

# The effect of out-wintering pad design on dirtiness score, somatic cell score and mastitis incidence in dairy cows

K. O'Driscoll<sup>1,2†</sup>, L. Boyle<sup>1</sup>, P. French<sup>1</sup>, B. Meaney<sup>1</sup> and A. Hanlon<sup>2</sup>

<sup>1</sup>Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland; <sup>2</sup>School of Agriculture, Food Science and Veterinary Medicine, Veterinary Sciences Centre, NUI Dublin, Belfield, Dublin 4, Ireland

(Received 4 September 2007; Accepted 4 February 2008)

*This study aimed to compare three woodchip out-wintering pad (OWP) designs, and indoor cubicle housing with regard to cow dirtiness scores during the winter housing period, and udder health during both the winter period and the following lactation, for spring-calving dairy cows. The treatments were: an uncovered (UP) and covered (CP) OWP with a concrete feed apron; an uncovered OWP with self-feed silage pit provided directly on the woodchips (SP); and indoor cubicle housing (IC). Data were compared during 2 years: year 1 was a case study while year 2 was an experimental study. In year 1, treatments were UP (space allowance = 12 m<sup>2</sup>/cow), CP (6 m<sup>2</sup>/cow) and IC. In year 2, all three OWP designs (12 m<sup>2</sup>/cow) were compared with IC. Animals were assigned to treatments at the end of lactation in the autumn, and remained there while dry until calving the following spring. Subsequently, all cows were at pasture during lactation. Outcome measures for analysis were cow dirtiness score, somatic cell score (SCS) and incidence of clinical mastitis during the dry period and during lactation. Quarter milk samples were also taken at drying off, calving and 3 weeks post partum both years, and at approximately 113 days in milk in year 2. Samples were analysed for presence of mastitis-causing agents and SCS was determined. Sub-clinical mastitis was diagnosed when cows had an SCS greater than 200 000, or California mastitis test greater than 1 in at least one quarter. In year 1, cows in CP were dirtier than cows in the other two treatments. These animals also had the highest SCS during lactation and tended to have more mastitis-causing agents isolated from quarter milk samples. In year 2, when all cows were stocked at the same density, cows in the sheltered OWP (i.e. CP) had similar dirtiness scores to cows in cubicles and significantly lower dirtiness scores than cows in the unsheltered OWP designs, i.e. UP and SP. However, there were no effects on SCS or quarter sample results. Cleaning of OWP's stocked at 12 m<sup>2</sup>/cow reduced cow dirtiness scores. However, cleaning of CP in year 1 when cows were stocked at 6 m<sup>2</sup>/cow had no effect on dirtiness scores. We conclude that dry cows stocked at 12 m<sup>2</sup>/cow on OWP's are unlikely to have udder health problems in the subsequent lactation. Furthermore, provision of shelter and cleaning of the woodchips are management factors that help to keep cows clean on OWP's.*

**Keywords:** dairy cow, dirt score, mastitis, out-wintering pad

## Introduction

Mastitis is one of the most important diseases affecting dairy cows (Grohn, *et al.*, 2005), with an estimated incidence of 25% of cows calving in Ireland (Berry and Amer, 2005). It has a significant economic impact resulting from the costs of prevention and treatment (Kaneene and Scott-Hurd, 1990), milk loss and increased culling (Grohn *et al.*, 2005). In addition to profitability, mastitis is a serious impediment to dairy cow welfare, causing pain and distress (Eshraghi *et al.*, 1999). The economic and welfare costs mean that research on the risk factors associated with mastitis is essential.

Incidence rate of clinical mastitis (CM) is affected by risk of exposure to environmental pathogens (Barkema *et al.*, 1999b). Housing conditions, management style and the cleanliness of the animals are factors that influence contact with these pathogens (Osteras and Lund, 1988; Bartlett *et al.*, 1992a; Barkema *et al.*, 1999b). Bartlett *et al.* (1992b) found increased prevalence of infection from coliforms and environmental *Streptococci* with worsening sanitary conditions. Furthermore, intramammary environmental pathogens are significantly associated with udder hygiene scores (Schreiner and Ruegg, 2003).

Somatic cell count (SCC) was identified as a useful indicator of both clinical and sub-clinical mastitis (Lund *et al.*, 1994; Poso and Mantysaari, 1996; Koivula *et al.*, 2005),

<sup>†</sup> E-mail: keelin.odriscoll@teagasc.ie

and changes in SCC over a lactation may even predict animals that are at risk from specific pathogens (Haas *et al.*, 2002). Furthermore, SCC and California mastitis test (CMT) values in early lactation can be used to detect cows with intramammary infection (IMI) (Sargeant *et al.*, 2001). Winter accommodation for dairy cows also has a significant effect on SCC, animals in loose housing systems having higher scores than tied cows (Bartlett *et al.*, 1992b). Schreiner and Ruegg (2003) found that linear SCC was also associated with leg hygiene score, and increased as udder hygiene score increased.

Alternatives to cubicle accommodation for dairy cattle are emerging (Barberg *et al.*, 2007; Gazzola *et al.*, 2007; O'Driscoll *et al.*, 2008). A potentially viable system consists of group housing cows on an organic bedding substrate without physical constructions such as cubicles. One example of this is a bedded pack system, which is of growing interest to dairy producers in the US (Barberg *et al.*, 2007). However, Barberg *et al.* (2007) reported that excellent cow preparation for milking procedures and management of the pack were necessary to achieve low bulk tank SCC. In Ireland (Hickey *et al.*, 2002; O'Driscoll *et al.*, 2006) and New Zealand (Fisher *et al.*, 2003; Tucker *et al.*, 2007) woodchip pads, or out-wintering pads (OWPs), are under investigation as an alternative winter confinement system for dairy cattle. However, Hourihan (2006) showed that woodchip pads become dirtier as stocking density and the number of weeks in use increase. This could have serious implications for the success of these systems for dairy cows, given the link between dirtiness and mastitis. Over half of all environmental pathogens acquired during the dry period persist to lactation (Todhunter *et al.*, 1995). Hence udder health may be compromised both during the winter, which coincides with the dry period for spring-calving dairy cows, and during the following lactation when the cows are at pasture. Currently there is no published literature on the implications for dairy cow health of confinement on woodchip pads. This paper describes findings from a case study and an experimental study, both of which aimed to compare different OWP systems for dairy cows with conventional cubicle housing. The parameters investigated were the incidence of CM during the dry period and during the subsequent lactation, animal dirtiness during the dry period and SCC during the subsequent lactation.

