The Effect of Out-Wintering Pad Design on the Synchrony of Dairy Cow Behavior

K. O'Driscoll,*†¹ A. Hanlon,† and L. Boyle*

*Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland

†School of Agriculture, Food Science and Veterinary Medicine, Veterinary Sciences Centre, NUI Dublin, Belfield, Dublin 4, Ireland

ABSTRACT

The study investigated differences in behavior synchrony of dairy cows during the winter confinement period when managed in 1 of 3 out-wintering pad (OWP) systems, or indoors in free-stall housing. There were 2 replicates of each treatment, and observations were carried out on 3 recording occasions in January and February 2006. On each recording occasion, behavior was recorded every 30 min between 0600 and 0130 h the following day ($n = 40$). The outcomes for measurement were eligible cows lying (ECL), cow comfort index (CCI), and proportion of animals feeding (AF). Autocorrelation as an indicator of synchrony was calculated using the Durban-Watson statistic and compared across treatments. A centered moving average was calculated, used to obtain the residual, and compared between treatments. Low autocorrelations were recorded in free stalls ($39.6 \pm 0.1\%$), indicating lower temporal behavioral synchrony than in the 3 OWP designs. Overall, the greatest proportion of ECL, CCI, and AF occurred in free stalls (60%). However, high proportions ($>90\%$) of ECL were recorded on OWP in the early morning, whereas the range of ECL in free stalls (22 to 87%) was lower. The low overall proportions for ECL (44, 52, and 54%) and CCI (48, 55, and 58%) in the OWP were caused by the cows standing without feeding during daylight hours. Nevertheless, these cows performed more synchronized lying at night, and their behavior was more highly autocorrelated (65.9 ± 0.1 , 73.3 ± 0.1 , and $52.3 \pm 0.1\%$) than cows in free stalls. Synchrony of behavior is part of the normal behavior repertoire of herd-living animals such as dairy cattle, and OWP may promote a more natural circadian behavior pattern than do free-stall systems. It is important that indices such as CCI and ECL are utilized at appropriate times of the day, when cows are expected to lie; that is, during the evening time. Estimated acceptable levels of these

indices may be dependent on the confinement system employed.

Key words: behavior, synchrony, comfort, out-wintering pad

INTRODUCTION

Woodchip out-wintering pads (OWP) are commonly used as a winter confinement system for cattle in Ireland (Hourihan, 2006) because they are a low-cost alternative to conventional free-stall housing. These systems do not appear to have a negative impact on udder, limb, or hoof health of nonlactating dairy cows (O'Driscoll et al., 2008a, b). Still, in addition to good health, it is necessary that confinement systems facilitate the performance of normal behavior if high animal-welfare standards are to be achieved (Wechsler, 2007). The environment of an OWP likely provides greater freedom of movement for animals than a free-stall barn due to the lack of physical barriers and the soft underfoot conditions (Boyle et al., 2008). Thus, the potential for expression of normal behavior on an OWP could be greater than in free stalls, because freedom of movement permits the expression of a wider range of behaviors.

Subtle species-specific behaviors may be just as insightful as obvious behavior anomalies (e.g., levels of responsiveness and stereotypies) when assessing an animal's ability to cope in differing environments. Behavioral synchrony is recognized in marine species (Connor et al., 2006) and considered an important indicator of dairy cow welfare (Miller and Wood-Gush, 1991). The term is used both to describe behaviors that are non-randomly distributed in a temporal manner (Hastie et al., 2003) and behaviors that occur among members of a group simultaneously (Connor et al., 2006).

Feeding and lying behaviors are essential to the well-being of the dairy cow. There is general agreement among veterinarians and dairy researchers that the majority of time that a cow is not feeding should be spent lying (Overton et al., 2002). Thus, a commonly used indicator of cow comfort in a group situation is the proportion of eligible cows lying (ECL). This is

Received October 1, 2007.

Accepted August 14, 2008.

¹Corresponding author: keelin.odriscoll@gmail.com

calculated by walking through the cows, counting the number lying down, and then dividing this number by the total number of cows not eating. Another index of cow comfort is the "cow comfort index" (CCI). This is calculated by dividing the number of cows lying by the total number in contact with the lying area, and gives an idea of the acceptability of the lying surface to the cow. Values of greater than 75 and 85% are considered desirable for ECL and CCI, respectively (Overton et al., 2003). These indices can be used to calculate group synchrony both at any given time and over time.

