# Sand Stalls, Sore Feet, and Sour Rumens –Perspectives on Lameness in Dairy Cows.

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## ABSTRACT

Lameness in dairy cows continues to be a major problem for the industry world-wide. Prevalence appears higher in free stall housed dairy herds than in tie stall herds in Wisconsin, and is especially a problem in free stall herds using mat or mattress stall surfaces compared to those herds using sand. This article describes some of the behavioral differences which contribute to this difference. In particular, lame cows housed in mattress free stall barns appear to spend longer standing in the stall, compared to lame cows in sand stalls. This time spent standing appears to reflect a difficulty in performing the process of lying down and standing up. Future stall design recommendations must be based on providing a stall in which lame cows can maintain normal daily activity patterns.

**KEYWORDS:** Sand, mattress, lameness, standing.

## INTRODUCTION

Lameness in dairy cows is only recently starting to receive more attention in North America, largely driven by the increased use of locomotion scoring to identify lame cows and an increasing awareness of the role of cow comfort. Until recently, the last major survey in the US, consisted of only 17 herds, predominantly tie stall housed, which suggested that lameness prevalence averaged around 15% of the herd (Wells *et al* 1993). Although widely quoted, this survey failed to reflect changes currently occurring in the dairy industry, with the growth in free stall housing.

In an attempt to gain more up to date information on the lameness status of herds in the Mid-West, we surveyed 30 Wisconsin dairy herds, half tie stall and half free stall housed, and determined lameness prevalence using a 4 point system of locomotion scoring described elsewhere (Nordlund *et al* 2004) where scores 3 and 4 were ‘clinically lame’. All the lactating cows on each farm were scored once in the winter and once in the summer. Lameness prevalence averaged 19.6% in tie stall barns in both summer and winter – a little higher than had been previously reported. Prevalence was higher still in free stall barns at 22.8% in the summer and 27.8% in the winter (Cook 2003), confirming our suspicion that lameness in free stall barns was worse than had previously been documented, and very similar to recent prevalence surveys performed in the UK. (Clarkson *et al* 1996,Whay *et al* 2002)

We also identified some differences in lameness prevalence by stall base type which had not been previously reported. Those herds using sand stalls appeared to have lower levels of lameness and, in particular, free stall herds using a rubber mat or mattress stall surface appeared to have the worst rates of lameness, especially in the winter (Cook 2003).

**Table 1. Mean prevalence of lameness during summer and winter among lactating cows on 29[†] dairy herds in Wisconsin classified as to housing type (free stalls vs tie stalls) and stall surface (sand vs mat or mattress [non-sand]).**

| | Free stalls | | Tie stalls | |
|---|---|---|---|---|
| Stall Base | Sand | Non-Sand | Sand | Non-Sand |
| Number of herds | 9[†] | 7 | 4 | 10[†] |
| Lameness Prevalence | | | | |
| Summer | 18.4 | 26.8*[,a] | 12.2[b] | 22.1 |
| Winter | 21.2[a] | 33.7*[,b] | 12.1[a] | 21.7[a] |

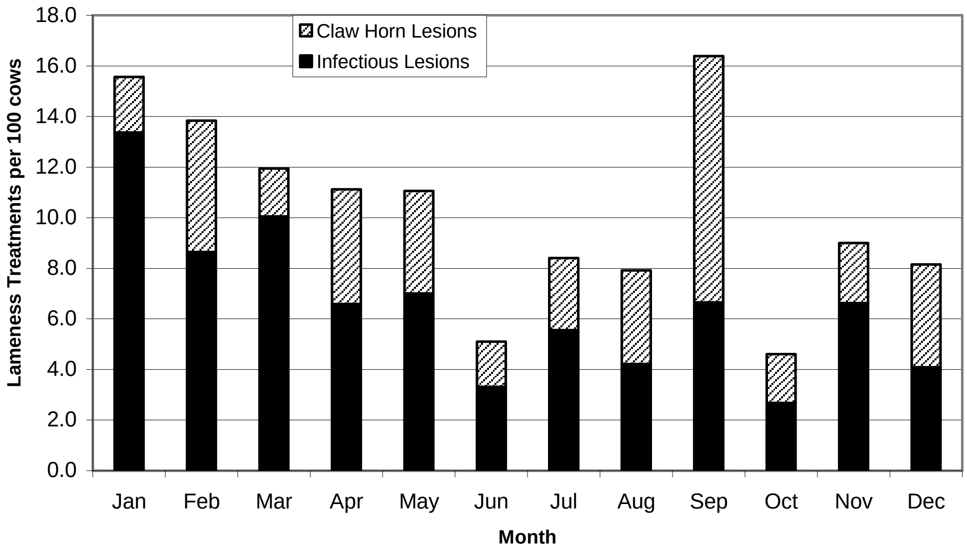
*Values were significantly (*P* = 0.007) different.
[a,b] In each row, values with different letter superscripts were significantly ($P < 0.05$) different.
[†] Includes cow data from one herd with segregated sand free stalls and non-sand tie stalls.