## Material and methods

The studies were conducted at Teagasc 'Ballydague' research farm, which is part of Moorepark Dairy Production Research Centre, between December 2004 and December 2005 (year 1) and December 2005 and December 2006 (year 2).

### Year 1 – case study

**Animals and treatments.** In all, 147 pregnant dairy animals (*Bos Taurus*) (44 nuliparous and 103 multiparous cows) were blocked according to breed (Holstein-Friesian, Normande, Montbeliarde, Norwegian Red, Montbeliarde × Holstein-Friesian, Normande × Holstein-Friesian), parity ( $1.78 \pm 1.58$ ),

expected calving date (21 February 2005  $\pm$  25.5 days) and body condition score (BCS) ( $3.09 \pm 0.29$ ) into 49 groups. One animal from each group was then randomly assigned to one of the following treatment groups from 6 December 2004: (i) indoor cubicle housing (IC); (ii) an uncovered woodchip pad with a concrete feed face (uncovered OWP, UP); and (iii) a covered woodchip pad with a concrete feed face (covered OWP, CP). Thus, as there were 49 blocks, and one animal from each was assigned to each treatment, there were 49 animals per treatment.

**Housing and management.** The cows used in this study were managed using a pasture-based spring-calving system. Cows were taken from pasture at the end of the grazing season (early winter) and put onto the treatments described, which roughly covered the dry period. Indoors, the cubicles were bedded with rubber mats, and were provided at a cow-to-cubicle ratio of 1:1. They were of a 'Super Dutch Comfort' design (O'Connell *et al.*, 1991) and were manually cleaned and treated with lime each day. An automatic scraper cleaned the solid concrete floor six times daily. The woodchip lying areas were constructed according to published guidelines (Hickey *et al.*, 2002). Cows on UP had a woodchip space allowance of 12 m<sup>2</sup> per head, while CP cows were provided with 6 m<sup>2</sup> woodchip surface. The latter OWP was sheltered on two sides by erecting a 1.83 m-high semi-porous barrier (Nicofence<sup>®</sup>; R.J.M. Mooney & Son Ltd, Dublin, Ireland), and overhead by a green polythene tunnel. Cows in all three treatments self-fed silage from a concrete-floored feed face with 60 cm space per cow. Manure was cleaned from the feed face areas in UP and CP once a day by a tractor.

The woodchips were scored weekly using a published scoring system (Hickey *et al.*, 2002). The scale ranged from 1 (clean woodchips) to 4 (thick faecal layer), using the technique described by O'Driscoll *et al.* (2008). A score of 1 or 2 constituted an acceptable level of cleanliness. Pads were managed so that each cow had a clean lying area of 2.2 m<sup>2</sup>. When this level was breached, dirty woodchips were removed and replenished with clean woodchips. Pads were cleaned on 20 December 2004, 18 January 2005 and 5 February 2005.

Between 6 and 15 December 2004, lactating and non-lactating cows were kept within their respective treatments, but separated by an electric wire on the OWPs, and a gate in IC. All cows were dried off by 16 December 2004, and for the remainder of the experiment cows were managed as a single group within each treatment. The mean calving date was 23 February 2005. Approximately 6 days prior to its calving date ( $5.9 \pm 4.41$  days, mean  $\pm$  s.d.) each cow was removed to a straw-bedded calving house. The correct stocking density for the remaining animals was maintained by adjustment of an electric wire or gate as appropriate. *Post partum*, cows remained with their calves until the next milking. Later they were returned to a different straw-bedded house for one night. Cows that calved prior to 14 February 2005 ( $n = 88$ ) were returned to their treatments

post calving, and separated from non-lactating animals by an electric wire or gate, as before. They remained here at night, and were at pasture by day, until 14 February, when they were at pasture day and night. Cows calving from 15 February onwards were at pasture by day and night. All cows were dried off by 30 November 2005.

During the winter housing period, fresh grass silage (dry matter (DM) 19.9%, crude protein (CP) 14.1%, dry matter digestibility (DMD) 72.7%, NDF 44.8%, ash 6.2%) was offered *ad libitum* daily in the morning at 1 kg above requirement in order to ensure animals were not restricted. Fresh water was available from self-filling troughs for each treatment. While at pasture, animals were managed as a single herd. The pasture consisted primarily of perennial ryegrass (*Loilum penne*). Cows were allocated fresh grass daily, and pre-grazing yield was maintained at between 1800 and 2200 kg DM/ha (>4 cm).

#### Year 2 – experimental study

**Animals and treatments.** In all, 96 pregnant dairy cows (*Bos Taurus*) (40 nuliparous and 56 multiparous) were blocked according to breed (Holstein-Friesian or Norwegian Red), parity ( $1.56 \pm 1.785$ ), expected calving date (22 February 2006  $\pm 20.1$  days) and BCS ( $3.09 \pm 0.29$ ) into 12 groups of eight animals. One animal from each group was then randomly assigned to one of two replicates of the following treatments (i) IC, (ii) UP, (iii) CP, and an uncovered OWP with a self-feed silage pit (SP). Multiparous and primiparous animals were assigned to treatment on 17 November 2005 and 5 December 2005, respectively. Thus, as there were 12 blocks, and one animal from each block was assigned to each treatment replicate, there were 12 animals per treatment replicate.

