**CASE STUDY: Characterization of milk yield, lying and ruminating behavior, gait, cleanliness, and lesions between 2 different freestall bases**

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**ABSTRACT**

The objective of this study was to compare cows housed in a freestall barn with Dual Chamber Cow Waterbeds (DCCW; Advanced Comfort Technology Inc., Sun Prairie, WI) as freestall bases to cows housed in a freestall barn with rubber-filled mattresses (MAT; Promat Inc., Woodstock, Ontario, Canada) as freestall bases. Forty-six cows were housed in the DCCW freestall barn, and 51 cows were housed in the MAT freestall barn. Milk yield was not significantly different between cows housed in the DCCW freestall barn (29.40 ± 1.02 kg/d) and the MAT freestall barn (28.61 ± 1.15 kg/d; P ≥ 0.05). Lying time was greater for cows housed on DCCW (10:32 ± 0:13 h/d) than for cows housed on MAT (9:47 ± 0:15 h/d; P < 0.01). Rumination time was greater for cows housed on MAT (6:44 ± 0:08 h/d) compared with cows housed on DCCW (6:29 ± 0:08 h/d; P = 0.03). Hock scores were lesser on cows housed in the DCCW freestall barn (1.86 ± 0.03) compared with cows housed in the MAT freestall barn (1.97 ± 0.04; P = 0.02). The differences observed between these 2 bed types with lying times demonstrate that DCCW may benefit animal well-being compared with the MAT treatment.

**Key words:** waterbed, lying time, freestall, cow comfort

**INTRODUCTION**

An important criterion for any housing design is that the facilities cause minimal injuries to cattle (Ruud et al., 2010a). To minimize hock and knee lesions, a stall surface must be nonabrasive and compressible (Fulwider and Palmer, 2004). Maintaining clean cattle is also important for a housing system. Cow cleanliness is important to safeguard clean milking procedures and animal well-being (Ruud et al., 2010b). The physical environment of cattle housing is also a significant factor affecting lameness incidence (Cook and Nordlund, 2009; Ito et al., 2010) because housing on concrete has a harmful effect on claw health (Fayed, 1997; Fregonesi et al., 2009). If the lying environment does not entice cattle to lie down, a higher incidence of lameness may occur (Cook and Nordlund, 2009).

An ideal stall surface will be cost effective, sturdy, provide a comfortable lying area, keep animals clean, and minimize labor (Natzke et al., 1982). Dual Chamber Cow Waterbeds (DCCW; Advanced Comfort Technology Inc., Sun Prairie, WI) were developed in 2003 with 2 chambers (front and back). They are marketed to decrease bedding use, decrease hock lesions, and increase useful life (Fulwider et al., 2007) because they may be longer lasting and suffer less compression than rubber-filled mattresses. The objective of this study was to compare cows housed in a freestall barn with DCCW to cows housed in a freestall barn with rubber-filled mattresses (MAT; Promat Inc., Woodstock, Ontario, Canada).

**MATERIALS AND METHODS**

**Animals and Housing**

This study was conducted in 2 freestall barns at the University of Kentucky Coldstream Dairy Research Farm. The DCCW freestall barn included 54 stalls with DCCW as the stall base, and the MAT freestall barn included 54 stalls with MAT as the stall base. Access to 4 freestalls in each barn was restricted because their widths were too narrow for cows, leaving cows with access to 50 stalls in each freestall barn.