Dairy cows on pasture display temporal patterns of grazing behavior (O'Connell et al., 1989; Linnane et al., 2001). One factor influencing bovine grazing behavior is exposure to daylight, and cattle on pasture are more likely to be standing and grazing at dawn and dusk (Linnane et al., 2001). Standing and feeding behavior might be influenced by the time of day, even in a nongrazing environment. This in turn could influence ECL and CCI values. Environmental temperature has an effect on both ECL and CCI (Overton et al., 2003), and ambient temperatures close to bovine body temperature are associated with reduced lying behavior. Moreover, in a recent experiment Tucker et al. (2007) found that animals exposed to near-constant rain and wind simulation spent as little as 4 h/d lying, which is outside the normal range of 10 to 14 h (Fregonesi and Leaver, 2002). Therefore, exposure to the prevailing weather could also affect CCI and ECL values of dairy cattle.

Although the synchrony of dairy cow behavior is described both at pasture and in free-stall housing (O'Connell et al., 1989; Overton et al., 2003), there is limited work comparing group synchrony in different confinement systems. The aim was to evaluate 2 indices of cow comfort (CCI and ECL) and the proportion of animals feeding (AF) in 3 OWP designs and indoors in free-stall housing and to compare behavior synchrony in each treatment. A secondary objective was to compare the ECL and CCI as methods of estimating cow comfort in OWP.

MATERIALS AND METHODS

The experiment was carried out at "Ballydague" Research Farm, which is part of Moorepark Dairy Production Research Centre (Fermoy, Co. Cork, Ireland) during January and February 2006.

Animals and Treatments

A randomized complete block design was used. Ninety-six pregnant dairy cows (*Bos taurus*; 40 primiparous and 56 multiparous) were blocked according to breed

(Holstein-Friesian or Norwegian Red), parity (parity 0 to 5), expected calving date [ECD; February 20, 2006 (February 6 to March 12, 2006), median (interquartile range)], and BCS (score 2 to 3.75; Lowman et al., 1976) into 8 groups. Then, 1 cow from each group was randomly assigned to 1 of 2 replicates of each of the following treatments: 1) indoor free-stall housing (free stall treatment); 2) an uncovered OWP with a concrete feed face (uncovered treatment); 3) an OWP that was completely covered over the woodchip area, but with an uncovered concrete feed face (covered treatment); and 4) an uncovered OWP with a self-feed silage pit (self-feed treatment) without a concrete flooring area.

The covered OWP was sheltered on 2 sides by construction of a 1.83-m-high semiporous barrier (Nicoference, R. J. M. Mooney and Son Ltd., Dublin, Ireland), and overhead by a polythene tunnel. The feed faces in each of the self-feed replicates were 13.5 m in length. To prevent spoilage of the silage it was necessary for 26 animals to feed from these areas. For this reason 14 "filler" nonexperimental animals (nulliparous, Holstein-Friesian animals) were allocated to each of the self-feed replicates from the start of the experiment.

Because cows were removed for calving, the number of animals in each treatment replicate was reduced to 5 ± 1 (mean $\pm$ SD) by February 19, 2006. Therefore, on that date, additional animals ($n = 4 \pm 1$) were assigned to each treatment replicate to maintain a group size similar to that at the start of the experiment ($n = 9 \pm 1$ animals per group). These animals were nulliparous and were allocated to treatments balanced for breed (Montbeliarde or Jersey), ECD [March 13, 2006 (February 27 to March 28, 2006)], and BCS (3 to 3.25).

Free stalls were bedded with rubber mats (depth, 23 mm; Farm Mat, Alfco Farm Services Ltd., Trim, Ireland) and provided at a 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. Cows were allocated 0.6 m/cow at a post-and-rail feed barrier. An automatic scraper cleaned the solid concrete floor 6 times daily. The wood-chipped lying areas were constructed as described by O'Driscoll et al. (2008a). Animals confined on uncovered and covered OWP were allocated 12 m² of woodchip space allowance and a concrete feeding area allowance of 2.52 m² per head. The woodchip areas were rectangular, with the feeding area located on one side. The feeding area was 4.2 m wide, and cows were allocated 0.6 m/cow at a post-and-rail feed barrier. The concrete feeding areas were cleaned 6 times daily by an automatic scraper. Cows in the self-feed treatment had a woodchip space allowance of 14.52 m² per head (i.e., equal to the total space allowance of uncovered and covered cows). This included the woodchip feeding area, because in this

treatment cows were not exposed to concrete. These treatment replicates were rectangular, and access to the silage pit was provided on one side. Cows were allocated 0.52 m at the feed face. The dimensions of the woodchip areas of all 3 OWP treatments changed over the course of the experiment because each time an animal was removed, the space allowance was adjusted to maintain the appropriate stocking density.

