The Dual Roles of Cow Comfort in Dairy Herd Lameness Dynamics

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Abstract

This article describes the dual roles of cow comfort in herd lameness dynamics – interacting with trigger factors to ensure that cows 'get lame' and interacting with the cow once she is lame to ensure that she 'stays lame'. Duration of daily standing activity, the surface that the cow is standing on, and hygiene of that surface are principal components of cow comfort that need to be addressed if we are to break the cycle of 'get lame – stay lame'.

Résumé

Cet article décrit les deux rôles du confort des vaches dans la dynamique de la boiterie dans un troupeau. Le confort interagit d'une part avec les facteurs déclencheurs assurant le développement de la boiterie et d'autre part avec la vache lorsqu'elle boite assurant la persistance de la boiterie. La durée de la période d'activité debout, la surface sur laquelle la vache se tient et l'hygiène de cette surface sont les composantes principales du confort des vaches auxquelles on doit faire face pour briser'le cycle voulant qu'une vache qui devient boiteuse reste boiteuse.

Introduction

Poor cow comfort has long been associated with increased rates of lameness in dairy cattle. Excessive time spent standing on concrete walking surfaces in intensively managed dairy herds appears to predispose cows to claw-horn lesion development.[1,11] Poor lying times have also been identified as a significant risk factor for lameness.[14] However, the mechanisms by which poor cow comfort alters herd lameness dynamics have been poorly described.

My interest in the effect of different housing systems on cow behavior will be described in this article – and I will make the case that increased time spent standing, when the cow would rather be lying down and the surface that she must stand on, are the major factors driving differences in lameness prevalence at the herd level.

Trigger Factors

Lesions of the claw horn, which include sole hemorrhage, sole ulcer and white line disease, are very common causes of lameness in dairy cattle and have traditionally been referred to collectively as 'laminitis'.[7] Laminitis is still regarded by many as a nutritional disease, despite a growing amount of evidence to suggest that lesions such as sole ulceration are merely 'clinical signs' on the sole surface of the hoof. In much the same way that we do not instantly know the causative agent when a cow presents with a cough, the presence of a claw-horn lesion merely represents the end result of several possible causative pathways.

In recent years, three main trigger factors for claw-horn lesion development have emerged from the literature. These include:

1. Calving-induced changes in the claw.

The suspensory apparatus of the third phalanx within the claw-horn capsule, described by Lischer *et al*,[16] appears to be weakened around calving time. An inevitable increase in the incidence of sole hemorrhage has been described around the time of first calving.[28] This appears to be associated with an up-regulation of certain gelatinoprotease enzymes (metalloproteinases and 'hoofase') in the corium of the claw; [21] a process which may be stimulated by changes in the concentration of hormones such as relaxin. These enzymes appear to weaken the bond between the third phalanx and the claw-horn capsule, leading to increased mobility during the periparturient period.

2. Nutrition induced changes in the claw.

The importance of biotin and trace elements such as zinc methionine in maintaining horn quality have been well demonstrated in recent years.[3] Work in Denmark on experimental induction of rumen acidosis and claw-horn changes using a fructan sugar (oligofructose) may help us improve our understanding of the actual mechanisms linking acidosis with claw-horn lesions.[23] At this time, increased mobility of the third phalanx is believed to be induced by one of two pathways: 1) lamellar hypoxia induced by arterio-venous shunting resulting from histamine release in the rumen, or 2) enzymatic stimulation and remodeling of the corium, triggered by an exotoxin released by *Streptococcus bovis*, which is known to overgrow in the rumen early in the course of sub-acute ruminal acidosis.[7]

3. Trauma induced changes to the claw.

Susceptibility of the outer claw of the hind foot to over growth and claw-horn lesion development has been well documented.[24] However, in large free stall and dirt lot dairy herds, where cows must walk long distances on concrete flooring, excessive removal of claw-horn has emerged as an important problem contributing to poor heel height, toe ulceration and white line fissures. This may be exacerbated by poor hoof trimming, with excessive removal of horn from the sole. In addition, differences in the rate of white line disease development observed between freestall and tie stall herds suggest that external forces may be required for this type of lesion to occur at frequencies as high, or higher, than sole ulceration.[5,19] Smooth, slippery concrete surfaces, areas where cows are made to turn sharply and surfaces which are excessively rough and traumatic are examples of the interaction of the claw with the floor which may result in an increased tendency for white line separation. In grazing herds, cow-track design has emerged as a major factor contributing to lameness and trauma to the claw.[4]