In both freestall barns, the brisket locator was a 7.62-cm schedule 40 polyvinyl chloride pipe. Stall dimensions were planned according to the MidWest Plan Service...
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(MWPS, 2000) for cows over 680 kg (1,500 lb). The stall length from brisket locator to curb side of the alley was 1.8 m. The neck rail height from bottom of the rail to top of the stall base was 1.2 m. Mean stall width was 1.2 m. Each DCCW was filled with 49 L of water, with the water flowing between 2 chambers (front and back). The MAT was filled with equally sized rubber crumbs and was 2.54 cm thick. The MAT cells were then covered with a CS wax–coated single top covering for every row of stalls. Each barn area was equipped with 2 automatic waterers in the concrete lot adjacent to the barns (Figure 1). The DCCW freestall barn area contained a galvanized water tank holding 390 L and a metal water dump tank holding 284 L. The MAT freestall barn area contained a Rubbermaid (Winchester, VA) water tank holding 568 L and a metal water dump tank holding 284 L. Cows shared a raised feed bunk, 27.4 m long, 1.37 m wide, 0.30 m deep, and 0.79 m high, available to both groups of cows from opposite sides of the bunk. Cows were fed a TMR, which was balanced to meet lactating cow requirements, consisting of grain mix, corn silage, alfalfa silage, whole cottonseed, and alfalfa hay at 0600 and 1330 h daily. Each feeding area had three 3 × 6 m and four 3 × 7 m shade cloths, which blocked 80% of the sun, attached to the top of the feed bunk. Automated sprinklers (built by University of Kentucky engineers) were located below the shade cloths the entire bunk length. The sprinklers sprayed water covering an area of 2 m and were manually turned around on 14°C. Depending on the day’s temperature, the sprinklers were cycled on for 4 min and cycled off for 8 to 15 min. Eight 1.22-m 6-blade box fans (Schaeffer, Sauk Rapids, MN) and four 0.91-m 3-blade round fans (Schaeffer) hung above the stalls in both freestall barns and were manually turned on around 18°C. Cows were milked twice daily at 0430 and 1530 h. Cows were provided daily exercise in a grass lot for 1 h mid-morning. Although cows may have consumed some grass, this was not taken into consideration when balancing their ration. During this exercise time, the stalls were scraped clean once daily by hand with a rake before freestall barns were cleaned once daily with a skid steer bucket and scrape tire. New kiln-dried sawdust (8.02 ± 0.11 kg per stall) was applied on top of the old sawdust in the stall, every other day with a skid steer bucket (Wadsworth et al., 2015). Care was taken by farm staff to ensure the same amount of sawdust was applied to stalls in each freestall barn. Sawdust measurements were determined every other week with a premeasured weigh tub after stalls had been bedded in 3 predetermined stalls in each row. The premeasured weigh tub was determined before the study start; weights were recorded on the side of the tub with premeasured weights of sawdust. The predetermined stalls were selected randomly with the same positions represented in each freestall barn. Three stalls were chosen in each row and 2 stalls represented each column of stalls the length of the freestall barn (Figure 1). Cows were balanced between freestall barns for parity, cow volume, breed, and DIM. Forty-six cows (n = 36 Holstein, n = 3 Jersey, and n = 7 crossbred) were housed in the DCCW freestall barn, and 51 cows (n = 35 Holstein, n = 7 Jersey, and n = 9 crossbred) were housed in the MAT freestall barn over the course of the study. However, stocking density never exceeded 100% in either freestall barn during the course of the study. All studies were performed with approval of the University of Kentucky Institutional Animal Care and Use Committee (IACUC protocol number: 2011–0920).

Measurements

Animal Measurements. The Milkline Milpro P4C (Gariga di Podenzano, Italy) milking system recorded daily milk yield (MY). IceQube (IceRobotics, Edinburgh, Scotland) sensors recorded total daily lying time (LT) and lying time per bout (LB). The IceQube sensors, which were validated for dairy cattle use by Munksgaard et al. (2006), were positioned on the left rear legs and used a 3-axis accelerometer to automatically record lying time and bouts in 15-min intervals. The HR Tag (SCR Engineers Ltd., Natanya, Israel), which was validated for dairy cattle use by Schirmann et al. (2009), recorded daily rumination time (RT). These neck collars positioned the data logger onto the upper left part of the cow’s neck. The data logger contained a microphone and a microprocessor that recorded the distinct rumination sounds. Rumination time was summarized automatically into 2-h intervals. Daily cow temperature was measured using the DVM Systems LLC (Boulder, CO) bolus. The DVM bolus monitored reticularum temperature using a passive RFID transponder (Phase IV Engineering Inc., Boulder, CO) fitted with a temperature sensor queried twice daily by parlor entrance readers. All first lactation heifers were fitted with monitoring devices and boluses 2 wk before calving date. All monitoring devices and boluses stayed on or in the cow for the rest of its lactations until it was culled from the farm. If a device or bolus discontinued working during the study, it was replaced with a working one.