**Housing and management.** Housing and management of IC and UP were as in year 1. However, animals accommodated in CP were allocated 12 m<sup>2</sup> woodchip space allowance per head. Cows in SP had a woodchip space allowance of 14.52 m<sup>2</sup> per head. This was equal to the 12 m<sup>2</sup> woodchip and 2.52 m<sup>2</sup> concrete feed area space allowance allocated in the UP and CP treatments. The concrete feeding areas of IC, UP and CP were cleaned six times daily by an automatic scraper. The feed faces in each SP replicate were 13.5 m in length. In order to prevent spoilage of the silage, it was necessary for 26 animals to feed from these areas. For this reason, 14 'filler' animals were allocated to each of the SP replicates. OWP dirtiness was scored as described in year 1. The OWP's were cleaned on 20 January 2006 and 3 March 2006.

All multiparous animals were dried off by 17 November 2005. Between 17 November 2005 and 5 December 2005, multiparous animals from both replicates of each treatment were confined in a single group, within their treatment. On 5 December 2005 they were split into their respective replicates, and the nuliparous animals were added. The mean calving date was 21 February 2006. Animals were removed for calving approximately 3 days prior to calving

( $3.2 \pm 5.51$  days) to a straw-bedded calving shed, and managed thereafter as in year 1. Cows that calved prior to 13 February 2006 ( $n = 40$ ) were kept on an uncovered non-experimental OWP by night and were at pasture by day. All calved cows were at pasture by day and night from 14 February 2006 onwards. Animals were at pasture for the remainder of lactation. All cows were dried off by 19 December 2006.

During the winter housing period, fresh grass silage (DM 19.7%, CP 16.7%, DMD 77.0%, NDF 42.2%, ash 8.4%) and water was provided *ad libitum*, as in year 1. While at pasture, animals were managed as during year 1. Animals that were kept on the uncovered OWP immediately *post partum* were offered freshly cut grass *ad libitum* each morning.

**Environmental measurements.** Local rainfall and mean daily wind speed data were obtained from a weather station located at Moorepark Dairy Production Research Centre approximately 10 miles from the experimental site. Data were recorded by a trained technician between 26 November 2004 and 18 February 2005, and between 22 November 2005 and 30 January 2006, i.e. between the initial and last dirtiness scoring dates for each year. Ambient air temperature and relative humidity (RH) were recorded using Gemini Tinytag Extra Dataloggers, TGX-3580 (Gemini dataloggers (UK) Ltd, Chichester, West Sussex, UK) between 20 December 2004 and 3 February 2005, and between 3 January 2006 and 28 February 2006. One datalogger was placed each in IC, CP and UP, and data were recorded at 10-min intervals. Dataloggers were suspended 2 m above the ground level. In year 1, dataloggers were positioned at the rear mid-point of the CP and UP treatments, and at the mid-point of the feed face in IC. In year 2, dataloggers were positioned at the rear and midway between the two replicate groups in CP, and above and between the feed faces of the two replicate groups in IC. The UP datalogger was positioned midway between the UP and SP treatments.

#### Animal measurements

As we wished to study the long-term effects of OWPs on health, animal measurements were made both during the winter treatment period and when the cows were returned to pasture after the winter treatment period.

**Animal dirtiness scoring.** Animals were scored for dirtiness only during the winter treatment period. During year 1, animals were scored every 2 weeks ( $14 \pm 0.6$  days, mean  $\pm$  s.d.), and during year 2 approximately every 2.5 weeks ( $17 \pm 3.3$  days). Previously published scoring systems use complex measurements (Hickey *et al.*, 2002) or require the use of equipment while cattle are restrained (Zdanowicz *et al.*, 2004; De Palo *et al.*, 2006). Due to the large number of animals in this study, and in order to avoid movement of the cows to a holding area, a scoring system was developed that facilitated rapid assessment of the hygiene of unrestrained cows. Prior to the experiment the scoring system was tested for intra-observer repeatability. An observer scored

**Table 1** Animal dirtiness scoring system

| Score | Definition  |
|-------|---|
| 1.0   | Clean skin and hair   |
| 1.5   | Mainly clean, some loose manure   |
| 2.0   | Approximately 50% of area being scored is clean, some loose manure, hair visible through manure |
| 2.5   | More than 50% of area being scored is soiled, some matting of hair                              |
| 3.0   | Most of the area being scored is dirty, much of the hair is matted                              |
| 3.5   | All of the area being scored is dirty, most of the hair is matted, little hair visible          |
| 4.0   | All of area being scored is matted, hair not visible  |

a set of cows ( $n = 30$ ) twice in a random order. Cows were scored on the left side of the body, which was subdivided into five areas; front leg, rear leg, hindquarter, belly and udder, and each section scored using a scale from 1 to 4 in 0.5 score increments (Table 1). The sum of these scores constituted the overall dirtiness score for each animal (max = 20; min = 5).

**Composite sample somatic cell count.** Cows were milked twice daily for the entire lactation after the treatment period, at approximately 0700 and 1530 h. Milk yield was measured at each milking for every cow using electronic milk meters. Clusters were removed automatically once milk flow fell below 0.2 kg/min. Individual cow milk samples were taken every other week (year 1;  $10.8 \pm 5.36$  days (mean  $\pm$  s.d.), year 2;  $15.4 \pm 5.84$  days) at one morning and one evening milking, and SCC was determined using the Bentley Somacount 300 (Bentley Instruments Incorporated, Chaska, MN, USA). Milk samples were representative of the four quarters and the entire milking. The last sample to be included in analysis during year 1 was taken on 8 November 2005, and in year 2 on 12 December 2006. On average,  $20.9 \pm 5.42$  samples were taken per animal during year 1, and  $17.0 \pm 3.69$  during year 2.