Management

All multiparous animals stopped lactating by November 17, 2005. Between November 17 and December 5, 2005, these cows were confined as a single treatment group in the confinement system in which they would remain during the course of the experiment. On December 5, they were divided into their respective replicates within each treatment and the remaining experimental animals (all nulliparous) were added to each replicate. Thus, at this time there were 12 cows in each treatment replicate in the free stall, uncovered, and covered treatments, and 26 cows in the self-feed treatment (12 plus 14 filler animals). The mean calving date was February 21, 2006 (February 2 to March 10, 2006). Approximately 3 d before calving (-3.2 ± 5.5 d) animals were removed from each treatment to a straw-bedded calving shed. The stocking rate in each treatment replicate was maintained by adjusting an electric wire (OWP) or metal gate (free stalls) each time a cow was removed to the calving shed.

Feeding

Fresh grass silage (DM 20.0%, CP 16.9%, DM digestibility 77.0%, NDF 41.9%, and ash 8.3%) was offered daily at approximately 0900 h on an ad libitum basis at approximately 3.5 kg above requirements for cows in the free stall, uncovered, and covered treatments. An electric wire above the feed area of self-feed was adjusted at the same time to permit access to fresh feed (DM 17.8%, CP 16.2%, DM digestibility 77.1%, NDF 43.0%, and ash 8.7%). Fresh water was available from self-filling troughs in all treatment replicates.

Environmental Measurements

Ambient temperature ($^{\circ}\text{C}$) was recorded using electronic temperature data loggers (Tinytag Extra Dual Channel Temperature/Relative Humidity, Gemini Dataloggers (UK) Ltd., Chichester, UK). The data loggers were suspended approximately 2 m above the ground, 1 between the 2 free-stall replicates, 1 outdoors adjacent to both the uncovered and self-feed treatments, and 1 between the 2 covered replicates. They

Table 1. Dates and times of the behavior recording occasions

Recording occasion	Date	Observation time
1	06-Jan-2006	1800 to 2130 h
	07-Jan-2006	0600 to 0930 h 2200 to 2330 h
	08-Jan-2006	0000 to 0130 h
	09-Jan-2006	1430 to 1730 h
	10-Jan-2006	1000 to 1400 h
2	09-Feb-2006	0600 to 1230 h 1430 to 2130 h
	10-Feb-2006	1300 to 1430 h
	11-Feb-2006	2200 to 0130 h
3	26-Feb-2006	2200 to 0130 h
	27-Feb-2006	1400 to 2130 h
	28-Feb-2006	0600 to 1330 h

were programmed to record environmental temperature at 10-min intervals.

Behavior Recording

Direct observations were carried out on 3 occasions (January 6 to 10, February 9 to 11, and February 26 to 28) between 0600 and 0130 h the following day by 2 observers using scan sampling ($n = 40$ sample points). Data collection was divided over several days on each occasion (Table 1). Every 30 min, the number of animals standing, lying, and feeding was recorded, as well as the location (i.e., lying area as represented by the free stalls indoors and by the woodchip area in all 3 OWP treatments, feed face, or alley). Observers visited each treatment in the same order at each sampling time, so that there was approximately 30 min between each observation for each treatment. The CCI, ECL, and AF values were calculated from these data for each treatment at each time point.

Statistics

Data were analyzed using SAS software (version 9.1.3, 1989; SAS Institute Inc., Cary, NC). All data were tested for normality before analysis by investigation of box and normal distribution plots. Environmental temperature (recorded every 10 min) was compared between treatments using a linear model (Proc Mixed). The model included terms for treatment (uncovered, covered, and indoors), recording occasion (1, 2, or 3), hour of the day (1 to 24), and relevant interactions. Differences in least squares means were investigated using the *t*-test, following Tukey's adjustment for multiple comparisons.

