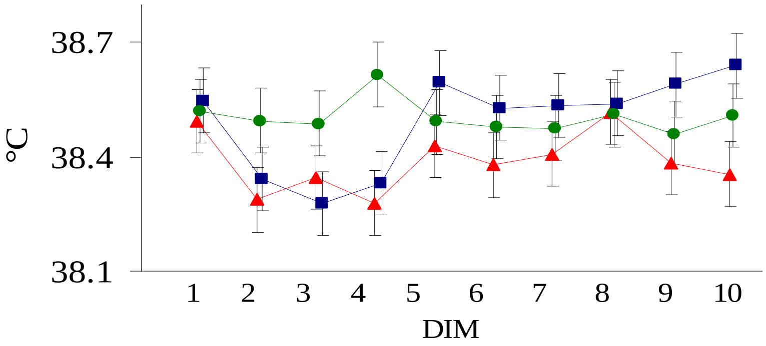


Figure 1 Rectal temperature over the first 10 DIM for LowNA (-●-), HighNA (-■-) and HighNZ (-▲).

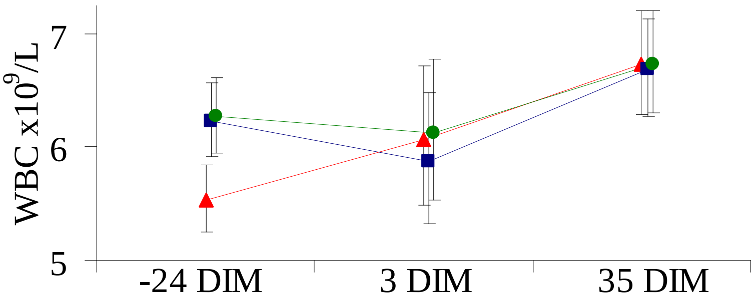


Figure 2 Peripartum changes in WBC for LowNA (-●), HighNA (-■-) and HighNZ (-▲-)

Days relative to calving had a significant effect on all of the haematological parameters and on APP concentration (results not shown). Such alterations are characteristic of the neuroendocrine changes associated with calving (Mallard et al., 1998). Genotype had a significant effect on mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and percentage of eosinophils. A genotype by time interaction was significant for the mean corpuscular haemoglobin concentration (MCHC), white blood cell count (WBC; Figure 2) and total neutrophil count. In summary, HighNZ animals showed an increased immune response compared to the other two genotypes. The fluctuation in WBC observed in the HighNZ cows was previously shown to be beneficial in disease resistance and recovery from the peripartum period (Mallard et al., 1998). No genotype effects or time interactions were observed for any of other haematological parameters or for the APP ($P>0.05$). Genotype did not affect the likelihood of greater assistance at calving or stillbirths. Likewise, genotype had no effect on the presence of metritis or cyclicity.

Conclusions

The WBC and rectal temperature differences suggest that HighNZ cows might have an improved immune response and be at less risk of peripartum diseases. However these results need to be evaluated in conjunction with data from clinical records collected over the same period.

3.3.2. Effect of Holstein-Friesian strain and feed system on locomotion score, clinical lameness and hoof disorders in pasture-based dairy cows

Introduction

Lameness is a painful and debilitating condition that is recognised as one of the most important welfare problems for dairy cattle. It also contributes to the overall cost of production on dairy farms with several direct and indirect costs (Green *et al.,* 2002). In addition, there are animal welfare costs that are difficult to quantify, such as the pain suffered by a lame cow. Hoof disorders (HD) are the main contributor to lameness in dairy cattle (Logue *et al.,* 1993). Furthermore, correlations between some hoof disorders and locomotion are strong (van der Waaij *et al.,* 2005). Such correlations indicate that the presence and increased severity of hoof disorders is highly related to deterioration in the locomotion ability of the cow (van der Waaij *et al.,* 2005). Factors affecting hoof disorders and locomotion can be generalised into management and genetics (e.g. genotype of dairy cow), although genotype by environment interactions also exist (Boelling and Pollot, 1998, Fatehi *et al.,* 2003). Significant genetic variation is reported for traits associated with hoof health (Politiek *et al.,* 1986, Emanuelson 1998, van der Waaij *et al.*, 2005) suggesting that genetic selection for improved hoof health is feasible. Genetic studies suggest that selection solely on milk production will increase genetic predisposition to inferior hoof health and lameness (Emanuelson 1998, Uribe *et al.,* 1995, Rauw *et al.,* 1998) although genetic correlations between milk yield and locomotion are favourable (Van Dorp *et al.,* 2004, Berry *et al.*, 2004). Nutrition and feeding management are important risk factors for hoof disorders and clinical lameness, in particular those associated with laminitis (Nocek, 1997, Amstel and Shearer, 2006). Abrupt changes in diets (e.g. dry cow to lactation cow diets) as well as diets high in available carbohydrates, low in effective fibre or a combination of both are known triggers of laminitis, sole ulcers, white line disease and heel erosion (Nocek, 1997, Cook *et al.,* 2004). The objective of this study was to quantify the effects of 3 genetic groups of Holstein-Friesian cows, selected on a total merit index, and managed in 2 contrasting grass-based systems of milk production on locomotion score, clinical lameness, and hoof disorders. The possible existence of genetic group by management system was also investigated.

Materials and methods

Experimental design and treatments

In 2006, 126 spring-calving Holstein-Friesian dairy cows of 3 genotypes of average (s.d.) economic breeding index (EBI, November 2005) value were randomly allocated to one of two FS: high concentrate (HC=2.8 LU/ha and 1,200 kg concentrate) or pasture system (LC=2.6 LU/ha and 500 kg concentrate). The 3 genetic groups were: Irish national average genetic potential of North American ancestry (€30 13.6, LOW-NA), North American high genetic potential (€70 9.7, HIGH-NA), and New Zealand high genetic potential (€80 18.7, HIGH-NZ).

Measurements

Following calving, HD were recorded on the hind feet by the same trained observer at 35 (s.d. 4) and 230 (s.d. 26) days in milk (DIM). HD per claw were classified on either an ordinal score of 0 (absent) to 4 (severe) or as a binary trait (0=absent; 1=present). Ordinal scored traits were digital dermatitis, heel erosion, white line disease, sole haemorrhages and binary scored traits were traumatic hoof lesions (sole ulcers, white line abscess, wall damage, under run soles and interdigital lesions). Locomotion score was assessed every second week throughout the year by one trained observer. Cows were assessed using a locomotion score system modified from O'Callaghan et al (2003). In brief, cows were observed walking on a level concrete surface after the morning milking and scored on 6 different aspects of gait. Definitions of the gait aspects are summarised in Table 2. Each individual aspect received a score from 1 to 5; 1 representing normal and 5 representing severely abnormal. Clinical lameness was based on the farm manager's assessment that the cow was sufficiently lame to be restrained for inspection and treatment. The cow was either correctively trimmed, a claw block applied and/or drugs administered. Cow number, date, diagnosis and treatment were recorded. Data were available for all cows from the beginning of the study until drying off or until an animal was removed from the study.

