The Influence of Cow Comfort on Lameness and Production

Nigel B. Cook MRCVS
Clinical Assistant Professor in Food Animal Production Medicine
University of Wisconsin-Madison
School of Veterinary Medicine

Introduction

In light of data suggesting that culling rates in North America continue to increase as milk yield increases, and with renewed interest in cow longevity, it is tempting to speculate that improvements in genetics and nutrition have outpaced the facilities in which we house our dairy cows. If we are to continue to milk high yielding dairy cows, whilst improving cow health and longevity, we must improve the environment in which we house them and question some of the management and feeding strategies which are now commonplace.

Clearly, management practices put great strains on a cow's individual daily time budget for lying, feeding, drinking, milking and socializing. Time spent in lock-ups for example, will ultimately affect time spent performing other activities throughout the remainder of the day. It is also becoming clear that while many cows in a group maybe unaffected by environmental design faults and management interventions, a small but significant population of cows are greatly affected. We believe that studies must be aimed at identifying this group of "outliers", for we suspect that poor health and productivity does not impact the whole group, but afflicts those individuals that struggle to cope and adapt to a situation.

This paper aims to review our current knowledge regarding cow comfort and its effect on lameness and productivity of the cow.

Cow Comfort – the Benefits

Two separate studies have shown that compared to the standing position, blood flow to the mammary gland when cows lay down is increased by 24-28% (Metcalf et al., 1992; Rulquin and Caudal, 1992). This may improve the delivery of nutrients to the udder and increase milk yield. Currently, the data that conclusively links improved cow comfort with increased production is sparse. Natzke et al., (1982) reported higher milk production in cows during a stall preference study, when stall utilization; which included standing in stalls, was highest.

We do know however, that lameness may have a significant impact on milk production (Warnick et al., 2001; Green et al., 2002), and there is a growing body of evidence which demonstrates the importance of cow comfort to the prevention of lesions of the claw horn and interdigital space.

What factors influence Cow Comfort and Lying Time?

The mechanics of rising and lying in the cow are complex (Nordlund and Cook, 2003), but within a given stall design, a significant amount of data would suggest that cows appear to prefer more cushioned surfaces (Wandel et al., 2002; Palmer and Wagner-Storch, 2003). The design and dimensions of the stall are also very important however. For the cow to rise on her rear legs she must transfer weight over the front knees, creating a point of balance which requires the cow's head to almost touch the ground in an area referred to as the "Bob Zone". Designs which inhibit this lunge and bob movement of the head may reduce stall usage by creating fear of slippage of the rear feet on the stall surface, due to inadequate weight transfer. Haley et al., (2000) found that when cows were restricted in tiestalls, they were more reluctant to change position from lying to standing and Krohn and Munksgaard (1993) found that in tiestalls, compared with loose housing, there is an increased frequency of interruption of the lying down movement. Haley et al. (2001) found that lying time increased in tiestalls from 10.4 hours per day on concrete to 12.2 hours per day on a mattress stall base. Cows lay down less frequently, but for longer periods on concrete, suggesting that they were reluctant to perform the actual process of standing and lying. These studies taken together confirm an interaction between lunging inhibition due to stall design, and rising surface.

In addition to stall design, cow comfort and stall usage will be influenced by a number of animal, environmental and management factors which will ultimately influence daily lying times. These include parity, stage of lactation, milk yield and times milked per day, health status, stocking rate, heat activity, social position, daily human interactions with the cow, and temperature.

First lactation heifers, when first exposed to freestalls in a competitive environment, may lie down for as little as 6.25 hours per day (Singh et al., 1993) and Chaplin et al. (2000) found that early lactation heifers lay down in the same stalls for only 9 hours per day, compared to 11.4 hours when they were pregnant.