For all other analyses, the group was considered the experimental unit. Each treatment was replicated 6 times (2 times per recording occasion) so there were

Table 2. The number of cows present in each treatment replicate during each recording occasion

Treatment ¹	Replicate	Recording occasion		
		1	2	3
Free stalls	1	12	5	6
	2	12	7	8
Uncovered	1	11	7	9
	2	11	6	8
Covered	1	12	7	6
	2	12	5	7
Self-feed	1	25	22	6
	2	24	21	7

¹Freestalls = indoor free stalls; Uncovered = uncovered out-wintering pad (OWP); Covered = covered OWP; and Self-feed = self-feed silage OWP.

6 experimental units per treatment. The outcomes for analysis were CCI, ECL, and AF.

Autocorrelation of Outcome Measures. Autocorrelation of juxtaposing data points was used as an indicator of behavioral synchrony over time. This was calculated for all outcome measurements for each treatment replicate using the Durban-Watson statistic (Proc Reg), and then compared between treatments using a linear model (Proc Mixed). The model included terms for treatment, recording occasion, treatment replicate, and all relevant interactions.

Analysis of Behavior Index Residuals. The arithmetic mean proportions of each outcome measure were non-normal in distribution and could not be analyzed in raw format. A centered moving average was computed including all treatments across observation periods for each measurement, to create a standardized baseline to compare behavior between treatments. The moving average was calculated using $m + 2$ data points, where m = the 40 observation points per day. This value was then subtracted from each observation to obtain the residual or deviation from the expected proportions CCI, ECL, and AF. Following this, the residuals were analyzed using a linear model (Proc Mixed). The model included terms for treatment, recording occasion, treatment replicate, environmental temperature, and all relevant interactions. Spearman correlations were calculated between environmental temperature and raw CCI and ECL values. To aid visualization of the mean values of CCI, ECL, and AF within each treatment over the observation period, graphs were constructed using arithmetic means.

Comparison Between ECL and CCI. To compare results within each treatment using both scales, the previously calculated residual values of ECL and CCI for each treatment were compared using a linear model (Proc Mixed). The model included terms for treatment, the scoring system used (ECL or CCI) and

the interaction. Differences in least squares means in all the linear models used were investigated using the *t*-test, following Tukey's adjustment for multiple comparisons.

RESULTS

Because of movement of animals from the treatments for calving, the number of cows in each treatment replicate varied throughout the experiment and can be seen in Table 2.

Environmental Measurements

Environmental temperatures differed between the treatments ($P < 0.001$). Temperature was greater in free stalls ($5.5 \pm 0.2^\circ\text{C}$) and covered ($5.8 \pm 0.2^\circ\text{C}$) than in uncovered ($4.5 \pm 0.2^\circ\text{C}$; $P < 0.05$, $P < 0.001$, respectively) treatments. Although there was no significant interaction between treatment and time of day, a narrower range of temperatures was recorded in free stalls (2.2 ± 1.6 to $9.4 \pm 1.6^\circ\text{C}$) than in uncovered (0.3 ± 1.6 to $11.2 \pm 1.6^\circ\text{C}$) or covered (1.1 ± 1.6 to $13.6 \pm 1.6^\circ\text{C}$). Temperature was $>10^\circ\text{C}$ between 1000 and 1230 h (inclusive) in covered and between 1100 and 1230 h in uncovered.

Autocorrelation of Outcome Measures

Autocorrelation of all the measurement variables varied between treatments. Treatment had an effect on ECL autocorrelation values ($P = 0.001$). Autocorrelation in both uncovered ($65.9 \pm 0.1\%$) and self-feed ($73.3 \pm 0.1\%$) treatments was greater than in free stalls ($39.6 \pm 0.1\%$; $P < 0.05$, $P < 0.01$ respectively), and covered was intermediate ($52.3 \pm 0.1\%$). Autocorrelation of ECL was greater at the first observation session ($72.8 \pm 0.1\%$) than at either the second ($47.4 \pm 0.1\%$; $P < 0.01$) or third ($53.2 \pm 0.1\%$; $P < 0.05$) observations. There was no difference between the second and third observations ($P > 0.05$). There was no interaction between treatment and inspection ($P > 0.05$).

Treatment had an effect on CCI autocorrelation values ($P < 0.001$). All OWP designs had greater autocorrelation values for CCI than did free stalls (64.8 ± 0.1 , 67 ± 0.1 , 48 ± 0.1 , and $4 \pm 0.1\%$ for uncovered, self-feed, covered, and free stalls, respectively; $P < 0.001$). Similar to ECL, there was no interactive effect of treatment and inspection, but there was an effect of inspection ($P < 0.01$). The value of CCI was greater at the first observation session ($59.5 \pm 0.1\%$) than at the second ($33.8 \pm 0.1\%$; $P < 0.01$). At the third observation session, CCI was intermediate between the first and second ($44.8 \pm 0.1\%$), but not different from

either ($P > 0.05$). There was an effect of treatment on autocorrelation of AF ($P < 0.05$), being lowest in free stalls (32.8%) and greatest in covered (54.9%). There was no other effect on AF ($P > 0.05$).