**Clinical mastitis.** The udder was inspected daily during the winter accommodation period, and twice daily at milking once the cows had calved, for redness, soreness and/or inflammation as indicators of clinical mastitis (CM). On identification of CM a sample of milk from the affected quarter was taken aseptically and analysed for bacteriological analysis. These recorded cases are referred to as CM, and are based solely on the herdsman's interpretation of CM (Pryce *et al.*, 1999).

**Quarter milk samples.** Quarter milk samples (QMS) were taken on three and four occasions during years 1 and 2 of the study, respectively, in order to estimate the levels of sub-clinical mastitis in animals from treatment. On each QMS test day, milk samples were collected aseptically from all udder quarters into individual sterile plastic containers after drawing foremilk. During year 1, QMS were taken

from all cows at drying off, and approximately 3 weeks ( $24.4 \pm 2.36$  days) *post partum*, and analysed for microbiology and SCC. During year 2, cows had QMS taken at drying off (30 November 2005), approximately 3 weeks *post partum* ( $18.3 \pm 3.52$  days), and on 14 June 2006 ( $113 \pm 23.0$  days in milk). All samples were analysed for microbiology as well as SCC quantification. QMS were also collected  $2.2 \pm 1.98$  and  $1.8 \pm 1.29$  days (years 1 and 2, respectively) post calving, and assayed for CMT and microbiology. IMI was considered to have occurred if a positive bacteriological result occurred, and SCC was greater than 200 000. Sub-clinical mastitis was diagnosed at each QMS examination when  $SCC > 200\ 000$  or  $CMT > 1$  in a sample from at least one quarter, but no macroscopic changes in either the udder or milk were evident (Dohoo and Leslie, 1991). Additionally, any cases of CM at each inspection date were recorded.

#### Statistical analysis

All data were analysed using the Statistical Analyses System (SAS, v.9.1; SAS Institute, Inc., Cary, NC, USA). Mean daily rainfall and wind speed measurements during the experimental period were compared between years 1 and 2. Daily rainfall was  $\log_{10}$ -transformed in order to approach a normal distribution. Transformed data were analysed using analysis of variance (ANOVA) (Proc GLM); however, mean rainfall per day is reported using untransformed arithmetic mean and interquartile range. Temperature and RH recordings were compared between treatments and years using repeated measures ANOVA (Proc Mixed). Recordings between 3 January and 3 February each year were used, as it was only between these dates that data from both years were available. Mean values for each recording day were used in the analysis. Fixed effects included treatment, year and the interaction between the two. Date was the repeated variable, nested within year. An autoregressive covariance structure (AR(1)) provided the best model fit.

The dirtiness scoring system was tested for intra-observer reliability using weighted Cohen's  $\kappa$  (Proc Freq).

For all other analyses, the animal was considered the experimental unit. Data were tested for normality prior to analysis, by examination of box and normal distribution plots. Dirtiness scores from both years were analysed using repeated measures ANOVA (Proc Mixed), in order to determine the effect of treatment over time within each winter accommodation period. For the case study, fixed effects were treatment, inspection day and the interaction between the two. Inspection day was the repeated variable. Cow was nested within treatment in year 1, and within treatment and replicate in year 2, and considered a random effect. For the experimental study a similar model was used, but cow was nested within replicate and treatment. In addition, the effect of replicate within treatment was examined. An autoregressive covariance structure (AR(1)) provided the best model fit for both years.

A log to the base 2 transformation of SCC to somatic cell score (SCS) was used to normalize the data distribution.

SCSs were analysed separately for each year, using repeated measures ANOVA (Proc Mixed). Fixed effects were treatment, sampling day (lactation week), and the interaction between the two, breed, lactation number (first lactation or greater than first lactation) and whether the cow was milked while on treatment. Lactation week was the repeated variable. Cow was nested within treatment in year 1, and within replicate and treatment in year 2, and was considered a random effect. An autoregressive covariance structure (AR(1)) provided the best model fit.

Differences in least squares means in all models were investigated using the *t*-test following Tukeys adjustment for multiple comparisons. Model fit was determined in all analyses by choosing models with the minimum finite-sample-corrected Akaike Information Criteria.

Quarter sample data and incidence of CM were analysed using generalised-estimating equations (GEE) (Proc Genmod), due to the binomial nature of the data. The logit of the probability that a cow exhibited CM during the experimental period and subsequent lactation, had an IMI at a QMS inspection, or had sub-clinical mastitis at any of the quarter sampling inspections was investigated, and odds ratios (OR) and 95% CI were reported. Differences in frequency of isolation of identified pathogens were also investigated in this way. Cow was included as a repeated effect. Each dependent variable had a separate model constructed. Treatment and test day were forced into the model as class variables. Parity and breed were also considered class variables and tested for significance and all relevant interactions were also investigated. Significance was based on GEE score.

## Results

### Environmental measurements

Mean daily rainfall between 26 November 2004 and 18 February 2005 was 2.7 mm (IQR: 0.1 to 3.2 mm). The total amount of rainfall during this period was 226 mm. In year 2, the mean daily rainfall was 2.1 mm (IQR: 0.0 to 2.2 mm), between 22 November 2005 and 30 January 2006, and the total amount was 144 mm. The difference in daily rainfall between the 2 years was not significant ( $P > 0.1$ ). Mean daily wind speed was higher during year 1 than during year 2 (year 1 =  $7.0 \pm 0.33$  m/s, year 2 =  $5.31 \pm 0.37$  m/s;  $P < 0.01$ ). There was no effect of year on RH, but there was an effect of treatment and also an interactive effect of treatment and year ( $P < 0.05$ ). There was no difference between RH in IC ( $92.3 \pm 1.42\%$ ) or in CP ( $91.6 \pm 1.60\%$ ), but both were higher than UP ( $82.4 \pm 1.42\%$ ;  $P < 0.001$ ). However, RH did not change within individual treatments between year 1 and year 2 (data not shown,  $P > 0.1$ ). There was no effect of treatment or interactive effect of treatment and year on temperature, but there was an effect of year, the temperature during year 1 ( $7.6 \pm 0.29^\circ\text{C}$ ) being higher than during year 2 ( $6.4 \pm 0.29^\circ\text{C}$ ;  $P < 0.01$ ). However, although there was an overall effect of year, there was no significant difference between years within each treatment.

