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The science of cow comfort

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Take home messages

- Achieving genuine improvements in housing for dairy cattle requires methodologies that accurately reflect the impact of the housing on the animal.
- We review three approaches to the study of cow comfort: measures of injuries, preference testing and measures of usage, namely standing and lying behaviour.
- For each approach a level of sophistication is required to avoid pitfalls. We discuss how inadequate controls and inappropriate measures can provide misleading results.

Introduction

Although ‘cow comfort’ is becoming a common buzzword among dairy producers and professionals, research on how housing features affect cattle is still in its infancy and only a few scientists are working actively in this area. Given the lack of research on animal housing, it is not surprising that dairy producers are faced with a bewildering range of recommendations. For example, recommendations for free-stall dimensions vary widely in producer-oriented articles; Schoonmaker (1999) suggested that stalls for adult Holsteins should be between 120 -130 cm in width and 255 –270 cm in length, whereas Leonard et al. (1997) recommended a width of only 111 cm and a length of 222 cm for adult cows. Some authors recommend sand bedding (e.g. Bickert, 2000) while many farmers still use sawdust or straw. Unfortunately, many recommendations have little scientific basis, and some that do are derived from basic work done 20-50 years ago that may not be relevant to the modern dairy cow.

Our group and a few others worldwide have begun to apply modern techniques to the scientific study of cow comfort. In this paper, we describe some of the research derived from asking three types of question: First, does the housing cause injuries to animals? Secondly, what types of housing do the animals actually prefer? And finally, how does the housing affect the animal’s behaviour? We address each of these questions in turn.

Measures of disease and injury

Although there is some debate about which measures of cow comfort are most appropriate, most scientists, farmers, and veterinarians agree that housing systems that cause disease or injuries to animals are undesirable. For example, choice of bedding material can alter the risk of udder infections, and much recent work has focussed on risks of organic versus inorganic bedding (see

Zdanowicz, 2003 for review). Several authors also have identified aspects of housing systems that contribute to a high prevalence of foot and leg problems (e.g. Vokey et al., 2001), including lameness and leg lesions. For the purpose of this section we will discuss the skin lesions that occur around the tarsal joint or hock.

A number of studies have now shown how stall features can contribute to the prevalence of hock lesions. For example, Rodenburg et al. (1994) scored lesions on a number of farms in Ontario and found differences depending on the type of surface used in the freestall. Specifically, they found more lesions on cows bedded on solid rubber mats than on those bedded on geotextile mattresses. A British study also found a higher prevalence of lesions on farms using solid mats than on those farms using mattresses (Livesey et al., 1998). Although mattresses cause fewer injuries than solid mats, a series of recent experiments have shown that lesions are more prevalent on farms using mattresses than on those with deep-bedded stalls (Weary and Taszkun, 2000; Wechsler et al., 2000; Vokey et al., 2001). Mattresses remain popular among many dairy producers, and research is required to identify improved methods of managing stalls with mattresses, so as to reduce the risk of injuries. More fundamentally, we need a better understanding of how and when lesions are likely to develop in order to design housing systems that prevent lesions.

Below we review two experiments described in Mowbray et al. (2003). In the first, we show how hock lesions develop over time for dairy cattle using stalls with deep bedding compared to those using geotextile mattresses. In the second, we show how lesions can be reduced by modifying the way mattresses are installed. For both experiments, hock lesions were scored twice per week for six weeks while the animals were in the milking parlour. Lesions were measured on the medial and lateral surfaces of the tarsal (hock) joint and on the dorsal, medial and lateral surfaces of the tuber calcis (point of the hock). For each visible area of hair loss we measured the diameter (cm) along both the x- and y-axes (i.e. horizontal and perpendicular to ground level), and calculated the area (cm²) affected. In addition, any area where the skin surface was broken (as evidenced by either an open sore or a scab of dried blood) was measured in the same way. Areas of skin breakage normally occurred within an area of hair loss.

Lesions on cows using mattresses versus deep-bedded sand

In the first experiment, lactating cows were randomly assigned to freestalls with either deep-bedded sand or geotextile mattresses on the day of calving. Stalls in the deep-bedded area had in excess of 20 cm of washed river sand over a dirt base. Stalls in the mattress area had a geotextile mattress covered with about 3 cm of kiln-dried sawdust bedding.

The results showed that skin lesions on the hocks of dairy cattle develop rapidly over the first 6 weeks of lactation (Fig. 1). The areas of hair loss and skin breakage on the tarsal joint increased more rapidly for cows housed in stalls with geotextile mattresses than for cows using deep-bedded stalls. Indeed, areas of both hair loss and skin breakage on the tarsal joint are more than 10 fold larger for cows housed on geotextile mattresses.

Interestingly, the injuries on the tuber calcis showed the reverse pattern, with much larger areas of hair loss on cows using deep-bedded stalls than on those using mattresses. Similarly, Weary and Taszkun (2000) reported a higher prevalence of these lesions for cows using deep-bedded

stalls than those using mattresses. In addition, they found that the difference in the total number of lesions was driven by the large number of lesions on the dorsal surface of the tuber calcis. The higher prevalence of these lesions on the dorsal surface is likely due to contact with the curb at the rear of the deep-bedded stalls; such contact is often not possible in freestalls fitted with geotextile mattresses.