Statistical analysis

Analysis of locomotion score data was undertaken for each of the 6 gait aspects individually as well as for the mean locomotion score calculated as the arithmetic mean of the 6 gait aspects. The hazard of a cow reaching a threshold of 3 (i.e. poor locomotion) at day *t* post-calving, given that it had not reached the threshold by time *t-1*, was modelled using Cox's regression survival analysis in PROC TPHREG (SAS, 2006). Only the first case of clinical lameness within cow, between calving and dry off or removal from study, was retained for analysis. Both survival analysis and logistic regression were undertaken to quantify the effect of genetic group, feed system and two-way interactions on clinical lameness. Two types of disorders were identified: those scored on an ordinal scale (i.e. digital dermatitis, heel erosion, white line disease) and those scored as a binary trait. Sole and white line haemorrhages were recorded on an ordinal scale; however due to low frequency of data points in high severity classes the data were rearranged into a binary trait. For all analyses, hoof measurements at 35 days and 230 days post-calving were analysed separately. All data were analysed using generalized estimates equations (GEE) in PROC GENMOD (SAS, 2006) utilising a logit link function and a binomial distribution.

Results

Compared to 35 DIM the incidence at 230 DIM decreased for digital dermatitis (33 to 19%), heel erosion (41 to 25%) and traumatic hoof lesions (23 to 13.4%) and increased for white line disease (23 to 40%) with no changes in the incidence of sole haemorrhages (10%) across DIM. There was no interaction ($P>0.05$) between genotype and FS for the different HD. The odds of digital dermatitis with a score ≥ 2 was lower ($P<0.05$) for High-NZ cows compared to the Low-NA cows at 35 DIM. Furthermore, at 230 DIM, no High-NZ animal had a digital dermatitis score of 4 compared to the other 2 genotypes. No difference in the odds of heel erosion or sole haemorrhages were found between genotypes. For white line disease the odds of severity ≥ 1 was greater ($P<0.05$) for the High-NA compared to the Low-NA animals at 230 DIM, but the difference reversed with increasing severity; the High-NA cows had lower ($P=0.05$) odds of white line disease at greater severity (i.e. score ≥ 4) compared to the Low-NA cows. No difference was found for the High-NZ cows. Low-NA cows had greater odds ($P<0.05$) of presenting traumatic hoof lesions at 230 DIM compared to High-NA or High-NZ cows (Table 1). Cows in the HC FS showed significantly greater odds of having severe digital dermatitis (i.e., score ≥ 3) and traumatic hoof lesions (i.e., sole ulcers) at both inspections (Table 1).

Table 1 Effect † of genotype and feed system on traumatic hoof lesions (binary traits) at two stages relative to calving

	Genotype§		Feed system	P-values	
DIM	HIGH-NA	HIGH-NZ		Genotype	Feed system
35	0.86 (0.40 – 1.85)	1.23 (0.57 – 2.63)	2.22 (1.16 – 4.23)	0.673	0.019
230	0.23 (0.08 – 0.68)	0.31 (0.11 – 0.91)	3.86 (1.16 - 12.84)	0.017	0.043

†Expressed as odd ratios and 95% CI. §LOW-NA and LC used as reference category for genotype and feed system, respectively

Across the different gait aspects the high EBI genetic groups had a lower hazard of reaching a threshold of 3 at *day t* of lactation given they had not reached that threshold by day *t-1*, albeit most were not significantly different from the LOW-NA group (Table 2). The lowest hazards in the high EBI genetic groups were observed for general symmetry, spine curvature and tracking with the HIGH-NA cows at less risk (P<0.05) than the LOW-NA cows. The HIGH-NZ were not different (P>0.05) from the LOW-NA cows. Feed system did not affect any of the aspects of locomotion (P>0.05) with the exception of head bobbing (P<0.05) where animals on the high feed system had lower hazards of having increased head bobbing.

Table 2 Effect of genetic group of Holstein-Friesian, feed system (low vs. high concentrate) and parity on the hazard of showing locomotion ability with a score of three or greater

Locomotion aspects	Genetic groups[2]		Feed System[2]	P-values		
	HIGH-NA	HIGH-NZ		Genetic group	Feed system	Parity
General symmetry[1]	0.74	**0.45**	1.34	**0.038**	0.252	**<.0001**
	0.42 - 1.30	**0.25 - 0.83**	0.81 - 2.20			
Speed[1]	0.94	0.59	0.66	0.199	0.112	**<.0001**
	0.53 - 1.65	0.32 - 1.08	0.39 - 1.10			
Head bobbing[1]	0.83	0.82	**0.58**	0.775	**0.041**	**<.0001**
	0.46 - 1.51	0.43 - 1.54	**0.35 - 0.98**			
Spine curvature[1]	0.63	**0.49**	0.87	**0.037**	0.574	**<.0001**
	0.37 - 1.08	**0.28 - 0.86**	0.54 - 1.41			
Tracking[1]	0.61	**0.50**	0.88	**0.025**	0.568	**<.0001**
	0.37 - 1.01	**0.30 - 0.84**	0.57 - 1.37			
Abduction / Adduction[1]	0.96	0.80	1.21	0.659	0.396	**<.0001**
	0.59 - 1.58	0.48 - 1.33	0.78 - 1.89			
Average[1]	0.84	0.51	0.74	0.236	0.325	**0.002**
	0.43 - 1.66	0.24 - 1.12	0.41 - 1.35			

[1] Expressed as hazard ratios and 95% confidence intervals.
[2] LOW-NA and low concentrate used as reference categories.
Bold print indicates significant (P<0.05)
Italic print indicate tendency (P ≤ 0.1 or P=0.05)

A total of 26 out of 126 cows (21%) were clinically lame at least once while 10 of these 26 cows were clinically lame more than once. Incidence of clinical lameness in the first 50, 100 and 200 days post-calving were 5%, 10% and 18%, respectively. Both high EBI genetic groups (i.e. HIGH-NA and HIGH-NZ) had lower odds (P<0.001) of clinical lameness in the first 200 days post-calving compared to the LOW-NA group (data not shown). The effect was also reflected in the hazard of getting clinically lame throughout lactation; where the HIGH-NA group had a lower hazard (P<0.05) of becoming lame than the LOW-NA cows. Feed system had no effect (P>0.05) on clinical lameness throughout lactation.

Discussion

The EBI index places emphasis on improved survival, fertility as well as health with increased milk solids production. Reduced survival of a cow has a direct relationship with high incidence of lameness (Booth, *et al.* 2004, Green *et al.,* 2002). Therefore, increased genetic merit for survival, fertility and health is expected to have a favourable influence on the likelihood of lameness. The results of this study support this hypothesis as higher EBI groups (HIGH-NA or HIGH-NZ) had equal or improved locomotion ability, less severe hoof disorders and less clinical lameness than animals of lower genetic potential (LOW-NA). Digital dermatitis is associated with environmental factors such as stocking rate, while sole ulcers are related to diet (Bergsten, 2001). Therefore the higher stocking rate in addition to a higher concentrate level associated with the HC FS probably favoured the development of these types of hoof disorders.