## CAUSES OF LAMENESS

So what were the causes of this lameness? From a subset of the 30 herds surveyed, we collected lameness treatment records to determine incidence rate from 10 herds, which averaged 22.2% lameness prevalence. A total of 1155 lameness treatments were recorded and the mean lameness treatment rate was 69.1 limb cases per 100 cows per year. Digital dermatitis was the most common lesion found, accounting for 56.8% of all treatments. Sole hemorrhage (6.4%), sole ulcer (18.4%) and white line disease (10.4%) were the most common claw horn lesions identified (Cook 2004).

We looked at lameness treatment rate by month (Figure 2). The rate was higher at the end of winter – probably when herds were not using footbaths and experiencing manure handling problems in cold weather conditions, but the rate was also markedly higher in September – two months after the period of heat stress in Wisconsin. Interestingly, if we compare the ratio of infectious lesions to claw horn lesions it switches in September – where claw horn lesions predominate.

**Figure 2. Lameness treatment rate (Limb cases per 100 cows) by month for 10 herds.**




We have therefore documented a distinct epidemiological pattern of lameness in Wisconsin dairy herds. In general, digital dermatitis dominates the total number of lesions observed. However, it is usually controlled by effective foot bath programs, unless weather conditions prevent their use in late winter. Claw horn lesions peak in the late summer and perhaps because of their persistency as a cause of lameness, contribute to a higher prevalence of lameness observed through the winter in free stall herds. In addition, although herds using sand have no advantage with regard to infection with digital dermatitis, we have documented a trend for a lower incidence of claw horn lesions in herds using sand stalls compared with those using mattresses – a reduction in the incidence of white line disease in particular.

## TRIGGER FACTORS FOR CLAW HORN LESION DEVELOPMENT

A variety of trigger factors may result in claw horn lesions, and our understanding of how lesions on the sole of the hoof occur has dramatically improved over the last 5 years. We have recently reviewed the environmental factors influencing claw horn lesion production (Cook *et al* 2004b). The main trigger factors include;

### 1. Changes induced at calving time

Work in the UK has elegantly shown that around the time of first parturition, there is a loosening of the connection between the pedal bone and the horn capsule of the claw, driven by activation of various gelatinoproteases in the dermal tissues (Webster 2001), (Tarlton *et al* 2002) These enzymes, which include metalloproteinases and 'hoofase', may be hormonally activated perhaps via relaxin release.

Transitioning heifers from a comfortable environment directly onto uncomfortable free stalls at calving time, and the feeding of poor quality low dry matter forage appear to exacerbate the damage caused by this enzymatic activation. Both of these events are common in UK herds, however they are not as common in the US. Forages are usually of higher dry matter, with less emphasis on grass silage, and transitioning is usually not as abrupt. Many herds house heifers in mini-free stall barns and bring them into the main barn 4-5 weeks prior to calving, where they are usually housed in free stalls mixed with mature close-up dry cows. In those free stall herds that housed first lactation heifers separate from mature cows after calving in our survey, we found that first lactation heifer lameness prevalence was significantly lower at 16.1% compared with mature cows at 33.0% (P=0.02).

Although this mechanism may be a major factor in some herds, we do not believe that it is the most important factor seen in the herds that we visit.

2. **Sub-acute ruminal acidosis (SARA)**

Laminitis has long been thought of as a nutritional disease. Clearly, this was an overly simplistic view of the disease process. However, we still believe that nutrition, and in particular SARA, is an important trigger factor for the development of claw horn lesions.

There are several reasons for this. First, we have collected much anecdotal evidence from in depth herd investigations that high levels of lameness are commonly, although not invariably, associated with a herd diagnosis of SARA achieved by records analysis, recreation of the ration fed and ruminocentesis to measure rumen pH. Second, recently a model that induces laminitis was successfully described using an oral dose of oligofructose (Thoefner *et al* 2004). This provides convincing evidence that carbohydrate overload can induce changes in the lamellae of the claw. Third, we have documented an increase in claw horn lesions in the late summer – following the typical period of heat stress in Wisconsin, which we know places high producing dairy cows at increased risk of SARA.