Overcrowding has been found to decrease lying times in freestalls. Friend et al., (1976) found that mean daily lying time was only significantly reduced in a pen with 12 lactating cows when stocking density reached 200% (2 cows per stall). Leonard et al., (1996) found that in a group of heifers housed at a stocking density of 200% pre and post-calving, lying times averaged 7.5 h per day with a wide range from 2.7 to 11.9h. Animals that consistently lay down for 5h per day or less were identified. Wierenga and Hopster (1990) described a study monitoring cow behavior in groups of 15-20 lactating dairy cows, comparing three levels of overstocking at 25%, 33.3% and 55%, with behavior at 0% overstocking. Lying behavior at night decreased significantly at 33.3%, but was compensated for by a significant increase in lying behavior during the evening. At 55% overstocking, this compensation mechanism was overwhelmed and a significant reduction in lying time was observed overall. Interestingly, these authors were able to identify high and low ranking individuals in the group. The behavior of high ranking cows was largely unaffected by overstocking, other than a reduction in standing in alleys in the evening at 33.3 and 55%. However, the behavior of low ranking individuals was significantly altered, even at 25% overstocking. A reduction in lying during the night was reported at all levels of overstocking. This was compensated for by increased lying in the evening up to 55%, but at this level of overstocking, the compensation mechanism was overwhelmed. This study clearly demonstrated the importance of detecting effects on “outliers” rather than looking at group means.

Cows have a strong motivation to lie down. Metz (1985) showed that following a three hour period of lying and feeding deprivation, cows chose to compensate for their loss of lying time in preference to feeding. Such data suggests that management changes, such as locking cows up for fertility treatments, may cause changes in cow behavior over the subsequent hours. Cows can compensate, provided that these challenges are not too frequent.

Ambient temperature has also been shown to affect stall preference for different materials. Extremes of temperature may have an adverse effect on sand preference; Palmer and Wagner-Storch (2003) showed that sand was the preferred choice at 21-60^{o}F, whereas a rubber crumb mattress (Pasture Mat®) was preferred at 1-20^{o}F and 61-100^{o}F, in a barn without heat abatement strategies.

Cow Comfort and Feet and Leg Hygiene

Increased time spent lying down in a clean dry comfortable stall will potentially mean less time spent in concrete alleyways and lead to cleaner drier feet. Cattle housed in wet, manure contaminated conditions are more likely to suffer infectious diseases of the foot (Bergsten, 1997; Cook and Cutler, 1995; Philipot et al., 1994), such as interdigital necrobacillosis (foot rot), heel horn erosion (HHE) and papillomatous digital dermatitis (heel warts; PDD).

Hygiene Score data collected by the author from Wisconsin dairy herds suggests that foot and leg hygiene in freestall barns is usually worse than in tiestalls, largely because of the quantity of manure present in the alleys.

Common reasons for poor leg hygiene in freestall barns include:

- Infrequent removal of alley manure
- Overstocking
- Use of a three row pen design rather than a two row design

Frequency and type of alley scraping will have a major impact on manure accumulation. Slatted floors are common in Europe, but they are coming under increased scrutiny due to poor air quality and high ammonia concentration levels in the barn. A recent study suggested that cows have no preference for grooved concrete or a slatted area (Stefanowska et al., 2002), which is in contrast to the author’s experience. The hot humid conditions during the summer in much of the US make it unlikely that slatted barns will become commonplace from purely an air hygiene point of view. Flushing and manual scraping are usually performed when the cows are in the collecting yard for milking, hence normally 2 or 3 times per day. Guidelines for the frequency of removal of manure based on hygiene and health assessments are unavailable. The author recommends a minimum frequency of three times a day for the control of infectious foot disease. Automatic scrapers have the potential to keep freestall cow’s lower limbs cleaner only if they are operated continuously and over a short distance, so that cows do not have to walk through a large wave of manure as it progresses through the pen.

