2-2003

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Recommended Citation

Tucker, C. B., Weary, D. M., & Fraser, D. (2003). Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. Journal of dairy science, 86(2), 521-529. https://doi.org/10.3168/jds.S0022-0302(03)73630-3

J. Dairy Sci. 86:521–529

Effects of Three Types of Free-Stall Surfaces on Preferences and Stall Usage by Dairy Cows

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ABSTRACT

One important criterion in choosing appropriate housing systems for dairy cattle is that the freestall provides a comfortable surface for the cow. This paper describes two experiments testing the effects of commonly used lying surfaces on stall preference and stall usage by Holstein cows. In both experiments, 12 cows were housed individually in separate pens. Each pen contained three free stalls with a different surface: deep-bedded sawdust, deep-bedded sand, and a geotextile mattress covered with 2 to 3 cm of sawdust. The animals were restricted to each surface in turn, in a random order for either 2 (Experiment 1) or 3 d (Experiment 2). Both before and after this restriction phase, the animals were allowed access to all three surfaces, and preference was determined, based on lying times. Of the 12 cows used in Experiment 1, 10 preferred sawdust before and nine after the restriction phase. During the restriction phase, average lying times and number of lying events during the restriction phase were significantly lower for the sand-bedded stalls ($P \leq 0.05$), and standing times were higher on mattresses ($P \leq 0.05$), compared with sawdust. Although these cows had some experience with all three surfaces during the experiment, they had been housed in sawdust-bedded stalls during their previous lactation. Cows used in Experiment 2 had spent their previous lactation in sand bedded stalls. In this experiment, about half the cows preferred sand and half sawdust, after the restriction phase. During the restriction phase of experiment, lying times and number of lying events were lower, and standing times were higher when the animals were restricted to the mattresses compared to either sand or sawdust ($P \leq 0.05$). These results indicate that (1) free stall surface can affect both stall preferences and stall usage, and (2) mattresses are less preferred.
(**Key Words:** comfort, well-being, behavior, cubicle)

INTRODUCTION

Dairy cattle spend approximately 8 to 16 h lying down per day, making the quality of the lying surface important to the animals (Dechamps et al., 1989; Webster, 1994; Haley et al., 2000; 2001). The lying surface is known to affect dairy cows in several ways, including behavior, and leg, hoof, and udder health.

Previous work has shown that cows tend to spend more time lying on softer surfaces (for review see Tucker and Weary, 2001). Lying times are lower and standing times higher when dairy cattle are forced to use hard surfaces, specifically concrete (O'Connell and Meaney 1997; Haley et al., 2000; 2001). Cows also have longer lying times on rubber mats than on concrete (Rushen et al., 1998; Chaplin et al., 2000), but the use of large amounts of bedding on concrete minimizes this difference (Manninen et al., 2002).

The lying surface in the stall also appears to affect leg injuries. Fewer leg injuries are reported on mattresses than concrete (Haley et al., 1999), with rubber as an intermediate (Rodenburg et al., 1994). Cows have fewer injuries on deep-bedded stalls than on mattresses (Weary and Taszkun, 2000; Wechsler et al., 2000). In addition, Nilsson (1992) found a positive relationship between lying surface penetration, or hardness and hock injuries. Claw health may also be improved by increased amounts of bedding (Colam-Ainsworth et al., 1989), and by use of rubber mats instead of concrete (Leonard et al., 1994; but see also Chaplin et al., 2000).

Lying surface may also influence udder health. Organic bedding, like sawdust, has higher bacteria counts than nonorganic bedding such as sand (Fairchild et al., 1982; Hogan et al., 1989), and these higher counts lead to higher counts on teat ends (Natzke and Le Clair, 1975; Rendos et al., 1975; Bishop et al., 1981; but see also Hogan and Smith, 1997). Although there is evidence that high bacteria counts on teat ends are related to udder infection (McDonald and Packer, 1968; DeHart et al., 1975), there is only limited evidence that higher counts in bedding increase the risk of udder infection (Natzke et al., 1975; Hogan et al.,