SCC Measurements. Somatic cell counts were obtained from a 90-mL composite milk sample from each cow. Somatic cell counts were analyzed using a Fossomatic FC somatic cell counter (Foss, Hilleroed, Denmark). Clinical mastitis was identified and recorded at each milking by visual assessment of milk (flakes, clots, or serous milk) and the udder (hardening, reddening, or heat). If clinical signs were displayed in the same quarter within 2 wk of the initial clinical diagnosis, the case was defined as the same clinical case.

Hock and Hygiene Measurements. To assess hock and hygiene conditions, pictures of each cow were collected weekly (one rear view and a profile of each side of the cow). Pictures were renumbered and scored by an observer blind to which freestall barn the cows were housed to minimize bias. Hock lesions were scored weekly using a 3-point system. Score 1 represented a cow without swelling or hair loss on both hocks. Score 2 represented a cow with hair
loss but no swelling on either hock. Score 3 represented a cow with swelling, hair loss, or a lesion draining on either hock. Hygiene was scored as described by Cook and Reniemann (2007), where score 1 represented no manure, score 2 represented minor splashing of manure, score 3 represented plaques of manure with hair showing through, and score 4 represented plaques of manure with no visible hair. The lower and upper leg, udder, and flank were the 3 zones assessed. Each zone was scored separately, and an overall hygiene score was calculated as the mean of the 3 areas.

Knee Measurements. Knees were scored every other week using the system described by Fulwider et al. (2007). Score 0 indicated no hair loss or swelling; score 1 indicated hair loss, but no swelling; score 2 indicated swelling; and score 3 indicated severe swelling. Lesion presence or not was also recorded biweekly on the left and right stifles, thighs, thurls, and the medial surface of the tuber calcis.

Gait Measurements. Gait was assessed every other week by the same observer as cows walked individually past the observer on a concrete walking lane 26 m long. Gait was evaluated as described by Olmos et al. (2009). Each cow was scored 1 (sound cow) to 5 (severely lame cow) for each aspect (general symmetry, speed, head bobbing, spine curvature, tracking, and abduction and adduction) observed. Final gait score was calculated as the mean of all gait aspects for each cow.

Cow Volume Measurements. Cow length, height, and width were measured monthly, and cow volume was determined by multiplying length, height, and width. Cow length was measured from the point of shoulder to the tuber ischii with a tape measure. Cow width was measured from outer point of hip bone to outer point of the opposite hip bone with a caliper. Cow height was measured from ground to the top point of the withers with a TeleTape Deluxe Livestock Tape Measure (Nasco, Fort Atkinson, WI). The first measurement of cow volume for each cow was used to determine cow groups.

Weather Measurements. Daily temperature–humidity index (THI) was calculated using daily weather from Kentucky Climate Data. The Kentucky Climate Data are calculated through the University of Kentucky College.
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of Agriculture via a 23X data logger (Campbell Scientific Inc., Logan, UT), located 6 km from the Coldstream Dairy Farm. Temperature–humidity index was computed using the following formula (NOAA, 1976): \[ \text{THI} = \text{temperature (°F)} - [0.55 - (0.55 \times \text{relative humidity/100})] \times [\text{temperature (°F)} - 58.8]. \] This study used maximum daily temperature and maximum relative humidity to calculate maximum THI, to assess effects across time.

**Cow Demographic**

Cow demographic information was obtained from PCDART (Dairy Records Management Systems, Raleigh, NC). Farm staff recorded cows exhibiting signs of estrus. The data for the day before, day of, and day after estrus were deleted from the data set to eliminate days where behavior was affected by estrus. Cow days were removed when DIM ≤ 14 and ≥ 100 DIM and when cows were removed from their respective freestall barns for sickness, other studies, extension projects, and teaching laboratories. Only cows with 60 d of data were kept in the final model.

**Statistical Analyses**

All data analyses were performed in SAS (Version 9.3, SAS Institute Inc., Cary, NC). Data points where MY was missing or equaled 0 were removed. The EXPAND procedure was used to interpolate missing days. Milk yield was summarized into daily MY. Variables used to predict MY were freestall barn, breed, and parity group (1 or ≥ 2).

