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Association between stall surface and some animal welfare measurements in freestall dairy herds using recycled manure solids for bedding

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ABSTRACT

The objective of this cross-sectional study was to investigate the association between stall surface and some animal welfare measurements in upper Midwest US dairy operations using recycled manure solids as bedding material. The study included 34 dairy operations with herd sizes ranging from 130 to 3,700 lactating cows. Forty-five percent of the herds had mattresses and 55% had deep-bedded stalls. Farms were visited once between July and October 2009. At the time of visit, at least 50% of the cows in each lactating pen were scored for locomotion, hygiene, and hock lesions. On-farm herd records were collected for the entire year and used to investigate mortality, culling, milk production, and mastitis incidence. Stall surface was associated with lameness and hock lesion prevalence. Lameness prevalence (locomotion score ≥3 on a 1 to 5 scale) was lower in deep-bedded freestalls (14.4%) than freestalls with mattresses (19.8%). Severe lameness prevalence (locomotion score ≥4) was also lower for cows housed in deep-bedded freestalls (3.6%) than for cows housed in freestalls with mattresses (5.9%). In addition, the prevalence of hock lesions (hock lesion scores ≥2 on a 1 to 3 scale, with 1 = no lesion, 2 = hair loss or mild lesion, and 3 = swelling or severe lesion) and severe hock lesions (hock lesion score = 3) was lower in herds with deep-bedded freestalls (49.4%; 6.4%) than in herds with mattresses (67.3%; 13.2%). Herd turnover rates were not associated with stall surface; however, the percentage of removals due to voluntary (low milk production, disposition, and dairy) and involuntary (death, illness, injury, and reproductive) reasons was different between deep-bedded and mattress-based freestalls. Voluntary removals averaged 16% of all herd removals in deep-bedded herds, whereas in mattress herds, these removals were 8%. Other welfare measurements such as cow hygiene, mortality rate, mastitis incidence, and milk production were not associated with stall surface.

Key words: lameness, recycled manure solids, stall surface, welfare

INTRODUCTION

Providing a clean, dry, and comfortable surface for cows to rest on is important to the welfare of dairy cows, as they spend approximately 12 h per day resting (Haley et al., 2001). Comfortable stalls are those that do not interrupt the natural movements of rising and lying behaviors. Several animal-based measurements such as cow preference, standing and lying behaviors, and the prevalence of lameness and hock lesions have been used to evaluate the comfort of freestalls. Observed differences in these measurements are often associated with stall surface, design, dimensions, and bedding management (Weary and Taszkun, 2000; Cook, 2003; Tucker and Weary, 2004).

When cows were given softer resting surfaces, they spent more time resting and less time standing (Haley et al., 2001). Greater amounts of bedding material provided on top of mattresses improved cow comfort as measured by lying times and cow preferences (Tucker and Weary, 2004). Deep-bedded stalls with either sand or sawdust bedding were preferred by cows compared with mattresses with 2 to 3 kg of sawdust (Tucker et al., 2003). Cow comfort, as measured by the cow comfort index was greater for cows in deep-bedded sand stalls than for cows housed on mattresses (Cook et al., 2005). Decreased lying comfort and the use of mattresses as a stall base have been implicated as risk factors for lameness (Dippel et al., 2009), which is considered one of the greatest animal welfare concerns in the dairy industry (Whay et al., 2003). Lameness was found to be less prevalent in herds using deep-bedded sand stalls than herds using mattresses (Cook, 2003; Espejo et al., 2006). Stall surface has also been shown to affect the prevalence of hock lesions, which are indicative of inadequate lying surfaces (Huxley and Whay, 2006). Lesions were observed less frequently in cows housed in deep-bedded sand stalls than cows on mattresses (Weary and Taszkun, 2000; Fulwider et al., 2007) and severe lesions were less prevalent in sand beds than on mattresses (Weary and Taszkun, 2000).

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Changes to the cow's physical environment and increases in physiological stress are considered probable causes for rising mortality rates (Nørgaard et al., 1999). Increases in mortality rates are a growing animal welfare concern in the dairy industry (Thomsen et al., 2004), as they may indicate suboptimal health and compromised animal welfare (Thomsen et al., 2006). In a recent study of approximately 6 million DHIA records from 10 Midwest states, mortality rate in herds with >500 cows was 8.1% (M. Shahid, University of Minnesota, St. Paul, unpublished results). In addition, overall mortality rates increased from 5.9% in 2006 to 6.8% in 2010. High cull rates in dairy herds, especially within the first 60 DIM may also signify inadequacies in welfare. Compromised animal health and injuries were cited most frequently as reasons that cows were culled before 60 DIM (Dechow and Goodling, 2008). Analysis of DHIA records from the upper Midwest and the Northeast United States between 1993 and 1999 showed that almost 80% of all culling was related to the health of dairy cows (Hadley et al., 2006).