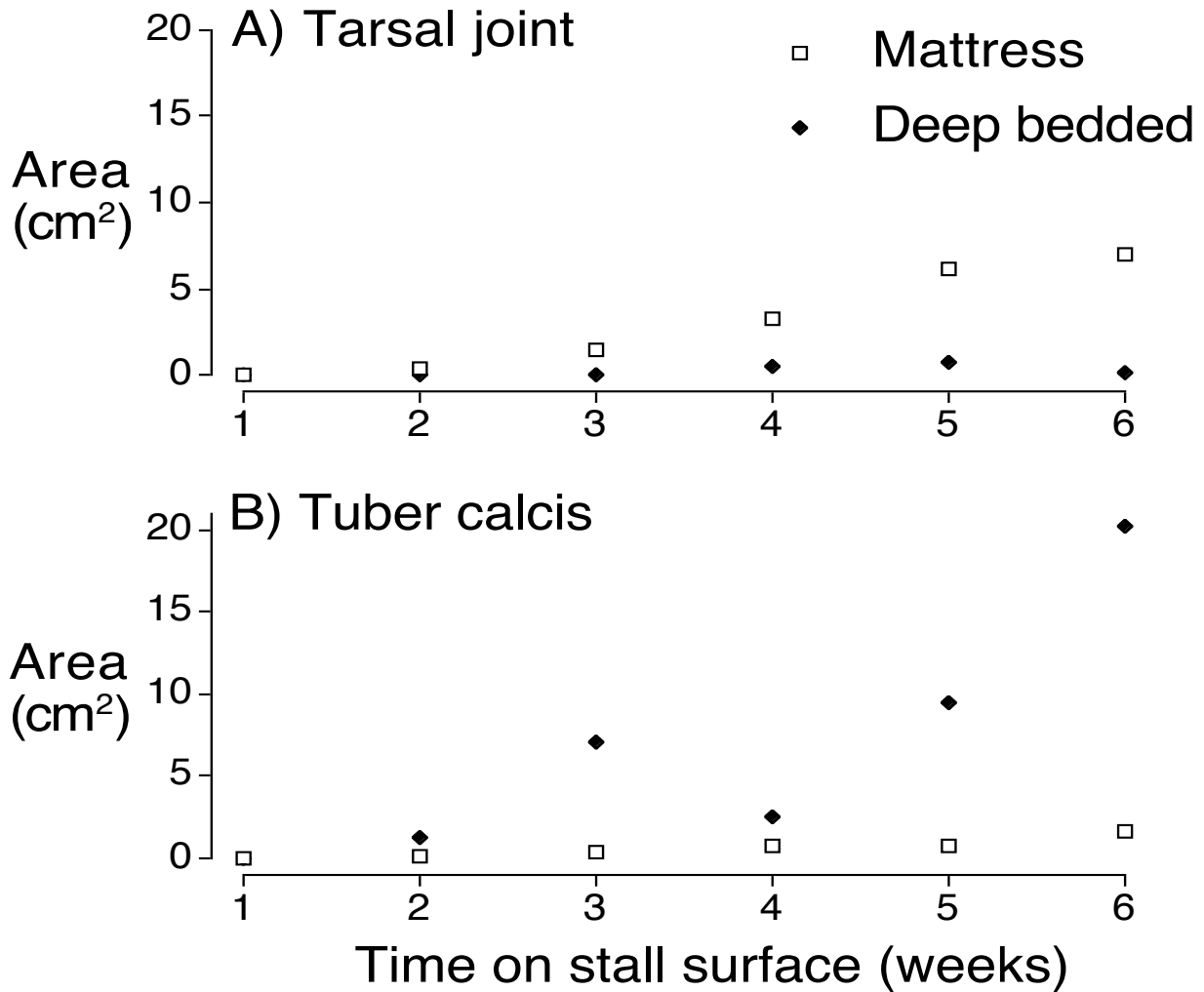


Figure 1. The mean area of hair loss on A) the tarsal joint (hock joint) and B) the tuber calcis (point of the hock). Data are shown separately for cows using stalls with geotextile mattresses, and those using stalls that were deep bedded with sand (Mowbray et al., 2003).

Lesions on cows using recessed mattresses covered with sand versus deep-bedded sand
 In the second experiment, cows were randomly assigned to the stalls with either deep sand bedding or geotextile mattresses recessed 5 cm below the curb, such that 3-5 cm of sand bedding could be maintained on the surface of the mattress. The mattresses recessed a few cm below the curb and covered with sand resulted in few lesions (Fig. 2), and there was no difference in the mean area of lesions on the tarsal joint for cows using recessed mattresses and cows using stalls with deep sand bedding. However, as in Experiment 1, we found that lesions on the tuber calcis were again more of a problem from cows using the deep-bedded stalls. This may be because in

deep-bedded stalls the rear curb is more likely to protrude in a way that it comes into contact with the point of the hock. This effect may be even more pronounced under typical commercial conditions when bedding is not always well maintained. In stalls with recessed mattresses covered with sand, the extent to which the curb protrudes is limited to 5 cm, even under conditions of poor stall maintenance.