Conclusions

The results of this study are in agreement with the predicted genetic potentials for survival for the three genetic groups evaluated. Furthermore, the present study emphasises the use of functional measures such as locomotion scores and hoof disorders to investigate differences within breeds and as tools for the further development of balanced breeding indexes.

3.4 Experiment 4

3.4.1. Hoof disorders, locomotion ability and lying behaviour in a confinement-TMR system compared to a pasture based system

Introduction

The aetiology of lameness is multifactorial and the majority of the factors that influence it are more closely related to the indoor period which, in the majority of milk producing countries, is all year round. Thus most studies of lameness in dairy cows have focused on the effects of housing systems on lameness (Bergsten 2001). Limited access to pasture has been reported as beneficial in reducing lameness by providing soft and hygienic walking surfaces, promoting exercise, reducing restlessness and increasing lying times in the cows (e.g. O'Connell, 1991; Krohn and Munksgaard, 1993; Hernandez-Mendo et al., 2007). As a result, there is a perception that housing causes lameness in cows, while cows at pasture do not experience lameness.

This belief is undermined by the fact that, in countries where pasture-based systems are standard practice (e.g. New Zealand and Ireland) there is an annual incidence of lameness of 28% (range from 4 to 54%; Arkins, 1981; Tranter and Morris 1991; Clark et al., 2007), which is similar to housed production systems (21% with a range from 2% to 54%; Clarkson et al., 1996; Nordlund et al., 2004). Poor quality of roadway surfaces, long walking distances to the milking parlour and bad herding skills contribute to the incidence of lameness in pasture-based systems. As in housed systems nutrition also plays a key role (Nordlund et al., 2004). Where there is an imbalance between energy provision and the energy the cow requires for maintenance and milk production as can occur with grass based diets this can lead to sub-clinical and/or clinical acidosis which increases the risk of laminitis (Arkins, 1981; Nordlund et al., 2004; Westwood et al., 2003).

Somers et al. (2003) stated that those systems that incorporate some access to outdoor areas or pasture have a reduced risk of hoof disorders compared to systems with no access to outdoor areas. Holzhauer et al. (2006) on the other hand showed that limited access to pasture increased the risk of infectious hoof disorders. These studies only showed the effect of pasture for short periods; thus, results might differ when assessed over a full lactation in the context of pasture-based dairy system management.

Consequently, the objective of this study was to compare lameness in cows kept indoors with cows at pasture over a complete lactation. In addition to clinical lameness cases hoof disorders, locomotion ability and lying times at different points throughout the production cycle were assessed.

Materials and methods

Experimental design and treatments

Forty six spring-calving Holstein-Friesians (12 heifers, 24 cows) were pair-blocked (expected calving date, parity, body condition score and genetic merit) and allocated to either a PASTURE or HOUSED system for a full production cycle (-40 to 305 days relative to calving). Treatment groups shared the same cubicle house (1.2 cubicles/cow) during the dry period (November 2006 until calving). In the dry period HOUSED animals were offered a diet formulated specifically for dry cows while the PASTURE animals received grass silage *ad libitum*. Both diets were fed using computerised feed boxes (1.2 m wide, Griffith Elder Ltd., Bury St. Edmunds, Suffolk, UK).

The HOUSED animals remained in the cubicle house for the duration of the study. As the PASTURE cows calved they were turned out to pasture on the day of calving during the day from 25th January and during day and night from 5th of February, 2007 onwards. The areas of the house allocated to the dry cow and milking cows were adjusted every two weeks during the calving season so as to maintain a ratio of 1.2 cubicles per cow. During lactation, the HOUSED cows were offered a Total Mixed Tation (TMR) diet formulated specifically for lactating cows. The PASTURE cows were managed in a rotational grazing system at a stocking rate of 2.5 cows/ha. Cows remained at pasture by day and night until mid-November, after which they were housed at night. All animals were milked twice a day, by the same staff. On average, the HOUSED cows walked 233m (SD = 5) a day; while PASTURE cows walked 2170m (SD=745.3) a day to and from the milking parlour.

Measurements

Six inspections (-40, 10, 35, 85, 120 and 210 days relative to calving) where made on both hind claws of each cow to obtain the severity of 5 disorders (sole and white line area haemorrhages, white line disease, heel erosion, digital dermatitis and other lesions). Locomotion ability was assessed (scale 1=normal to 5=abnormal) every 2 weeks for tracking, spine curvature, speed, head bobbing, general symmetry and abduction/adduction of the cows limbs. Clinical lameness records were kept throughout the study for all animals. Lying times of 13 cows per treatment were recorded automatically using voltage data-loggers (Tinytag Plus, Re-Ed volt, Gemini Dataloggers (UK) Ltd., Chichester, UK) every 5 minutes for 48hrs at 33, 83 and 193 days-post calving.

Statistical analysis

All data were analysed using SAS. Lesion scores for all claws and hooves were added to give a single total score for each animal at each inspection. Sole and white line area haemorrhages, white line disease, heel erosion and digital dermatitis were treated as continuous variables. In the case of traumatic and other lesions observed, the data were dealt with as binary variables (1= total score ≥1 or 0 = total score <1). Transformed data were analysed by ANOVA using mixed models for repeated measures (PROC MIXED). Digital dermatitis was analysed by the Wilcoxon Rank test. The likelihood of traumatic or other lesions in the hooves of cows in both treatments at different inspections was analysed using generalized estimating equations (GEE) for repeated measures with logit link function and a binomial distribution (PROC GENMOD). Results are presented as odds ratios and 95% CI. The odds ratio is an estimation (likelihood) of an event (i.e. traumatic hoof disorders) to occur in the exposed group versus the reference group or class. In all instances PASTURE, was the reference group. Therefore an odds ratio of 1 indicated that the likelihood of traumatic hoof disorders is equal in both groups. However, an odd ratio greater than 1 indicates a greater risk of traumatic hoof disorders compared to the reference class. Analysis of locomotion score data was undertaken for each of the 6 gait aspects individually as well as for the mean locomotion score calculated as the arithmetic mean of the 6 gait aspects. The hazard of a cow reaching a threshold of 3 (i.e. poor locomotion) at day *t* post-calving, given that it had not reached the threshold by time *t-1*, was modelled using Cox's regression survival analysis (PROC TPHREG; SAS, V.9). Hazard ratios were calculated and can be interpreted the same way as the odd ratios as previously explained. A logistic regression was undertaken to quantify the likelihood of treatment group and two-way interactions on clinical lameness. Days relative to calving were divided into 4 periods: 0 to 60, 0-120, 0-180 and 0-300 days. The logit of the probability of clinical lameness within each time period was modelled by logistic regression (PROC GENMOD) utilising a logit link function and a binomial distribution. Records obtained from the behaviour data-loggers were filtered using a windows-based programme (Tinytag® Explorer, Gemini Dataloggers, (UK) Ltd., Chichester, UK) and adjusted prior to statistical analysis as described by O'Driscoll et al. (2008b). Data (total lying time, lying bout duration and no. lying bouts ≥ 5min per 48hrs) were analysed by ANOVA using mixed models for repeated measures (PROC MIXED).