Infectious causes of lameness, particularly digital dermatitis (heel warts) and interdigital phlegmon (footrot), are also common in intensively managed dairy herds. Digital dermatitis is triggered by the introduction into a herd of the putative agents involved – namely one or more spirochetes from the genus *Treponema*, principally via bought-in cattle,[29] but wet manure-contaminated hoof conditions appear to be essential for infection and spread.[2]

Whatever the trigger factor, integral to the mechanism for development of sole hemorrhage, ulceration or white line disease, is the requirement for the weight of the animal to place downward pressure on the third phalanx within the claw-horn capsule, thereby compressing the corium beneath the bone and initiating claw-horn lesion development. Cow comfort, therefore, has a role to play in determining duration and timing of standing behavior and what type of surface the cow is standing on.

Dual Roles of Cow Comfort: Role 1

When we consider the dual roles of cow comfort in herd lameness dynamics (shown in Figure 1), the first role is where poor cow comfort results in time spent standing when the cow would rather be lying down, at a time when they are exposed to one of the three trigger factors described above. This occurs in five main situations: 1) changes in behavior during transition; 2) poor stall design, enforcing aberrant standing behavior; 3) enforced standing time resulting from very long milking times; 4) changes in behavior during periods of heat stress and 5) cow management effects on time budgets. Additionally, if the surface the cow must stand on is traumatic, slippery or causes excessive wear, then lesions of the white line may become more likely, and if the hygiene of the surface is poorly maintained, then infectious causes of lameness become more prevalent.

a. Changes in Standing Behavior

1. During the transition period

Webster [28] showed a reduction in sole hemorrhage around calving time in heifers kept in a straw-bedded pack barn compared to a poorly designed freestall barn. While time budgets were not recorded, increased lying time in straw yards compared to similar freestall housing has been documented by others,[18] and it is now common in the UK to advise that first lactation heifers be kept separate from mature cows on a straw-bedded area up to around 30 days in milk.[3] Our knowledge of how the time budgets of heifers and mature cows change through the transition period is rudimentary. In a study tracking mature cows through a sand free stall facility from pre-fresh to post-fresh groups via a straw-bedded maternity pen, daily time standing increased by three hours from four days before calving to one day after.[12] It is likely that greater increases would be observed in heifers introduced to freestalls for the first time, in facilities with poor stall designs, in overstocked pens, and where cows are subjected to multiple pen moves close to calving, creating repeated social disturbances.

2. During stall use

Non-lame, high-yielding dairy cows in well designed, well bedded comfortable stalls lie down for around 12 hours per day and stand in stalls for around two hours per day.[8] Stall designs which fail to provide for the movements of lying and rising, adequate resting space, or a cushioned surface will tend to reduce lying behavior to less than 10 hours per day and increase standing time in the stall. In one study, freestalls with a concrete surface and a restrictive divider design resulted in reduced lying time, increased periods spent perching (standing half in and half out of the stall), significantly worse claw hemorrhage scores and an increased rate of clinical lameness in heifers two months after calving, as compared to heifers kept in a stall with greater surface cushion and a less-restrictive divider design. Correlation between reduced lying behavior and worsening claw health was observed in heifers in the more comfortable stalls.[13] The significance of perching in the stall, rather than total time spent standing in the