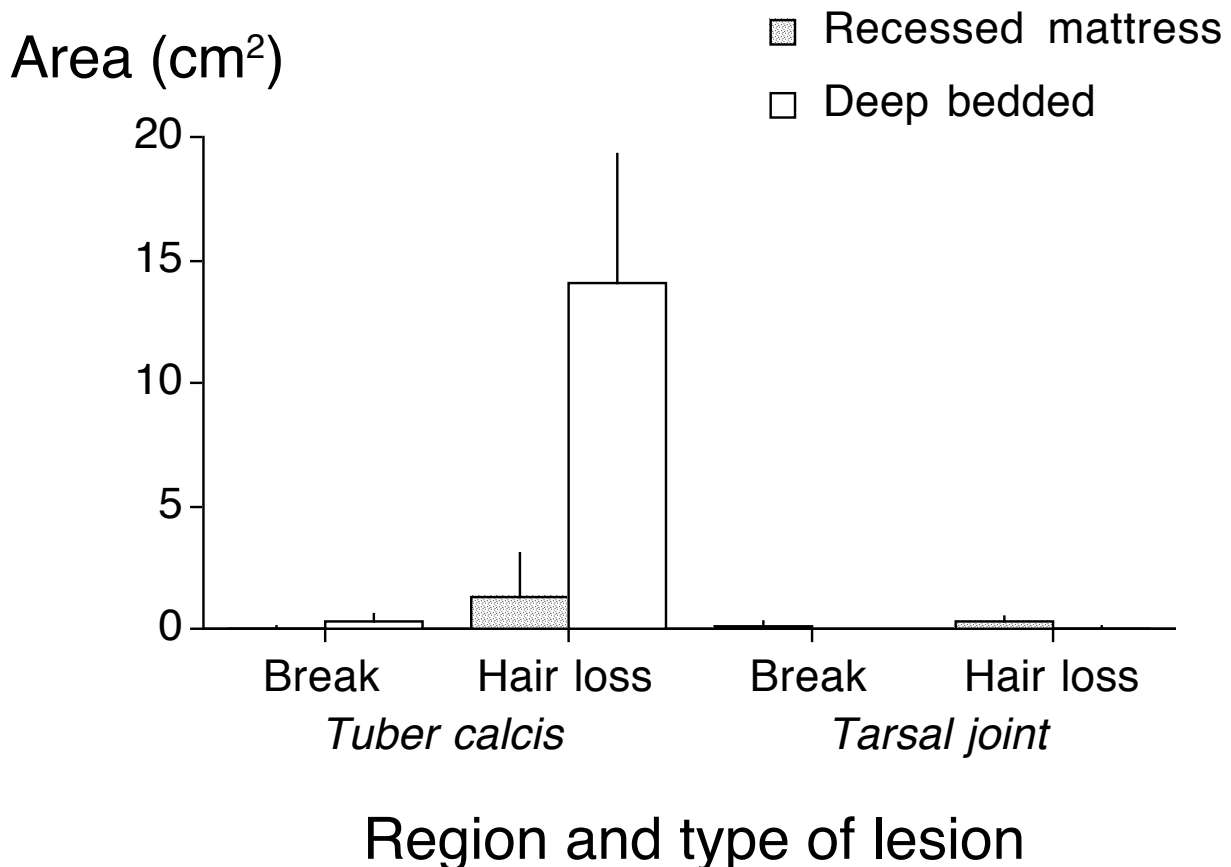


Figure 2. The mean (+ SE) area of hair loss and skin breakage (break) on the tuber calcis and tarsal joint. Values are shown separately for cows using stalls with a deep (20 cm +) sand base and those using geotextile mattresses recessed below the curb covered with 3-5 cm of sand bedding (Mowbray et al., 2003).

Weary and Taszkun (2000) argued that although the surface of the mattress is not sufficiently abrasive to cause lesions, friction between the leg and mattress may allow for heat build up that reduces the strength of the skin. Mowbray et al. (2003) attempted to reduce the frictional injuries by adding limestone flour to bedding, but this was not effective in reducing injuries either because the flour did not reduce friction as anticipated, or because reduced frictional heat is not an important cause of hock injuries in dairy cattle.

In addition to frictional heat, another possible cause of such skin lesions is pressure from body weight of the animal that reduces blood flow to skin over the area of contact with the lying surface (e.g. O'Sullivan et al., 1997; Spector, 1994). Such pressure ulcers or “bed sores” would

likely be affected by the addition of bedding, as more pliable materials support a greater proportion of the cow's surface area thus reducing pressure at any one point.

To make good use of injuries as a measure of cow comfort, we need to be aware of potential shortcomings with both how injuries are assessed and the interpretation of these data. Injuries are often evaluated using qualitative methods of assessment (e.g. subjective scores used by Weary and Tazskun, 2000), or with quantitative measurements such as surface area of the hair loss as in the preceding example. The quantitative measurements have the advantage of being more repeatable, and more amenable to parametric statistical analyses. The choice of the method of assessment should ultimately depend of how well it reflects the way that the injury actually affects the animal, either in terms of the pain experienced, or in predisposing the animal to other injuries, infections or physical impairments such as abnormal gait. Unfortunately, for these leg injuries, and for many other types of injuries such as hoof lesions, little or no research is yet available to establish these links.