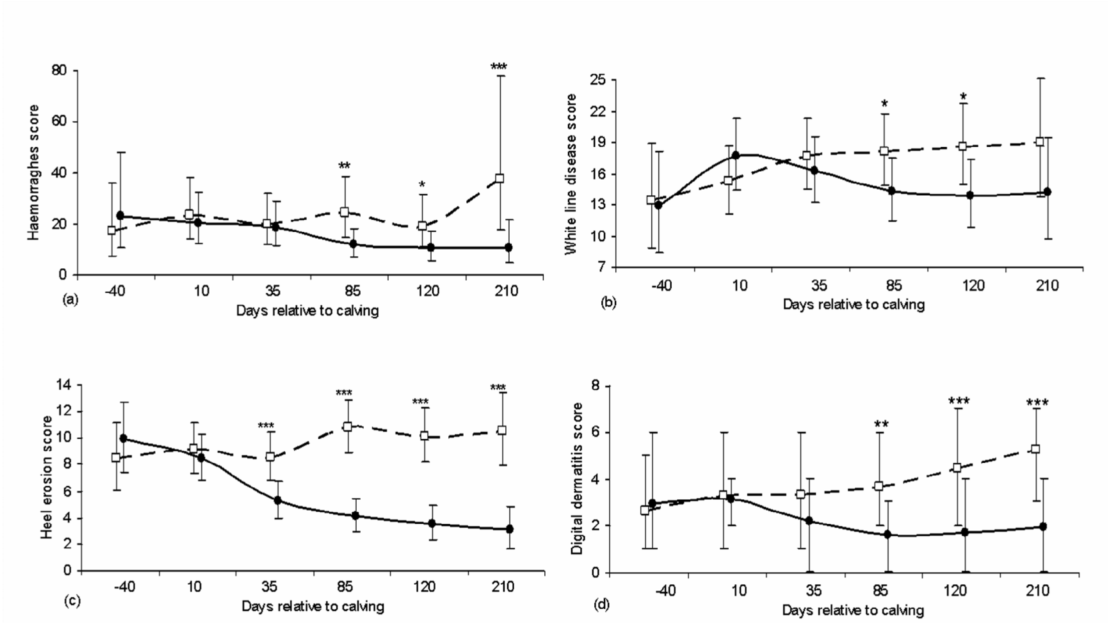
Results

A total of 17 animals (HOUSED=13; PASTURE=4 cases) out of 46 (37%) were clinically lame at least once from day 0 to 300 post-calving. Compared to PASTURE cows, the HOUSED animals had higher odds of presenting clinical lameness; being significant (P<0.05) from day 180 post-calving onwards. The mean duration of a lameness case (duration = mean lameness prevalence (%)

x 365 days / annual lameness incidence) for the PASTURE animals was 35 days vs. 40 days for the HOUSED animals.

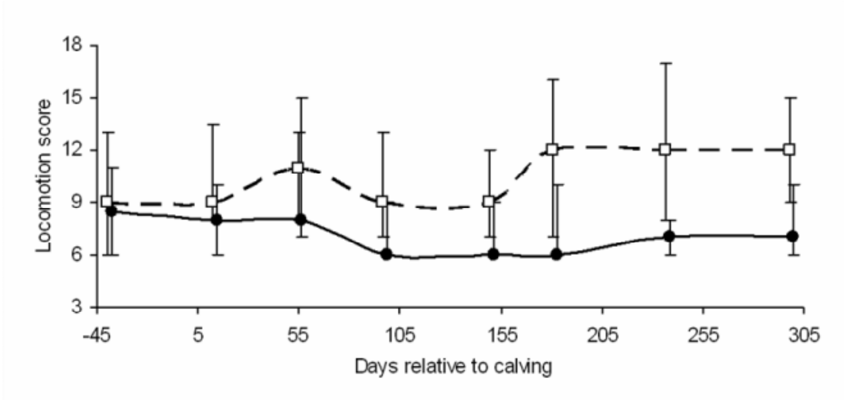
There was a treatment by inspection interaction for sole and white line area haemorrhages, white line disease, heel erosion and digital dermatitis (Figure 1). In summary, PASTURE cows showed a reduction in the mean score of sole and white line haemorrhages and heel erosion between the inspections conducted at -40 days and 210 days relative to calving (P<0.05). A similar trend was observed for digital dermatitis (P=0.05). For white line disease there was an increase (P<0.05) between the inspection at day -40 and the inspection at day 10 relative to calving and a reduction at inspection on day 85 relative to calving (P=0.05). The mean white line disease score at the day 210 did not differ from the mean score at -40 days relative to calving. In HOUSED cows there was an increase in the mean score for all hoof disorders (P<0.05) from inspection -40 to that at 210 days relative to calving. Treatment groups differed from each other from the inspection day 85 post-calving onwards. This was the case for sole and white line area haemorrhages, white line disease, heel erosion and digital dermatitis. Across all inspections HOUSED cows had a higher odds (1.95, 95%CI 1.03 – 3.68; P=0.039) of presenting traumatic or other type of lesions. The odds increased with inspection, being not significant at -40 (0.5, 95%CI 0.12-1.95; P>0.05) to highly significant at 210 (22.8, 95%CI 4.13 – 125.67; P<0.001) days relative to calving.

Figure 1 Mean scores at 6 different inspections (expressed as days relative to calving) for (a) sole and white line area haemorrhages (95%CI), (b) white line disease (95%CI), (c) heel erosion (95%CI) and (d) digital dermatitis (interquartile range) for Holstein-Friesian cows on different production systems [PASTURE (-●-, n=23) vs. HOUSED(- - □ - -, n=23)]
* (P<0.05), ** (P<0.01), *** (P<0.001) Indicates significant differences at specific inspections between treatment groups (PASTURE vs. HOUSED)



A descriptive summary of the mean locomotion score (Figure 2) shows that the two treatment groups differed between treatment groups immediately after calving. HOUSED cows showed an increase (i.e. a deterioration), while PASTURE cows showed a decrease (i.e. improvement). Furthermore, HOUSED cows had a greater hazard (P<0.01) of scoring ≥3 for tracking, head carriage, general symmetry and abduction/adduction (hazard ratios: 2.5, 2.8, 2.7 and 3.6 respectively) and for spine curvature (2.1, P=0.069). Total lying times were shorter (F=12.45, P<0.001) for HOUSED compared to PASTURE cows (18.1h, s.e. 0.71 vs 20.5h, s.e. 0.73). HOUSED cows also had more lying bouts (F=10.22, P<0.05) than PASTURE cows (22.8, s.e. 1.37 vs 16.3, s.e. 1.45).