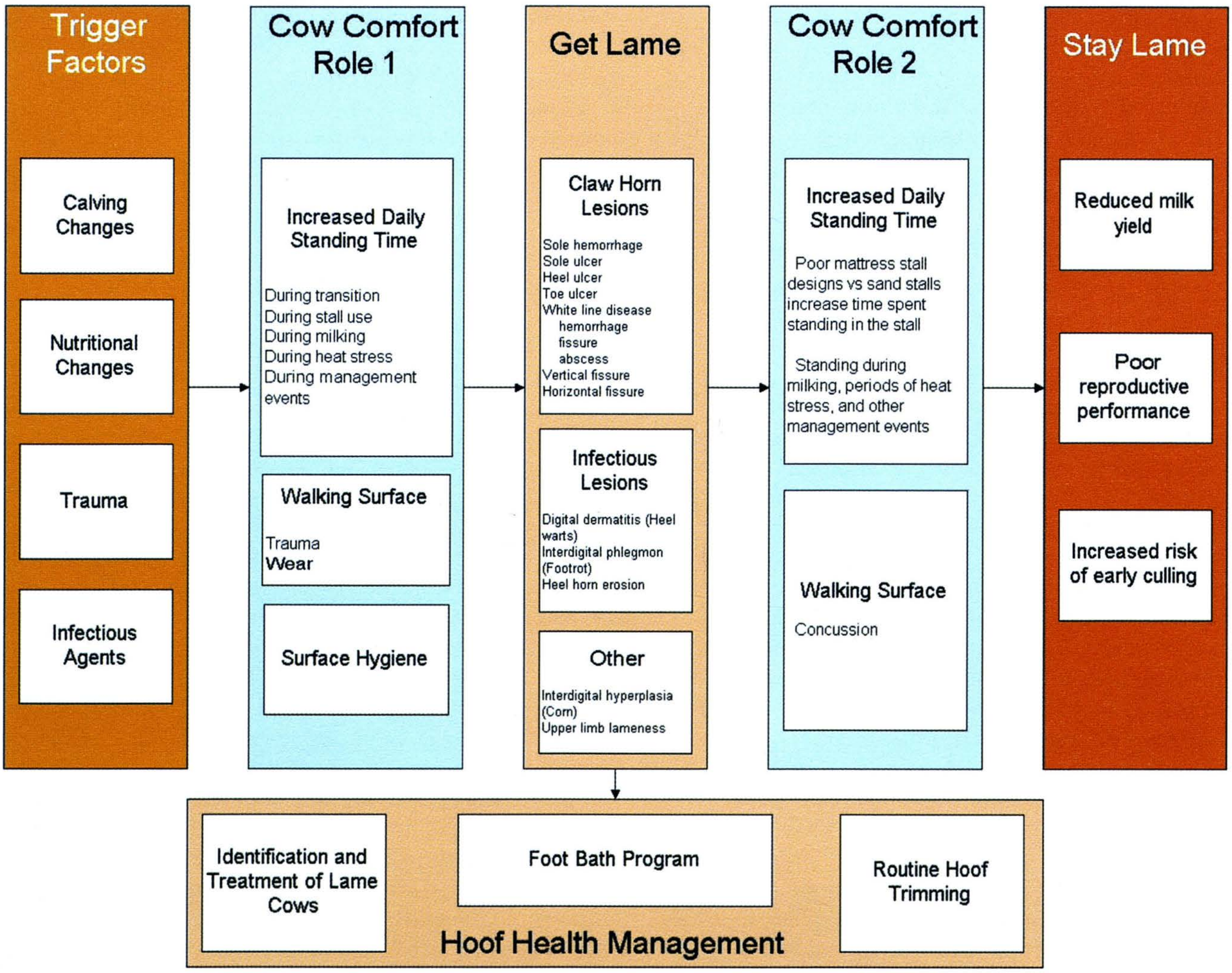

Figure 1. The 'get lame-stay lame' hypothesis to explain the dual roles of cow comfort in herd lameness dynamics.

stall, may have been over-stressed as a risk factor for lameness, and may merely be a function of neck rail placement.[9]

Conditions of overstocking create changes in daily stall use patterns of subordinate 'outlier' cattle, placing them at increased risk for increased daily standing times.[31] Overstocked dairy heifers with short daily lying times are known to be at increased risk for claw-horn lesion development.[14]

3. During milking

Groups in large freestall dairy herds are typically designed to be no larger than 4.5 times the number of milking stalls in the parlor. Assuming parlor throughput exceeds four turns per hour, this target will return cows to the pen from the parlor within one hour – leading to total daily milking times of two to three hours in two and three times-a-day milked herds. This recommendation, however, assumes that the order of throughput through the parlor is random. We know that this is not the case[17] – which means that while some cows can be milked three times in less than 30 minutes per day, other cows spend much longer being milked, especially in large management groups milked through inappropriately sized milking facilities. The problem is particularly acute in large grazing herds which manage only one group of cows. Under-sized parlors result in daily milking times which can exceed seven hours per day. Such problems are exacerbated in early-lactation primiparous cows, which may commingle at the rear of the holding area.

4. During periods of heat stress

The highest rates of claw-horn lesion development are seen in the late summer in North America.[5] It has been suggested that this could be due to an increase in the rate of sub-acute ruminal acidosis (SARA), an increase in standing times, or a combination of the two.[20]

While heat stress associated ruminal acidosis has been documented, changes in behavior when cows become heat-stressed have not been investigated in detail.