Received January 17, 2002.
Accepted August 19, 2002.
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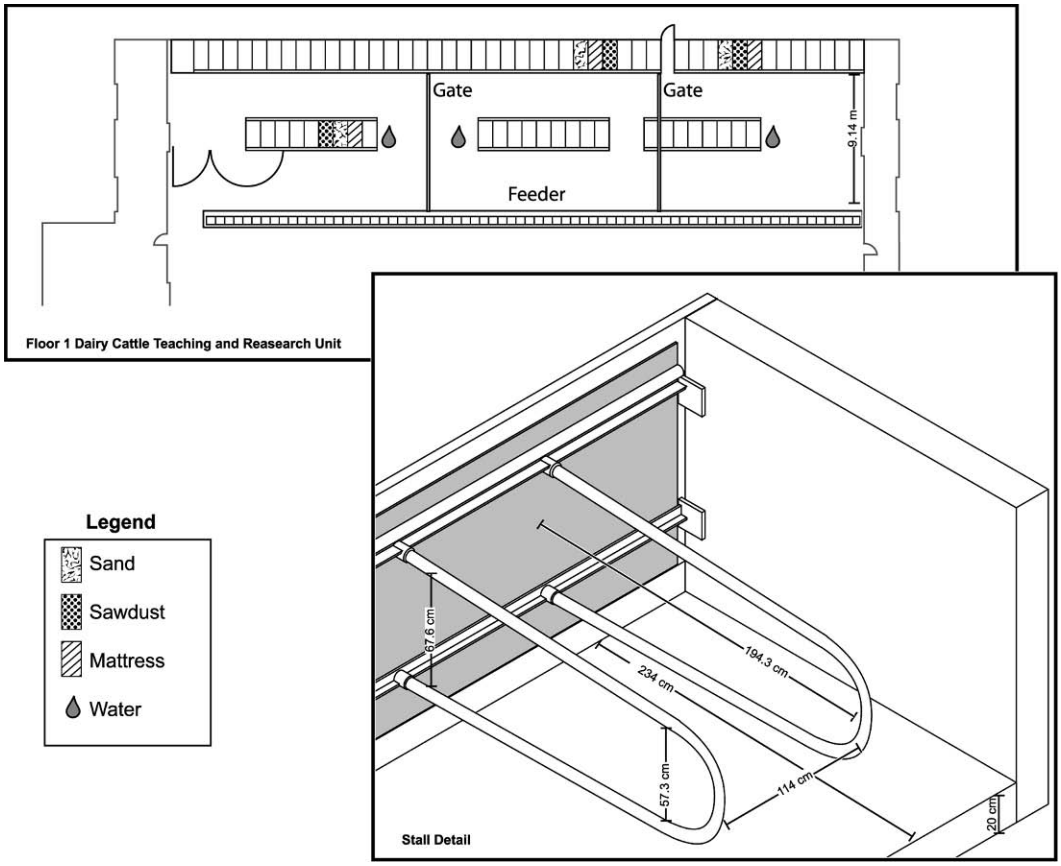

Figure 1. Layout of test pens used in experiments 1 and 2.

1989). Nonetheless, the potential relationship between organic bedding and mastitis, combined with the costs of maintaining deep-bedded systems, have led to increased use of geotextile mattresses.

Environmental preference testing, a technique that allows animals to choose between alternative options, has been used since the 1970s to identify housing features that are important to the animals (Fraser and Matthews, 1997). Preferences often correspond with other measures of biological functioning such as injury and can provide insight into which, in this case, stall surface is likely to be most comfortable (e.g., longest lying times, minimize injury). Preference testing for dairy cattle lying surfaces has involved a variety of substrates, because different bedding materials are available in different geographic regions. Several patterns have emerged from this literature. First, cows tend to prefer mattresses ahead of concrete stalls (Herlin, 1997; O'Connell and Meaney, 1997). Solid rubber mats are preferred to concrete but are less preferred than mattresses (Natzke et al., 1982; Herlin, 1997). The amount of bedding also influences preference. For example, Jensen et al. (1988) showed that cows preferred concrete when bedded with 4 to 5 kg of straw, but choose mattresses when little bedding remained (see also Gebremedhin et al., 1985; Manninen et al., 2002).