Figure 2 Smooth curve of 'total locomotion score'[1] of two production systems [PASTURE (-●-) vs. HOUSED (- - □ - -)] from -40 to 300 days relative to calving. The arithmetic populations means (PASTURE n=23; HOUSED n=23) and interquartile range are shown at selected points (-40, 10, 55, 95, 150, 180, 240 and 300 days relative to calving).



Across the 3 x 48hrs recording periods, PASTURE cows spent longer times lying than HOUSED cows (20.5 hours, SE 0.73 vs. 18.1, SE 0.71; P<0.001). Lying bouts (minutes) were longer for the PASTURE compared to the HOUSED cows (50.3, 95%CI 45.44 – 55.68 vs. 39.3, 95%CI 36.27 – 42.54; P<0.0001) across the 3 x 48hrs recording periods. Moreover, PASTURE cows presented a lower number of lying bouts ≥5min than HOUSED cows (16.3, SE 1.45 vs. 22.8, SE 1.37; P<0.01) across the 3 x 48hrs recording periods.

Discussion

By the end of lactation cows at pasture had less severe hoof disorders than HOUSED cows. These results are in agreement with studies that compared the prevalence of hoof disorders in systems with no access to outdoor areas (i.e. pasture) against systems that included some access to pasture (e.g. Frankena et al., 1991). Differences between treatments were found from day 85 post-calving onwards for all hoof disorders, apart from heel erosion, where treatments differed as early as 35 days post-calving. All cows were exposed to a similar environment until calving. Thus it appears that for PASTURE cows a minimum of 85 days grazing was necessary to recover from the housing period and calving event which occurred just prior to turnout.

From the first inspection at 40 days prior to calving to 210 days post-partum, the severity of all hoof disorders increased for the HOUSED cows. This increase can be explained as a cumulative effect of walking or standing on concrete floors and the constant contact with moist and abrasive substances (i.e. slurry) (Somers et al., 2003, 2005; Bergsten, 2001). Furthermore, HOUSED cows showed reduced lying times compared to PASTURE cows which could also contribute to the increase in severity of all hoof disorders. Other contributory factors were the higher level of milk production and higher prevalence of udder problems in the HOUSED cows (see section 3.4.2). High levels of milk production mean that cows had a higher risk of an abnormal posture due to udder enlargement, leading to abnormal weight-bearing on the hooves. Similarly, cows with mastitis have a painful udder that can alter posture leading to episodes of abnormal weight-bearing on the hooves (Sogstad et al., 2006).

PASTURE cows showed a reduction in the severity of sole and white line haemorrhages but not in white line disease. These two disorders are interrelated and characteristic of laminitis problems although they are poorly correlated. Laminitis aetiology is not fully understood but sub-clinical acidosis is an important trigger (Nordlund et al., 2004). Westwood et al., (2003) noted that a pasture-based system can lead to sub-clinical episodes of acidosis with a negative impact on the quality of the hoof. Hence, PASTURE cows may have been at greater risk of sub-clinical laminitis and this may have been manifested as white line disease. However walking on farm roadways is another important cause of white line disease primarily because stones or grit from the road can penetrate the soft white line area of the hoof.

The incidence of clinical lameness for the PASTURE treatment group (17%) is comparable to previous reports in pasture-based systems (Arkins, 1981; Tranter and Morris 1991; Clark et al., 2007). However for the HOUSED treatment group the incidence (56%) was higher than that reported for confinement systems (21% with a range from 2% to 54%; Clarkson et al., 1996; Nordlund et al., 2004). Given the constant monitoring of the cows, more problems may have been detected than those commonly observed and treated on commercial farms. The treatment differences in clinical lameness in the present study are in agreement with Bergsten (2001) where cows at PASTURE had reduced cased of lameness.

Records of clinical lameness cases, across treatments, (37%) were directly related to the percentage of cows reaching an average locomotion threshold ≥3 (i.e. poor locomotion). HOUSED cows having a greater risk of poor locomotion score than cows at PASTURE. This is in agreement with the results of other authors who reported that cows with partial access to pasture had better locomotion (Hernandez-Mendo et al., 2007; Onyiro and Brothersone, 2008).

Cows at pasture lay for longer and with fewer interruptions than HOUSED cows. Similar lying times and trends were reported previously (O’Connell, 1991; Krohne et al., 1991; Krohn and Munksgard, 1993). It has been suggested that dairy heifers have an inelastic demand for lying of between 12 and 13 hrs per day (Jensen et al., 2005). Assuming similar demand times for cows, PASTURE provided closer lying times in relation to the cow demands than the HOUSED system. Thus, the lower lying times of HOUSED cows, as observed in this study, indicates that this system constrains the normal lying times of the dairy cows.

Conclusions

From the results of this study, it appears that cows require a grazing period of at least 85 days after calving to recover from the peripartum events contributing to the risk of lameness. Cows in a PASTURE system at the end of lactation will have less severe hoof disorders, reduced risk of having a locomotion disability and a reduced likelihood of being treated for clinical lameness compared to similar cows in a HOUSED system. Furthermore, cows in a PASTURE system have longer undisrupted lying periods than cows in a HOUSED system; thus a PASTURE system in a temperate climate (e.g. Ireland) facilitates the normal resting pattern required for a dairy cow. Nevertheless findings on white line disease indicates that both sub-clinical acidosis resulting in laminitis and walking on farm roadways are potential risk factors for white line disease in cows at grass.

3.4.2. Peripartum health of Holstein-Friesian cows in a confinement-TMR system compared to a pasture-based system

Introduction

The greatest challenge to a dairy cow's health is in the peripartum period [(-10 to 10 days relative to calving (DRC)] where nutrition and management impacts greatly on peripartal health outcomes. During the transition period (from three weeks before to three weeks after calving) the dairy cow is at risk of consuming less energy and protein than needed to meet requirements. This can impair the transition from a non-lactating to a lactating state resulting in sub-clinical and clinical diseases. The environment of the peripartum cow also plays a key role in the level of stress experienced by the dairy cow which can also influence peripartal health outcomes. The objective of this study was to monitor several indicators of health and sub-clinical disease in the post-calving period and to relate the results to the incidence of disease recorded. It was predicted that HOUSED animals on a TMR diet would have higher levels of food ingestion in the early post-partal period than cows at pasture, facilitating better energy balance. However the effect of the confined environment being supposedly more stressful would mean that cows at grass would have an overall higher level of health post-partum.

Materials and methods

Experimental design and treatments

Forty-six Holstein-Friesian spring-calving cows were randomised [parity, weight, calving date and predicted milk yield] and allocated to two management systems: HOUSED (cubicle housing with a total mixed ration (-60 to 300 days relative to calving =DRC)] vs. GRASS [cubicle housing with grass silage (-60 to -1 DRC) pre- and rotational pasture with concentrate post-partum (0 to 300 DRC)].