The welfare of dairy cows across various housing systems has been well documented (Cook, 2003; Fulwider et al., 2007). However, to our knowledge, little, if any, information exists regarding the welfare of cows bedded with recycled manure solids (**RMS**). Increased costs and reduced availability of other common bedding sources has prompted many dairy producers to search for more feasible alternatives such as sand or RMS. Although sand can be considered the ideal bedding source for dairy cows, not all producers are willing and able to convert to sand bedding, as it presents several challenges related to manure management. Interest in using RMS for bedding is growing, especially in the Midwest United States and information is lacking related to its use on farms and influence on the welfare of dairy cows. Therefore, the objective of this study was to investigate the association between stall surface and some animal welfare measurements (locomotion, hock lesions, hygiene, mortality, herd turnover rates, milk production, and clinical mastitis incidence) in herds using RMS as bedding for dairy cows.

MATERIALS AND METHODS

This cross-sectional observational study was conducted between July and October of 2009 and included 34 dairy operations in the upper Midwest United States that used RMS for bedding the freestalls of lactating dairy cows. Herds were selected on the basis that they had been using RMS as a primary bedding source for the lactating herd for a period of at least 1 yr before our visit. In an effort to not limit our sample size, the source and mechanisms for obtaining RMS were not included in our criteria for farm selection. Sources and mechanisms used by farms in the study included RMS obtained from mechanical separation after anaerobic digestion, RMS obtained from mechanical separation of raw manure, and mechanically composted RMS. Dairy producers using RMS as bedding for freestalls were identified by extension educators, industry representatives, and other producers. Following the identification of potential herds for use in the study, dairy producers were contacted to confirm the use of RMS for a period of at least 1 yr and to obtain their consent to participate in the study.

Data Collection

Farms were visited once to perform on-farm data collection, which included visually scoring at least 50% of the cows in each lactating pen for locomotion, hygiene, and hock lesions. The objective was to obtain an estimate of these scores for each pen. The observer was present for the entire milking shift and entered the parlor to score cows for hygiene and hock lesions (each cow scored for both of these measurements), and then left the parlor before the cows were released and scored cows for locomotion in the return alley as they left the parlor. This process had to be repeated various times to collect a representative number of cows from each pen and at the beginning, middle, and end of each milking group. Individual cow identifications were not collected; therefore, it is expected that not all cows were scored for both locomotion and hygiene/hock lesions. Records from the dairy on-farm herd management software were downloaded during the visit to the farm and in early January 2010 to perform a 12-mo analysis of each farm (culling, mortality, milk production, and mastitis incidence). Daily bulk tank milk information from January to December 2009 was obtained from each herd's milk processor when accessible.

Animal Measurements. Animals were evaluated for lameness using a 5-point locomotion scoring method (Flower and Weary, 2006). Locomotion scores (**LS**) were identified as 1 = normal locomotion, 2 = imperfect locomotion, 3 = lame, 4 = moderately lame, and 5 = severely lame. Locomotion scoring was performed by one observer as cows were exiting the milking parlor. As previously mentioned, a representative number of cows from the beginning, middle, and end of each lactating pen were scored for locomotion to avoid biasing the results. Lameness prevalence for each lactating pen was calculated as the number of animals with LS $\geq$3 divided by the total number of animals scored in the pen. Severe lameness prevalence by pen was calculated as the number of animals with LS $\geq$4 divided by the total number of animals scored in the pen.

Cows were scored for hock lesions (**HL**) and hygiene in the milking parlor by 1 observer. Hock lesions were scored on a 3-point scale with 1 = no lesion, 2 = hair loss (mild lesion), and 3 = swollen hock with or without hair loss (severe lesion). Hock lesion prevalence by pen was calculated as HL $\geq$2 divided by the total number of cows scored in the pen. Severe hock lesion prevalence by pen was calculated as HL = 3 divided by the total number of cows scored in the pen. Cow hygiene was assessed by the amount of dirt on the udder and lower hind legs and was based on a 5-point scale, with 1 = clean and 5 = dirty (Reneau et al., 2005). Across all farms, 37,271 cows were scored for locomotion and 29,565 cows for hock lesions and hygiene to represent the average score in each pen.