Recently, we tracked 14 high-yielding dairy cows housed in a three-row freestall pen, with mattress freestalls and fans and soakers located over the feed bunk through the summer. Between four daily filming sessions, that had a mean daily average temperature humidity index (THI) of between 56 and 74, we observed a 3 hour per day increase in standing time between the coolest session and the hottest session. Behavior changes were most notable during the period between noon and 6 pm. The increase in standing time was shared between time spent in the alley and time spent in the stall. These data, together with an increased susceptibility to SARA, could explain the increase in claw-horn lesion development observed in the period from September to November.

5. During other abnormal events

Excessive time spent locked up at the feed bunk may have a detrimental effect on daily time budgets. While cows are quite capable of compensating for a one to two-hour change in routine, if lockup is prolonged and in association with other stresses – such as an overstocked three-row pen, then the ability of the cow to compensate and 'catch up' on lying time may be exceeded. It is perhaps unfortunate that the cows we most commonly lock up for long periods are the fresh cows, immediately post partum, at a time when they are most susceptible to changes in total daily standing time.

We believe that changes in daily standing time of the order of two to four hours per day, when enforced by environmental or managemental circumstances during periods when the cow would rather lie down, are biologically significant. This represents two to four hours of increased weight bearing, which is potentially damaging to the foot when the change coincides with exposure to one of the trigger factors.

b. Standing and Walking Surface

In many herds, where cows are predominately exposed to concrete flooring surfaces, white line disease emerges as a problem. Concrete areas that are excessively slippery or rough, especially where cows must make sharp turns, put increased stresses on the white line junction two thirds of the way back from the toe – the area of greatest ground reaction force when the cow stands and walks. [26] Where cows must walk down inclines greater than 2% and over more than approximately 200 feet of concrete, the issue of wear becomes an important factor making lesions of the claw horn more likely. This may be directly from thinning of the sole, or indirectly via a change in hoof balance and loading, as there is a tendency for cows with shallow rear-claw angles to be more susceptible to white line disease and lameness.[30]

With a focus on preventing slipping, trauma and wear, it is easy to prioritize where alternative flooring surfaces should be sought. Long transfer lanes, parlor holding areas and slippery corners where cows are forced to turn sharply are ideal places for rubber flooring. The decision to use rubber flooring in freestall pens is less clear. Proponents will rightly point out that rubber flooring improves the locomotion of lame and non-lame cows, increases stride length[22] and allows cows to show improved signs of estrus and mounting activity. However, it is less clear whether this actually impacts herd lameness dynamics. Three studies measuring the time budget of cows in freestall pens fitted with rubber flooring all show increased time spent standing on the rubber alley floor, less time lying in the stalls and an increased likelihood of alley lying – changes which are more likely to be detrimental to foot health.[10,15,25] Vokey *et al* [27] studied various combinations of sand and mattress freestalls with rubber and concrete flooring and found that the optimal combination with regard to foot health was a sand stall – rubber alley combination, suggesting that we should be cautious over use of rubber flooring in alleys when stall design may be compromised.

c. Surface Hygiene

The cleaner and drier walking surfaces are managed, the less likely we will have problems with infectious causes of lameness. In Europe, slatted floor barns are more common than in the US. Larger barns and more extreme climatic conditions may be the reason for this difference. Where concrete flooring prevails, the design of the pen (number of rows of stalls and width of the alleys), the degree of overstocking (cows per square foot of alley surface) and frequency of alley scraping, flushing or vacuuming are the main determinants of leg hygiene.[6] Where automated alley scrapers are used, they should be timed to move through the pen when the minimum number of cows are standing in the alleys, in order to avoid the situation where cows must walk through a wave of manure. For example, one hour after the delivery of fresh feed, one hour after return to the pen from each milking and around 2 to 4 am when feeding activity is at a minimum.

Once lesions develop and cows become lame, they must be identified and treated as soon as possible. If they are not, then changes in behavior forced upon them by the pain associated with lameness place the cow at great risk for staying lame for a very long period of time, hence the concept of 'get lame – stay lame.'

We now know that lame cows behave differently from non-lame cows, and in compromised environments they lie down for fewer hours per day. This is the second role for poor cow comfort in herd lameness dynamics – acting to ensure that once a cow becomes lame, she stays lame.