Measurements

One blood sample was collected by coccygeal venipuncture into 7 mL heparinised glass tubes (BD Vacutainer Systems, Plymouth, UK), at a consistent time, following the morning milking, on average, 29±9.30 days and 15±6.95 days before date of calving, on the day of calving (±0.60), 10±0.51 days and 35±1.86 days after day of calving. Blood samples were analysed for acute phase proteins [(APP) haptoglobin and serum amyloid A], cortisol and white blood cell (WBC) differential; as non-specific indicators of sub-clinical ill-health. All cows were examined for 10 consecutive days starting on the day of calving, at a consistent time, before the morning milking for temperature and general demeanour. A GLA M750 digital thermometer (GLA Agricultural Electronics, San Luis Obispo, California) was utilised for temperature measurement. Each cow was classified into a group based on the presence or absence of fever. Cows with rectal temperatures greater or equal to 39.5°C were considered to have fever. For the HOUSED cows appetite was checked in the feed shed records using the Elder Griffin® automated feed system and by a rumen fill scoring (RFS) system. The grazing cows' appetite was based only on rumen fill score. The rumen fill was scored with the observer standing at the left hind side of the cow. The paralumbar fossa between the last rib, the transverse processes and the hip bone was observed. Disease records were based on the farm manager records. Clinical signs of mastitis were recognized during the milking process by the farm manager or by the milkers. These signs included milk with abnormal colour and consistency, a swollen, warm, or painful udder, or history of reduced milk production. Cows with mastitis that were not diagnosed in the milking parlour were identified due to high cell counts (Moorepark Food Research Centre, Fermoy, Co. Cork).

Statistical analysis

All data were analysed using SAS. Mixed models for repeated measures were used in continuous variables. Proportions were analysed using Chi-square tests and score data using the non-parametric Mann-Whitney test.

Results

No differences (P>0.05) were found between treatments for APP, cortisol or WBC differential. However, GRASS cows tended to have lower rectal temperatures (38.4ºC, se= 0.07 vs. 38.7ºC, se=0.07 P=0.022) than HOUSED cows (Figure 1). Although, both treatments showed an increase in rumen fill from day 0 to 10; HOUSED cows had a higher rumen fill (P<0.05) than GRASS cows (Figure 2). There were significantly more cases of mastitis in the HOUSED cows compared to in cows at GRASS (44 *vs.* 24; P<0.05). However, the number of cows affected was similar in both treatments i.e. 30 (P>0.05).

Figure 1 Average rectal temperatures (^{o} C) of HOUSED/TMR (n=23, --□--) and GRASS (n=23, -●-) cows in the 10 days post partum

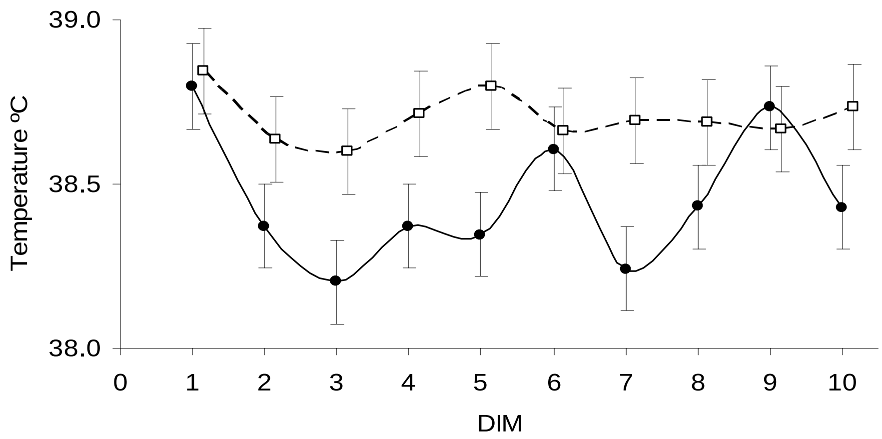
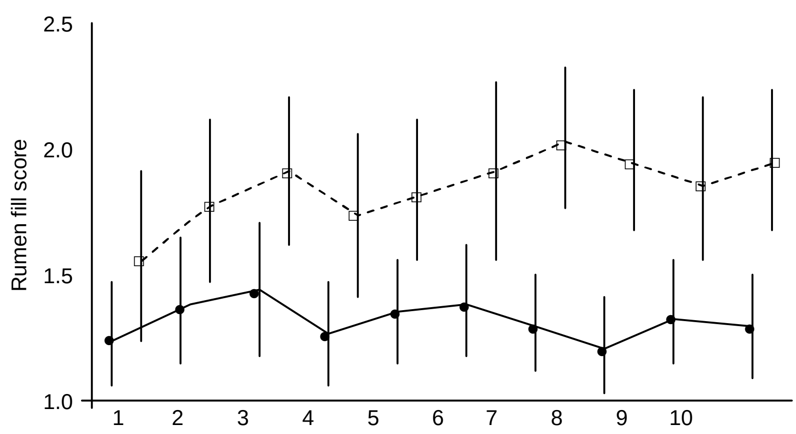


Figure 2 Average rumen fill score of HOUSED/TMR (n=23) and GRASS (n=23) cows in the 10 days post partum



Discussion and conclusions

According to Zaaijer and Noordhuizen (2003) the expected rumen fill score for the first week postpartum is 2. In the present experiment, the average score for the HOUSED cows on a TMR diet in the first 10 days after calving was 1.80 which was in good agreement with these authors. However, the rumen fill score in the same period for the grazing cows was 1.30. This suggests that these animals had a lower dry matter intake in the postpartum period than TMR cows. The results on rectal temperatures are also probably a reflection of the nutritional differences between the treatments. On the other hand while the number of animals affected by mastitis was the same in both treatments there were fewer cases of mastitis outdoors. This indicates that more animals had recurring cases of clinical mastitis indoors. This is consistent with the literature and is probably a reflection of poorer hygiene indoors and also possibly of higher levels of stress indoors. Nevertheless the difference between treatments in clinical mastitis was not reflected in the sub-clinical indicators of disease that were measured.

3.4.3. Reproductive welfare of spring calving dairy cows in a confinement-TMR system or a pasture-based management system

Introduction

The postpartum period is very important in the production cycle of the dairy cow, because it determines productive and reproductive responses during lactation. Compact calving is crucial to the reproductive and economic success of production systems employing a seasonal calving pattern meaning that animals must breed over a short period with rapid uterine involution and a high pregnancy rate. It was hypothesised that cows at GRASS would show better reproductive health and fertility ultimately leading to better reproductive performance

Materials and methods

A total of 46 Irish Holstein-Friesian spring-calving cows (mean milk yield 6,742 kg) were blocked [lactation number (1 to 8), body condition, body weight, calving date, predicted milk yield] and allocated to two management environments [cubicle housing with a total mixed ration pre- and postpartum (HOUSED) and rotational pasture with grass silage pre- and grass and concentrate postpartum (GRASS)]. The occurrence of reproductive disorders [dystocia, retained foetal membranes from 0 to 10 days in milk (DIM) and endometritis (Metricheck™) 35-49 DIM], the commencement of luteal activity (CLA) (from thrice weekly milk sampling for progesterone analysis, EIA) and reproductive performance following a seasonal breeding period (98 days) were recorded. Puerperal metritis was also recorded during the first ten days in milk. The vulva, perineum and tail were inspected for the presence of fresh discharge. If any discharge was present, it was classified as 1) clear mucus, 2) predominantly clear mucus with pus, 3) mucopurulent (approximately 50% of mucus and 50% of pus), 4) purulent (more than 50% of pus) or red-brown. The smell was recorded when present.