The mechanism of induction of change in the hoof has yet to be fully elucidated. However, there are two strong possibilities. The first refers to the production and passage of vaso-active substances from the rumen to the foot, where arterio-venous shunting of blood and lamellar hypoxia occur. This theory is strengthened by the finding of a rumen adapted bacterium *Allisonella histaminiformans*, which produces histamine from histidine in the rumen, and that histamine absorption is increased at low pH (Garner *et al* 2002). Perhaps a more attractive theory however, is the production and passage of an exotoxin of *Streptococcus bovis* from the rumen or more likely the hind gut to the foot, where it has been shown in vitro to activate the same metalloproteinases present in the dermis of the claw that are similarly activated around calving time (Mungall *et al* 2001). *S.bovis* increases dramatically in the rumen at low pH (Tajima *et al* 2001), and the convergence of two potential trigger factors along one common pathway makes the theory rather attractive. Once the connection between the pedal bone and the horn capsule of the claw is loosened, weight bearing serves to move the pedal bone distally, compressing the dermal tissues of the sole and thereby triggering lesions which appear at the sole surface some time later.

SARA is common in high producing dairy herds in the US (Stone 2004). Rations are frequently much lower in ADF and NDF than those seen in the UK, which are obvious risk factors, however we have been more interested in environmental factors which may influence SARA. We use a SARA induction program to experimentally create conditions of low rumen pH for a short period of time. This program relies on the fact that when cows are made hungry – by withdrawing feed overnight, and presented with fresh feed (spiked with grain) the next morning, they over eat. This larger than normal feed meal is the source of volatile fatty acids which drive rumen pH downward.

Thus, we believe that situations where cows become hungry, and subsequently consume a larger than normal feed meal are a significant trigger for SARA in our high producing dairy herds. Interestingly, my colleague Gary Oetzel has recently shown that rumen pH is already at pH less than 5.5 before significant quantities of rumen lactate appear. Thus, although there is much talk of the role of lactic acid in rumen acidosis and laminitis, we do not believe that this is the reason why we see SARA and lame cows. Modifiers of rumen lactate production are unlikely to be successful in controlling SARA, rather we should concentrate on feeding management that makes sure that feed meals are consistent, and methods that may enhance buffering to control this disease.

We are therefore advocating barn designs and consistent management of feeding where cows can 'eat when they wish to eat'. Stocking density recommendations by number of cows per stall give a false sense of security. We need to consider the number of rows of stalls in the pen and cows per feed space and the dimensions of that feed space. Workers at the University of British Columbia have shown that when given more access to feed (1.0m per cow vs 0.5m per cow), cows' space out more at the feed bunk and subordinate cows show increased feeding activity – suggesting that they were not gaining access to the feed bunk when they wanted to at 0.5m per cow (DeVries *et al* 2004). We have recently shown that during the 90 minute period after return of the cows from milking, there is a significant difference in bunk utilization between 2-row and 3-row barns, which may reflect increased competition at the feed bunk in 3-row pens. This difference is associated with a doubling in agonistic interactions at the bunk in 3-row pens compared to 2-row pens. Such interactions have previously been suggested as a potential reason for lameness and claw trauma (Leonard *et al* 1998). Although we have yet to document a difference in lameness prevalence between barns with different numbers of rows, managing the feeding of cows in 2-row pens to limit SARA appears to be easier and more consistent than in 3-row pens.

### 3. Excessive removal of sole horn

Excessive wear due to walking on rough concrete, or excessive removal of sole horn by poor hoof-trimming, may trigger lesions of the claw horn. These typically occur in the toe region and result in toe ulcers. These appear to be somewhat unrelated to similar lesions on the sole which occur due to alteration in the position of the pedal bone, and must be recognized and dealt with in a very different way. Use of rubberized walking surfaces along return alleys from the parlor, in the parlor holding area and along cross walks has been successful in reducing hoof wear in many dairies world-wide. Benefits of this material when located at the feed bunk are equivocal at present and worthy of further research (Vokey *et al* 2001), (Fregonesi *et al* 2004).