Analysis of Behavior Index Residuals

Mean daily pattern of ECL, CCI, and AF within each treatment are shown in Figure 1. The greatest (arithmetic) mean proportion of ECL over the entire observation period was in free stalls (60%), and the lowest was in self-feed (44%), with uncovered and covered being intermediate (52 and 54%, respectively). The greatest mean values for ECL in the OWP were in the early morning (>90%) and late evening. However, the range of mean ECL values in free stalls (22 to 87%) was lower than in the OWP treatment, and was more uniform, with several small peaks and dips occurring throughout the observation period. Indeed, treatment had an effect on ECL residual values ($P < 0.001$). There was no difference in the residual ECL values between uncovered and covered, but the difference between residual ECL values was significant ($P < 0.05$) between all other treatment pairs.

Similar to the ECL index, the greatest (arithmetic) mean CCI value was in free stalls (78%) and the least was in self-feed (48%). Again, values in uncovered and covered were intermediate (55 and 58%, respectively). Treatment had an effect on residual CCI ($P < 0.001$). Similar to results for the ECL index, there was no difference in the residual CCI values between uncovered and covered, but all other treatment pairs were different from each other ($P < 0.05$).

Ambient temperature had an effect on residual ECL ($P < 0.001$) and CCI ($P < 0.001$) values. Nevertheless, there was no clear evidence that as temperatures increased, ECL and CCI decreased (Figure 2). Spearman correlations between environmental temperature and residual ECL values were low and negative ($\rho = -0.31$), as were correlations between environmental temperature and residual CCI values ($\rho = -0.24$), although both correlations were significant ($P < 0.001$). Temperature, ECL, and CCI over the recording period are shown in Figure 3.

Treatment was the only variable that had an effect on residual AF values ($P < 0.01$). Animals in free stalls had the greatest mean values for AF (32%), and animals in self-feed the lowest (23%). Nonetheless, the only difference in AF between treatments was between self-feed and free stalls ($P < 0.01$) and between self-feed and uncovered (30%; $P < 0.01$). There was no difference between covered (28%) and any other treatment ($P > 0.05$).

Comparison Between ECL and CCI

Overall, residual CCI values were greater than residual ECL values ($P < 0.001$; Table 3). Within treatments, however, it was only in free stalls that this difference was significant ($P < 0.001$). The self-feed treatment had the lowest values for both.

DISCUSSION

The spring-calving management strategy adopted during the experiment meant that group size varied over the course of the experiment. Animals in large groups move less per unit time than those in smaller, less-dense groups (Estevez et al., 1997). However, there is evidence that this was due more to a barrier effect (i.e., restricted movement due to blocking by other animals when animals are densely stocked) than to the actual group size (Estevez et al., 2007). Cows at high density utilize less space and interact with fewer herd-mates compared with cows at a lower stocking density (Arave et al., 1974). To maintain a constant stocking density, pen size was reduced as group size decreased. Hence, it was assumed that the differences in group size between treatments would not have an effect on animal movement and behavior. The results showed that there was no interaction between treatment and recording occasion; thus, our assumption was upheld. Although there was an effect of inspection on autocorrelation values, the analysis suggests that differences between treatments, and differences between treatments were consistent across time.

Autocorrelation is a measure of how behavior is structured over time. High autocorrelation values for all variables in each of the 3 OWP treatments indicated that within these groups the proportion of animals performing an action was dependent on the proportion performing that action previously. Thus, the behavior of cows in these groups was nonrandomly distributed in a temporal manner and can be considered synchronized (Hastie et al., 2003). Autocorrelation of behavior occurred in all treatments but was greater in the OWP than in the free stalls. It is possible that the soft surface and lack of physical barriers in all 3 OWP enabled greater freedom of movement than in the indoor environment and that this resulted in more autocorrelation of behavior than in free stalls.