Statistical analysis

Proportions were analysed using Fisher's exact or chi-square while the collated records for continuous variables were analysed using Wilcoxon's or T-test in SAS, as appropriate.

Results and discussion

The raw average milk production for the treatments was of 6,186 kg vs. 7,299 kg for GRASS and HOUSED cows, respectively. Cows managed in the GRASS environment had a lower incidence of dystocia (4.4 *vs*. 17.4%, P=0.08), puerperal metritis (17.4 vs 47.8%, P=0.06), endometritis (9.1 *vs*. 31.8%, P=0.07) and an earlier CLA (median, and interquintile range: 23, 20-31 *vs*. 34, 28-50 days, P=0.09) (Table 1). Overall, reproductive performance was suboptimal and did not differ significantly between the groups. However, it is posited that the lower incidence of uterine disorders and earlier CLA of the GRASS cows may have contributed to their numerically higher submission rate (82.6 *vs.* 60.9%, P=0.19), shorter calving to service (70 *vs.* 75.7 days, P=0.38) and calving to conception (102 *vs.* 107.1 days, P=0.29) intervals and higher final pregnancy rate (73.9 *vs*. 60.9%, P=0.53).

Table 1 Uterine involution, luteal activity, oestrus cyclicity and reproductive performance of Holstein-Friesian cows managed under two production systems

PARAMETERS	GRASS	HOUSED	P-value
Calving and uterine abnormalities within 10 days-post calving			
Dystocia No. (%)	1 (4)	4 (17)	0.079
Retained foetal membranes No. (%)	2 (9)	3 (13)	0.500
Puerperal metritis No. (%)	4 (17)	11(48)	0.059
Uterine involution and resumption of cyclicity at 35 to 49 days post-calving			
Resumption of oestrus cyclicity No. (%)	21 (91)	20 (87)	1.000
Endometritis No. (%)	2 (9)	7 (32)	0.066
Reproductive performance			
Commencement of luteal activity days; median (range)	23 (20 - 31)	34 (28 - 50)	0.085
Calving to service interval days; mean (s.e.)	70 (3.6)	76 (5.2)	0.379
Calving to conception interval Days; median (range)	102 (102 -132)	107 (78-136)	0.293
Submission rate (21d) No. (%)	19 (83)	14 (61)	0.190
First service conception rate No. (%)	9 (39)	8 (35)	1.000
6-week pregnancy rate No. (%)	10 (43)	11 (48)	1.000
Overall pregnancy rate No. (%)	17 (74)	14 (61)	0.529
Service per conception days; mean, median (range)	1.9; 1(1,3)	1.6; 1(1,2)	0.292

Conclusions

Though this is a biologically plausible explanation, limited experimental units may have reduced the probability of detecting the numerical differences in reproductive performance as statistically significant. It is speculated that treatment-induced differences in body condition loss pre- and postpartum and differential peripartum immune suppression may have contributed to these findings. In conclusion, cows managed in a GRASS environment appeared to have an earlier onset of uterine involution and luteal activity and this appeared to be associated with better reproductive performance however; the limited scale of this study precludes robust inference.

3.4.4. A comparison of the sexual behaviour of Holstein Friesian cows in a confinement – TMR system compared to a pasture based system

Introduction

Materials and Methods

The sexual ethogram of 46 spring-calved cows in cubicle housing with a total mixed ration (HOUSED) was compared to that of cows in a rotational pasture based system with concentrate supplementation (GRASS). Cows were blocked and randomly allocated to treatment and were monitored by one observer from ten days postcalving for nine weeks on the same farm. The occurrence of nine behaviours (ano-genital sniffing given or received, chin resting given or received, head-to-head butting, mounting attempts, evasion of mounting attempts, mounting and standing to be mounted see Table 1) was recorded during the thrice daily (6.00, 12.00 and 19.00h) 20 minute visual observation sessions. Milk sampling for progesterone analysis (EIA) was carried out on Mondays, Wednesdays and Fridays to determine the dates of true standing oestrus.

Table 1 Ethogram of oestrus behaviours

Behaviour	Definition	Photograph
Licking or sniffing ano-genital region of another	The animal brings its head within approximately 10 cm of the ano-genital region of another for more than approximately 5 seconds and appears to either lick or sniff the region.	
Ano-genital region licked or sniffed by another	Another animal brings its head within approximately 10 cm of the ano-genital region of this animal for more than approximately 5 seconds and appears to either lick or sniff the region.	
Resting chin	The animal rests or rubs its chin on the rump area of another animal.	
Chin resting received	Another animal rests or rubs its chin on the rump area of this animal.	
Head-to-head butt	The animal stands facing another and butts the head of the other animal with its own head. Recorded in bouts. A bout begins when the heads of the two animals make contact and ends when there is no contact between the heads for 10 seconds or more, or when one of the animals begins another activity.	
Attempted mount	The animal attempts to mount any part of the body of another cow but the animal being mounted evades mounting so the mounting cow does not manage to clasp the other with her front legs and instead returns to the ground. Behaviour is only classed as an attempted mount if the animal raises both front feet off the ground.	

Evades mounting attempt	The animal moves away forwards, sideways or backwards from another animal that is attempting to mount her.	 (Photograph by G. Olmos)
Mount	The animal orientates herself behind another cow, then raises her body above that of the other cow and clasps the cow with her front legs in front of the other cow's pelvic bone. The mounting cow may or may not engage in thrusting forwards and backwards. She dismounts by dragging her front legs back over the rump of the other cow.	
Stands to be mounted	The animal stands still whilst another cow mounts her. She does not try to move away from the other cow but may move a few steps over the duration of the mount to balance the weight of the other animal. The behaviour begins when the mounting cow clasps her two front legs in front of the pelvic bone of the cow that is standing and ends when the animal that is mounting returns its front feet to the ground or when the animal that is standing begins to move away from the mounting animal.	

Statistical analysis

Data in the 24h before and after standing oestrus, (seven peri-oestral observation periods), were analysed by proc FREQUENCY, GENMOD, NPAR1WAY, TTEST and UNIVARIATE, as appropriate, in SAS.

Results

In both treatment groups the median number of attempted mounts, ano-genital sniffs given, chin resting given or received and head-to-head butting changed over the 48h peri-oestral period peaking during the standing oestrus observation session ($P<0.05$). For HOUSED cows there was no difference in the median number of mounts given or evaded or ano-genital sniffs received over time ($P>0.05$). During the standing oestrus session, GRASS cows stood to be mounted more frequently than the HOUSED cows (median, Q1, Q3: 2.5,1,3 and 0.0,0,1, respectively, $P<0.01$). Numerically, the frequency of seven other behaviours was higher in the GRASS compared to the HOUSED treatment group during this session also ($P>0.05$).