In the present study, we compared three stall surfaces commonly used in British Columbia: deep-bedded sawdust, deep-bedded sand, and geotextile mattresses covered with 2 to 3 cm of sawdust. Our objectives were to determine: 1) the preferences for stall surface, 2) how the different surfaces affect stall usage when animals are restricted to a single option for a few days and, 3) the relationship between these two measures.

MATERIALS AND METHODS

Experiment 1

Twelve Holstein cows served as subjects. All cows were open and nonlactating, had been housed in soil-based, sawdust-bedded stalls for the previous lactation. During the experiment, each cow was housed alone in a test pen containing a feed trough, a waterer,

Table 1. Lying times (h per 24-h period) for the three experimental surfaces during first and second free-choice phases for Experiments 1 and 2.

	First free-choice phase			Second free-choice phase		
Cow	Sawdust	Sand	Mattress	Sawdust	Sand	Mattress
Experiment 1[1]						
1	14.2	0.0	0.0	0.0	16.7	0.0
2	14.3	0.0	0.0	15.1	0.0	0.0
3	15.3	0.0	0.0	15.1	0.0	0.0
4	13.4	0.0	0.0	7.8	0.0	7.3
5	15.8	0.0	0.0	14.5	0.0	0.0
6	10.7	0.0	0.0	13.3	0.0	0.0
7	0.0	0.0	11.3	2.5	0.0	11.2
8	12.0	0.0	0.0	13.8	0.0	0.0
9	12.2	0.0	0.0	14.3	0.0	0.0
10	7.8	0.0	7.9	16.9	0.0	0.0
11	14.6	0.0	0.0	17.1	0.0	0.0
12	17.0	0.0	0.0	0.0	14.6	1.7
Experiment 2[2]						
1	15.9	1.0	0.0	16.0	0.0	0.0
2	14.7	0.0	0.0	0.0	16.8	0.0
3	14.6	0.0	0.0	0.0	15.0	0.0
4	0.0	15.0	0.0	3.0	6.5	1.8
5	0.6	11.4	1.8	0.0	16.4	0.0
6	12.7	0.0	0.0	14.6	0.0	0.0
7	0.0	15.9	0.0	1.1	13.4	1.1
8	14.6	0.0	0.0	10.4	5.2	0.0
9	18.8	0.0	0.0	18.6	0.0	0.0
10	11.8	1.1	2.8	10.5	0.0	0.0
11	0.0	17.6	0.0	0.0	15.9	0.0
12	13.9	0.0	0.0	0.1	5.4	7.8

[1]Based on 24 h of recording.

[2]Based on 48 h of recording, except for cows 9 and 10 which were recorded for only 24 h due to a technical difficulty.

alley space, and three free stalls side by side, all accessible from the alley (Figure 1). Each stall in a test pen was bedded with a different material: sand, sawdust, or a rubber-filled geotextile mattress (Pasture Mat of Promat, Ltd.) covered with 2 to 3 cm of sawdust. Three similar test pens were used for the experiment, and the three types of bedding were balanced over the three stall locations (right, center, left) in the three pens. The stalls were 1.14 m wide and 2.34 m long, with no neck rail or brisket board. The sawdust used for the bedding was green hemlock sawdust (not wood chips) with an average particle size of approximately 7×2 mm. The sand was washed river sand and was a mix of grains with a diameter ≤ 2 mm and very few small pebbles averaging 4 mm in diameter. The sand and sawdust was between 30 and 40 cm deep. Feces were removed and bedding leveled to the curb (with new bedding added if necessary) each day during the morning and afternoon feedings (8:00 and 15:00). The animals were fed grass hay ad libitum. The average temperature in Vancouver during the experiment was 11.2°C, with a minimum of −1.0°C and a maximum of 25.2°C.