Dual Roles of Cow Comfort: Role 2

The cow comfort factors discussed previously which increased daily standing times have a role to play in exacerbating the severity and duration of lameness. Consider the greater effect of a poor transition on cows that are already lame when they leave the far dry group, the greater effect of heat stress on cows that already have a sole ulcer, and the greater effect of long milking times on cows that are often at the back of the holding area because they were slow to leave the pen due to lameness.

For cows that are already lame, the interaction of the claw with the walking surface becomes even more important. The pain associated with this interaction is a major reason why gait is modified so that we observe lameness as a result of lesion development. For lame cows, concussion is an obvious effect of having to stand and walk on a hard concrete surface.

a. Stall Design and Standing Time

Lame cows modify their stall use behavior compared to non-lame cows in poorly designed stalls.[8] The acts of rising and lying down become incredibly difficult when cows develop a sore foot. In poorly designed mattress stalls they spend much longer standing in the stall at the start and during a stall use session than non-lame cows. While normal cows may spend around two hours per day standing in stalls, slightly and moderately lame cows in poorly designed mattress stalls remain standing in the stall for up to six hours per day on average and show a reduction in lying time. In contrast, in deeply bedded, well managed sand stalls, lame cows show no such modification in behavior – they maintain resting times at around 12 hours per day and stand in the stall typically less than two hours per day.

We believe that this difference in lame cow behavior between the two types of stall is related to surface traction and cushion. The rear foot is cushioned and gains traction in a deep, loose bed of sand, making standing and lying down, even with a sore foot, relatively easy. In contrast on a smooth surface mattress stall, the toe of the weight-bearing rear foot is driven into the surface, making rising much more challenging to a cow with a sore foot.

These poor environments, in which lame cows struggle to gain appropriate periods of rest, result in a failure to cure and extended periods of lameness – effectively making sure that if a cow becomes lame, she stays lame.

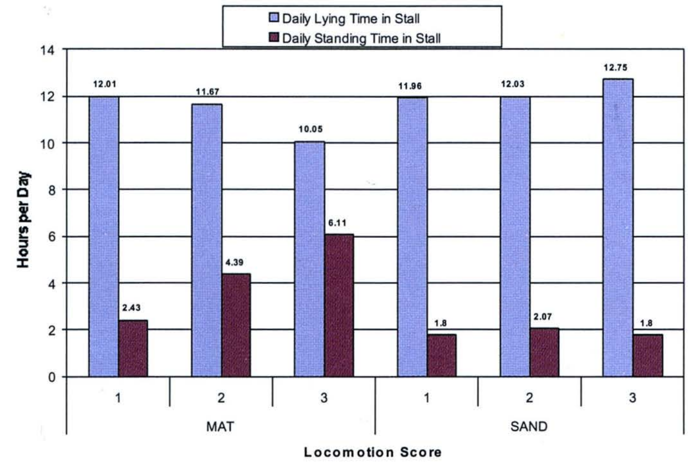

Figure 2. Stall use behavior in non-lame (score 1), slightly lame (score 2) and moderately lame (score 3) cows in barns with deep sand (SAND) and rubber crumb-filled mattress (MAT) freestall surfaces.

Figure 3. Compare how the toe of the main weight-bearing limb of the cow interacts with the stall surface during rising and lying movements. The cushion and traction of sand is in stark contrast to the small surface area of contact on a mat or mattress stall.

b. Walking Surfaces for Lame Cows

Once a cow is lame, she is even more sensitive to the surface that she must stand and walk upon. Where the predominant flooring surface is concrete, the concussion created by walking on an unforgiving surface makes lame cows look even worse. Using rubber transfer lanes between the pens and the parlor is a great way to improve the gait of lame and non-lame cows and improve the speed of transfer of these cows between the two areas of the farm. Note that rubber transfer lanes help cows that are already lame by reducing concussion (role 2) and prevent new cases of lameness by reducing wear and trauma due to slipping (role 1).