**Table 2** Results of weighted Cohen's  $\kappa$  analysis for intra-observer reliability of the dirtiness scoring system

|              | Weighted $\kappa$ | P value |
|--------------|-------------------|---------|
| Belly        | 0.57              | 0.001   |
| Front leg    | 0.75              | 0.001   |
| Hind leg     | 0.67              | 0.001   |
| Hind quarter | 0.70              | 0.001   |
| Udder        | 0.68              | 0.001   |
| Total        | 0.72              | 0.001   |

### Animal dirtiness

Results on the repeatability of the dirtiness scoring system are shown in Table 2.

Animal dirtiness scores were recorded  $5.8 \pm 1.25$  (mean  $\pm$  s.e.) times, and  $4.5 \pm 0.50$  times per cow in years 1 and 2, respectively. There was no difference between treatments at the initial examination in either year ( $P > 0.1$ ; Figure 1). Dirtiness scores in IC did not change during the housing period in either year ( $P > 0.1$ ).

Overall, in year 1, dirtiness scores of cows in both the UP (stocking density  $12 \text{ m}^2/\text{head}$ ) ( $10.1 \pm 0.18$ ) and CP (stocking density  $6 \text{ m}^2/\text{head}$ ) ( $11.3 \pm 0.18$ ) treatments were higher than those of cows in IC ( $8.9 \pm 0.18$ ;  $P < 0.001$ ). However, there were differences between the treatments in the changes over time. Scores recorded in cows on the CP treatment were consistently higher than those in IC ( $P < 0.001$  on all examination dates) (Figure 1a). However, dirtiness scores of cows in UP were similar to those recorded in CP cows prior to the pads being cleaned (20 December and 18 January) but decreased to levels similar to those recorded in the IC treatment after the pads were cleaned (Figure 1a). In contrast, dirtiness scores of cows in CP did not decrease after cleaning, but cleaning caused them to increase at a slower rate, as evidenced by the absence of a difference in animal dirtiness scores between 10 and 23 December 2004, 7 and 21 January 2005 or 4 and 18 February 2005.

During year 2, cows in the CP and IC treatments had the lowest dirtiness scores ( $8.3 \pm 0.27$ ,  $8.8 \pm 0.28$ ;  $P > 0.1$ ). Cows on SP and UP had the highest scores ( $9.8 \pm 0.27$ ,  $9.7 \pm 0.28$ ;  $P > 0.1$ ). The difference between SP and both CP and IC was significant ( $P = 0.001$ ,  $P < 0.05$ , respectively), as was the difference between CP and UP ( $P < 0.01$ ). Furthermore, cows in IC tended to have lower scores than those in UP ( $P = 0.1$ ).

Cows in CP had scores similar to cows in IC on all examination dates ( $P > 0.1$ ), and there was no change in dirtiness scores of animals in these treatments throughout the housing period ( $P > 0.1$ , Figure 1b). In contrast, dirtiness scores of cows in UP and SP increased after the initial examination date ( $P < 0.05$ ), until after the OWPs were cleaned on 20 January 2005 when dirtiness score decreased.

### Somatic cell scores

During both years several lactation weeks were poorly represented by samples. In years 1 and 2, samples taken

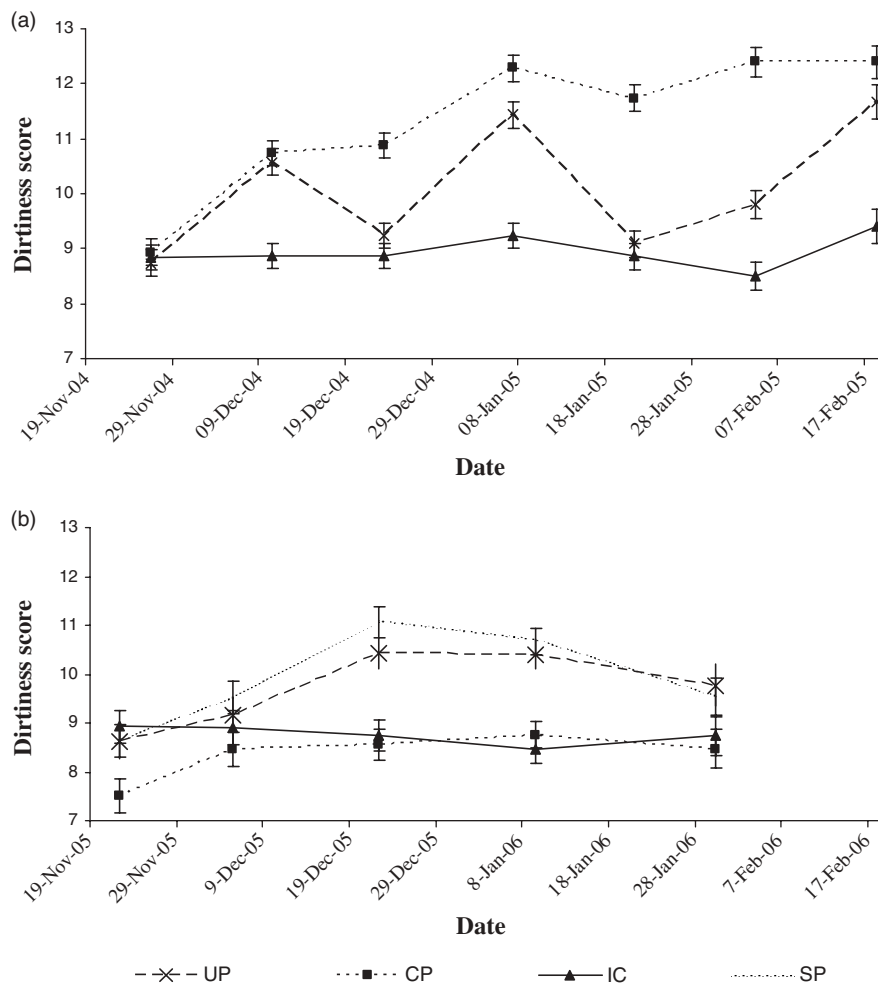


Figure 1 Mean cow dirtiness score at each examination date in each treatment during years 1 (a) and 2 (b).