More work is also required to understand the mechanisms by which housing causes different injuries or disease. Studies like the one described above can be useful in providing specific improvements, but a better understanding of the ways in which the injuries develop and the mechanisms involved are needed to provide more general recommendations.

Measures of preference

Preference testing, or asking the animal to make choices between different options, is a technique that has been used to improve animal housing since the 1970s (Fraser and Matthews, 1997). The first preference tests examined the choices of hens for different types of cage flooring (Hughes and Black, 1973) and preference testing has since been used in many experiments to assess housing conditions for agricultural animals. Preferences are of interest because they can provide insight into what aspects of housing the animal perceives as important. In essence, preference tests ask animals to "vote with their feet" and provide information about what is important to them through their behaviour.

We have used preference experiments as a first phase in identifying key features of the freestall. Below we review some recent work on the preferences of dairy cattle for different types of lying surface. These studies serve to illustrate potential problems with this approach and how they can be avoided.

Cow preferences for different lying substrates

Bedding for dairy cattle has been the topic of several preference tests, all comparing different surfaces in different ways. As we reviewed in Tucker and Weary (2001), the general conclusion from this bedding preference literature is that dairy cattle prefer softer surfaces. However, this literature also shows some design problems that can occur with cattle housing experiments. For example, Herlin (1997) compared cow preferences for concrete, rubber mats (15 mm thick), and "comfort" mats (21 mm thick), by offering a group of 18 cows six stalls of each type. He found that cows were more likely to spend time lying down on comfort mats than on the rubber and, they were more likely to use the rubber than the concrete. However, in an experiment like this

there are two problems. First, preferences of individual animals may not be independent (some cows may chose to associate with or avoid certain animals), and secondly, the extent of preference may be underestimated as not all animals can chose the same option (e.g. all 18 animals might have chosen the comfort mats if 18 stalls with this option had been provided).

Our approach around to the first problem is to house cows individually, so that the animal's choices are independent of the choices of other cows. To address the second problem we provide each cow with equal access to all options. For example, Tucker et al. (2003) used this approach to compare preferences for three stall surfaces commonly used in British Columbia: deep-bedded sawdust, deep-bedded sand, and geotextile mattresses covered with 2-3 cm of sawdust. In this study cows were housed alone in a test pen containing a feed trough, a waterer, alley space, and three freestalls presented side-by-side. Also, three similar test pens were used for the experiment and the three types of bedding were balanced over the three stall locations (right, centre, left) in the three pens.

This study consisted of two experiments, each illustrating an important design consideration in preference tests. The results from the first experiment showed that animals must at least be familiar with each of the options before testing preferences. The second showed that the environment the animal was reared in can affect their preferences.

Both experiments consisted of three phases. The first 7 days cows had free access to all three stalls/freestall surfaces. During the next 6 days cows were allowed access to only one of the three stalls for a 2-day period, then another stall for the next 2 days, then the third, with the order of access to the three stalls assigned randomly without replacement. During the final 2 days cows were again allowed free access to all three stalls. The time spent lying in each of the stalls was measured using 24-h video recording of the last day in of both free-choice phases.

The first experiment used 12 cows from a farm where cows primarily had access to stalls deep bedded with sawdust. The time spent lying down in each of the three stalls for both the free-choice phases is shown in Table 1. Two important points immerge. One is that cows vary in the lying surfaces they prefer: although most cows spent most or all their time lying in stalls with sawdust, cow 10 preferred lying in the mattress stall. Secondly, the preference results during the second phase differed from the first, illustrating the effect of providing animals with at least some familiarity with each option before testing. For example, after having some experience with the deep-bedded sand stalls during the restriction phase of the experiment, two cows (1 and 12) switched their preferred substrate from sawdust to sand.

Table 1. Lying times (h per 24-h period) for the three experimental surfaces during first and second free-choice phases shown individually for the 12 cows used in Experiments (Tucker et al., 2003).

Cow	First free-choice phase			Second free-choice phase		
	Sawdust	Sand	Mattress	Sawdust	Sand	Mattress
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.
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

This clear effect of experience with the environmental options provided the motivation for the second experiment. Specifically, we wanted to see if we could replicate the strong preference for the deep-bedded sawdust stalls, with animals that had been reared with exposures to *both* sand and sawdust. Thus, for the second experiment the subjects were cows from a farm using primarily sand bedding for the lactating dairy cattle. Other aspects of the design were very similar to that for the first experiment, but as can be seen in Table 2, about half of the cows in this experiment showed a preference for the sand bedded stalls, far more than was the case in the first experiment when cows came from a farm with little or no previous experience with sand.

Table 2. Lying times (h per 24-h period) for the three experimental surfaces during the second free-choice phase for 12 cows from a farm using sand-bedded stalls.

Cow	Second free-choice phase		
	Sawdust	Sand	Mattress
1	16.0	0.0	0.0
2	0.0	16.8	0.0
3	0.0	15.0	0.0
4	3.0	6.5	1.8
5	0.0	16.4	0.0
6	14.6	0.0	0.0
7	1.1	13.4	1.1
8	10.4	5.2	0.0
9	18.6	0.0	0.0
10	10.5	0.0	0.0
11	0.0	15.9	0.0
12	0.1	5.4	7.8

In summary, preference testing can be a powerful source of insight into how cattle perceive aspects of their environment, and how the animals rank the various options provided. Although the concept of preference testing is simple, designing and executing tests that avoid the pitfalls described above requires thought and effort.