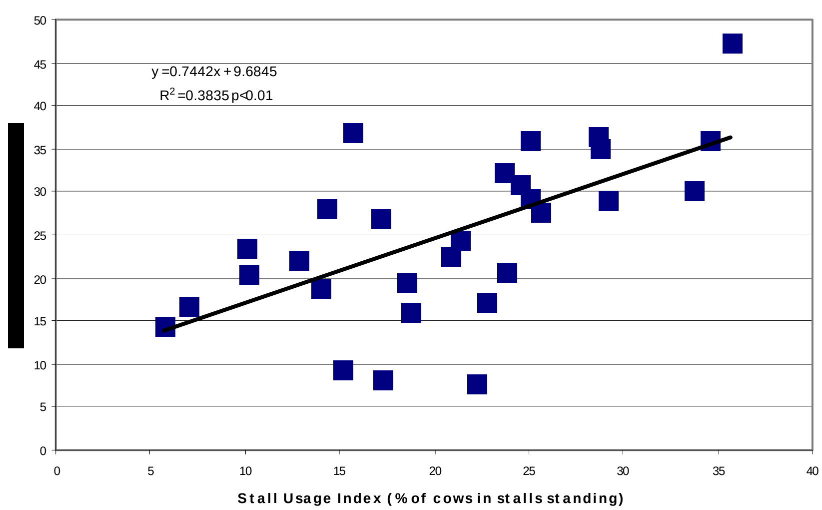
Overstocking will lead to more manure being deposited per square foot of alleyway and exacerbate existing problems, particularly in six row freestall barns, milked and scraped only twice daily. A three row freestall pen with three crossovers, designed to house 100 cows, will have approximately 4070 square feet of alleyway and crossovers. A two row freestall pen, also designed to house 100 cows tail to tail, with the same number of crossovers, will have approximately 5004 square feet of alleyway area. That equates to 20% less surface area for the same quantity of manure. Unless we scrape more frequently, the manure level in the pen will be deeper, resulting in dirtier feet and legs and an increased risk of PDD (Cook, 2002a).

Cow Comfort and Laminitis

On two similar farms with near identical stall designs and rations, Colam-Ainsworth et al., (1989) elegantly demonstrated that a laminitis problem in early lactation in first lactation heifers on one farm was associated with a dramatic difference in the amount of straw bedding being used on the concrete stall surfaces. The problem farm used 75% less bedding, which was associated with a greater time spent standing in alleys and half in freestalls. An increase in the amount of bedding being used appeared to alleviate the problem.

Aspects of stall design, such as lack of surface cushion, low divider rails (<34cm, 13.5”), limited borrowing space and high rear curbs (>16-20cm, 6.5-8”) have all been related to an increase in lameness or laminitis (Faull et al., 1996; Leonard et al., 1994; Philipot et al., 1994) A stall usage index, measured as the proportion of cows in stalls that were standing, either completely in or half in stalls, one hour before milking, was significantly related to lameness prevalence in a recent Wisconsin lameness survey (Cook, 2002b) (Figure 1).

Figure 1. The relationship between Stall Usage Index and Lameness Prevalence in Wisconsin Freestall herds



In the United Kingdom, the research effort toward understanding laminitis has been targeted at the interaction of the environment with diet and other changes around calving time in first lactation heifers. Such an approach is supported by recent epidemiological survey data which suggests that those individuals that suffer lameness during the first lactation are more susceptible to lameness in subsequent lactations, during the second lactation in particular, and especially with claw horn lesions (Hirst et al., 2002).

Leonard et al., (1996) presented data from 43 heifers housed in a freestall barn with access to two stall designs pre and post-calving. The first allowed for side lunging and was bedded with a rubber mat and the second was a more restrictive divider design with a concrete stall surface. The authors noted reduced lying and increased periods spent standing half in and half out of stalls in heifers housed in the pen with the more restrictive divider style and firmer stall surface. These heifers, after calving, suffered significantly worse claw hemorrhage scores and an increased rate of clinical lameness in the two months after calving compared with heifers in the less restrictive stall with greater surface cushion. Correlation between reduced lying behavior and worsening claw health was observed in heifers in the more comfortable stalls.

Overstocking has been used to trigger dramatically reduced lying times in autumn calving heifers post-calving (Leonard et al., 1996). Using a restrictive stall divider design, pens were stocked at 2 heifers to 1 stall immediately after calving. Under such conditions a wide range of lying times were recorded (2.7 to 11.9 hours per day), with a mean of 7.5h. Worsening claw hemorrhage scores were significantly associated with reduced lying times four months after calving. In those autumn calving heifers classified as short lying (lying approximately 5 hours per day), four of seven developed clinical lameness, compared to a rate less than 10% in medium (7h/day) and long (10h/day) lying groups. The authors noted that lesions occurred only after a prolonged period of overstocking and enforced short lying, and that the lesions were worse when the housing treatment was combined with calving and feed change.

