Designing Better Environments for Dairy Cattle to Rest

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Take-Home Messages

- Adequate rest is essential to maintain the health, welfare, and productivity of dairy cows. Good stall design is essential to allow cows enough time to rest.
- Hard flooring or lack of bedding in both free-stalls and tie-stalls reduces the time that cows spend resting and increases the time they stand in the stalls.
- Cattle spend less time lying down and more time standing with their front legs in free-stalls that are too narrow.

Lying and Standing Behaviour: What Do We Know?

To maintain good health and welfare and high levels of productivity, it is essential that dairy cows have enough time to lie down and rest. Good design of the lying areas for dairy cows is important to ensure that they have adequate rest. An increased risk of lameness can result from poorly designed stalls that lead cows to spend more time on standing on wet concrete.

There have been many studies looking at how much time dairy cows spend lying down and these results are summarised in Table 1. Average lying times ranged between 9.4 and 14.7 h per 24 h across experiments. However, when given comfortable places to lie down, lactating cows tend to lay down for at least 12 h a day. Dairy cows divide this time into an average of 8.2-14.1 lying bouts per day, with average bout duration ranging from 0.9 to 1.4 h.

Table 1. Summary of mean values for lying behaviour (lying time in h/24h, number of lying events/24 h, and bout length in h) across different housing systems (tie-stall, loose housing, free-stall, and pasture) with various surface materials. The dash (-) indicates that the paper did not include this measure over a 24-h period, if at all.

Source	Surface	Lying time	# of lying events	Bout length
Tie-stalls				
Dechamps et al., 1989	Concrete: American yoke	10.5	10.6	-
Dechamps et al., 1989	Concrete: bar at back	11.5	13.4	-
Haley et al., 2001	Concrete	10.4	9.0	1.3
Haley et al., 2001	Mattress	12.3	13.1	1.0
Hultgren, 2001	Rubber slatted floor	12.2	-	0.9
Hultgren, 2001	Solid floor	12.2	-	1.0
Krohn and Munksgaard, 1993	Mat & straw	13.0	-	-
Loose housing: bedded areas				
Fregonesi and Leaver, 2001	Straw yard: Expt 1:HS[1]	13.2	-	-
Haley et al., 2000	Pen with mattresses	14.7	13.6	1.1
Krohn and Munksgaard, 1993	Deep bedding (unspecified)	10.1	-	-
Mogensen et al., 1996	Straw pen: herds with 1.8 m^2	13.1	11.0	-
Singh et al., 1994	Straw yard	9.7	-	-
Loose housing: Free-stalls				
Fregonesi and Leaver, 2001	Straw: Experiment 1:HC[2]	11.9	-	-
Manninen et al., 2002	Straw: winter	12.9	11.9	1.1
Manninen et al., 2002	Rubber mat: winter	12.5	10.7	1.2
Manninen et al., 2002	Sand: winter	7.5	6.8	1.1
Schrader, 2002	Straw	-	-	1.4
Wechsler et al., 2000	Kraiburg mat	11.4	13	1.1
Wechsler et al., 2000	Straw mattress	11.6	13	1.1
Pasture				
Singh et al., 1993	Pasture: 1st observation	9.6	-	-
Krohn et al., 1992	Pasture/indoor bedded area	10.1	-	-

[1]High-yielding cows housed in strawyard
[2]High-yielding cows housed in cubicle

Lying time is thought to be important to dairy cattle based on several lines of evidence. When prevented from lying down for 3 h, dairy cows will forego eating in order to lie down (Metz, 1985). Additionally, several physiological changes are associated with reduced lying time; these include a decrease in circulating levels of growth hormone (Munksgaard and Løvendahl, 1993), and a short-term increase in plasma cortisol levels (a common physiological response to stress) (e.g. Fisher et al., 2002). The most worrying consequence of insufficient rest, however, is an increased incidence of lameness (Leonard et al., 1994, Singh et al., 1993).

Cattle also spend time standing in the areas provided for lying, like free-stalls. However, the standing behaviour performed in the free-stall has not been documented to the same extent as lying behaviour. Previous research has identified two broad categories of standing in free-stalls based on the number of legs in the stall at one time. For example, Stefanowska et al. (2001) reported that their experimental animals spent between 35 and 60 minutes standing with all four legs in the free-stall, and between 91 and 174 minutes per day standing with only the front legs in the stall and the back legs in the alley. These estimates of standing times are similar to those of Galindo et al. (2000), who reported mean values of 81 min (all four legs in the stall) and 89 min (only the front legs in the stall) standing time per day.