High ECL recorded in all treatments in the early morning and in the evening (i.e., during hours of darkness) compared with during the day are in accordance with results from previous studies (O'Connell et al., 1989; Overton et al., 2003), indicating synchronization of lying behavior during the night, which is the normal resting period for cattle (Hassoun, 2002). Nonetheless,

Figure 1. Arithmetic mean of values of eligible cows lying (ECL, A), the cow comfort index (CCI, B), and the proportion of animals feeding (AF, C) at each recording time for each treatment. UP = uncovered out-wintering pad (OWP); IC = indoor free stalls; CP = covered OWP; and SP = self feed silage OWP. ECL = the number of cows lying down divided by the total number not eating; CCI = the number of cows lying divided by the total number touching the lying area; AF = the number of cows feeding divided by the total number of cows.

Figure 2. Scatter plots showing the relationship between residual eligible cows lying (A) and the cow comfort index (B) values, and environmental temperature. Eligible cows lying = the number of cows lying down divided by the total number not eating; cow comfort index = the number of cows lying divided by the total number touching the lying area.

low ECL values (<1%) were recorded in all OWP at 1730 and 1800 h. After 1900 h, there was a distinct reduction in the proportion of animals feeding, and ECL values began to increase. It is possible that there is a lag period between an animal ending a feeding bout and lying down. Therefore, if cows stand without feeding for a period during or at the end of a feeding bout, they are classified as eligible to lie. This may explain the low ECL values at times when the animals are feeding.

As expected, the CCI resulted in greater mean values than the ECL index. The difference between the 2 indices was only significant in free stalls. This is likely because of animals that could only be standing at the feed face or in contact with the lying area in all 3 OWP

treatments, whereas cows indoors had the option of standing in the passageways. In free-stall systems, ECL and CCI that are considered acceptable are different (85 and 75%, respectively), and a group of cows can have quite different CCI and ECL values at the same moment in time. Our results indicate that in OWP both indices yield similar results.

The CCI functions using an assumption that the more acceptable the lying surface, the sooner a cow will lie down after entering the lying area. Thus, to obtain high CCI values, cows must lie down almost immediately on entering this area. Cows usually change their posture infrequently (O'Driscoll et al., 2008c) and often stand for periods between feeding bouts without lying.

Moreover, cows spend more time standing without feeding when on soft surfaces compared with hard (Tucker et al., 2006). The motivation for lying during the day may have been reduced for cows on OWP because of the comfortable underfoot surface (woodchips). Indeed, prolonged standing may not be as much of a problem for dairy cows if the conditions underfoot are comfortable, than if they are standing on concrete or on mats (defined as hard bedding; Clarkson et al., 1996). It was proposed that the temporal pattern of standing and lying could be a result of exposure to natural light patterns (Linnane et al., 2001). Estimations of acceptable values of CCI and ECL may need to be adjusted for more extensive, non-free-stall accommodation systems for dairy cattle. Our results highlight the importance of carrying out observations of cow behavior at a time when the behavior may be expected to occur. Estimates of ECL and CCI should be carried out at dawn or in the evening in all environments because it is at these times that cattle should be lying down.

The similarity of the CCI and ECL values in the uncovered and covered OWP indicates that shelter did not influence cow lying behavior. The differences between these 2 treatments and the OWP on which cows self-fed silage was likely because the latter did not have a concrete feeding area. As such, animals in that treatment were more likely to be in contact with the lying area when not feeding. This was compounded by the fact that self-feed animals had a lower space allowance at the feed face than animals in the other 2 OWP treatments. Increased competition at the feed face resulted in more displacements and increased time

Table 3. Residual values of eligible cows lying (ECL) and cow comfort index (CCI) in each treatment¹

Item	ECL	CCI	P-value
FS	0.012 ± 0.018 ^b	0.168 ± 0.019 ^b	0.001
UP	-0.066 ± 0.017 ^a	-0.034 ± 0.017 ^{ac}	NS
CP	-0.050 ± 0.017 ^{ab}	-0.005 ± 0.018 ^c	NS
SP	-0.142 ± 0.017 ^c	-0.105 ± 0.018 ^a	NS

^{a-c}Values within the same index (column) with different superscripts are different.

¹ECL = eligible cows lying (i.e., the number of cows lying down divided by the total number not eating); CCI = cow comfort index (i.e., the number of cows lying divided by the total number touching the lying area). A positive value of ECL or CCI indicates that the observed value was greater than expected. P-values represent differences between the 2 indices for each treatment.