Preference tests also have other known weaknesses that cannot be addressed simply by designing better choice tests. Perhaps the most important of these is that the preferences shown are only relative to the options provided. Thus a strong preference for one option doesn't mean that it is actually good, only that it is better than the alternative. One way to assess how access to preferred alternatives actually affect the animals is to study their behaviour when they have access to only one option. We now turn to these types of housing usage studies.

Measures of usage

Which measures of stall usage most relevant?

To determine which measures of usage are most appropriate in assessing cow comfort, it is important to develop an understanding of how a cow behaves when she is comfortable. Haley et al. (2000) used a simple comparison between a housing system considered “high comfort” (a large box stall with mattresses) and one considered “low comfort” (a tie stall with concrete flooring). They measured many behaviours including lying, standing, and eating times, the number of times the cows stood up, and various leg and head positions during lying. Lying times were four hours longer (Figure 3) and cows stood up and changed positions more often in the high-comfort housing. Cows also spent more time standing without eating in the low-comfort stalls. This study provides some insight into behavioural measures likely to change if a cow is uncomfortable, namely, time spent lying and standing, and the number of times she changes position between lying and standing.

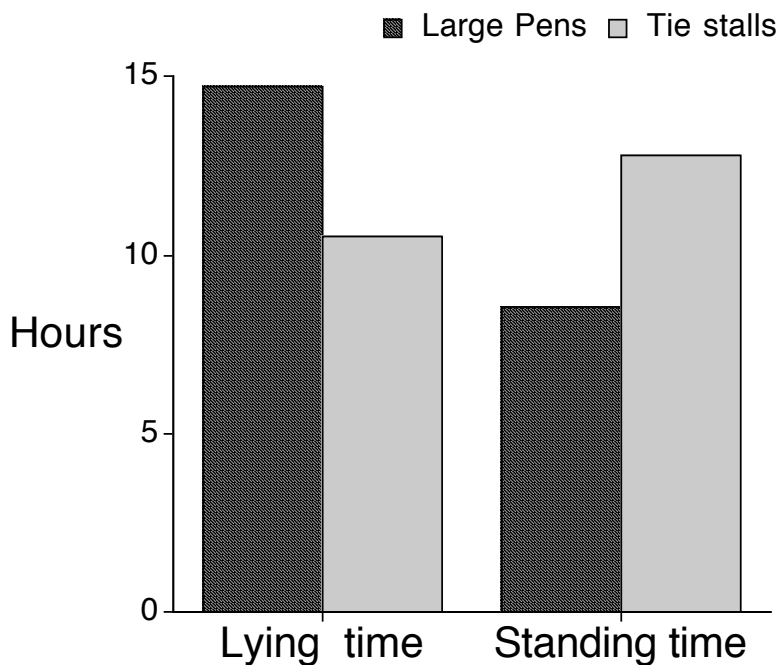


Figure 3. Cows spent more time lying and less time standing in large pens bedded with mattresses (high comfort) than in concrete tie-stalls (low comfort). Adapted from Haley et al., 2000.

How should these behaviours be measured?

Given that the frequency and duration of lying and standing behaviour are useful indicators of comfort, what is the best way of actually measuring these? The gold standard is to observe animals continuously for several 24-h periods, but this is obviously very labour intensive. In some cases less intensive observational methods can be used, but the accuracy of these methods will depend upon the nature of the behaviour. Characteristics of a behaviour that are likely to affect such accuracy include the amount time cattle spend performing the activity, the number of times they perform the behaviour, and the consistency of the behaviour over time, both within a 24-h period and across longer periods.

Among studies, estimates of time spent lying vary, but indoor-housed, lactating dairy cattle typically spend between 9.4 and 14.7 h a day lying down, divided into 8.2-14.1 lying bouts (reviewed in Tucker, 2003). Thus compared to many other behaviours, lying bouts are both relatively frequent and of long duration, and these characteristics allow us to accurately estimate these measures using a relatively modest sampling method (Martin and Bateson, 1993).

One common method of reducing the amount of time spent observing animals is to use scan sampling. Instead of following animals continuously, the behaviour is recorded instantaneously

at defined intervals, such as once every 10 minutes. To determine if this sampling method is adequate to accurately evaluate lying time, we can simply correlate the estimates of lying time generated by scan sampling with the estimates from continuous sampling. In one recent study we did just this, and found that the two estimates for lying time have a Pearson correlation coefficient of 0.99. Indeed, lying time can be accurately estimated using less frequent scanning interval. Using data from one recent experiment (Fregonesi et al., 2002), in which the behaviour of 48 cows was recorded using time-lapse video for 12 days, we correlated the estimates of lying time for the 10-min scanning interval with progressively less frequent scans (Fig. 4). From this Figure we can see that scan samples collected every 20 – 60 minutes can provide a reasonable estimate of the amount of time cows spend lying down. Less frequent scans result in lower correlations, and considerable day-to-day variability in the correlation coefficient.