Data points with missing LT values were removed. Any days that had 0 h of LT or 24 h of LT were deleted because this was most likely a technology error. Next, LT SD was calculated for each cow, and if the SD was > 3 SD away from the mean, then the day was deleted to eliminate outliers. The UNIVARIATE procedure was used to calculate the 1st and 99th percentiles of LT, those were removed to eliminate outliers, and this created the final LT data set. Variables used to assess LT were freestall barn, breed, parity (1 or ≥ 2), and MY.

Lying bouts were edited by deleting LB that were less than 1 min or that were >24 h per day because this was likely a technology error. Then LB were classified into mean h per d and number of daily bouts. The UNIVARIATE procedure was used to calculate the 1st and 99th LB percentiles, those were removed to eliminate outliers, and this created the final LB data set. Variables used to assess LB were freestall barn, breed, parity (1 or ≥ 2), and MY.

Rumination time was summarized by day. Any RT <250 min/d was deleted to remove any outliers, unhealthy cows, or tags that may have been misplaced on the cow’s neck. Next, any RT >3 SD away from the mean was removed. The UNIVARIATE procedure was used to calculate the 1st and 99th RT percentiles, those were removed to eliminate outliers, and this created the final RT data set. Variables used to assess RT were freestall barn, breed, parity (1 or ≥ 2), and MY.

Reticulorumen temperatures were edited by removing temperatures that occurred from bouts of drinking by removing temperatures <37°C. Z-scores were calculated by subtracting the cow’s 7-d backward rolling mean baseline from the daily data and then dividing by the standard deviation. Observations with Z-scores ≤ −3 were removed from the cow’s 7-d backward rolling mean baseline. Variables used for evaluating reticulorumen temperature were freestall barn, parity (1 or ≥ 2), and breed.

The UNIVARIATE procedure first calculated the 1st and 99th percentile for SCC. Once calculated, the 1st and 99th percentile were removed from the data set to remove outliers. The MEANS procedure calculated the average SCC for each cow for the final data set. From the final data set, somatic cell score (SCS) was computed using the following formula: SCS = \log_{10} (SCC/100) + 3. Somatic cell score was used to show the linear relationship between SCS and MY (Shook, 1993). Variables used to assess SCS were freestall barn, breed, parity (1 or ≥ 2), and MY.

Cow volume was first edited by removing the 1st and 99th percentile of cow volume using the UNIVARIATE procedure to remove outliers. Mean cow volume was determined for each cow over the study period using the MEANS procedure. The MEANS procedure was used to determine the average cow volume for each freestall barn. Cow volume was used in a separate model to determine LT.

The MEANS procedure was used to calculate the mean hock scores, lesion average (left and right stifles, thighs, thurls, and the medial surface of the tuber calcis) hygiene scores, knee scores, and gait scores for each cow for the whole study period for the final data set. The variables used to evaluate each score were freestall barn, breed, parity (1 or ≥ 2), and LT.

All dependent variables were averaged using the MEANS procedure before being evaluated using the ANOVA in the GLM procedure for 97 cows [Holsteins (n = 71), Jerseys (n = 10), and crossbreds (n = 16)]. All 2-way interactions were tested, and stepwise backward elimination was used to remove nonsignificant interactions (P ≥ 0.05). Main effects were kept in the model, and significant fixed effect means were separated using the T method.

All analyses were designed to evaluate differences between the MAT barn and the DCCW barn. A poststudy power test was performed, and final sample size was determined adequate (n = 97) to determine a difference in LT. The power for this analysis was 0.94.

**RESULTS AND DISCUSSION**

**MY**

Milk yield was not different between the DCCW freestall barn and the MAT freestall barn (P ≥ 0.05; Table 1). Stage of lactation, breed, ration, and ambient conditions affect MY. Therefore, a direct comparison of lying surfaces in a freestall barn will probably not detect MY differences.
However, parity and breed were predictors of MY ($P < 0.05$; Table 1). Primiparous cow MY was lesser than multiparous cow MY. Holstein MY was significantly greater than crossbred MY and Jersey MY. Crossbred MY was not different from Jersey MY. These results concur with other study results (Dechow et al., 2007).