Both standing and lying in the bedded area are thought to be important because the flooring surface outside the lying area is often concrete. A number of studies (reviewed in the companion paper by Rushen et al. in this volume) have shown that use of concrete floors in dairy barns tends to be associated with poorer quality hooves. Standing entirely in the stall reduces the cows' contact with concrete and with any slurry in the alley, and this reduced exposure to moisture is associated with a lower incidence of hoof injuries (Fitzgerald et al., 2000) and higher sole dry matter content (Bergsten and Pettersson, 1992; see the companion paper in this volume by Rushen et al.). We do not yet know whether standing with only the front legs in the stall provides the same advantages to cows. However, when cows stand with only the front two legs in the stall, this may result in more weight being placed on their hind legs, which could increase the risk of lameness. Cows that spent more time standing with only the front legs in the stall are more likely to have more claw lesions (e.g. Flower and Weary, 2002), but it is not clear if the injuries result from the behaviour, or vice-versa.

■ Using Behaviour to Assess Housing Systems

To assess the impact of housing design on dairy cattle, we have conducted a series of experiments comparing various features of stalls, with special emphasis on the amount of time that cows spend lying and standing.

Time spent lying and standing can provide information about how comfortable cows find a given housing system. For example, Haley et al. (2000) compared dairy cattle behaviour in two housing systems, a 'high comfort' environment (large pen, with mattresses surface, bedded with straw) with a 'low comfort' environment (tie-stall with concrete bedded lightly with straw). They found that cows spent an additional 4 h/day lying down in the 'high-comfort' pen compared to the 'low-comfort' tie-stall. There were no differences in the amount of time spent eating, but cows in the 'low comfort' environment spent more time standing without eating. There were many differences between the two types of pens tested in this experiment including the amount of space provided and the lying surface. Recently, we've gained insight into how these two specific housing features influence the behaviour and comfort of dairy cattle.

Lying Surface

The level of comfort of both tie-stalls and free-stalls will depend greatly on the type and quality of the floor surface in the stall. Optimal stall surfaces should provide adequate thermal insulation (depending on the temperature), an appropriate degree of softness, appropriate degree of friction, a low risk of abrasion and should be easy to maintain and clean. Both the physical properties and the maintenance of the stall surface are critical to avoid injury and allow adequate rest. Indeed, lying times are lower and standing times higher when dairy cattle are forced to lie down on hard surfaces like concrete (e.g. Haley et al., 2001). However, when concrete is covered with bedding, lying times are similar to those seen with soft mats (e.g. Manninen et al., 2002). Lying times also tend to be longer and standing times shorter for deep-bedded stalls compared to wood-covered stalls or mattresses (Muller and Botha, 1997; Tucker et al., 2003). Various types of mats and mattresses, often alleged to improve cow comfort, are now available to dairy producers, but little research has actually evaluated these products.

Free-Stall Surfaces In one recent experiment at UBC, we examined the effect of the amount of sawdust bedding on the time spent lying and standing by cows housed in free-stalls (Tucker et al., submitted). Each stall was fitted with a geotextile mattress, and bedded with one of three levels of kiln-dried sawdust: 0, 1, and 7.5 kg. The lower two levels of bedding (0 and 1 kg) reflected the use of sawdust in common commercial practice. The largest amount of sawdust (7.5 kg) was chosen to provide an extremely well-bedded option, similar to that found in deep-bedded stalls. We found that cows spent, on average, 1.5 h more time lying down when 7.5 kg of sawdust was provided, compared to the bare mattress (Figure 1). Cows increased lying times on the 7.5-kg option by lying down more often during the day, not by lying down for longer periods of time. In addition, cows spent less time standing with only the front legs in the stall when the mattresses were heavily bedded. Both these changes in standing and lying behaviour indicate that cows are hesitant to lie down on poorly bedded

mattresses. Thus, to improve lying times and reduce time spent standing with only the front legs in the stall, geotextile mattresses are best managed with copious bedding.