Recent studies have attempted to extract the housing effect from the effect of change in diet and events around calving time. Webster (2001) noted that claw lesion scores observed in heifers housed either on straw bedded packs or in freestalls from 4 weeks before, to 24 weeks after calving, worsened after calving. However, lesions were more severe in heifers housed in freestalls than on a bedded pack, and were exacerbated by the feeding of low dry matter feed. Livesey et al., (1998) also reported that white line and sole hemorrhage scores were exacerbated by freestall housing, compared to housing in straw yards, and by the feeding of a high concentrate diet, in heifers post calving.

From these data, time around calving, and the onset of lactation, appear to be significant risk factors for claw horn lesion development. Systemic changes at this time appear to set in motion a chain of events which are influenced by environmental and dietary factors. Tarlton and Webster (2002) have shed light on the exact nature of these systemic changes. Using hoof explants from age matched maiden heifers and heifers killed pre and post calving, they demonstrated a deterioration of the structural integrity of the hoof around calving time, which would allow the pedal bone to sink within the hoof capsule. An increase in the concentrations of activated MMP-2 (a metalloproteinase enzyme) and a novel gelatinlytic protease (“Hoofase”) were identified in the tissues of the corium at 2 weeks pre-calving – suggesting a causal link between the enzyme activation and the change in hoof structure.

An excessive amount of time spent weight bearing and/or insufficient time spent lying, may facilitate the breakdown of the connection between the pedal bone and the horny capsule of the claw wall, triggered by changes in the elasticity of the connective tissues of the corium and an increased mobility of the pedal bone, thereby explaining the worsening in claw lesion scores observed in those animals subjected to sub-optimal environments after calving. The findings of Leach et al., (1997) support the view that the initial lesion occurs in the corium of the laminar region of the claw, and that damage to the corium of the sole occurs later, following sinking of the pedal bone. They observed claw hemorrhage in first calving heifers monitored from 4 weeks before to 32 weeks after calving. White line hemorrhage was most severe at 9 weeks, compared to sole hemorrhage which was maximal at 14 weeks post calving.

However, while first lactation laminitis is important to the overall epidemiology of lameness in dairy cows, the author is aware that cows in North American conditions may face other significant risk factors. Sub-acute ruminal acidosis (SARA) is commonly found in high producing dairy herds (Nordlund et al., 1995) and rates of clinical lameness treatment often increase in September, following summer heat stress. Work in Australia, using equine hoof explants has suggested an alternative pathway of metalloproteinase activation and subsequent laminitis.

Mungall et al., (2001) showed that streptococcal pyrogenic exotoxin B (SpeB), released from *Streptococcus bovis* may activate MMP-2 and separate lamellar explants dose dependently. There exist some anatomical differences in the site of the lesion in horses and cattle. The separation in the horse occurs at the dermal-epidermal junction, whereas in the cow, it is the connective tissue of the corium which undergoes change, hence the suggestion that the condition be referred to as coriosis, rather than laminitis (Lischer and Ossent, 2002). However, these data do demonstrate a link between *S.bovis*, an organism with a significant role in SARA, and damage to the integrity of the hoof caused by MMP-2, which maybe activated by its exotoxin.

Environmental stressors, such as poor stall comfort, overstocking and heat stress behavior, coupled with SARA may potentially trigger coriosis (laminitis) at other stages of lactation and in cows beyond first lactation. Leonard et al., (1996) noted that in overstocked conditions there were individuals in a pen that consistently had short daily lying times. It is likely that these short lying animals are low ranking in the pen hierarchy, and are more susceptible to disease.

Galindo and Broom (2000) have confirmed that low ranking individuals spend less time lying and more time standing still and standing half in freestalls than middle and high ranking cows. Hierarchy position was determined using an index of displacement based on mutual stall evictions between individuals. Excessive time spent standing half in stalls was identified as a significant risk factor for interdigital and heel lesions. Increased total time standing>45% of the time significantly increased sole lesions and lameness cases. The survival time to lameness for low ranking cows was significantly shorter than for high ranking animals, with more than 60% suffering clinical lameness within the 25 week period of the study. In a second study, Galindo et al., (2000) further examined standing behavior in low ranking individuals in a group of 40 lactating dairy cows housed in stalls with a restrictive stall design. Low rank cows stood still in alleys and half in freestalls for significantly longer than high rank cows. Importantly, these authors were able to track behavior patterns as individuals became lame during the study period. Compared to those individuals that remained sound, the lame cows were of lower rank and stood for significantly longer half in stalls. Mean time standing still in alleys was not significantly different.