Stall Measurements. Freestall dimensions—stall width, body resting length, total stall length, neck rail height, and bedding depth—were measured during the farm visit. Stall width was measured as the width between 2 freestall loops on center. Body resting length consisted of the space from the base of the brisket board (if existing) to the edge of the curb at the back of the stall. Total stall length was measured from the center of 2 rows of freestalls facing head-to-head to the edge of the curb in the back of the stall. Neck rail height was measured as the distance between the bottom of the neck rail to the stall surface. Measurements from each farm were assumed similar between each pen unless obvious differences in stall dimension were observed or mentioned by the herd manager, in which case another set of measurements were collected. An average of each stall measurement was calculated for each herd based on the measurements of a representative number of randomly selected stalls (>8). The depth of bedding was estimated before the addition of fresh bedding by measuring thickness of bedding with a tape measure in stalls with mattresses. In deep-bedded stalls, bedding depth was estimated in the back third of the stall using a steel rod manually driven through the bedding material to the base of the stall and measuring the portion of the steel rod above the stall surface. In both cases, 3 measurements were taken in each stall and averaged per pen.

Mastitis Incidence. Herd clinical mastitis incidence was calculated as the number of cases per 100 cow years (36,500 d) at risk. Both the number of clinical mastitis cases and cows at risk during the year of 2009 were obtained from the on-farm record system. Each reported clinical mastitis case was considered to be a new case if a 14-d period had passed between the previous and current case of clinical mastitis (Barkema et al., 1998b). The number of cows at risk during the year was calculated as the average of the weekly lactating herd size as reported in the on-farm record system. Herd managers were asked about the consistency and completeness of recording mastitis cases. Three herds with mattresses and 4 with deep beds were excluded from the analysis due to incomplete record keeping.

Culling and Mortality. Culling and mortality were collected from on-farm records and DHIA records when no on-farm records were available. Two herds with mattresses and 1 herd with deep-bedded freestalls were excluded from analysis due to inaccurate record keeping. Herd turnover rate was calculated as the number of animals that left the farm (died or sold) over the course of 1 yr divided by the average herd inventory (dry and lactating cows). Herd turnover rate for cows less than 60 DIM was calculated as the number of animals that died or were sold within the first 60 DIM divided by the number of animals that freshened during the year (Fetrow et al., 2006). Reasons for culling as reported in the records were categorized as injuries, low production, dairy (cow sold to another farm for production), mastitis, breeding, feet and legs, udder conformation, aborted, sick, and a category for miscellaneous and unknown reasons. Voluntary culls consisted of culling animals for dairy purposes (cows with good milk production that can go to another herd), low milk production, and bad disposition. Involuntary culls consisted of culling due to injury, sickness, reproduction, death, lameness, udder conformation, abortions, and miscellaneous or unknown reasons. Mortality rates were calculated as the total number of adult animals that died during the year divided by the average herd inventory. Reasons for mortalities as reported in the records were categorized as injury, mastitis, lameness, euthanasia, miscellaneous, and unknown reasons.

Statistical Analysis

The MEANS procedure (SAS Institute Inc., Cary, NC) was used to describe average farm measurements such as herd size, parity, DIM, daily milk weights, SCC, and stall dimensions. A linear mixed model (MIXED procedure; SAS Institute Inc.) was built to evaluate the association between stall surface (deep-bedded vs. mattress) and the outcome variables: lameness prevalence, hock lesion prevalence, hygiene score, mortality rate, herd turnover rate, milk yield, and mastitis incidence. Lameness prevalence, hock lesion prevalence and hygiene scores were analyzed using pen within farm as the experimental unit with farm as random effect. Herd turnover rates, mortality rates, milk yield, and mastitis incidence were analyzed using farm as the experimental unit. Milk yield was analyzed by herd on a monthly basis, using milk production as a repeated measure.

Stall surface was the fixed explanatory variable used in all models. Fixed explanatory covariates were average pen DIM, parity, and milk yield (for models where pen was the experimental unit), and average herd DIM, parity, or milk yield (for models where herd was the experimental unit). In addition, stall dimensions and bedding frequency were used as explanatory covariates in the models for lameness, hock lesions, and hygiene. Tukey-Kramer adjustment was used for multiple comparisons of least squares means in categorically distributed variables. Normality and homogeneity of variance were visually evaluated using residual plots. Variables that were deemed nonnormal were arcsine transformed for analysis and back transformed with the 95% confidence interval for interpretation.