**LT**

Daily LT were longer for cows housed on DCCW than for cows housed on MAT ($P < 0.01$; Table 1). This result may indicate that cows may prefer a more comfortable resting area by lying down longer on the DCCW. Cows have a basic desire to lie down (Munksgaard and Simonsen, 1996); therefore, LT is important. Lying times in this study were lesser than industry standards and do not concur with other studies (Tucker et al., 2003; Cook et al., 2004). However, stall length in this study was shorter and may have contributed to lesser LT.

Holstein LT was longer ($P < 0.01$) than crossbred and Jersey LT, but crossbred and Jersey LT were not different ($P > 0.05$; Table 1). In a separate LT model, cow volume was a predictor of LT ($P < 0.01$; $r = 0.32$; Figure 2). Cows that were larger in volume had longer LT than smaller cows. Holsteins are a considerably larger breed than crossbreds and Jerseys, and because the majority of the herd was Holstein, LT analyzed either by breed or by size were confounded. Large breed cattle may need to rest more to take weight off their feet. If the cows’ feet and legs are sore, their LT may increase (Steensels et al., 2012). Primiparous cows had shorter LT ($P < 0.01$) compared with multiparous cows. Lying time increases with age, perhaps because of increased weight or milk production (Steensels et al., 2012). Milk yield was a predictor of LT ($P < 0.01$; $r = −0.31$; Figure 3). As cows produced more milk, they lay down for less time. High yielding cows may be associated with lesser LT because they may need to be at the bunk consuming more feed to support nutrient demands (Fregonesi and Leaver, 2001). These results concur with other study results (Fregonesi and Leaver, 2001; Bewley et al., 2010).

Lying bout length was not different between the DCCW freestall barn and the MAT freestall barn ($P ≥ 0.05$; Table 1). Number of bouts was not different between the DCCW freestall barn and the MAT freestall barn ($P ≥ 0.05$). Holstein LB length was longer ($P < 0.05$) than Jersey but not crossbred. Crossbred LB length was not different from Jersey LB length ($P ≥ 0.05$; Table 1). Parity was a predictor of LB length; primiparous cow LB length was shorter than multiparous cow LB length ($P < 0.01$; Table 1). Parity × MY interaction was also a predictor of LB length ($P = 0.04$). The number of lying bouts in this study was similar to those reported in other studies (Drissler et al., 2005). Breed and MY were not predictors of number of bouts ($P ≥ 0.05$). Number of bouts was different for differing parities. Primiparous cows had more bouts compared with multiparous cows ($P < 0.01$; Table 1). The differences in lying bout duration and frequency are similar to other studies (Vasseur et al., 2012). The differences between parities may be because primiparous cows have a lower social rank, making them susceptible to being displaced from their stall more often than a multiparous cow. The authors also speculated that primiparous cows might still be getting accustomed to their surroundings, causing them to rise more often (Vasseur et al., 2012).

**Rumination**

Rumination time was greater for cows housed on MAT compared with cows housed on DCCW ($P = 0.03$; Table 1). These RT are similar in length to other studies (Kononoff et al., 2002; Couderc et al., 2006). Although these RT are statistically significant, they may not be biologically significant. This study did not address feeding behavior, so DMI is unknown; therefore, determining true significance is beyond this study. Primiparous cow RT was greater compared with multiparous cows ($P < 0.01$; Table 1). This result is in contrast to other studies where multiparous cows had longer RT compared with primiparous cows (Bowman et al., 2003). As mentioned previously, this study did not address feeding behavior and DMI was not recorded; therefore, more research is needed to determine why the results for this study are opposite from other studies. Breed was a significant predictor of RT ($P < 0.01$; Table 1). Milk yield × breed interaction was also a predictor of RT ($P = 0.02$; Figure 4). As MY increased, RT increased. Daily RT increased the most for crossbred cows as milk production increased. Schirrmann et al. (2012) indicated that increased RT was associated with lesser feeding times. Crossbreds may have lesser feeding times due to lesser MY, thus increased RT. However, as discussed previously, this study did not include feeding behavior. This model may also not have enough crossbreds and Jerseys to show the true interaction between MY and breed as a predictor of RT.