Cook (2002c), in a selection of well managed Wisconsin dairy herds noted significantly lower lameness prevalence in herds utilizing sand stall bases, compared to those using either a mat or a mattress stall base. It is therefore possible that cows managed in herds with sand stalls exhibit less aberrant stall use behavior than cows in herds using other stall surfaces.

Cow Comfort and Hock Damage

Although perhaps not of major significance to overall lameness problems on most farms, hock abrasion and ulceration is of significance to individuals and an important welfare issue. It may also be used as an indicator of cow comfort. Mattresses have the distinct disadvantage over sand in that they carry a much greater risk of hock damage. In one study, 91% of cows on mattresses and only 24% of cows on sand had evidence of hock abrasion (Weary and Taszkun, 2000).

References

Alban L, Agger JF, Lawson LG: Lameness in tied Danish dairy cattle: the possible influence of housing systems, management, milk yield, and prior incidents of lameness. *Prev Vet Med* 29:135-149, 1996.

Anderson N: Observations on cow comfort using 24 hour time lapse video. *Proc 12th Int Symp Lameness in Ruminants*, Orlando, pp 27-34, 2002

Bergsten C: Infectious diseases of the digits. p 89-100. In *Lameness in Cattle. 3rd Edition*. WB. Saunders Co. Philadelphia, 1997

Chaplin SJ, Tennent HE, Offer JE, Logue DN, Knight CH: A comparison of hoof lesions and behaviour in pregnant and early lactation heifers at housing. *The Vet J* 159: 147-153, 2000.

Chaplin SJ, Tierney G, Stockwell C, Logue DN, Kelly M; An evaluation of mattress and mats in two dairy units. *App. Anim. Behaviour Sci* 66 263-272, 2000.

Colam-Ainsworth P, Lunn GA, Thomas RC, Eddy RG: Behaviour of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers. *Vet Rec* 125: 573-576, 1989

Cook NB, Cutler KL: Treatment and outcome of a severe form of foul-in-the-foot. *Vet Rec*136: 19-20, 1995.

Cook NB: Two row barns or three-row – that is the question! *UK Vet* 7: 1-3, 2002a

Cook NB: Lameness prevalence and the effect of housing on 30 Wisconsin dairy herds. p 325-327, *Proc 12th Int Symp Lameness in Ruminants,* Orlando, 2002c

Faull WB, Hughes JW, Clarkson MJ, Downham DY, Manson FJ Merritt, JB, Murray RD, Russell WB, Sutherst JE, Ward WR: Epidemiology of lameness in dairy cattle: the influence of cubicles and indoor and outdoor walking surfaces. *Vet Rec* 139: 130-136, 1996

Friend TH, Polan CE, McGilliard ML: Freestall and feed bunk requirements relative to behavior, production and individual feed intake in dairy cows. *J Dairy Sci*. 60: 108- 116, 1977

Galindo F and Broom DM: The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. *Res Vet Sci* 69: 75-79, 2000

Galindo F, Broom DM, Jackson PGG: A note on possible link between behaviour and the occurrence of lameness in dairy cows. *App Anim Behav. Sci*. 67: 335-341, 2000

Gaworski MA, Tucker CB, Weary DM, Swift ML. Effects of stall design on dairy cattle behavior. *Proceedings of the Dairy Housing Conference*, p 139-146, 2003

Green LE, Hedges J, Schukken YH, Blowey RW, Packington AJ: The inpact of clinical lameness on the milk yield of dairy cows. *J Dairy Sci*. 85:2250-2256, 2002

Haley DB, Rushen J, de Passille AM: Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. *Can J Anim Sci* 80: 257-263, 2000

Haley DB, de Passille AM, Rushen J: Assessing cow comfort: effect of two types and two tie stall designs on the behaviour of lactating dairy cows. *Appl Anim Behav Sci* 71: 105-117, 2001

Hirst WM, Murray RD, Ward WR, French NP: A mixed-effects time to event analysis of the relationship between first lactation lameness and subsequent lameness in dairy cows in the UK. *Prev Vet Med* 54: 191-201, 2002

Hultgren J: Observational and experimental studies of the influence of housing factors on the behaviour and health of dairy cows. *Doctoral thesis*. Uppsala, Sweden, 2001.