RESULTS AND DISCUSSION

Herd Characteristics

Of the 34 dairies included in this study, 22 were from Wisconsin, 6 from Minnesota, 4 from South Dakota, and 2 from Iowa. Nineteen of the 34 farms housed cows in deep-bedded freestalls and 15 farms housed cows in freestalls with mattresses (i.e., pasture mats, rubber mats, or water beds). Postdigested RMS were used in 21 of the 34 herds in the study, 9 herds used RMS from separated raw manure, and 4 herds used drum-composted RMS. Average lactating herd size was 1,519 and 1,078 cows for deep-bedded and mattress herds, respectively. Herd size for farms with deep beds ranged from 130 to 3,673 cows, whereas farms with mattresses ranged in size from 154 to 2,378 cows. Holstein was the primary breed on 32 of the 34 dairies used in this study, with the other 2 herds consisting of Jerseys. Average annual bulk tank SCC (**BTSCC**) was 268,000 and 282,000 cells/mL for herds with deep beds and mattresses, respectively. Stall lengths (mean ± SD) were 232.2 ± 15.0 and 217.9 ± 15.7 cm, stall widths were 119.6 ± 4.8 cm and 118.4 ± 4.6 cm, body resting lengths were 178.1 ± 6.4 and 175.0 ± 5.3 cm, and neck rail heights were 117.3 ± 5.8 and 117.6 ± 6.1 cm for deep-bedded and mattress-based freestalls, respectively. Prior to the addition of new bedding, bedding depth across herds with deep-bedded freestalls averaged 22.1 cm and ranged between 7.6 and 30.5 cm. In herds bedding RMS on top of mattresses, bedding depth averaged 9.1 cm and ranged from 5.1 to 15.2 cm. Sixty percent of farms added fresh bedding to the freestalls 3 or more times per week, whereas the remaining 40% added at least once per week. Farms using deep-bedded freestalls leveled the stall surface regularly, whereas farms with mattresses found it difficult to retain bedding in the stalls.

Lameness

Cows housed in deep-bedded freestalls (n = 145) had a lower ($P < 0.001$) prevalence of lameness (14.4%) than cows housed in freestalls with mattresses (19.8%; n = 90). Severe lameness prevalences were also different ($P < 0.001$) between deep-bedded (3.6%) and mattress- (5.9%) based freestalls (Table 1). These results are similar to those reported by Cook (2003) and Espejo et al. (2006) who also observed an association between lameness prevalence and stall surface. In both studies, lameness prevalence was compared between herds with deep-bedded sand and mattress-based freestalls. Cook (2003) observed that lameness prevalence in sand stalls was lower during the winter (16.5%) and summer (18.9%) than the prevalence observed in non-sand stalls during winter (24.4%) and summer (26.9%). High-producing Holstein cows in Minnesota had a lameness prevalence of 17.1% in herds with sand-based freestalls compared with 27.9% in herds with mattresses (Espejo et al., 2006). It is interesting to note that the lameness prevalence for deep beds in the current study was similar to the lameness prevalence observed with deep-bedded sand in previous studies. Differences in lameness prevalence likely occur between deep-bedded and mattress based stalls due to greater resting comfort in deep-bedded stalls. When provided the choice between deep beds with either sand or sawdust bedding and mattresses with 2 to 3 kg of bedding, cows showed a preference for deep beds (Tucker et al., 2003). Several studies have shown cows prefer stalls with greater surface cushion and spend more time lying down and less time standing when stall surfaces provide a greater degree of comfort (Haley et al., 2001; Tucker and Weary, 2004). The use of mattresses as a stall surface has been implicated as a risk factor for lameness in dairy cows (Dippel et al., 2009). Deep-bedded freestalls likely provide greater comfort than mattresses with small amounts of bedding.

Hock Lesions

Skin lesions are often found on the tuber calcis and tarsal joints (hock) of dairy cows and are believed to occur when the hock comes into contact with the lying surface. Several studies have documented the prevalence and severity of hock lesions in relation to stall surface and indicate that cows experienced fewer and less severe lesions when housed in deep-bedded stalls

Table 1. Least squares means and 95% confidence intervals for prevalence of lameness, severe lameness, hock lesions, and severe hock lesions in deep-bedded and mattress-based freestall herds using recycled manure solids for bedding

	Deep bed		Mattress		
Measurement (%)	LSM	95% CI	LSM	95% CI	*P*-value
Lameness	14.4	13.0–15.8	19.8	17.7–21.9	<0.001
Severe lameness	3.6	3.1–4.2	5.9	5.1–6.8	<0.001
Hock lesion	49.4	45.4–53.4	67.3	62.4–71.9	<0.001
Severe hock lesion	6.4	5.6–7.3	13.2	11.8–14.7	<0.001

with sand compared with stalls with mattresses (Weary and Taszkun, 2000; Mowbray et al., 2003; Fulwider et al., 2007). Results from the current study using RMS as a bedding source agree with these findings. Cows in deep-bedded stalls with RMS had a lower ($P < 0.001$) prevalence of hock lesions (49.4%) than cows in stalls with mattresses (67.3%), and cows in deep-bedded stalls also had less ($P < 0.001$) severe lesions (6.4%) than cows in mattress-based stalls (13.2%; Table 1). Although these results agree with previous research between sand and non-sand stalls, the prevalence of hock lesions in deep-bedded stalls with RMS was found to be greater than that reported in deep-bedded stalls with sand (Weary and Taszkun, 2000; Fulwider et al., 2007). The greater prevalence of hock lesions observed in deep-bedded stalls with RMS may be due to the differences in bedding material. Although sand also conforms to the cow when resting, it is a very dense bedding material in comparison to RMS, which is very soft and fluffy. When cows lie down on RMS, the bedding material is compressed by the weight of the cow, likely exposing the rear curb of the stall, which is believed to be responsible for the increase in prevalence of lesions on the tuber calcis of cows in sand stalls (Weary and Taszkun, 2000; Mowbray et al., 2003). Although the location of lesions was not specifically documented in the current study, the majority of lesions in herds with deep beds were noted as occurring on the tuber calcis. In addition, we observed a lower prevalence of hock lesions in herds using mattresses than reported by Weary and Taszkun (2000) and Fulwider et al. (2007). This may be due to greater amounts of RMS being added to the stalls by dairy producers, as the material is produced daily and available in large quantity on each farm.