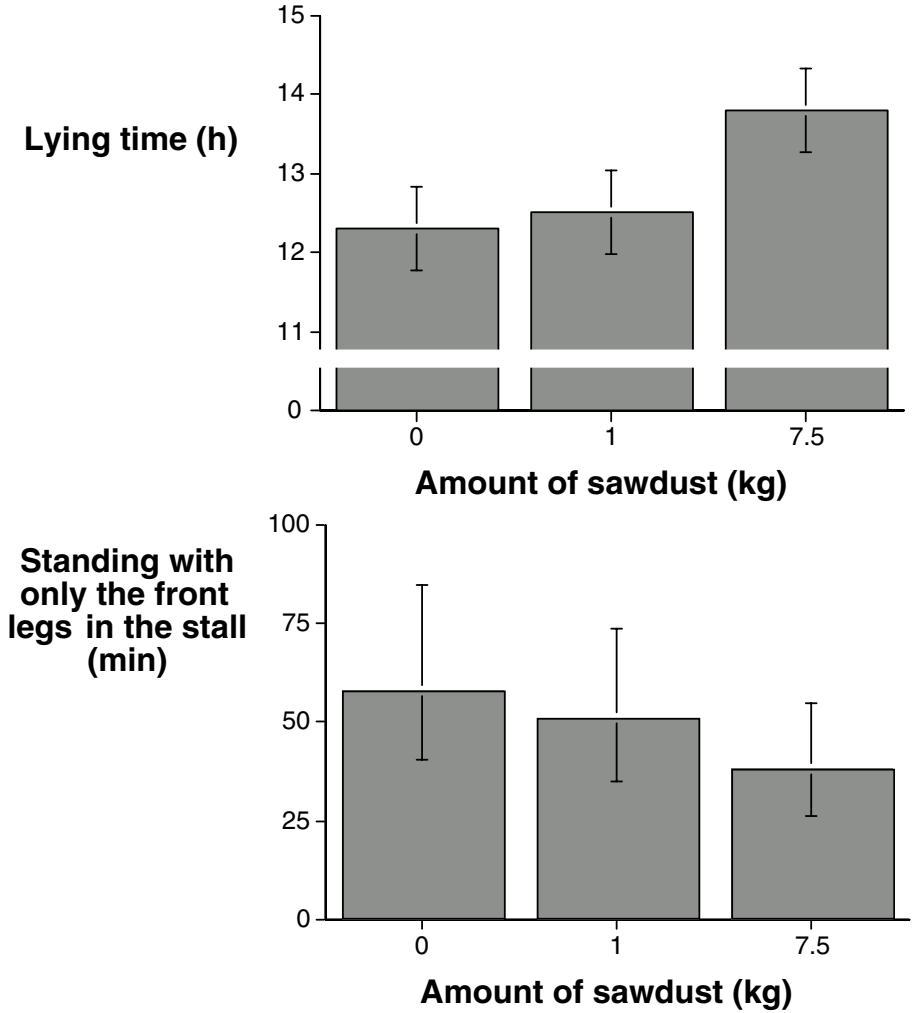

Figure 1. Time per day spent lying (top) and standing with only the front legs (bottom) in the stall in response to three levels of kiln-dried sawdust on geotextile mattresses. Adapted from Tucker and Weary, submitted.

As we have described previously (e.g. Tucker and Weary, 2001), these changes in behaviour due to the floor surface of the stall correspond with other measures of cow comfort. Previous work has shown that mattresses with little

bedding are associated with a higher incidence and more severe hock lesions compared to deep-bedded surfaces (e.g. Weary and Taszkun, 2000). Indeed, Nilsson (1992) found hock injuries were more common when cattle were housed on surfaces with less penetration (or harder surfaces). By covering mattresses with a thick layer of bedding (as in 7.5 kg of sawdust treatment), the surface will be softer and is likely to reduce the incidence of leg injuries. Claw health may also relate to lying surface: increased amounts of bedding (Colam-Ainsworth et al*.,* 1989), and rubber mats instead of concrete (Leonard et al., 1994), reduce problems with hoof health.