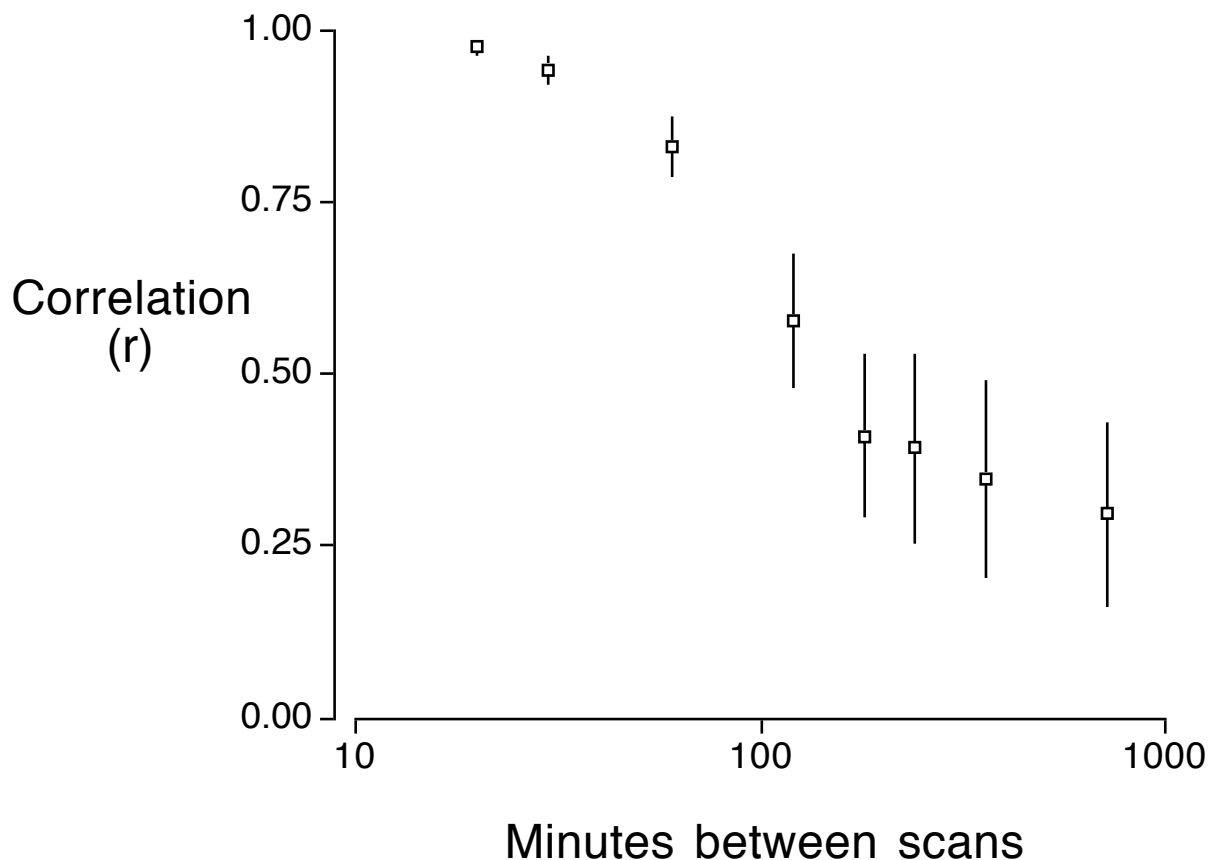


Figure 4. The effect of sampling frequency on estimates of lying time. Each correlation coefficient describes the relationship between estimates of lying time assessed with 10-min scan intervals versus longer intervals. Each correlation was based on values from 48 cows. The squares represent the average correlation across the 12 observational days and error bars show the standard deviation across days (from Fregonesi et al., 2002).

When animals spend less time engaged in a given activity, more intensive sampling is required. For example, cows spend only about 6% of the day standing with their front two legs in the stall

(Fregonesi et al., 2002). Estimates of time spent in this position from continuous recordings were still highly correlated ($r = 0.96$) with estimates from scans once every 10 min. However, scanning less frequently resulted in substantially lower correlations and more variable correlation coefficients, as illustrated in Figure 5. Thus behaviours related to cow comfort can be assessed accurately using more efficient sampling techniques than simple continuous observation, but the choice of the technique depends upon the behaviour.