Trios of animals were tested simultaneously, one in each test pen. During the first 7 d (first free-choice phase), cows had free access to all three stalls. During the next 6 d (restriction phase), cows were allowed access to only one of the three stalls for a 2-d period, then another stall for the next 2 d, then the third, with the order of access to the three stalls assigned randomly without replacement. Access to a single stall was achieved by hanging a 5×10-cm wooden board between stall partitions. During the final 2 days (second free-choice phase), cows were again allowed free access to all three stalls.

Behavior of the cows was video recorded during the last 24 h of both free-choice phases and of each restriction period for a total of 5 d of recording for each cow. Each pen was recorded at three frames/s using a Panasonic AG-6720 VHS Time Lapse Video Cassette Recorder, a Panasonic WJ-FS 10 Digital Frame Switcher, and three Panasonic WV-BP330 CCTV cameras. These recordings were watched continuously, and the following behaviors were measured: 1) time spent lying in the stall, 2) time spent standing in the stall, and 3) the number of lying events. Standing was scored when the front two or all four hooves were in the stall, and was scored before, after, between or independent of lying events. Lying outside the stall was not recorded.

Experiment 2

In this experiment, another 12 pregnant Holstein cows were used, but these cows had all been housed in sand-bedded free stalls during at least two lactations, as well as immediately before the start of the experiment. Their previous exposure to sawdust was limited to the 2 mo before each calving, when they were housed on a sawdust pack.

All other aspects of this experiment were identical to those in Experiment 1 with two exceptions: 1) the restriction period in each stall and the second free-choice phase lasted for 3 d instead of just 2, and 2) behavioral recording took place in the last 48 h of each restriction period and free-choice phase, instead of 24 h. The average temperature in the City of Vancouver during this experiment was 15.2°C, with a minimum of 1.7°C and a maximum of 27.0°C.

Statistical Analysis

In both experiments, during the free-choice phases, lying times in the three stalls were compared using Friedman's rank test. This comparison established a preference for each cow. For data from the restriction phase, preferred surfaces (Experiment 1: sawdust, experiment 2: sand and sawdust) were compared with nonpreferred surfaces in paired tests. For these comparisons, all behaviors with a normal distribution (lying behavior except on sand in Experiment 1; number of lying events), were analyzed using paired T-tests. Response variables with non-normal distributions or unequal variances (all standing behavior and lying behavior on sand in Experiment 1) were analyzed using the non-parametric Wilcoxan rank sum test. In Experiment 1, the analysis was based on 24 h of information for each phase. In Experiment 2, the analysis was based on 48 h of information per phase. Video recordings from one cow in restriction phase (sawdust) and two cows in the free-choice phase of Experiment 2, were lost due to equipment malfunction for 24 h.

RESULTS

Experiment 1

In the first free-choice phase, there was a significant difference among surfaces in lying time, with 10 of 12 cows choosing deep-bedded sawdust ($P < 0.01$), and two choosing mattresses (Table 1). In the restriction phase, lying times and the frequency of lying events were significantly lower on sand than on the preferred sawdust and nonpreferred mattresses ($P \leq 0.05$, Table 2). This difference was driven partly by two animals with extremely low lying times on sand (Figure 2). The cows spent more time standing on the mattresses than on sawdust ($P \leq 0.05$, Figure 3). In the final stage, after the cows had been restricted to each surface, there was still an overall preference for sawdust ($P < 0.05$); nine animals ranked sawdust as their first choice in this phase, one animal continued to prefer the mattress, and two converted to sand as their first choice.

Experiment 2

In the first free-choice stage, eight cows chose sawdust as their first choice, four chose sand, and none chose the mattress (Table 1). Ten of 12 cows (seven choosing sand, three choosing sawdust) spent over 90% of their time lying on their first choice. In the restriction phase, lying times and number of lying events were lower on the mattresses than on the sawdust or sand ($P \leq 0.01$, Table 2). Variance was similar for all three surfaces, and most animals experienced lower lying times and fewer lying events when restricted to mattresses (Figure 2). In addition, standing time was higher on the mattresses than on the sawdust or sand ($P \leq 0.05$), due to several animals with extremely high standing times on mattresses (Figure 3). After the restriction phase there was still no overall preference for one substrate ($P > 0.2$); five of the 12 cows ranked sawdust as their first choice, six chose sand, and one chose the mattress.