from cows that were more than 37 and 41 weeks into lactation, respectively, were removed from the analysis. In year 1, lactation weeks 1 and 2, and in year 2 lactation weeks 1, 8 and 10 were removed for the same reason. Thus in the final analysis, there were  $20.3 \pm 5.08$  and  $15.4 \pm 3.17$  samples per cow included from years 1 and 2, respectively.

There was no interactive effect of treatment and lactation week on SCS during either year ( $P > 0.1$ ). During year 1, there was an effect of treatment on SCS ( $P < 0.05$ ). Cows on CP had a higher SCS ( $16.2 \pm 0.13$ ) than IC cows ( $15.7 \pm 0.13$ ;  $P < 0.05$ ). However, there was no difference between UP ( $16.0 \pm 0.13$ ) and either of the other treatments ( $P > 0.1$ ). During year 2 there was no difference in SCS between any of the treatments ( $15.5 \pm 0.22$ ,  $15.0 \pm 0.24$ ,  $14.9 \pm 0.24$ ,  $15.6 \pm 0.23$ ; IC, UP, SP, CP respectively;  $P > 0.1$ ).

#### Clinical mastitis and quarter milk samples

In year 1, cows were dried off in groups ( $19 \pm 11$  cows per group) between 19 November 2004 and 16 December 2004 (mean date = 6 December 2004  $\pm 7.3$  days). Four cases of

CM (as diagnosed by the stockperson) were recorded in IC, two cases in CP and two in UP during the winter accommodation period. In all, three cases were recorded in IC, nine in CP and seven in UP post calving. However, treatment did not affect the proportion of animals that developed CM ( $P > 0.1$ , data not shown).

There was no difference in the proportion of animals from each treatment diagnosed with sub-clinical mastitis at any of the quarter sampling test dates ( $P > 0.1$ , data not shown). However, there was an effect of test day ( $P < 0.001$ ). The proportion of animals that had at least one quarter affected with sub-clinical mastitis at drying off, calving and the 3 weeks post calving test was 84%, 55% and 46%, respectively. The odds of an animal having at least one affected quarter was lower at calving than at drying off (OR = 0.25, CI = 0.12 to 0.52,  $P < 0.001$ ), and at 3 weeks post calving than at drying off (OR = 0.17, CI = 0.09 to 0.35,  $P < 0.001$ ).

Treatment tended to have an effect on the proportion of animals that had an IMI ( $P = 0.08$ ), with a higher proportion in CP than UP (OR = 2.0, CI = 0.99 to 4.04;  $P = 0.05$ ). There also tended to be fewer cows in UP that had an IMI

than in IC (OR = 0.5, CI = 0.23 to 1.04;  $P = 0.06$ ). There was an effect of test day ( $P < 0.05$ ), with a higher proportion of animals having an IMI isolated 3 weeks post calving than at drying off (OR = 1.95, CI = 1.10 to 3.49;  $P < 0.05$ ). In these cases IMI refers to an intramammary infection associated with either contagious or environmental bacteria, or both.

One cow each from UP and CP had *Streptococcus dysgalactiae*, and one cow from IC had *Actinomyces pyogenes* isolated from a quarter sample at calving. There was no effect of treatment on the number of *Streptococcus uberis* isolates identified. These organisms are all environmental pathogens. The other two pathogens that were isolated over the course of the experiment were *Staphylococcus aureus* and non-haemolytic staphylococci, both of which are contagious mastitis-causing agents. There was no effect of treatment on the frequency that these pathogens were isolated. At drying off, *S. aureus* was identified in a quarter sample from seven cows from UP and IC and five cows from CP. At calving, this pathogen was isolated from six cows from UP and CP and 12 cows from IC. There was an effect of test day ( $P < 0.01$ ), and at the extra examination all treatments had more *S. aureus*-infected milk samples than at drying off (OR = 2.18, CI = 1.23 to 3.85;  $P < 0.01$ ). There was no effect of test day on the frequency of isolation of non-haemolytic staphylococci.

In year 2 animals were dried off on 17 November 2005. There was only one case of CM during the winter accommodation period, and this occurred in SP. During lactation there were 10 animals that had at least one instance of CM in CP, eight in IC, seven in UP and five in SP, but no treatment effect ( $P > 0.1$ ).

There was no difference in the proportion of animals in each treatment diagnosed with SCM at drying off, at calving, 3 weeks post calving or on 14 June 2006 ( $P > 0.1$ , data not shown). However, there was an effect of time. The herd percentage of animals having at least one quarter affected at drying off, calving 3 weeks post calving and on 14 June was 64%, 57%, 32% and 25%, respectively. There was no difference between drying off and calving, but at both of the subsequent examinations there were fewer animals with sub-clinical mastitis than at drying off ( $P < 0.001$ ). There was no effect of treatment or inspection on the proportion of animals that had IMI ( $P > 0.1$  in all cases, data not shown).

One cow each from SP and CP had *S. uberis* and *Escherichia coli* (environmental pathogens) isolated from a quarter sample at calving. As in year 1, two other pathogens were isolated, *S. aureus* and non-haemolytic staphylococci. There was no effect of treatment on the frequency that these pathogens were isolated. At drying off, *S. aureus* was identified in a quarter sample from one cow from UP and IC, two cows from SP and three cows from CP. At calving, this pathogen was isolated from two cows from UP and IC and from one cow from SP and CP. However, there was an effect of test day ( $P < 0.001$ ), and at the extra examination all treatments had more *S. aureus*-infected milk samples than at drying off (OR = 3.41, CI = 1.16 to

10.00;  $P < 0.05$ ). More cows had *S. aureus* isolated from at least one quarter on 14 June ( $P < 0.01$ ) than at drying off (OR = 3.72, CI = 1.38 to 10.05). There was no effect of test day on the frequency of isolation of non-haemolytic staphylococci.