**Reticulorumen Temperatures**

Mean maximum THI throughout the study was 64.39 ± 0.82. Reticulorumen temperatures were not different between cows housed in the DCCW freestall barn and cows housed in the MAT freestall barn ($P ≥ 0.05$; Table 1). Fulwider and Palmer (2004) stated that water has the ability to hold and save heat. Wadsworth et al. (2015) discovered that over a 15-mo study, the stall temperature in the DCCW freestall barn was 13.29°C compared with that in the MAT barn, which was 10.52°C. Although these differences in the freestall bases were significant, they may not have had a cow cooling or heat effect. Reticulorumen temperatures were not different between primiparous and multiparous cows ($P ≥ 0.05$; Table 1). Reticulorumen temperatures were not different among the Holstein, Jersey, and crossbred cows ($P ≥ 0.05$; Table 1). The lack of significance for reticulorumen temperature among different
<table>
<thead>
<tr>
<th>Aspect evaluated</th>
<th>Freestall barn</th>
<th>MAT</th>
<th>Parity</th>
<th>Breed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>DCCW</td>
<td>MAT</td>
<td>Primiparous</td>
<td>Multiparous</td>
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<tr>
<td>Milk yield (kg/d)</td>
<td>29.40 ± 1.02</td>
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<td>Lying time (h/d)</td>
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<td>Lyingbout length (h/bout)</td>
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<td>Number of lying (bouts/d)</td>
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<td>11.42 ± 0.53</td>
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<td>Rumination time (h/d)</td>
<td>6.29 ± 0.08</td>
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<td>6.22 ± 0.07</td>
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<td>Overall hygiene</td>
<td>1.38 ± 0.05</td>
<td>1.32 ± 0.05</td>
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<td>1.34 ± 0.05</td>
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<td>Knee score</td>
<td>0.64 ± 0.10</td>
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<td>0.68 ± 0.09</td>
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<td>Hock score</td>
<td>1.86 ± 0.03</td>
<td>1.97 ± 0.04</td>
<td>1.84 ± 0.04</td>
<td>1.99 ± 0.04</td>
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<td>Left stifle lesions</td>
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<td>Right stifle lesions</td>
<td>0.07 ± 0.05</td>
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<td>0.02 ± 0.05</td>
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<td>Left thigh lesions</td>
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<td>Right thigh lesions</td>
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<td>Left thurl lesions</td>
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<td>Right thurl lesions</td>
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<td>Left medial surface</td>
<td>0.09 ± 0.04</td>
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<td>Right medial surface</td>
<td>0.09 ± 0.04</td>
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<td>Gait score</td>
<td>2.45 ± 0.07</td>
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<td>Somatic cell score</td>
<td>2.87 ± 0.31</td>
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<table>
<thead>
<tr>
<th>Freestall barn × parity (1 or ≥2)</th>
<th>MAT × 1</th>
<th>MAT × 2</th>
<th>DCCW × 1</th>
<th>DCCW × 2</th>
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<tr>
<td>Overall hygiene</td>
<td>1.41 ± 0.07</td>
<td>1.23 ± 0.06</td>
<td>1.32 ± 0.06</td>
<td>1.44 ± 0.06</td>
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<tr>
<td>Gait score</td>
<td>2.38 ± 0.10</td>
<td>2.52 ± 0.08</td>
<td>2.19 ± 0.08</td>
<td>2.64 ± 0.08</td>
</tr>
</tbody>
</table>

Superscript letters indicate significantly different (P ≤ 0.05).