²FS = indoor free stalls; UP = uncovered out-wintering pad (OWP); CP = covered OWP; and SP = self-feed silage OWP.

spent idling while standing (Huzzey et al., 2006). The low AF value in the self-feed treatment was likely a reflection of increased competition at the feed area. Cows that were displaced during a feeding bout would have been classified as both eligible to lie and in contact with the bed area even though they were unlikely to have finished feeding.

Our results show that although both ECL and CCI can be used as indicators of cow lying behavior, their values can be affected by the housing system that is being assessed. Even within a housing system different indices can yield different results, such as in the indoor system in the current study. This finding supports previous research in a free-stall-based system (Overton et al., 2003). Cow comfort index and ECL assess uti-

Figure 3. Arithmetic average of eligible cow lying (ECL) and cow comfort index (CCI) values and environmental temperature (Temp), in all treatments, at each time point recorded during the study. ECL = the number of cows lying down divided by the total number not eating; CCI = the number of cows lying divided by the total number touching the lying area.

lization of the bedding area using all animals within a system or group. The potential for the qualities of a housing system such as bedding and flooring (e.g., hardness, moisture content) to alter motivation within individual animals to lie down or alter their posture will affect these values (Stefanowska et al., 2001), because individual behavior alters group ECL and CCI values. This does not alter the management goals that are desirable to achieve—that cows have comfortable lying conditions that promote adequate lying behavior.

It is possible that the behavior of cows confined on OWP follows a more natural circadian rhythm as evidenced by the greater proportion of cows lying at night, and less lying during the day compared with those in free-stall housing. Hassoun (2002) showed that cows on pasture spend more time resting at night than during the day. It is possible that confining cows on OWP could reduce the behavioral disruption associated with transition to winter housing (O'Connell et al., 1989). Future research could attempt to estimate "normal" ECL and CCI on pasture over a 24-h period and compare these with confinement systems.

Although a negative relationship exists between both the cow comfort and eligible cow lying indices and environmental temperature, this relationship was weaker than expected. Although environmental temperature may affect the indices, outcomes are more influenced by time of day, housing environment, and management routines. Although Overton et al. (2002) found that normal management tasks did not alter cow behavior, cows in that study were lactating and probably more habituated to contact with humans than nonlactating cows. Furthermore, associations between lying behavior and environmental temperature are found when temperatures are high (e.g., 13 to 42.8°C). In contrast, both the range of temperatures and the maximum recorded temperature in this study were much lower, and the influence of environmental temperature could be less.

Unexpectedly, cows in this experiment did not display clear temporal patterns of feeding. Cows on pasture exhibit peaks in grazing behavior at dawn, dusk, and around midnight (Linnane et al., 2001). Still, there were no clear peaks in the proportion of animals feeding in any of the treatments at these times. On the other hand, ensiled grass fed ad libitum may not stimulate the same patterns in feeding behavior as fresh grass at pasture, because its composition and availability remain relatively constant.

Synchrony of behavior is thought important in the cohesion of social bonds (Clayton, 1978) and is recognized as central in sustaining good welfare for herd-living animals such as cattle (Miller and Wood-Gush, 1991). Thus, confinement systems such as OWP that

promote the expression of synchronized behavior may have some benefits for dairy cows.

ACKNOWLEDGMENTS

The authors would like to thank Noel Byrne and the Ballydague farm staff for their care of the experimental animals during the study. We especially thank Samuel Dann (University College Dublin) for his help in data collection.