## Discussion

The dirtiness scoring system used in this experiment was developed in order to facilitate rapid assessment of the hygiene of unrestrained cows. As a  $\kappa$  value of greater than 0.7 is highly acceptable (Sim and Wright, 2005), the system was considered sensitive and reliable enough to detect treatment differences.

Animal dirtiness scores in the cubicle house and in the uncovered OWP with the concrete feed area were similar in both the case study and the experimental study. Although ambient temperatures were lower in year 2 compared with year 1, there was no difference between years in both temperature and RH within any treatment. Thus environmental conditions were consistent enough not to have altered the lying behaviour (Overton *et al.*, 2002). This could have impacted the dirtiness score by affecting the contact time between the animal's coat and the woodchip.

During the experimental study, cows that had shelter on the OWP were cleaner than those in the two unsheltered OWP designs. Moreover, dirtiness scores of cows that were sheltered from the weather did not change significantly during the accommodation period regardless of whether they were indoors in cubicles or outdoors on a covered OWP. In contrast, dirtiness scores of cows on both unsheltered OWPs increased after the initial inspection and were higher than at the beginning of the trial at all but the last inspection, which was just after the OWP's were cleaned. Hickey *et al.* (2002) found no effect of shelter on animal hygiene, but cattle in that experiment were only sheltered by windbreaks and not overhead. Our results suggest that the amount of environmental moisture on the OWP (represented by daily rainfall) had the greatest impact on animal and bedding hygiene. Indeed, moist manure is more likely to adhere to an animal's coat. In comparison to the uncovered OWP where cows were fed from a concrete feed face, the feeding area of the uncovered OWP with the SP was much dirtier, as it was not possible to remove soiled material on a regular basis. Nevertheless, there was no difference in animal dirtiness scores between both uncovered pad designs. This is probably due to cows in the self-feed system selecting areas away from silage to lie down.

During the case study, animals that were confined on the covered OWP had much higher dirtiness scores than cows in the cubicle house. However, there was no difference between these treatments during the experimental study. This can be explained by the fact that during the experimental study the stocking density in the covered OWP was much lower than during the case study. At high stocking densities there is a greater manure load per area of woodchip than at low stocking densities. Previous work

with OWP systems for beef cattle also reported that animal hygiene score was reduced as stocking density increased (Hickey *et al.*, 2002). Although that study found no health or welfare concerns for beef animals at the high stocking density, the potential for dairy cow welfare to be compromised is greater at high stocking densities, as compromised udder health is one of the main health problems of dairy cows (Grohn *et al.*, 2005). Indeed, intramammary environmental pathogens are significantly associated with udder hygiene scores (Schreiner and Ruegg, 2003). Hence it is not surprising that the high dirtiness scores of animals confined at the high stocking density in the covered OWP in the case study was reflected in a higher tendency for mastitis-causing agents to be isolated, and higher lactation SCC in these animals. In contrast, the lower stocking density in this OWP design during the experimental study resulted in good animal hygiene and similar udder health status to the other treatments.

In both years of the experiment, there was an increase in the number of cows with *S. aureus* isolated from at least one quarter sample at the post-calving examinations. This pathogen is contagious, as opposed to environmental, and is transmitted mainly at milking time (Harmon, 1994). This explains the rise post calving, and is not a reflection of poor hygiene during the winter confinement period.

After the OWP's were cleaned and fresh woodchips applied, the dirtiness scores of cows confined to the two unsheltered OWP treatments decreased to a level similar to those recorded in cows confined indoors in cubicles. This could be an important management application, as movement of dirty animals to clean accommodation prior to calving can improve animal hygiene and reduce the risk of IMI during the subsequent lactation. However, in the case study, dirtiness score of animals confined at the higher stocking density did not decrease to the level of the animals indoors after cleaning of the OWP's. This could have been because the woodchips became dirty again before the animals' coats had a chance to become clean. Hourihan (2006) showed that animal dirtiness scores increased as OWP dirtiness score increased. The results from the case study indicate that 6 m<sup>2</sup> per animal is too high for dry cows on OWP's to maintain acceptable hygiene levels.

Results from both studies indicate that dairy cow hygiene on OWP's is affected by both stocking density and shelter. However, it was only during the case study that animals confined in the covered OWP at a high stocking density developed more udder health problems, than animals kept in traditional indoor cubicle housing. Further investigation is warranted in order to determine the optimum stocking density. Although animals on uncovered OWP's had higher dirtiness scores than cows indoors, this did not affect SCS or mastitis incidence post calving during either study. Therefore management of these OWP's was sufficient so that milk quality and animal health were not compromised. Although further work is necessary to elucidate specific interactions between animal hygiene during the dry period and udder health, these findings have important implications for the management of dry cows on OWP's.

## Acknowledgements

The authors would like to thank Frank Buckley and Noel Byrne for their technical assistance and the Ballydague farm staff for their care of the experimental animals during the study. They especially thank Jane Hourihan for her help in data collection and technical advice on animal dirtiness scoring.