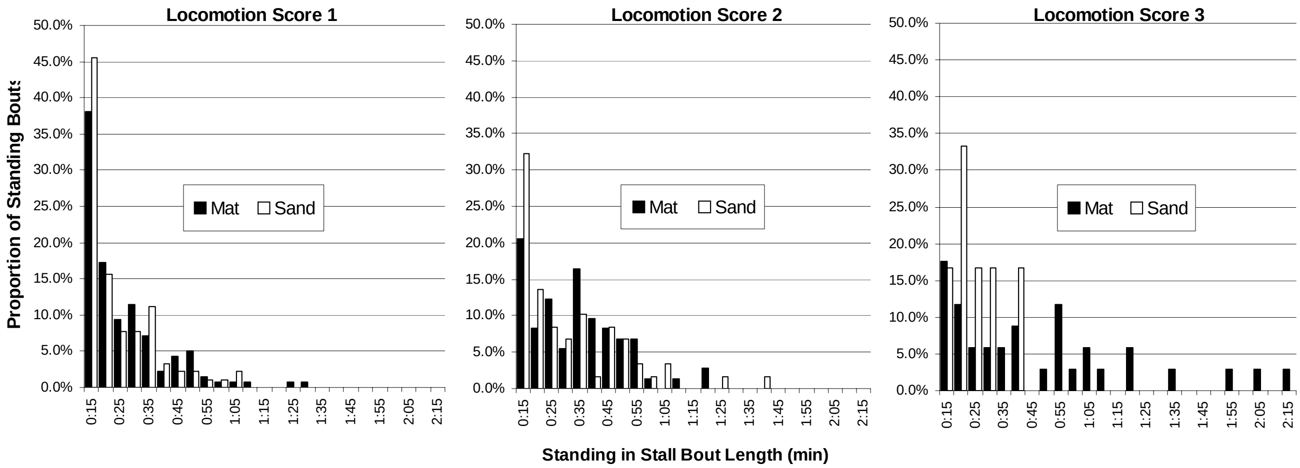
4. **Reduced lying and increased standing time**

Several studies, particularly in the UK, have suggested that very low lying times, or excessive time spent standing – especially perching with the front two feet on the stall platform and rear two feet in the alley, are significant risk factors for claw horn lesions and lameness (Colam-Ainsworth *et al* 1989,Leonard *et al* 1994). Both of these make sense as increased weight bearing will put further pressure on the connection between the pedal bone and the claw horn capsule, potentially causing more damage to the sole. However, we now suspect that they are not true trigger factors – but serve to exacerbate existing lesions.

Having found that herds using sand stalls appeared to have a lameness advantage compared to herds using a mat or mattress, we wanted to see whether cows in sand stall facilities adopted different behavior patterns which might contribute to this difference. We visited 12 expanded free stall dairy herds, averaging 300 cows per herd, six using sand and six using a rubber crumb mattress stall surface. Each herd was locomotion scored and for one 24 hour period the high group mature cow pen was video filmed. 10 cows per farm were color marked and tracked for the entire period recording location (alley, stall or milking parlor), activity (standing, lying, feeding, drinking) and time spent performing each activity (Cook *et al* 2004a).

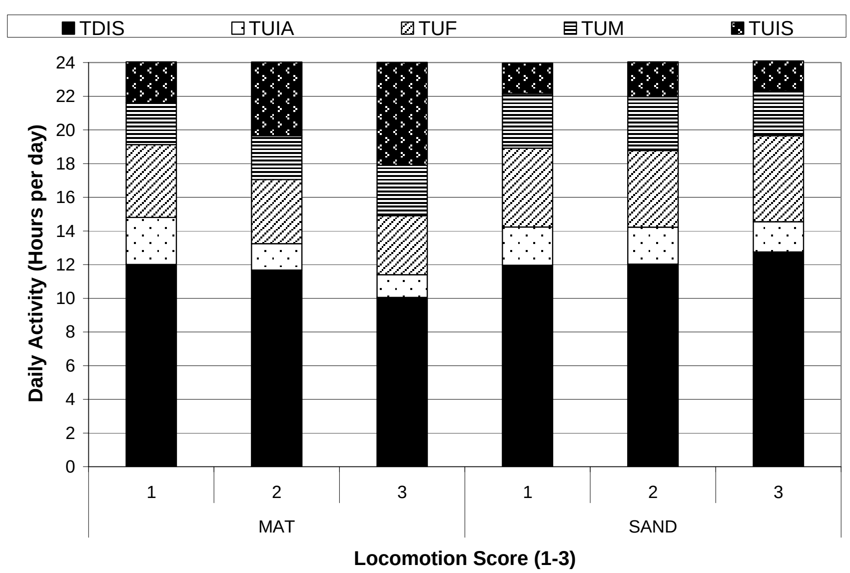
The mean lameness prevalence in the sand herds in this study was 11%, and in the mattress herds it was 24% - confirming the trend we had previously identified. Perhaps unexpectedly, we did not find a difference in overall lying time between cows in sand herds and cows in mattress herds. In fact, we found that normal non-lame cows behave similarly in sand and mattress stall herds - the only significant difference is that they stand in mattress stalls for 44 min longer per day ($P=0.048$). However, the most marked behavioral differences were found in lame cows. Slightly lame cows stood for 4.4h/d and moderately lame cows stood for 6.1h/d in mattress herds – significantly different from equivalent cows in sand stalls which stood for only around 2 h/d ($P<0.001$). Examination of the distribution of standing bouts by duration shows that both slight and moderately lame cows in mattress herds have a greater number of long duration standing bouts (Figure 2).