Tie-Stall Surfaces Two studies at Lennoxville (Haley et al., 2001; Rushen et al., 2001) examined the advantages of providing soft rubber mats or geotextile mattresses to cows in tie-stalls. Cows kept on the softer mats or mattresses spent an extra 1.5 hours per day lying down compared to cows that were kept in tie-stalls with bare concrete floors. Cows housed on concrete floors spent more time standing idle, which supports the idea that an increase in the time that cows stand without eating may be an indicator of a lack of stall comfort. Just like the experiment with free-stall bedding described above, the main reason why the cows on concrete lay down for a shorter period of time was because they lay down less often, not because they lay down for shorter periods of time. In fact, once the cows on concrete lay down, they stayed lying down for longer than the cows on the rubber mats. The hesitancy of the cows to lie down on concrete probably resulted from pain in the knees. The incidence of swollen knees was much higher and became worse the longer the cows were kept on concrete (Figure 2). Furthermore, the cows that had the most swollen knees were also the cows that lay down the least. Thus it seems that the concrete floors led to swollen knees, which, in turn, made the cows unwilling to lie down. The concrete floors also increased the occurrence of cuts and abrasions on the legs but these were most frequent when the cows were initially placed in the stalls (Figure 2).

It is clear from these results that bare concrete floors in tie-stalls substantially reduce the time that cows spend lying down and increase the chance of injury to the legs, leading especially to swelling in the front legs. Lightly-bedded concrete is insufficient to maintain cow comfort and should be avoided.

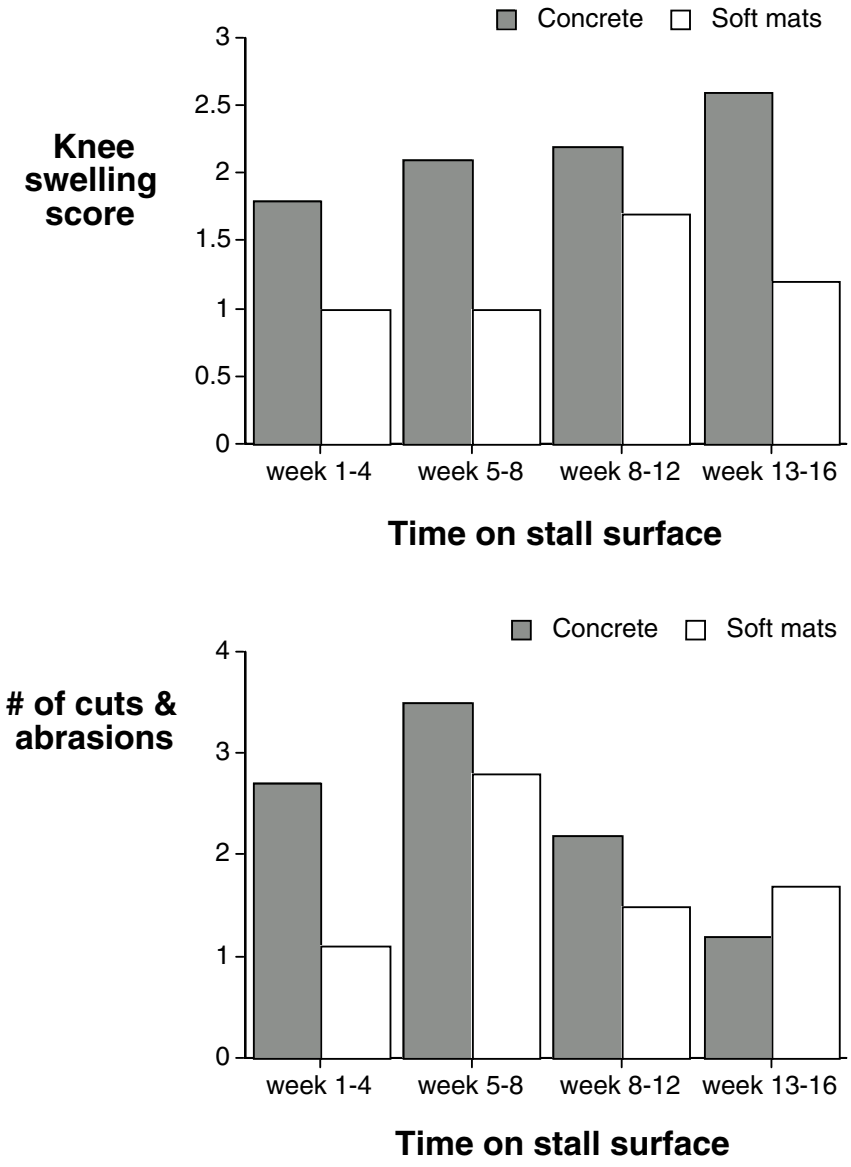

Figure 2. The occurrence of swollen (front) knees (top) and of cuts and abrasions on the legs (bottom) for cows kept in tie-stalls either with a bare concrete floor or with a soft rubber mat. The knee swelling score ranges from 0 to 8, where 8 indicates both knees were swollen on all four weeks. A score of 2 indicates either that both knees were swollen for one week or that one knee was swollen for two weeks etc. The score for cuts

on legs indicates the average number of cuts or abrasions found on all legs.