Discussion

These results demonstrate that HOUSED cows do not show the same peri-oestral increase in mounting behaviour characteristic of GRASS cows. The lower libido of HOUSED cows was attributed to slippery underfoot conditions, more lameness, the stress of confinement and possible nutritional interactions. These results have implications for oestrous detection systems which rely on mounting behaviour alone.

3.4.5. Evaluation of oestrus detection efficacy and accuracy by three methods in a confinement or pasture management system with Holstein–Friesian cows

Introduction

In Ireland the majority of dairy cows are at pasture once they calve in the spring until housing in the autumn. There has been an increase in year-round housing elsewhere. With the widespread use of artificial insemination in all milk production systems accurate oestrus detection is essential. The primary behavioural sign that a cow is in oestrus is that she stands to be mounted i.e. is in 'standing oestrus'. Most producers rely on visual observations with or without the added aid of tail paint' to detect standing oestrus but there is increasing interest in automated system to detect oestrus. The objective of this experiment was to compare the efficacy of three methods of oestrus detection [visual observation (VO), tail paint (TP) and radiotelemetry-HeatWatch® (HW)] in two management systems [cubicle housing with a total mixed ration (HOUSED) and in a rotational pasture system with concentrate supplementation (GRASS)].

Materials and methods

Experimental design and treatments

Forty six Holstein-Friesian spring-calving cows were randomised [parity, weight, calving date and predicted milk yield] and allocated to two management systems: HOUSED (cubicle housing with a total mixed ration (-60 to 300 days relative to calving=DRC)] vs. PASTURE [cubicle housing with grass silage (-60 to -1 DRC) pre- and rotational pasture with concentrate post-partum (0 to 300 DRC)]. All cows were subjected to three oestrus detection methods simultaneously from ten days post-calving for nine weeks. The HeatWatch patches (previously described by Dransfield et al., 1998) and tail paint being applied 10 days post partum. The occurrence of nine selected behaviours associated with oestrus was recorded during thrice daily 20 minute visual observation sessions by the same observer. Morning sessions began at 06:05 and 06:35, the midday sessions at 12:00 and 12:30 and the evening sessions at 19:00 and 19:30. The treatment observed first was alternated each day. Thrice weekly milk sampling for progesterone analysis (EIA) were used to determine the dates of true standing oestrus events (oestrus detection accuracy).

Measurements

The efficiency and accuracy of the three detection methods, the success of each detection method in each treatment and the number of silent ovulations, sub and standing oestrus events in each treatment were compared using Pearson Chi-Square tests using the Frequency procedure in SAS. The number of mounts recorded by HeatWatch and by visual observations over the entire standing oestrus and the number of mounts recorded during visual observation sessions by HeatWatch and by visual observations were both paired, non-parametric data and were analysed using sign tests (univariate procedure in SAS).

Results

All three detection methods had a higher oestrus detection efficacy in the GRASS (VO 59, TP 65 and HW 69%) compared to the HOUSED treatment (VO 20, TP 26 and HW 37%) ($P<0.001$) (Figure 1). In the PASTURE treatment there were 49 ovulations and in the HOUSED treatment there were 46 ovulations. There was no difference between the efficiencies of the three methods within either treatment ($p>0.10$). Within each treatment there was no difference between the accuracy of the three methods (PASTURE: VO 97%, TP 94%, HeatWatch 97% and HOUSED: VO 100%, TP 92% and HeatWatch 77%). There was a tendency for HeatWatch to be more accurate in the PASTURE than HOUSED treatment (Fisher's exact test, $p= 0.076$). During visual observation sessions, VO detected more mounts received by cows in standing oestrus (median = 2) than HeatWatch (median = 0) (Sign test, N=12, M=5.5, $p<0.01$).

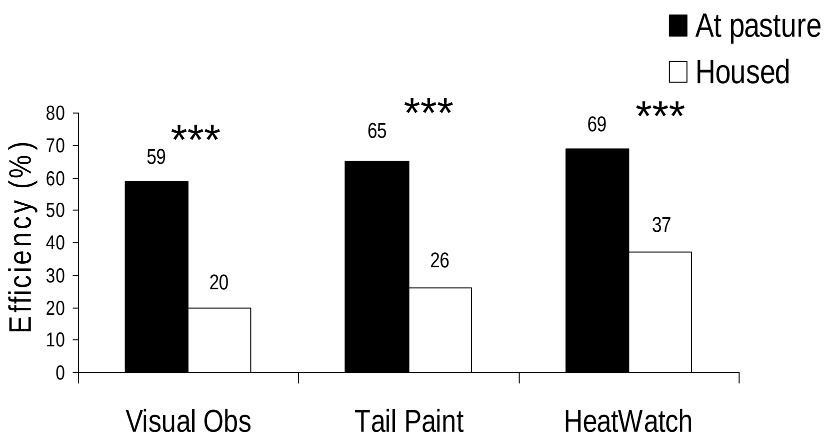


Figure 1 Detection efficiencies of three different methods of oestrous detection in a pasture based compared to an indoor confinement environment
*** P<0.001

More cows expressed sub-oestrus (39 vs 13%) and fewer expressed standing oestrus (52 vs 91%) in the HOUSED compared to the GRASS treatment, respectively (P<0.05). The intervals between calving and first, second and third standing oestrus were longer in the HOUSED than the GRASS treatment, significantly so for second standing oestrus (69 and 55 days, respectively, P<0.05). During the observation sessions there was a higher frequency of standing to be mounted in GRASS than in HOUSED cows (median, Q1, Q3: 3,2,4 and 1,1,1.5, respectively, P<0.01).

Discussion

The fact that there was no difference between the efficiency of the three detection methods in either treatment is in agreement with the findings of Rae et al. (1999). However Peralta et al. (2005) found that three times per day visual observation had a slightly higher detection rate than HeatWAtch for dairy cows kept in a free stall barn. This is in contrast to the trend found for higher efficiency of HeatWatch than visual observations in the HOUSED treatment. During visual observation sessions HeatWatch recorded fewer occasions of animals standing to be mounted than the observer. In addition the composite duration of standing oestrus was numerically but not significantly longer than the HeatWatch duration. This agrees with the findings of Cavalieri et al. (2003) who monitored animals continuously by visual observations and by HeatWatch. They found that HeatWatch missed a mean of 42% of mounts per standing oestrus and that the duration of standing oestrus was 24% less when measured by HeatWatch than when measured by consdtant visual observations. It could be that HeatWatch patches were being displaced by the mounting activity. Alternatively it could be that the design of the system is responsible because there is lag phase of between 30 and 60 seconds between the mount being registered by the patch and it being transmitted to the receiver. This results in some signals not being received. This has some implications for the use of HeatWatch in research. All detection methods were more efficient at pasture. Detection methods not based on mounting should be used indoors. Heatwatch did not detect all mounts that occurred.

Conclusions

These results have implications for management of oestrus in confinement systems indicating that irrespective of the oestrus detection method employed, significantly less oestrous events will be detected than if cows were given access to pasture.

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