1Daily milk yield was calculated using the Milton Line Milpro P4C milking system (Gariga di Podenzano, Italy).
2Calculated using IceRobotics IceQube sensors (Edinburgh, Scotland).
3Rumination times were calculated using the HR Tag (SCR Engineers Ltd., Natanya, Israel).
4Overall hygiene score was the average hygiene scores of the legs, udder, and flank areas using a 4-point system: 1 (clean) to 4 (dirty; Cook and Reniemann, 2007).
5Knee score differences between freestall barns. Knee scores were calculated using a 4-point system: 0 (no hair loss or swelling) to 3 (severe swelling; Fulwider et al., 2007).
6Hock score differences between freestall barns, parity, and breeds. Hocks were calculated using a 3-point system: 1 (no swelling, no hair loss) to 3 (swollen hock or draining lesion; Nocek, 2011).
7Lesion scores were calculated as present or not.
8Gait scores were calculated using a 5-point system: score 1 (sound cow) to 5 (extremely lame cow; Olmos et al., 2009).
9Somatic cell score was calculated using the following formula: SCS = log₂ (SCC/100) + 3.
breeds is different from other studies (Liang et al., 2013) and needs further investigation.

Cow Hygiene

No differences for overall hygiene were observed between freestall barns and parity ($P \geq 0.05$; Table 1). Breed was a predictor of overall hygiene ($P < 0.01$; Table 1). Holsteins were overall dirtier ($P < 0.01$) than Jerseys and crossbreds, but no differences were observed between Jerseys and crossbreds ($P \geq 0.05$). Holsteins had the greatest MY, meaning they would have the greatest intake. This increased intake would potentially produce more manure, making Holsteins dirtier (Phillips, 1993). Freestall barn × parity interaction was a predictor of overall hygiene ($P < 0.05$; Table 1). The MAT-housed primiparous cows overall were dirtier than the MAT-housed multiparous cows ($P < 0.01$). The DCCW-housed multiparous cows were dirtier than the MAT-housed primiparous cows ($P < 0.01$). The DCCW-housed multiparous cows may have been dirtier than the MAT-housed multiparous cows because cows housed on the DCCW had higher LT than the MAT-housed cows. Canadian researchers evaluating the associations between lying behavior and cow hygiene reported that a higher LT was associated with poorer hygiene (Devries et al., 2012).

SCS

No differences were observed between freestall barn, breed, and parity for SCS ($P \geq 0.05$; Table 1). Milk yield was the only predictor of SCS ($P < 0.01$, $r = -0.32$). As MY increased, SCS decreased. Cows with the greatest SCS had lesser MY. These results concur with other studies evaluating MY versus SCC (Raubertas and Shook, 1982; Hand et al., 2012). Because so few cases of clinical mastitis were observed ($n = 2$) per freestall barn over the course of the study, clinical mastitis was not considered in the model.

Knee, Hock, and Lesion Scores

Predictors of knee scores were freestall barn and LT × freestall barn interaction ($P < 0.05$; Table 1). Cows housed in the DCCW freestall barn had lesser numerically knee scores than cows housed in the MAT freestall barn. Parity was not a predictor of knee scores ($P \geq 0.05$). Knee scores were not different among breeds ($P \geq 0.05$; Table 1).

Predictors of hock scores were freestall barn, breed, and LT × parity interaction ($P < 0.01$). Hock scores were lesser for cows housed in the DCCW freestall barn compared with cows housed in the MAT freestall barn ($P = 0.02$; Table 1). The presence of moisture, constant pressure, and friction on the skin are factors associated with skin lesions (Spector, 1994). The MAT freestall barn surface may have
been more abrasive, causing the difference in skin lesions. The MAT freestall barn surface may also not be compressible and may not move with the cow as the cow stands up, so a cow’s hocks may rub on the surface causing abrasions. These results concur with another study (Fulwider et al., 2007). Fulwider et al. (2007) visited 85 farms that used rubber-filled mattresses, deep-bedded sand, or waterbeds as stall bases to compare lesions and knee scores among cows on different stall bases. Hocks were scored on a 0 (no lesions) to 3 (severe lesions) system. These researchers discovered that cows on rubber-filled mattresses had worse hock scores than cows on sand and waterbeds, where percentages of hocks scoring 3 were 3.0, 0.2, and 0.4, respectively. In this study, primiparous cow hock scores were lesser than multiparous cow hock scores (P < 0.01; Table 1). Hock scores were different between breeds (P = 0.04). Holstein hock scores were less (P < 0.05) than Jersey hock scores but not crossbred hock scores. Crossbred hock scores were not different from Jersey hock scores (P ≥ 0.05; Table 1). Hock lesions may occur when the weight of the animal places pressure on the hock when lying down, therefore reducing blood flow to the area, causing lesions (Spector, 1994). In humans, being male is a risk factor for having bed sores because males weigh more than females (Spector, 1994). If weight is a risk factor for skin lesions, then Holsteins should have a higher prevalence and severity of lesions. However, the model may not have had enough Jersey and crossbred cows in it to show their true hock scores.