Stall Configuration and Size

The comfort of the animals will also depend upon the dimensions and configuration of the space provided for lying. Below, we describe two experiments looking at both stall configuration and dimensions.

Although recommendations for stall dimensions are available, there is little research to indicate just how much space cows actually need. In an experiment at UBC, Ceballos et al. (in press) filmed cows as they lay down and used kinematic techniques to provide accurate measures of the space envelope used by the cows. The cows used approximately 260 to 290 cm of longitudinal space when lying down, and this is more than is provided by current industry recommendations for stall length. Cows used approximately 70 to 100 cm of lateral space (120% to 180% of hip width), an estimate that is within current recommendations for stall width. As the cows were lying down, the largest horizontal movements of the hip occurred at two heights: one between 90 and 135 cm, and the second below 50 cm above the lying surface. The largest backward and forward movement of the nose occurred at 10 to 30 cm above the surface. These results show the heights that should be left free when positioning stall partitions so as to ensure that cows do not hit the stall partitions when lying down. These results also show that kinematic techniques are promising ways of assessing the spatial requirements of cattle, and represent a promising new approach to improve stall design.

In addition to understanding the space required during the lying down movement, we have also conducted several experiments to understand how stall size and configuration influence cow position and lying times.

Tie-Stall Configuration Research at Lennoxville (done in collaboration with Derek Haley) has shown that some types of stall front used in tie-stalls can reduce the effective space available to the cows. For example, when stalls are fitted with the type of front that consists of a series of vertical bars with a narrow gap in between (shown in Figure 3), the cows are much less likely to lie down with their head in front of the bars than when more open front stalls are used. Our research looked at the location of the cow within the stall, and we found that the cows were positioned about 5 cm further back (on average) in the stall when lying down with this type of stall front. Furthermore, cows were more likely to place their heads in the stalls of neighbouring cows and their rear hooves in the gutter behind the stall. Thus the type of stall front illustrated in Figure 3 reduced the effective length of the stall. We recommend that farmers using tie-stalls use a stall configuration that allows the cows to use the space to its maximum. Simple horizontal bars appear to be most suitable.

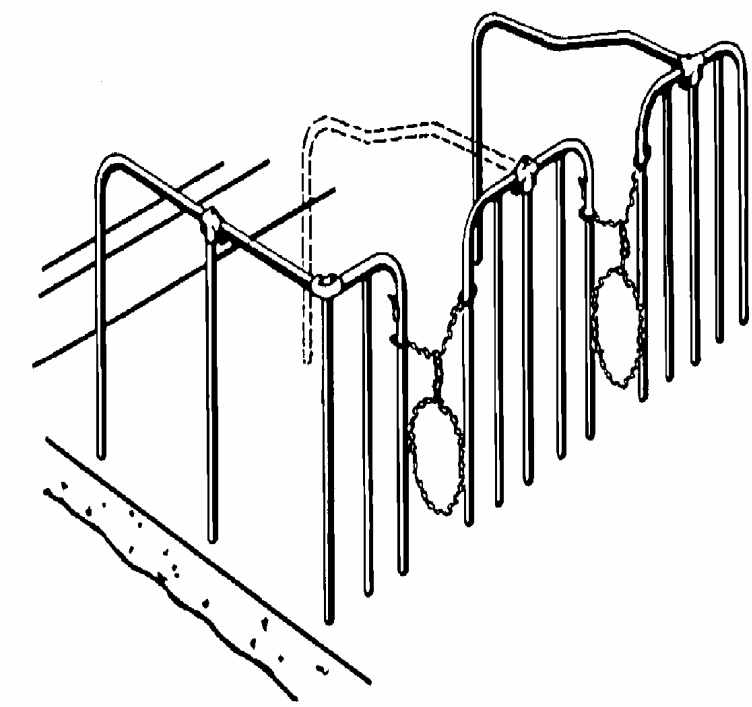

Figure 3. A common type of stall front found in tie-stalls. Use of such stall fronts can prevent the cows placing their heads in front of the bars when lying down. This reduces the effective length of the stall by up to 5 cm, increases the chance that cows will place their rear hooves in the gutter behind the stall and increases the chance that cows will try to place their heads into their neighbours stall.