Severe hock lesion prevalence was 5.4 and 13.0% in deep-bedded and mattress-based stalls, respectively. These numbers are similar to 2.5% for deep-bedded sand and 17% for mattress based herds (Fulwider et al., 2007). An assessment of cow comfort on 491 dairy operations throughout the United States revealed that cows bedded with dry or composted manure solids had a greater percentage of cows with severe hock lesions (2.7%) compared with sand (0.7%), straw (1.9%), and sawdust (1.5%) bedding (Lombard et al., 2010).

Hygiene

Good cow hygiene is important in the control and prevention of environmental mastitis in dairy cows. Increases in the hygiene scores of the lower rear legs and udders of cows were found to be associated with increases in SCS (Reneau et al., 2005). Cow cleanliness is often influenced by the environment where cows are housed and varies between farms with similar housing systems. Barkema et al. (1998a) found herds with low BTSCC had cleaner cows and provided cleaner housing for cows than herds with medium and high BTSCC. Previous work has shown that stall surface can affect cow hygiene (Fulwider et al., 2007). Stall surface was not associated with cow hygiene in the current study. Hygiene score (LSM ± SE) was 2.49 ± 0.03 with deep beds and 2.53 ± 0.05 for herds with mattresses.

Mastitis and Milk Production

Mastitis is a multifactorial disease that continues to challenge dairy producers despite the use of management and intervention practices (Bradley, 2002). Estimates of annual losses attributed to mastitis range from $140 to $300 per cow, with almost 70 to 80% of the losses coming from reduced milk production (Fetrow et al., 2000). Additional financial losses associated with mastitis arise from culling, mortality, and costs related to treatment (Bradley, 2002). Recently, only lameness or injury was reported more often than mastitis as the primary cause of death among US dairy cows (USDA, 2007). High incidence rates of mastitis may indicate problems with management or the environment. Mastitis not only represents a considerable financial loss to dairy producers, it also raises welfare concerns about the well-being of dairy cows.

Incidence rates of clinical mastitis in the current study were 66.3 and 49.0 cases per 100 cow years for deep-bedded and mattress herds, respectively, and ranged from 9.3 to 108.7 cases per 100 cow years in deep-bedded herds and 13.2 to 107.6 cases per 100 cow years in herds with mattresses. No association was found between clinical mastitis incidence and stall surface. Incidence rates in the current study were greater than 22.8 cases per 100 cow years reported by Peeler et al. (2000) and 23.0 cases per 100 cow years found by Olde Riekerink et al. (2008). These differences are likely due to discrepancies associated with environmental conditions, housing systems, and herd management, as previous research has shown variations of such factors to be associated with mastitis (Peeler et al., 2000).

Daily milk production was similar between stall surfaces. Herds with deep beds averaged 34.8 kg/cow per day with a range of 18.2 kg to 45.5 kg/cow per day. In herds with mattresses, daily milk production was 35.1 kg per cow with a range of 23.6 to 44.1 kg. Milk production is influenced by several factors other than housing and is not a direct indicator of cow welfare. Additionally, both low and high milk production have been identified as a potential welfare risk for dairy cows (Whay et al., 2003). For this reason, milk production should probably not be recommended as a welfare measurement between housing systems and dairy operations.

Mortality

Herds using RMS in deep-bedded and mattress based stalls were found to have similar mortality rates. Mortality rates were 8.2% for herds with deep beds and 8.6% for herds with mattresses. These results are higher than the mortality rate of 5.9% reported by Smith et al. (2000) in the northern region of the United States. However, in a recent study of approximately 6 million DHIA records from 10 Midwest states, mortality rate in herds with >500 cows was 8.1% (M. Shahid, Univ. of Minnesota, St. Paul, unpublished results). Mortality rates appear to be a growing problem among US dairy operations and represent an important welfare concern. The Dairy 2002 US Department of Agriculture Animal and Plant Health Inspection Service, Veterinary Services (USDA:APHIS:VS) National Animal Health Monitoring System (NAHMS) survey reported annual mortality rates on US dairy operations of 4.8% (USDA, 2002), whereas the Dairy 2007 survey indicated that number had increased to 5.7% (USDA, 2007).