DISCUSSION

Preference experiments require attention to several methodological issues that we have attempted to address in our experimental design (Fraser and Matthews, 1997). Firstly, preference results can be affected by the animals' previous experience either as long-term exposure (e.g., during rearing) or as short-term exposure to the various options in the course of the preference test (Dawkins, 1976, 1983; Petherick et al., 1990). Many studies do not describe the free stall surfaces the animals experienced during rearing, nor do they ensure that the animals have some exposure to the surfaces they are asked to choose between (e.g. Sonck et al., 1999). In our studies, we used animals that had substantial experience with both sawdust (Experiment 1) and sand (Experiment 2), and we ensured that all the cows were exposed to all three surfaces during the restriction phase before the final determination of preference. Social factors may influence bedding choices; for example, subordinate animals may avoid certain stalls because of proximity to

dominant animals. To avoid this problem, each animal was housed individually in our experiments. Thirdly, it is important in preference testing to ensure that the different surfaces are not confounded with location; in our studies, bedding treatments were presented in a different order in each test pen. Finally, preferences are relative, that is, a nonpreferred option may nevertheless be acceptable. By measuring lying and standing times when the animals were restricted to a single surface, we were able to assess whether the forced use of a less preferred substrate would affect the animals' behavior.

In Experiment 1, cows showed an overwhelming preference for sawdust, and this preference persisted even after the animals had short-term exposure to both sand and mattresses. In Experiment 2, most individual animals had clear preferences, with 10 of 12 cows spending over 90% of their time lying on their first choice in the first free-choice phase. In this experiment, most animals ranked either sand or sawdust first. Mattresses were rarely preferred in either experiment.

Based on the results of Haley et al. (2000, 2001), we had expected that restricting animals to less preferred surfaces would result in a reduction in lying time, fewer lying events, and an increase in standing time. This was largely born out in Experiment 2, where mattresses were the nonpreferred surface and, during restriction to mattresses, lying times and number of lying events were reduced, and standing times increased.

In Experiment 1, the lying and standing behavior painted different pictures of how cows respond to nonpreferred surfaces. Because the number of lying events followed the same pattern as lying time, we will discuss only the results for the latter variable. In this experiment, sawdust was the preferred surface, but cows did not reduce their lying times when restricted to mattresses, suggesting that these cows also found this surface acceptable for lying. Interestingly, cows actually spent more time standing in the stall when restricted to the stalls with mattresses, perhaps because these cows found this surface especially suitable for standing. The amount of standing on all surfaces was much higher in Experiment 1 than in experiment 2, perhaps due to differences in hoof health that are known to affect standing times (Fregonesi et al., 2002).

The response in lying behavior to restriction to sand was more variable than to mattresses in Experiment 1. Some animals maintained high lying times on sand, but two animals completely rejected this less preferred surface, lying not at all or in the concrete alley. The rejection of the lying surface raises concerns about the suitability of sand for some individuals. However, in Experiment 1, confining animals to sand for 2 d was sufficient for two animals to switch their first choice from sawdust to sand, and previous exposure to sand for cows in Experiment 2 made sand roughly as desirable as sawdust for lying. Manninen et al. (2002) also reported lower lying times on sand and also found that additional experience with sand improved acceptance of this surface for most animals. In combination, these results suggest that at least some cows will require a period of adjustment when switching to sand bedding, but after a period of exposure this bedding is acceptable for dairy cows. The question of how long an adjustment period is required is still open. We know from these experiments that restriction of just a few days to different surfaces has little effect on preferences of most animals, but housing animals for several lactations on a surface appears to improve acceptance.

Table 2. Mean ± s.e.m time (h) spent lying, standing, and the number of lying events for three bedding surfaces during the restriction phase period.