Free-Stall Size In another recent experiment, we examined the effect of free-stall width on dairy cattle behaviour (Tucker et al., in press). We compared the lying and standing times of cattle housed in free-stalls measuring 106, 116, or 126 cm between partitions. Animals spent an additional 42 min/ 24 h lying in stalls measuring 126 cm in width compared to stalls those 106 cm wide (Figure 4). Cows lay down for longer in the wide stalls, perhaps because they had less contact with the partitions in these larger, more comfortable stalls. Free-stall width also influenced the time spent standing with only the front legs in the stall; animals averaged 58 min / 24 h in the widest stalls and 85 min / 24 h in the narrowest.

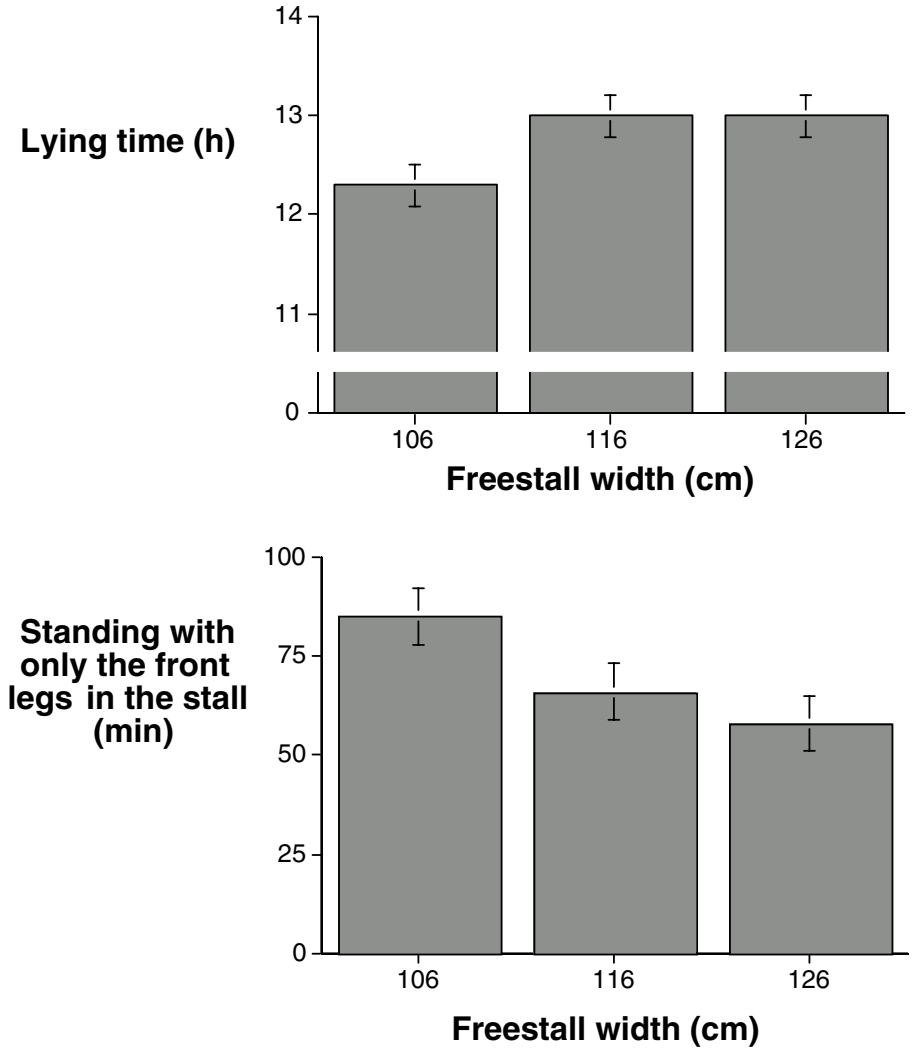

Figure 4. Time per day spent lying (top) and standing with only the front legs (bottom) in the stall in response to free-stall width. Adapted from Tucker et al., in press.

In addition to changes in lying and standing behaviour described above, the amount of time spent standing with all four legs in the stall tended to be longer in wider stalls. There are good reasons for dairy cattle to avoid standing on uncomfortable flooring surfaces, by standing entirely in or lying down in the free-stall. As reviewed by Rushen et al. (this volume), hoof health may be

improved by limiting exposure to hard, uncomfortable flooring surfaces outside of the stall.