Producer-attributed causes for mortalities among herds in the current study were similar between stall surfaces (Table 2). Miscellaneous causes were reported most often, followed by unknown reasons, injuries, mastitis, euthanasia, and lameness. Euthanasia of cows was only reported by 9 of the 34 dairy operations in this study. This result may be due to limitations by management software in recording multiple reasons for causes of death or may suggest that producers are not euthanizing downer cows. Almost half of all mortalities were found to occur before 60 DIM. In herds with deep beds, 47.2% of mortalities occurred before 60 DIM (range of 18.7 to 74.0%). Herds with mattresses reported 42.7% of deaths occurred before 60 DIM (range of 33.8 to 55.3%).

Herd Turnover

The decision to remove cows from a dairy herd involves consideration of several factors related to the health and performance of individual cows as well as salvage values and milk and feed prices (Dohoo and Dijkhuizen, 1993). Optimal turnover rates of 25% have been suggested (Rogers et al., 1988); however, turnover rates can vary greatly between herds depending upon farm objectives. Expanding dairies and operations with limited replacement animals are likely to retain more cows than dairy operations not looking to expand or with excessive replacements.

Table 2. Least squares means and standard errors of mortality rates, percent of mortalities before 60 DIM, and reasons for dairy cow mortalities in deep-bedded and mattress-based freestall herds using recycled manure solids for bedding

	Deep bed		Mattress		
Characteristic	LSM	SE	LSM	SE	*P*-value
Mortality rate (%)	8.2	0.7	8.6	0.9	0.73
Mortalities ≤60 DIM[1]	47.2	3.0	42.7	3.3	0.32
Mastitis[1]	12.0	1.8	12.7	2.0	0.79
Injury[1]	15.9	2.2	14.7	2.4	0.71
Lameness[1]	1.4	0.8	1.3	0.8	0.93
Euthanized[1]	4.3	2.7	2.4	3.0	0.64
Unknown[1]	25.6	6.0	27.2	6.7	0.86
Miscellaneous[1]	40.8	4.7	41.7	5.3	0.90

[1]Expressed as a percentage of all reported mortalities.

Herd turnover rates for herds with deep beds and mattresses were 37.2 and 38.6%, respectively, and were not associated with stall surface. Turnover rates ranged from 24.5 to 49.0% in herds with deep-bedded stalls and 23.5 to 50.6% in herds with mattresses. Stall surface was associated with removals due to voluntary and involuntary reasons ($P = 0.04$). Voluntary removals were 16.1% of herd removals in deep-bedded herds, whereas only 7.9% of removals in herds with mattresses. Reasons for removals for deep-bedded and mattress herds are listed in Table 3. Overall, reported reasons for removing cows were similar between deep-bedded and mattress herds; however, herds with deep beds reported removing more cows for low milk production (15.0%; $P = 0.02$) compared with herds with mattresses (7.1%). We suggest that is likely the reason for the observed difference between stall surface for voluntary and involuntary removals. Other than the percentage of cows leaving herds due to death, mastitis was recorded most frequently as the reason for removal in herds using RMS, whereas reproduction and infertility have been indicated as the primary reason among US dairy operations (USDA, 2007).

Herd turnover rates within the first 60 DIM were 10.4 and 9.4% in herds with deep beds and mattresses, respectively, and were not associated with stall surface. Sixty-day turnover rates for deep beds ranged between 4.2 and 22.7% and for mattresses between 6.7 and 15.7%. These results are slightly higher than 6.8% reported by Dechow and Goodling (2008) whose study included cows 21 d before expected calving dates. Reasons for removal before 60 DIM are listed in Table 4. Herds with deep beds reported removing fewer cows because of abortion (0.7%) than herds with mattresses (3.6%; $P = 0.03$). We do not have an explanation for this difference. Overall, death was reported as the most frequent reason cows left herds during the first 60 DIM for both deep-bedded and mattress herds.

CONCLUSIONS

The use of RMS in deep-bedded freestalls appeared to provide cows with a more welfare-friendly resting surface than the use of RMS on top of mattresses. Herds with deep beds had a lower prevalence of lameness and hock lesions compared with herds with mattresses. Additionally, the prevalence of severe lameness and severe hock lesions in herds with deep-bedded stalls was lower than those observed in herds with mattresses. Cows bedded with RMS irrespective of stall surface appeared to be rather clean despite the negative perception of bedding cows with their own manure. However, clinical mastitis incidence suggests udder health may be compromised when using RMS as bedding for lactating dairy cows. Mortality rates and reasons implicated in dairy cow mortalities were similar between stall types and conform to recent trends in dairy cow mortality in large Midwest dairy herds. Similar herd turnover rates were found between deep-bedded and mattress-based herds; however, removals due to voluntary and invol-