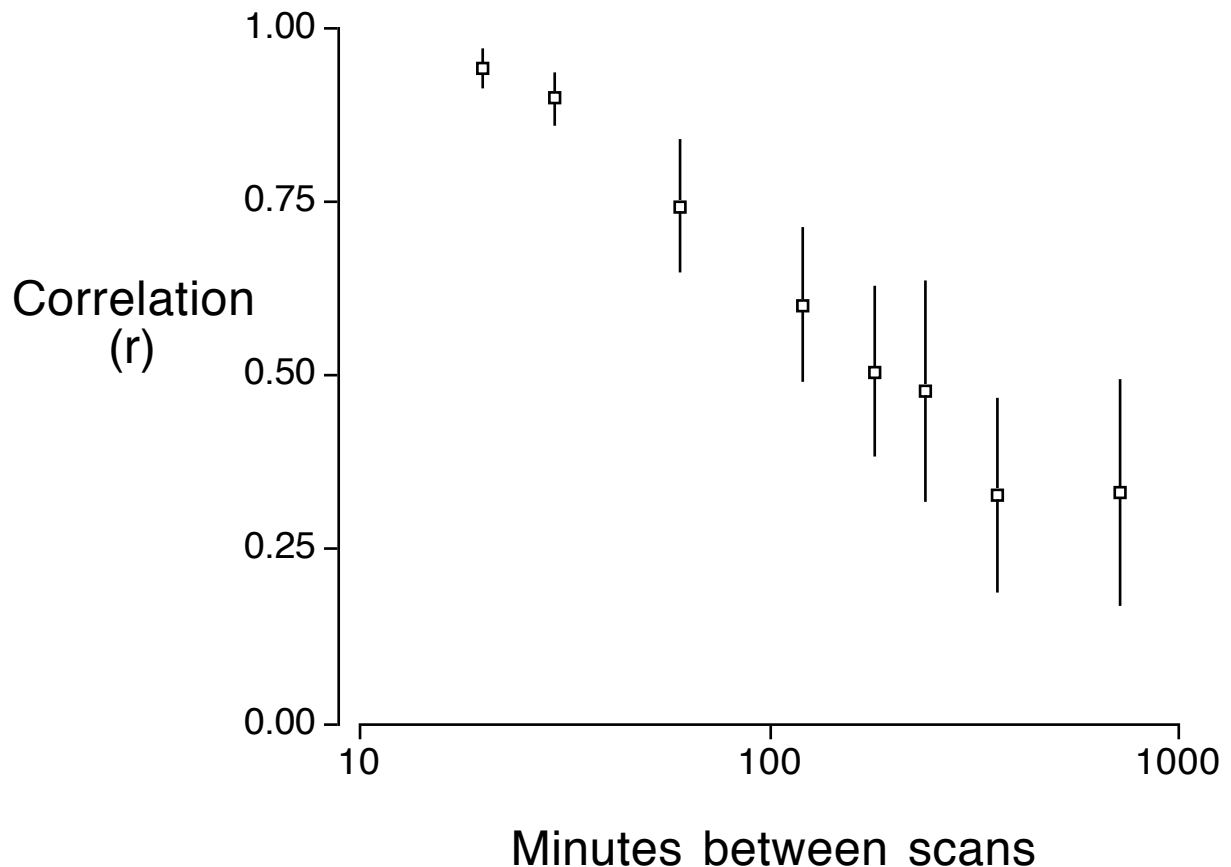


Figure 5. The effect of sampling frequency on estimates of time standing with the front two feet in the stall. Each correlation coefficient describes the relationship between estimates of lying time assessed with 10-min scan intervals versus longer intervals. Each correlation was based on values from 48 cows. The squares represent the average correlation across the 12 observational days, and error bars show the standard deviation across days (from Fregonesi et al., 2002).

When should the behaviours be assessed?

The work described above on sampling frequency is based on 24-h recordings taken from time-lapse video. In many cases applied researchers studying working dairy farms would find it much more convenient to use live sampling for more limited time periods. For example, one research recently told us he walks or drives down the side of the barn counting the total number of stalls, and the number with cows lying down in them. Can sampling methods such as this provide an accurate estimate of these behaviours? To answer this question we have to appreciate the extent of diurnal variability in the behaviours. Using the same data described above (Fregonesi et al., 2002), we can see that time of day has a strong effect on lying behaviour (Fig. 6). In the early

hours of the morning almost all cows are lying down. Many cows are standing or are outside of the stalls at around milking times (about 5 am and 4 pm for this group), which was also the time that fresh feed was provided to these cows.