However, providing cows with more comfortable free-stalls has some drawbacks. In the experiment described above, the widest stalls (126 cm) were more than twice as likely to become soiled with faeces compared to the narrowest option (106 cm). Extensive faecal contamination of stalls may be a factor in transmission of environmental mastitis. Indeed, Schreiner and Ruegg (2003) found that the milk of cows with dirtier udders had higher somatic cell counts and more intramammary environmental pathogens than milk from cows with clean udders. In addition, faeces introduce additional moisture to the stall. Exposure to moisture is associated with a higher incidence of sole lesions (Fitzgerald et al., 2000) and lower dry matter content in the hoof (Bergsten and Pettersson, 1992; see the companion paper in this volume by Rushen et al.). It is clear that faeces are undesirable in the free-stall.

However, should we be using faecal contamination alone as a measure of good stall design? Gaworski et al. (2003) used a 1-m^2 metal grid, containing 100 equal sized squares at the back of the stall to measure the amount of faecal contamination. They found that free-stalls that had higher occupancy rates were more likely to contain faeces (Figure 5); in other words, stalls that are used little stay clean. It thus seems inappropriate to use stall cleanliness as the only measure for evaluating free-stall design. Rather, we recommend that producers minimise the effects of faeces in well-used stalls with additional stall maintenance. Well-used stalls will require additional maintenance, much like a well-used truck requires more frequent oil changes.

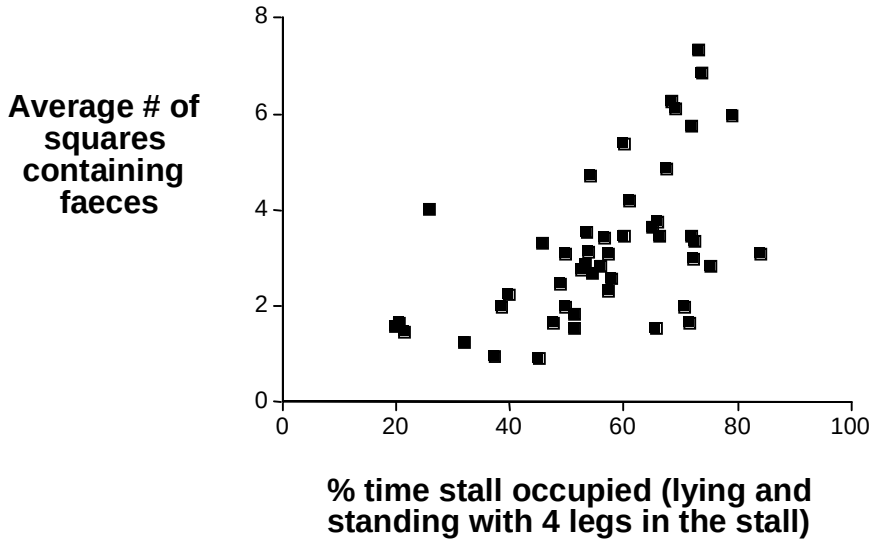

Figure 5. Relationship between stall cleanliness (number of squares containing faeces) and stall usage (lying and standing with four legs in the stall, expressed as a percentage of time present in pen). R^2=0.30; adapted from Gaworski et al., 2003.

■ Future Directions of Dairy Cattle Housing Research

Much work to date has focused on the physical design of dairy cattle housing and many questions remain unanswered. For example, future research could investigate which physical properties of lying surfaces are important to dairy cattle. We could compare free-stall surfaces that differ in only one physical property (e.g. compressibility, thermal conductance, coefficient of friction), rather than using materials like sawdust, where resilience is likely correlated with thermal insulation. This approach would allow the results to be useful to a broader range of farmers, regardless of the bedding types available in their region. In addition to the physical environment, we need to know more about the best way to manage these environments (e.g. free-stall maintenance and stocking density). Finally, additional information is required about longer-term effects of cow comfort on more vulnerable cows in the herd, such as those that are lame, socially subordinate, or in the early stages of lactation.

■ Acknowledgements:

The research reported in this article was funded by the Dairy Farmers of Canada, the Natural Sciences and Engineering Research Council of Canada and Agriculture, and Agri-Food Canada's MII funds. We thank everyone who helped us in this research, especially the following: Isabelle Blanchet, Art Ceballos, Derek Haley, David Fraser, Marek Gaworski, David Sanderson, and Marjolaine St.-Louis.

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