	Surface		
Behavior	Sawdust	Sand	Mattress
Experiment 1[1,2]			
Lying (h)	14.3 ± 0.83	10.9 ± 1.57[a]	14.3 ± 0.54
Standing (h)	1.1 ± 0.35	0.7 ± 0.11	1.7 ± 0.40[a]
Number of lying events	9.1 ± 0.73	6.7 ± 1.06[a]	9.3 ± 0.68
Experiment 2[1,2]			
Lying (h)	15.0 ± 0.40	14.9 ± 0.62	13.3 ± 0.54[a]
Standing (h)	0.4 ± 0.08	0.4 ± 0.10	0.6 ± 0.08[a]
Number of lying events	10.5 ± 0.57	10.0 ± 0.48	8.5 ± 0.55[a]

[a]Significantly different from the preferred material (sawdust in Experiment 1; sawdust and sand in Experiment 2).

[1]Based on 12 cows per experiment but only 11 cows were included in sawdust restriction information in Experiment 2.

[2]Based on 24-h recording in Experiment 1 and 48-h in Experiment 2. Results for Experiment 2 are presented as per 24 h.

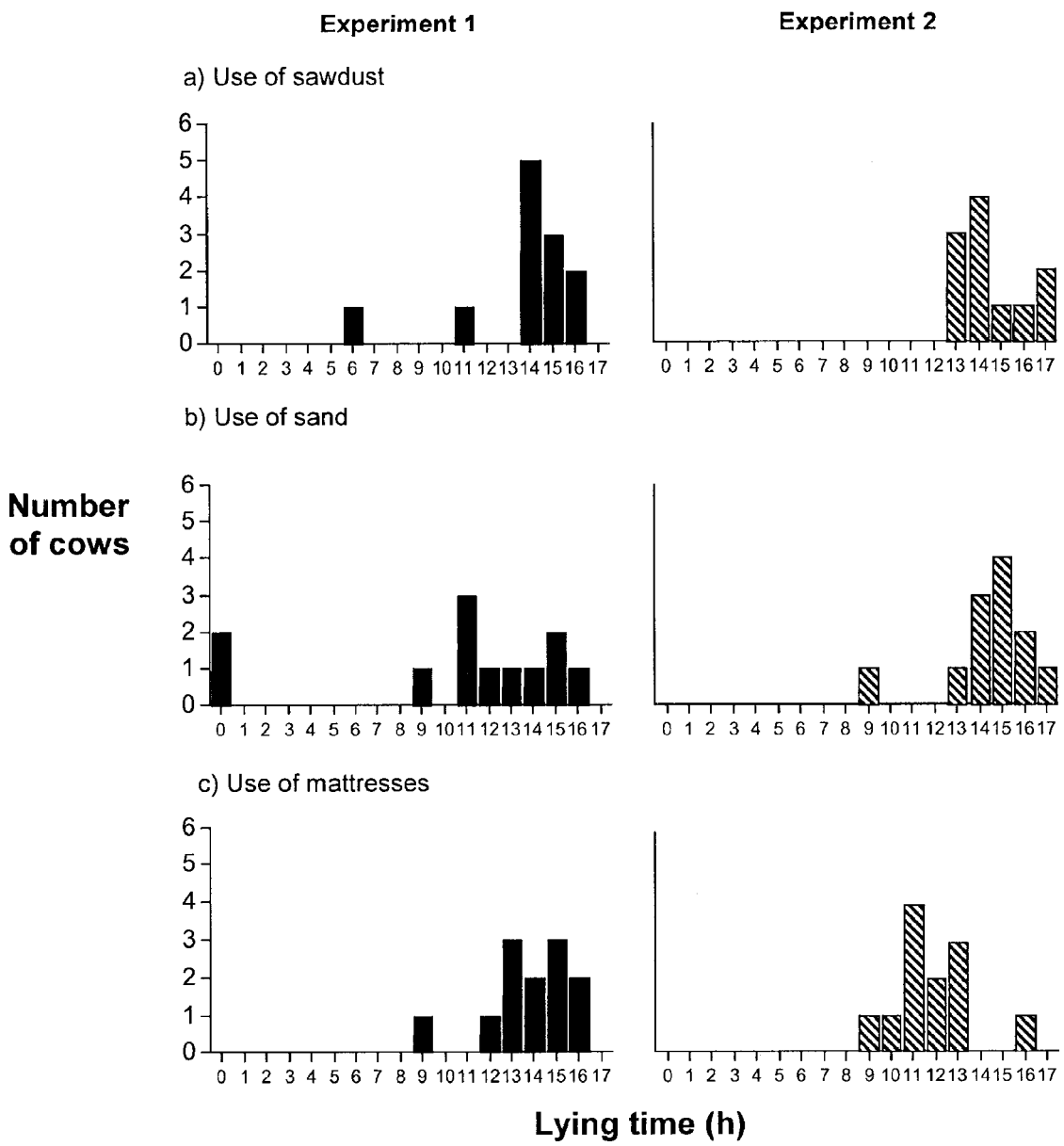

Figure 2. Frequency distributions of lying times during the restriction phase in Experiment 1 (left-hand panel, solid bars) and Experiment 2 (right-hand panel, striped bars). In Experiment 1, the distribution for sand (b) was noticeably flatter than that for sawdust (a) or mattresses (c), reflecting the variability in response to sand. In Experiment 2, the distributions for all three surfaces were very similar; however, for most animals, lying times were lower on mattresses compared to sand or sawdust.

In Experiment 1, cows showed good acceptance of mattresses for lying in the restriction phase, but in Experiment 2, lying time was significantly lower on mattresses than on either of the deep-bedded surfaces. This discrepancy may be explained by the cows in Experiment 1 being familiar with sawdust and thus finding any sawdust-bedded surface acceptable (i.e., either the deep-bedded sawdust or mattresses bedded with sawdust). The general trend in the literature is more consistent with the findings in Experiment 2, showing a preference for deep-bedded surfaces over those covered with wood, mats, or concrete (Muller and Botha, 1997; Lowe et al., 2001; except see Manninen et al., 2002). In addition, mattresses are associated with higher incidence and more severe hock lesions compared to deep bedding with either sand or sawdust (Weary and Taszkun, 2000). More work is required to determine whether alternative methods of