Breaking the Cycle of 'Get Lame – Stay Lame'

In addition to reducing the risk factors for each of the triggers of lameness, and improving the identification and treatment of lame cows, improving cow comfort can have a major impact on reducing the effects of the trigger factors (role 1) and improving the rest and recovery of cows that are already lame (role 2), which ultimately impacts herd lameness dynamics.

a. Cow Comfort Improvements to Reduce the Impact of the Trigger Factors – Role 1

Changes that we can make to reduce the effects of the trigger factors include the following:

1. Exposing heifers to concrete throughout the rearing period and allowing them to learn to use freestalls several weeks before calving;
2. Moving heifers to the close-up group at least 30 days before calving;
3. Keeping heifer groups split from mature cow groups throughout the transition period.

Note: as an alternative to 1-3, heifers may be managed on bedded packs throughout the transition period up to 30 days-in-milk (DIM) and then introduced to freestalls.

4. Stocking all transition cow groups to provide no less than 30 inches of bunk space per cow and one stall per cow.
5. Improving stall design to accommodate large pre-fresh cows, mature cows and first- lactation heifers, and ensure resting times in non-lame cows and heifers of around 12 hours per day throughout lactation.
6. Minimizing the number of pen moves throughout the transition period.
7. Minimizing time spent in lockups, especially within three weeks of calving by using sick cow screening systems that do not require a mini-exam of every cow in the pen.
8. Using soakers to cool cows at a start temperature of 70°F (21.1°C), increasing soaker frequency with increasing temperature.
9. Using recirculation fans over stalls above 70°F to improve stall usage.
10. Minimizing time out of the pen during milking by splitting groups and ensuring that milking facilities are adequately sized and operating at the number of turns per hour expected.
11. Reducing slipping, trauma and wear by strategically using rubber flooring in transfer lanes, holding areas and other high-risk surfaces. Similarly, in grazing herds we can improve cow track maintenance.

b. Cow Comfort Improvements to Provide an Environment where Lame Cows can Cure – Role 2

Currently, there is no evidence to confirm that any type of mattress stall can mimic the properties of sand and ensure that lame cows can maintain normal time budgets. In such facilities, early identification and treatment of lame cows to remove the cause of pain is paramount. Alternative resting areas such as straw bedded packs may be used for lame cow recovery, but since stall use behavior changes are detected even in slightly lame cows, this is not an ideal solution, as most facilities will only have enough space for moderate and severely lame cows.

Sand bedding is, without a doubt, the optimal stall surface for lame cows. Deep beds of sawdust or digested manure solids may behave similarly, but this has yet to be proven and until then, a deep sand freestall bed remains the gold standard to which we compare everything else. While sand helps cows compensate for many stall design inadequacies, lunge obstructions, high-brisket locators and stalls that are too narrow still challenge lame cows more than non-lame cows. For that reason, many sand herds also use a recovery area for lame cows consisting of an open sand bedded area, where cows may rise and lie down free of hindrance.

Providing cows the option to spend time on an area of pasture close to the freestall barn and a rest from walking on concrete is another option that is being looked at to improve the comfort of lame cows.

Herd Cow Comfort Interventions – Closing the 'Lameness Gap'

Over the last three years, many herd managers have made the decision to improve cow comfort –with stall design being the main focus of attention. Some have removed rising and lying obstructions, widened stalls and improved existing facilities, while others have made the bold step of removing the mattresses and converting the farm over to using sand-bedded stalls, with associated costs involved in adapting manure handling. We have been fortunate enough to track many of these herds after stall improvements have been made, and common to all is an increase in milk production that can be used to offset the costs of remodeling.

Interestingly, if we examine the mean mature equivalent 305 milk production (ME305) for first-lactation heifers compared to mature cows, we typically see that the first-lactation heifers are about 1,000 lb (454.5 kg) above the mature cows in the average US dairy herd. However, in the herds that have improved cow comfort, mature cow ME305 climbs rapidly so that within about 1.5 years, it is the same as, or greater than, that of the heifers in most herds. Note the increase in mature cow ME305 in the 150-cow dairy shown in Figure 4, following a mattress stall remodel. Larger mature cows that used to be too big for the stalls, and frequently got lame and injured in the past, are now fit, healthy and able to milk to their potential. In general, the more dramatic the remodel, the bigger the improvement, with greatest improvements seen in herds that have changed to sand bedding.