**Figure 2. Distribution of standing bouts by duration in 10 min increments by locomotion score (1 = non-lame, 2 = slightly lame, 3 = moderately lame) for cows in sand herds and cows in mattress herds.**




This increase in stall standing of 2-4 h/d has effects on the daily time budget – with a compression of other activities, notably standing in the alley, feeding, and in moderately lame cows, lying time – which was reduced to 10h/d in moderately lame cows (Figure 3).

**Figure 3. Daily activity time budgets for 60 cows in SAND herds and 60 cows in MAT herds by locomotion score where 1 = non-lame, 2 = slightly lame and 3 = moderately lame. TDIS = Time down in stall, TUIA = Time up in alley, TUF = Time up feeding, TUM = Time up milking TUIS = Time up in stall**



These data appear to suggest that cows strive to maintain a relatively fixed amount of lying time per day – approx 12h/d in this study. However, the desire to lie down is limited by the pain associated with the actual process of rising and lying and the fear of slipping. We believe that lame cows in sand stalls suffer less fear of slipping because of the traction provided by the bedding material when rising and probably less pain, consequently they lie down more promptly. Lame cows in mattress stalls may suffer more pain and fear of slipping when rising and lying and are reluctant to lie back down again on the smooth mattress cover. In contrast to several other studies, which have suggested that stall standing replaces time spent standing in the alley (Wagner-Storch *et al* 2003), (Tucker *et al* 2003) which is therefore beneficial to the cow, we now realize that stall standing is not in place of standing in the alley – it is enforced during a stall use session (bouts of standing and lying in the stall between entry and exit from the stall), while the cow prepares to lie down again. Moderately lame cows in mattress stalls spend so long standing between lying bouts that they are only able to fit in half as many stall use sessions per day (4.6) as non-lame cows and lame cows in sand stalls (8.5).

Extended time spent standing in the stall in lame cows may be detrimental to claw health, increasing the duration of lameness and explaining the higher prevalence observed in mattress herds. Whether the standing is with all four feet on the platform or perching is perhaps immaterial – the hoof is still exposed to an increased duration of weight bearing at a time when the cow would rather be lying down. Perching appears to be a response of the cow to poor stall design or comfort, this response may be magnified in cows with a sore foot, hence it is probable that lame cows perch more than non-lame cows.

Stall designs which fail to allow for adequate lunge and bob room increase weight bearing and stress on the rear feet during standing and lying movements, and inadequate surface area and neck rails located too low and too near the rear curb further hamper the ability of lame cows to lie down and stand up in the stall. These cows are at increased risk of hock damage and stall entrapment and injury. Cows on sand appear to compensate better for these design faults, because their rear feet are afforded improved traction.

## IMPLICATIONS FOR THE INDUSTRY

Our findings are relevant to future research into cow behavior and stall design. Many studies of mattress surfaces for dairy cows quote lying times of 12 to 14 hours per day or more (Chaplin *et al* 2000,Tucker *et al* 2003). The term ‘cow comfort’ has become synonymous with measurement of daily lying time and documentation of cow preference for softer more cushioned lying surfaces (Fulwider and Palmer 2004,Wagner-Storch *et al* 2003). However, it is clear from our work that the behavior of lame cows must be taken into consideration. Stalls must be designed so that lame cows maintain normal daily activity patterns - we already know that non-lame cows are tolerant to a wide range of stall types.

We have documented the needs of the cow when using a stall (Nordlund and N.B.Cook 2003) and contributed to the recommendations for stalls which are being used in the industry today. It remains to be seen whether mattress stalls, with revised dimensions and designs, permit lame cows to use them more easily, but the initial signs are encouraging. Until then, we recommend that lame cows (at least severe and moderately lame) should be removed from poorly designed mattress stalls and permitted to recover on a well managed straw yard or area of clean sheltered pasture, where they may show more normal patterns of resting behavior.

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