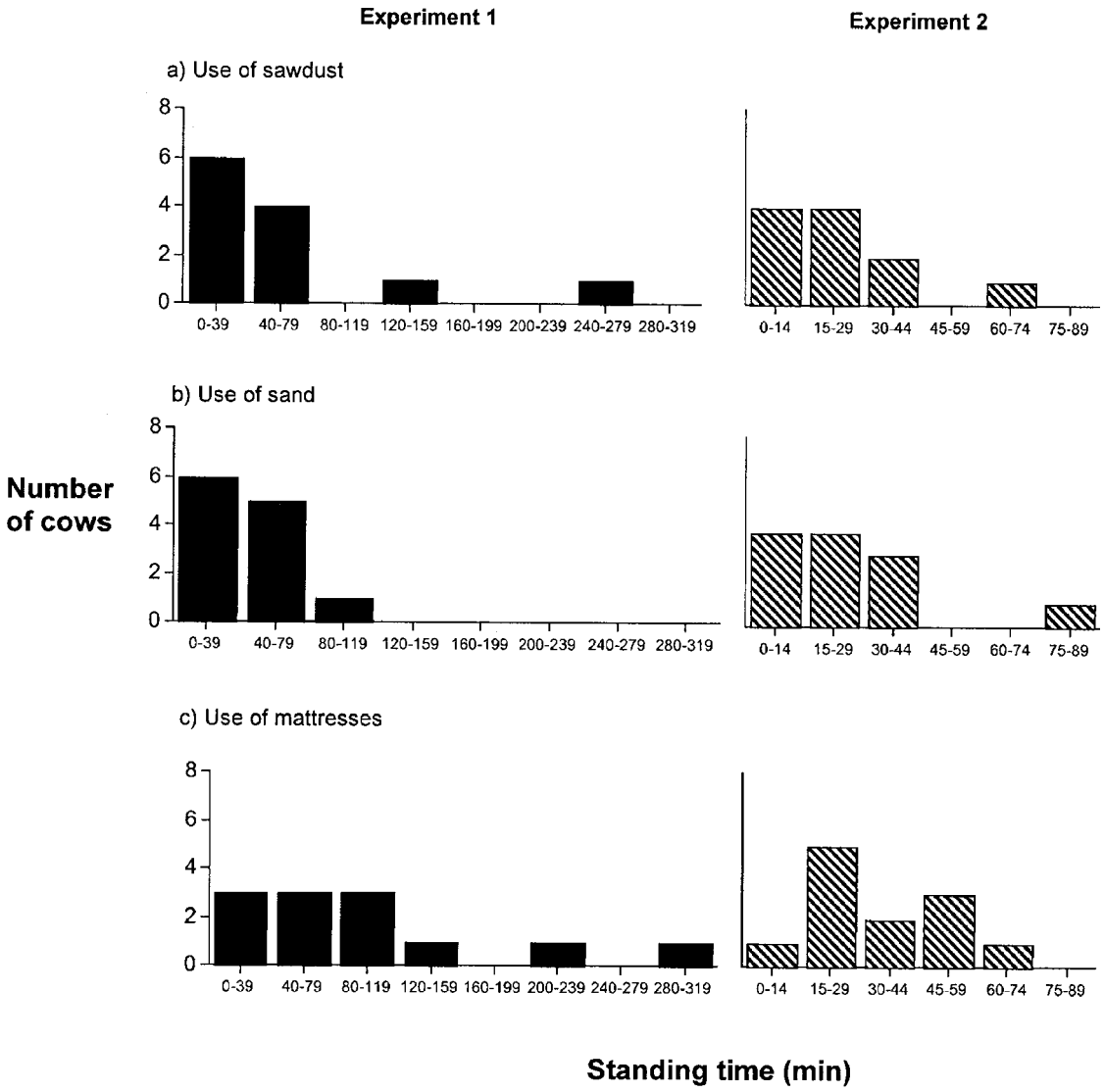

Figure 3. Frequency distributions of standing times during the restriction phase in Experiment 1 (left-hand panel, solid bars) and Experiment 2 (right-hand panel, striped bars). Standing was more variable on mattresses (c) than on sawdust (a) or sand (b) in both experiments 1 and 2. Standing times were higher in Experiment 1 than Experiment 2.

managing mattresses (such as the use of more bedding) could reduce injuries and increase acceptance.

More work is required on how differences between cows, such as in stage of lactation, age, social status, and health could affect their requirements for lying and standing in the stall. For example, time constraints, such as time spent in the parlor and time spent feeding, would likely differ with stage of lactation, and animals would have less time to spend performing other behaviors, such as lying down. In addition to cow factors, physical aspects of bedding could influence preference including thermal properties, texture, and footing. Indeed, it is possible that surface characteristics that are desirable for lying (e.g., softness) may not be the properties of surfaces most suitable for standing (e.g., stability). An analytical approach that examines how specific surface characteristics affect both lying and standing in free stalls is needed.

CONCLUSIONS

In conclusion, exposure to certain surfaces can cause reduced lying times for some animals, as seen with sand in Experiment 1 and mattresses in Experiment 2. Dairy producers should use caution when switching

bedding types, as previous experience may influence the behavioral response to new surfaces. Overall, there was a preference for softer surfaces, either sawdust or sand compared to mattresses. These results agree with other preference findings and correspond with the reduced incidence and severity of leg injuries found in animals housed on soft surfaces.

ACKNOWLEDGMENTS

We thank Dave Davis for his cooperation and the use of his animals; Amanda Zimmerman, Dominique Falconer, and Fay Wan for their excellent work in running segments of this study; Jeff Rushen for insightful comments on a previous draft of this manuscript; and members of the UBC South Campus Research and Teaching Complex, especially Ted Cathcart, Chris Shingara, Derek Masselink, Megan Atwood, and Barb DeCook, for their help in maintaining the experimental facilities. This research was supported by the Natural Sciences and Engineering Research Council of Canada through the Industrial Research Chair in Animal Welfare, and by contributions from the Dairy Farmers of Canada, the Beef Cattle Industry Development Fund, the BC Dairy Foundation, the BC SPCA, members of the BC Veterinary Medical Association, and many other donors listed on our web site at www.agsci.ubc.ca/animalwelfare.

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