## References

- Barberg AE, Endres MI, Salfer JA and Reneau JK 2007. Performance and welfare of dairy cows in an alternative housing system in Minnesota. *Journal of Dairy Science* 90, 1575–1583.
- Barkema HW, Schukken YH, Lam TJGM, Beiboer ML, Benedictus G and Brand A 1999b. Management practices associated with the incidence rate of clinical mastitis. *Journal of Dairy Science* 82, 1643–1654.
- Bartlett PC, Miller GY, Lance SE and Heider LE 1992a. Environmental and managerial determinants of somatic cell counts and clinical mastitis incidence in Ohio dairy herds. *Preventive Veterinary Medicine* 14, 195–207.
- Bartlett PC, Miller GY, Lance SE and Heider LE 1992b. Managerial determinants of intramammary coliform and environmental streptococci infections in Ohio dairy herds. *Journal of Dairy Science* 75, 1241–1252.
- Berry D and Amer P 2005. Derivation of a health sub-index for the economic breeding index in Ireland. Moorepark Production Research Centre, Fermoy, Co. Cork, Ireland.
- De Palo P, Tateo A, Zezza F, Corrente M and Centoducati P 2006. Influence of freestall flooring on comfort and hygiene of dairy cows during warm climatic conditions. *Journal of Dairy Science* 89, 4583–4595.
- Dohoo I and Leslie K 1991. Evaluation of changes in somatic cell counts as indicators of new intramammary infections. *Preventive Veterinary Medicine* 10, 225–237.
- Eshraghi HR, Zeitlin IJ, Fitzpatrick JL, Ternent H and Logue D 1999. The release of bradykinin in bovine mastitis. *Life Sciences* 64, 1675–1687.
- Fisher AD, Stewart M, Verkerk GA, Morrow CJ and Matthews LR 2003. The effects of surface type on lying behaviour and stress responses of dairy cows during periodic weather-induced removal from pasture. *Applied Animal Behaviour Science* 81, 1–11.
- Gazzola P, Boyle L, French P, Hanlon AJ and Mulligan F 2007. Foraging behaviour of dry cows in out-wintering systems. *Proceedings of the 41st Congress of the International Society for Applied Ethology, Merida, Mexico, 30 July–3 August 2007*, pp 44.
- Grohn YT, Gonzalez RN, Wilson DJ, Hertl JA, Bennett G, Schulte H and Schukken YH 2005. Effect of pathogen-specific clinical mastitis on herd life in two New York State dairy herds. *Preventive Veterinary Medicine* 71, 105–125.
- de Haas Y, Barkema HW and Veerkamp RF 2002. The effect of pathogen-specific clinical mastitis on the lactation curve for somatic cell count. *Journal of Dairy Science* 85, 1314–1323.
- Harmon RJ 1994. Physiology of mastitis and factors affecting somatic cell counts. *Journal of Dairy Science* 77, 2103–2112.
- Hickey MC, French P and Grant J 2002. Out-wintering pads for finishing beef cattle: animal production and welfare. *Animal Science* 75, 447–458.
- Hourihan J 2006. Survey of factors affecting the dirtiness of out-wintering pads and out-wintered cattle in Ireland Masters of Agricultural Science. University College Dublin, Dublin, Ireland.
- Kaneene JB and Scott-Hurd H 1990. The national animal health monitoring system in Michigan. III. Cost estimates of selected dairy cattle diseases. *Preventive Veterinary Medicine* 8, 127–140.
- Koivula M, Mantysaari EA, Negussie E and Serenius T 2005. Genetic and phenotypic relationships among milk yield and somatic cell count before and after clinical mastitis. *Journal of Dairy Science* 88, 827–833.
- Lund T, Miglior F, Dekkers JCM and Burnside EB 1994. Genetic relationships between clinical mastitis, somatic cell count, and udder conformation in Danish Holsteins. *Livestock Production Science* 39, 243–251.
- O'Connell J, Meaney W and Giller PS 1991. An evaluation of four cubicle designs using cattle behaviour criteria. *Irish Veterinary Journal* 44, 8–13.

## O'Driscoll, Boyle, French, Meaney and Hanlon

O'Driscoll K, Boyle L, French P, Meaney B and Hanlon A 2006. Effect of winter housing on cow dirt score, somatic cell score and mastitis incidence in dairy cows. *Animal Science* 84(Suppl. 1), 93.

O'Driscoll K, Boyle L, French P and Hanlon A 2008. The effect of out-wintering pad design on hoof health and locomotion score of dairy cows. *Journal of Dairy Science* 91, 544–553.

Osteras O and Lund A 1988. Epidemiological analyses of the associations between bovine udder health and housing. *Preventive Veterinary Medicine* 6, 79–90.

Overton MW, Sisco WM, Temple GD and Moore DA 2002. Using time-lapse video photography to assess dairy cattle lying behavior in a freestall barn. *Journal of Dairy Science* 85, 2407–2413.

Poso J and Mantysaari EA 1996. Relationships between clinical mastitis, somatic cell score, and production for the first three lactations of Finnish Ayrshire. *Journal of Dairy Science* 79, 1284–1291.

Pryce JE, Nielsen BL, Veerkamp RF and Simm G 1999. Genotype and feeding system effects and interactions for health and fertility traits in dairy cattle. *Livestock Production Science* 57, 193–201.

Sargeant JM, Leslie KE, Shirley JE, Pulkrabek BJ and Lim GH 2001. Sensitivity and specificity of somatic cell count and California mastitis test for identifying intramammary infection in early lactation. *Journal of Dairy Science* 84, 2018–2024.

Schreiner DA and Ruegg PL 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. *Journal of Dairy Science* 86, 3460–3465.

Sim J and Wright CC 2005. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Physical Therapy* 85, 257–268.

Todhunter DA, Smith KL and Hogan JS 1995. Environmental Streptococcal intramammary infections of the bovine mammary gland. *Journal of Dairy Science* 78, 2366–2374.

Tucker CB, Rogers AR, Verkerk GA, Kendall PE, Webster JR and Matthews LR 2007. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. *Applied Animal Behaviour Science* 105, 1–13.

Zdanowicz M, Shelford JA, Tucker CB, Weary DM and von Keyserlingk MAG 2004. Bacterial populations on teat ends of dairy cows housed in free stalls and bedded with either sand or sawdust. *Journal of Dairy Science* 87, 1694–1701.