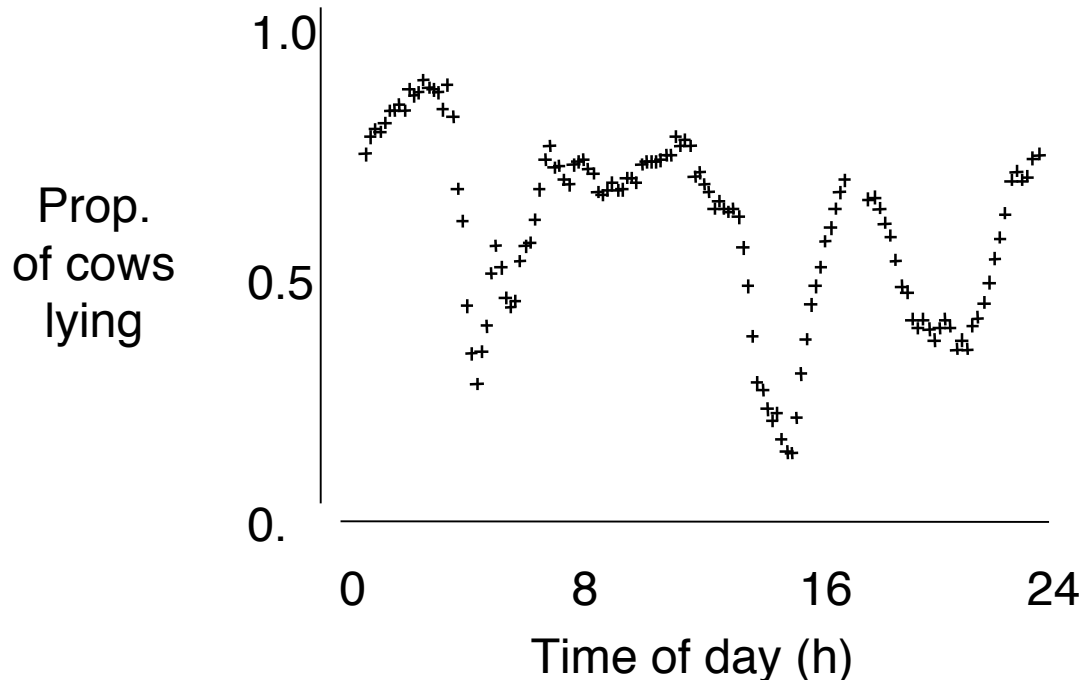


Figure 6. The diurnal variation in the proportion of cows lying down in the freestall. Data are from 48 cows followed for 12 days (from Fregonesi et al., 2002).

Given this diurnal variation in lying behaviour, and, indeed, in the other behaviours associated with cow comfort, the risks associated with observations restricted to a limited time of day become apparent. Using a scan sampling interval of once every hour generates 24 scans over a 24-h period, and the estimate of lying time from these data correlates reasonably well (average $r = 0.83$; Fig 4) with the estimate from scans taken every 10 min over the 24 h. However, when these 24 scans are taken over just 4 consecutive hours in a day (rather than over a 24-h period), the correlation coefficient varies from just 0.11 to 0.79 depending upon the day and when the 4 hours occur in the diurnal pattern. Sampling repeatedly (24 times) between midnight and 4 am produces an estimate that is reasonably correlated (average $r = 0.67$) with the 24-h estimate, but sampling during the following 4 h provides a much poorer fit (average $r = 0.32$). These data demonstrate that great care is required in interpreting measures of lying behaviour collected over a restricted part of the day. Indeed, these diurnal patterns are often influenced by management procedures including milking times, the delivery of fresh feed, feed push up, etc. Other authors have described the diurnal patterns for their facilities (e.g. Haley et al., 2000) and care should be taken to evaluate these patterns before determining the appropriate sampling regime.

Where should the behaviours be assessed?

Estimates of stall use can also be affected by where the stalls are in the barn. In some experiments we have found that cows never enter one stall in the pen, while seemingly identical stalls are occupied more than 80% of the available time. There has been very little work to date on how cows perceive stalls in different areas of the barn. In one recent study, Gaworski et al. (2003) showed that stalls in the row closest to the feed alley were occupied 41% more frequently than were stalls in more distant rows, and that stalls on the end of each row tended to be avoided. Which stalls are most popular may well vary from barn to barn, depending upon layout, but factors such as these may help explain producer dissatisfaction with 6-row versus 4-row barns (Bewley et al., 2001). The important caution, from the perspective of accurately estimating stall use, is that large differences in usage can occur even among identically configured stalls within the same barn.

Problems in assessing changes in lying behaviour

Even with data on the most relevant variables, collected in the most complete and rigorous manner, we still need to be able to correctly interpret the changes in the behaviour. There are many more factors that can affect interpretation, and we address a few of these below.

One important point to keep in mind is that the time an animal spends engaged in one behaviour, such as lying down, will depend on the alternatives available to the cow and the other demands upon her time. For example, it is well known that high-producing animals have high metabolic requirements, and spend more time eating than low-producing cattle. This time spent eating seems to be at least partly at the expense of lying time, as higher producing cattle also spend less time lying down (Fregonesi and Leaver, 2001). The effect of alternatives available to cows can also be important. For example, providing rubber flooring elsewhere in the pen increases the time that cows spend standing on this surface, and reduces the time they spend lying down in the freestall (Fregonesi et al., 2002). In both the case of the high-producing cow and the animal with access to rubber flooring, simplistically equating lower lying times with reduced comfort would not be advisable. Well-designed experiments and within-cow comparisons of treatment differences can help avoid such problems, but these issues pose much difficulty in interpreting comparisons among farms.

Given that cows can change their lying behaviour depending upon other demands on their time budgets, and that they spend less time lying down when given a more comfortable location to stand, to what extent should we consider a reduction in lying time problematic? The effects of reduced lying time on dairy cattle have been assessed in several studies (see Tucker 2003 for review). The most convincing evidence that a reduction in lying time is problematic comes from cases where the change in lying behaviour leads to physical injuries. For example, in some cases at least, reduced lying times necessarily result in increased time spent standing on concrete flooring, and prolonged standing on this surface is associated with an increased risk of sole

lesions (e.g. Colam-Ainsworth et al., 1989). Much more work is required to understand these and other effects of reduced lying in cattle.

Conclusions

The study of cow comfort is still in its early stages, but a few techniques have emerged as useful. We have reviewed work on injuries, preferences, usage, and in each case examined some of the challenges in using these approaches in a meaningful manner. In most situations, well-established solutions are available to help overcome these challenges. Dairy research professionals need to ensure that their studies avoid these various pitfalls, and that the conclusions drawn from new research on cow comfort provides the maximum benefit to dairy producers and the cows in their care.

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