Table 3. Least squares means and standard errors of herd turnover rates, voluntary and involuntary removals, and producer-attributed reasons for removal in deep-bedded and mattress-based freestall herds using recycled manure solids for bedding

	Deep bed		Mattress		
Item	LSM	SE	LSM	SE	*P*-value
Characteristic					
Herd turnover rate	37.2	1.7	38.6	2.0	0.62
Voluntary removal[1]	16.1	2.3	7.9	2.8	0.04
Involuntary removal[2]	83.9	2.3	92.1	2.8	0.04
Removal reason					
Death[3]	22.6	2.0	22.7	2.3	0.99
Mastitis[3]	16.7	1.9	17.6	2.3	0.76
Injury[3]	3.6	0.7	4.1	0.8	0.62
Production[3]	15.0	2.2	7.1	2.5	0.02
Reproduction[3]	11.2	1.9	14.1	2.1	0.31
Feet and legs[3]	4.8	0.9	5.0	1.0	0.89
Sickness[3]	6.8	1.3	8.1	1.4	0.56
Udder conformation[3]	2.4	0.8	2.7	0.9	0.78
Abortion[3]	1.8	1.0	4.6	1.1	0.05
Dairy[3]	2.4	1.1	0.5	1.2	0.26
Miscellaneous or unknown[3]	12.8	2.8	16.4	3.2	0.41

[1]Percent of cows removed for low milk production or dairy sale.

[2]Percent of cows removed due to death, injury, sickness, reproduction, feet and legs, udder conformation, aborting, and miscellaneous or unknown reasons.

[3]Expressed as a percentage of all herd removals.

Table 4. Least squares means and standard errors of turnover rates by 60 DIM and reasons for removal during the first 60 DIM in deep-bedded and mattress-based freestall herds using recycled manure solids for bedding

	Deep bed		Mattress		
Item	LSM	SE	LSM	SE	*P*-value
Characteristic					
Turnover by 60 DIM	10.4	0.9	9.5	1.0	0.43
Removal reason[1]					
Death	41.5	3.7	36.7	4.1	0.39
Mastitis	10.6	1.5	8.1	1.8	0.30
Injury	4.1	0.8	3.3	0.9	0.49
Production	7.3	1.7	4.9	2.0	0.39
Reproduction	1.3	0.5	1.1	0.6	0.81
Feet and legs	3.8	0.9	4.8	1.1	0.59
Sickness	8.6	1.7	9.3	2.0	0.81
Udder conformation	4.1	1.4	4.6	1.7	0.81
Aborted	0.7	0.8	3.6	1.0	0.03
Dairy	1.1	0.5	0.4	0.6	0.41
Miscellaneous or unknown	16.9	3.7	23.2	4.4	0.39

[1]Expressed as a percent of all removals by 60 DIM.

untary reasons were found to be different. Death was indicated as the primary reason for herd removal both during lactation and before 60 DIM.

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REFERENCES

Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, H. Wilmink, G. Benedictus, and A. Brand. 1998a. Management practices associated with low, medium, and high somatic cell counts in bulk milk. J. Dairy Sci. 81:1917–1927.

Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, H. Wilmink, G. Benedictus, and A. Brand. 1998b. Incidence rate of clinical mastitis in dairy herds grouped in three categories by milk somatic cell counts. J. Dairy Sci. 81:411–419.

Bradley, A. J. 2002. Bovine mastitis: An evolving disease. Vet. J. 164:116–128.

Cook, N. B. 2003. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. J. Am. Vet. Med. Assoc. 223:1324–1328.

Cook, N. B., T. B. Bennett, and K. V. Nordlund. 2005. Monitoring indices of cow comfort in free-stall-housed dairy cows. J. Dairy Sci. 88:3876–3885.

Dechow, C. D., and R. C. Goodling. 2008. Mortality, culling by sixty days in milk, and production profiles in high- and low-survival Pennsylvania herds. J. Dairy Sci. 91:4630–4639.

Dippel, S., M. Dolezal, C. Brenninkmeyer, J. Brinkmann, S. March, U. Knierim, and C. Winckler. 2009. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries. J. Dairy Sci. 92:5476–5486.

Dohoo, I. R., and A. A. Dijkhuizen. 1993. Techniques involved in making dairy cow culling decisions. Compend. Contin. Educ. Pract. Vet. 15:515–519.

Espejo, L. A., M. I. Endres, and J. A. Salfer. 2006. Prevalence of lameness in high-producing Holstein cows housed in freestalls barns in Minnesota. J. Dairy Sci. 89:3052–3058.

Fetrow, J., K. V. Nordlund, and H. D. Norman. 2006. Culling: Nomenclature, definitions, and recommendations. J. Dairy Sci. 89:1896–1905.