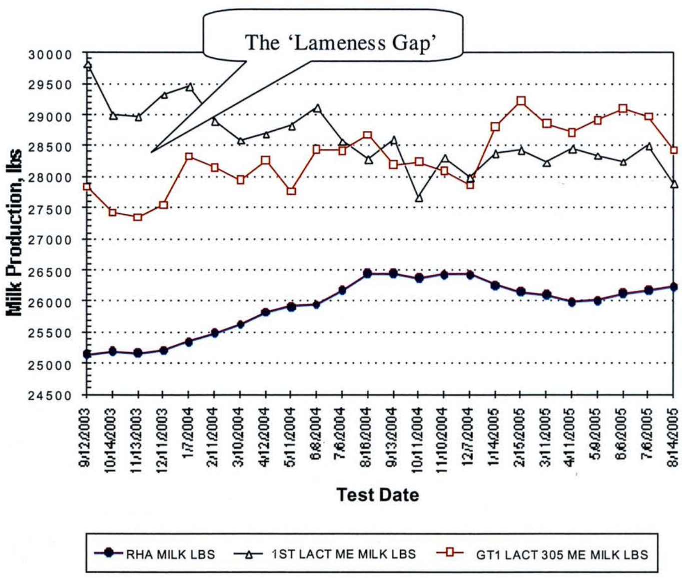

Figure 4. Milk production (rolling herd average (RHA), ME305 first lactation and ME305 mature cow) for a 150-cow-freestall housed herd following stall improvements in November 2003. Stalls were widened, lunge obstructions removed and mattress cushion was improved.

Using this information, it is now easy to construct a partial budget for stall changes and facility improvements if we model what would happen over a three-year period, if mature cows perform as well as the first-lactation heifers on an ME basis and close up the 'lameness gap'. Table 1 below estimates that there would potentially be almost $100,000 return after three years, supporting stall improvements that could amount to around $300 per stall for this 300-cow herd using data obtained from Dairy comp 305. The calculations are based on ME milk rather than real milk, but in general, they have held up under on-farm conditions.

The reality for the example herd in Table 1 was that mattress stalls were widened and neck rails adjusted at minimal expense in the fall of 2003, and over the last two years rolling herd average increased by 3,000 lbs (1,363.6 kg) per cow. Improvements in lameness have resulted in a reduction in the proportion of cows being blocked from around 20% of cows trimmed to virtually none (Figure 5).

Conclusions

Within this article, I have made the case that cow comfort is the most important factor determining prevalence of lameness in a dairy herd, by interacting with trigger factors to ensure that cows get lame, and interacting with the cow once she becomes lame to ensure that she stays lame.

We now understand where to impact lameness and break the cycle of 'get lame-stay lame,' by focusing on the dual roles of cow comfort. Extensive interventions

Table 1. An estimate of increased milk production and revenue for a 300-cow dairy. The analysis assumes that a change in cow comfort allows mature cows to milk to the level of the first-lactation heifers.

Parity	Inventory	305ME	Difference from L1	Year 1 Milk	Year 2 Milk	Year 3 Milk
1	104	29957				
2	83	28804	1153	95699	95699	95699
3	37	25743	4214		155918	155918
4	56	27518	2439			136584
Sum increased milk production (lbs)				95699	251617	388201
Milk Price less feed costs ($/lb)	0.13		Increased revenue ($)	12441	32710	50466
Cumulative revenue ($ per year)				**12441**	**45151**	**95617**

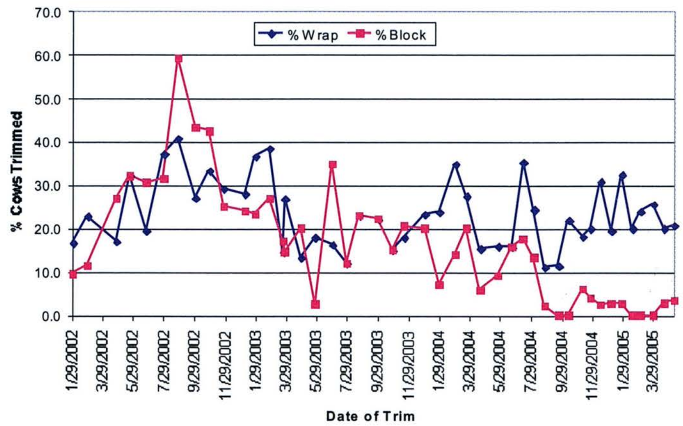

Figure 5. Change in proportion of cows receiving hoof blocks and wraps at each visit over the last three years.

have been economically justifiable based on the increased production achieved by maintaining a herd of more mature, healthier cows that are no longer broken down with chronic claw-horn lesions.

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