REFERENCES

- Arave, C. W., J. L. Albright, and C. L. Sinclair. 1974. Behavior, milk yield, and leucocytes of dairy cows in reduced space and isolation. *J. Dairy Sci.* 12:1497–1501.
- Boyle, L. A., R. M. Boyle, and P. French. 2008. Welfare and performance of yearling dairy heifers out-wintered on a woodchip pad or housed indoors on two levels of nutrition. *Animal* 2:769–778.
- Clarkson, M. J., W. B. Faull, J. W. Hughes, F. J. Manson, J. B. Merritt, R. D. Murray, J. E. Sutherst, W. R. Ward, D. Y. Downham, and W. B. Russell. 1996. Epidemiology of lameness in dairy cattle: The influence of cubicles and indoor and outdoor walking surfaces. *Vet. Rec.* 139:130–136.
- Clayton, D. A. 1978. Socially facilitated behaviour. *Q. Rev. Biol.* 53:373–392.
- Connor, C. R., R. Smolker, and L. Bejder. 2006. Synchrony, social behaviour and alliance affiliation in Indian Ocean bottlenose dolphins, *Tursiops aduncus*. *Anim. Behav.* 72:1371–1378.
- Estevez, I., I. Andersen, and E. Nævdal. 2007. Group size. Density and social dynamics in farm animals. *Appl. Anim. Behav. Sci.* 103:185–204.
- Estevez, I., R. Newberry, and L. Arias de Reyna. 1997. Broiler chickens: A tolerant social system? *Etologia* 5:19–29.
- Fregonesi, J. A., and J. D. Leaver. 2002. Influence of space allowance and milk yield level on behavior, performance and health of dairy cows housed in strawyard and cubicle systems. *Livest. Prod. Sci.* 78:245–257.
- Hassoun, P. 2002. Cattle feeding behaviour at pasture: A methodology related to on farm measurements. *Anim. Res.* 51:35–41.
- Hastie, G. D., B. Wilson, L. H. Tufft, and P. M. Thompson. 2003. Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Mar. Mamm. Sci.* 19:74–84.
- Hourihan, J. 2006. Survey of factors affecting the dirtiness of out-wintering pads and outwintered cattle in Ireland. MS thesis. University College Dublin, Ireland.
- Huzzey, J. M., T. J. DeVries, P. Valois, and M. A. von Keyserlingk. 2006. Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. *J. Dairy Sci.* 89:126–133.
- Linnane, M. I., A. J. Brereton, and P. S. Giller. 2001. Seasonal changes in circadian grazing patterns of Kerry cows (*Bos taurus*) in semi-feral conditions in Killarney National Park, Co. Kerry, Ireland. *Appl. Anim. Behav. Sci.* 71:277–292.
- Lowman, B. G., N. Scott, and S. Somerville. 1976. Condition Scoring of Cattle. Rev. ed. Bull. No. 6. East of Scotland College of Agriculture, Edinburgh, UK.
- Miller, K., and D. G. M. Wood-Gush. 1991. Some effects of housing on the social behaviour of dairy cows. *Anim. Prod.* 53:271–278.
- O'Connell, J., P. S. Giller, and W. Meaney. 1989. A comparison of dairy cattle behavioral patterns at pasture and during confinement. *Ir. J. Agric. Res.* 28:65–72.
- O'Connell, J., W. Meaney, and P. S. Giller. 1991. An evaluation of four cubicle designs using cattle behaviour criteria. *Ir. Vet. J.* 44:8–13.
- O'Driscoll, K., L. Boyle, P. French, and A. Hanlon. 2008a. The effect of out-wintering pad design on hoof health and locomotion score of dairy cows. *J. Dairy Sci.* 91:544–553.

- O'Driscoll, K., L. Boyle, P. French, B. Meaney, and A. Hanlon. 2008b. The effect of winter housing on cow dirt score, somatic cell score and mastitis incidence in dairy cows. *Animal* 2:912–920.
- O'Driscoll, K., L. Boyle, and A. Hanlon. 2008c. A brief note on the validation of a system for recording lying behaviour in dairy cows. *Appl. Anim. Behav. Sci.* 111:195–200.
- Overton, M. W., D. A. Moore, and W. M. Sisco. 2003. Comparison of commonly used indices to evaluate dairy cattle lying behavior. Pages 125–130 in *Proc. Fifth Int. Dairy Housing Conf.*, Fort Worth, TX.
- Overton, M. W., W. M. Sisco, G. D. Temple, and D. A. Moore. 2002. Using time-lapse video photography to assess dairy cattle lying behavior in a free-stall barn. *J. Dairy Sci.* 85:2407–2413.
- Stefanowska, J., D. Swierstraa, C. Braam, and M. Hendriks. 2001. Cow behaviour on a new grooved floor in comparison with a slatted floor, taking claw health and floor properties into account. *Appl. Anim. Behav. Sci.* 71:87–103.
- Tucker, C. B., D. M. Weary, A. M. de Passille, B. Campbell, and J. Rushen. 2006. Flooring in front of the feed bunk affects feeding behavior and use of freestalls by dairy cows. *J. Dairy Sci.* 89:2065–2071.
- Tucker, C. B., A. R. Rogers, G. A. Verkerk, P. E. Kendall, J. R. Webster, and L. R. Matthews. 2007. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. *Appl. Anim. Behav. Sci.* 105:1–13.
- Wechsler, B. 2007. Normal behaviour as a basis for animal welfare assessment. *Anim. Welf.* 16:107–110.