Fetrow, J., S. Stewart, S. Eicker, R. Farnsworth, and R. Bey. 2000. Mastitis: An economic consideration. Pages 3–47 in Proc. Natl. Mast. Council, Atlanta, GA. Natl. Mastitis Counc. Inc., Madison, WI.

Flower, F. C., and D. M. Weary. 2006. Effect of hoof pathologies on subjective assessments of dairy cow gait. J. Dairy Sci. 89:139–146.

Fulwider, W. K., T. Grandin, D. J. Garrick, T. E. Engle, W. D. Lamm, N. L. Dalsted, and B. E. Rollin. 2007. Influence of free-stall base on tarsal joint lesions and hygiene in dairy cows. J. Dairy Sci. 90:3559–3566.

Hadley, G. L., C. A. Wolf, and S. B. Harsh. 2006. Dairy cattle culling patterns, explanations, and implications. J. Dairy Sci. 89:2286–2296.

Haley, D. B., A. M. de Passillé, and J. Rushen. 2001. Assessing cow comfort: Effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. Appl. Anim. Behav. Sci. 71:105–117.

Huxley, J., and H. R. Whay. 2006. Cow based assessments. Part 2: Rising restrictions and injuries associated with the lying surface. UK Vet. (Kiev) 11:1–6.

Mowbray, L., T. Vittie, and D. M. Weary. 2003. Hock lesions and free-stall design: Effects of stall surface. Pages 288–295. In Proc. 5th Intern. Dairy Housing Conf. American Society of Agriculture Engineers, St. Joseph, MI.

Lombard, J. E., C. B. Tucker, M. A. G. von Keyserlingk, C. A. Kopral, and D. M. Weary. 2010. Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms. J. Dairy Sci. 93:4668–4676.

Nørgaard, N. H., K. M. Lind, and J. F. Agger. 1999. Cointegration analysis used in a study of dairy-cow mortality. Prev. Vet. Med. 42:99–119.

Olde Riekerink, R. G. M., H. W. Barkema, D. F. Kelton, and D. T. Scholl. 2008. Incidence rate of clinical mastitis on Canadian dairy farms. J. Dairy Sci. 91:1366–1377.
Peeler, E. J., M. J. Green, J. L. Fitzpatrick, K. L. Morgan, and L. E. Green. 2000. Risk factors associated with clinical mastitis in low somatic cell count British dairy herds. J. Dairy Sci. 83:2464–2472.
Reneau, J. K., A. J. Seykora, B. J. Heins, M. I. Endres, R. J. Farnsworth, and R. F. Bey. 2005. Association between hygiene scores and somatic cell scores in dairy cattle. J. Am. Vet. Med. Assoc. 227:1297–1301.
Rogers, G. W., J. A. M. Van Arendonk, and B. T. McDaniel. 1988. Influence of production and prices on optimum culling rates and annualized net revenue. J. Dairy Sci. 71:3453–3462.
Smith, J. W., L. O. Ely, and A. M. Chapa. 2000. Effect of region, herd size, and milk production on reasons cows leave the herd. J. Dairy Sci. 83:2980–2987.
Thomsen, P. T., A. M. Kjeldsen, J. T. Sørensen, and H. Houe. 2004. Mortality (including euthanasia) among Danish dairy cows (1990–2001). Prev. Vet. Med. 62:19–33.
Thomsen, P. T., A. M. Kjeldsen, J. T. Sørensen, H. Houe, and A. K. Ersbøll. 2006. Herd-level risk factors for the mortality of cows in Danish dairy herds. Vet. Rec. 158:622–626.
Tucker, C. B., and D. M. Weary. 2004. Bedding on geotextile mattresses: How much is needed to improve cow comfort? J. Dairy Sci. 87:2889–2895.
Tucker, C. B., D. M. Weary, and D. Fraser. 2003. Effect of three types of free-stall surfaces on preferences and stall usage by dairy cows. J. Dairy Sci. 86:521–529.
USDA. 2002. Part I: Reference of dairy health and management in the United States, 2002. US Department of Agriculture Animal and Plant Health Inspection Service: Veterinary Services, Centers for Epidemiology and Animal Health (USDA:APHIS:VS,CEAH), National Animal Health Monitoring System, Fort Collins, CO.
USDA. 2007. Part I: Reference of dairy health and management in the United States, 2007. US Department of Agriculture Animal and Plant Health Inspection Service: Veterinary Services, Centers for Epidemiology and Animal Health (USDA:APHIS:VS,CEAH), National Animal Health Monitoring System, Fort Collins, CO.
Weary, D. M., and I. Taszkun. 2000. Hock lesions and free-stall design. J. Dairy Sci. 83:697–702.
Whay, H. R., D. C. Main, L. E. Green, and A. J. Webster. 2003. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. Vet. Rec. 153:197–202.