Lesions on the left stifle were significantly less for cows housed on the DCCW than the MAT (P < 0.05; Table 1). The DCCW may provide a more cushioned surface allowing for less stifle lesions on cows compared with the more abrasive MAT surface. Predictors (P < 0.05) for lesions on the right stifle were parity and the interaction of parity by LT. Primiparous cows had lesser right stifle lesions than multiparous cows. Lying time was the only predictor (P < 0.05) for lesions on the left and right thigh, where freestall barn, breed, and parity were not predictors (P ≥ 0.05). The interaction of LT × freestall barn was the only significant predictor for lesions on both the left and right thurll, where freestall barn, breed, and parity were not predictors (P ≥ 0.05). Parity was the only predictor for lesions on the left and right medial surface of the tuber calcis, where primiparous cows had fewer lesions than multiparous cows (P < 0.05; Table 1). Older cows may be heavier than younger cows. This weight when lying down may cause them to have more lesions.

**Gait**

Gait score differences were shown across freestall barn, parity, breed, and freestall barn × parity interaction (P < 0.05). Crossbred gait scores were worse (P < 0.05) than those of Jerseys but not Holsteins. No difference (P > 0.05) between Holstein and Jersey gait scores existed. As discussed previously, crossbred and Jerseys may not have enough numbers in the model to fully represent gait. Holsteins were assumed to have the worst gait scores because of their increased size and weight, placing stress on their hooves. Freestall barn × parity interaction was a predictor of gait (P < 0.05; Table 1). The MAT-housed multiparous cows had a worse gait score than did the DCCW-housed primiparous cows. The DCCW-housed primiparous cows had a lesser gait score than did the DCCW-housed multiparous cows. The MAT-housed primiparous cows gait score was not different from MAT-housed multiparous cows or DCCW-housed primiparous or multiparous cows. The physical environment in which the cow is housed in relation to standing and lying surfaces is a significant factor in lameness incidence rate (Cook and Nordlund, 2009). The amount of time that the cow’s hooves are exposed to manure and concrete is detrimental to claw health when housed in freestalls (Fayed, 1997; Fregonesi et al., 2009). Perhaps this is the reason why multiparous cows in both freestall barns had greater gait scores than primiparous cows. The multiparous cow hooves have been exposed to concrete for a longer time, potentially making them have a worse gait. Multiparous cows also had an increased LT; although this is to be expected, they may also lie down more to reduce the load off their feet and to relieve pain (Fayed, 1997).

In this study, cows lay down longer on the DCCW compared with the MAT, which may benefit cow comfort and highlights that DCCW may be more comfortable, allowing cows to lie down longer. Milk yield was not significantly different between DCCW and MAT. Cows had lesser hock scores on the DCCW compared with MAT, which may indicate that the MAT surface was more abrasive than the DCCW. Although these results are promising for the benefit of cow comfort, the authors caution that the results were only from 2 freestall barns at the University of Kentucky Coldstream Dairy Farm. Therefore, the study was unable to be replicated in additional barns.

**IMPLICATIONS**

In this study, the DCCW-housed cows lay down longer than the MAT-housed cows and had lesser hock scores. Because animal well-being is becoming increasingly important, new ways to house cattle are forthcoming. Rubber-filled mattresses are a more popular surface to house cattle than the DCCW. However, these new results may help change current industry practice. Although these results are hopeful, the authors caution that they were only from the 2 freestall barns at the University of Kentucky Coldstream Dairy Farm. This study was not repeated, so further research may repeat the study or compare DCCW to the current industry gold standard of deep-bedded sand.

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**LITERATURE CITED**