Krohn CC and Munksgaard L: Behaviour of dairy cows kept in extensive or intensive environments II: Lying and lying down behaviour. *Appl Anim. Behav Sci* 37: 1-16, 1993

Leach KA, Logue DN, Kempson SA, Offer JE, Ternent HE, Randall JM: Claw lesions in dairy cattle: Development of sole and white line hemorrhages during the first lactation. *The Vet J*. 154: 215-225, 1997

Leonard FC, O'Connell JM, O'Farrell KJ: Effect of different housing conditions on behaviour and foot lesions in friesian heifers. *Vet Rec* 134: 490-494, 1994

Leonard FC, O'Connell JM, O'Farrell KJ: Effect of overcrowding on claw health in first-calved friesian heifers. *Br Vet J* 152: 459-472, 1996

Lischer Ch J, Ossent P: Pathogenesis of sole lesions attributed to laminitis in cattle. p 82 - 89. Proc *12th Int Symp Lameness in Ruminants*, Orlando, 2002

Livesey CT, Harrington T, Johnston AM, May SA, Metcalf JA: The effect of diet and housing on the development of sole haemorrhage, white line haemorrhage and heel horn erosion in Holstein heifers. *Anim Sci*. 67: 9-16, 1998.

Metcalf JA, Roberts SJ, Sutton JD: Variations in blood flow to and from the bovine mammary gland measured using transit time ultrasound and dye dilution. *Res Vet Sci* 53: 59-62, 1992

Metz JHM: The reaction of cows to a short-term deprivation of lying. *Appl Anim Behav Sci*. 13: 301-307, 1985

Mungall BA, Kyaw-Tanner M, Pollitt CC: In vitro evidence for a bacterial pathogenesis of equine laminitis. *Vet Microbiol*. 79:209-223

Natzke RP, Bray DR, Everett RW: Cow preference for freestall surface material. *J Dairy Sci*. 65: 146-153, 1982

Nordlund K, Cook NB: A flowchart for evaluating dairy cow freestalls. *Bovine Practitioner* 37:89-96, 2003.

Nordlund KV, Garrett EF, Oetzel GR: Herd based rumenocentesis; a clinical approach to the diagnosis of subacute rumen acidosis. *Compen, Contin. Educ. Pract*. Vet. 17: S48-S56, 1995

Oltenacu PA, Hultgren J, Algers B: Associations between use of electric cow-trainers and clinical diseases, reproductive performance and culling in Swedish dairy cattle. *Prev Vet Med* 37: 77-90, 1998

Palmer RW and Wagner-Storch AM. Cow preference for different freestall bases in pens with different stocking rates. *Proceedings of the Dairy Housing Conference*. p155-164, 2003

Philipot JM, Pluvinage P, Cimarosti I, Sulpice P, Bugnard F: Risk factors of dairy cow lameness associated with housing conditions. *Vet Res* 25:244-248, 1994

Phillips CJC, Rind MI: The effects on production and behaviour of mixing uniparous and multiparous cows. *J Dairy Sci* 84: 2424-2429, 2001

Rulquin H, Caudal JP: Effects of lying or standing on mammary blood flow and heart rate of dairy cows. *Ann Zootech* 41: 101, 1992

Singh SS, Ward WR, Lautenbach K, Hughes JW, Murray RD: Behaviour of first lactation and adult dairy cows while housed and at pasture and its relationship with sole lesions *Vet Rec* 133: 469-474, 1993

Singh SS, Ward WR, Hughes JW, Lautenbach K, Murray RD: Behaviour of dairy cows in a straw yard in relation to lameness. *Vet Rec* 135: 251-253, 1994.

Stefanowska J, Swierstra D, Van den Berg JV, Metz JHM: Do cows prefer a barn compartment with a grooved or slotted floor? *J Dairy Sci* 85:79-88, 2002.

Tarlton JF, Webster AJF: A biochemical and biomechanical basis for the pathogenesis of claw horn lesions. p 395-398. Proc *12th Int Symp Lameness in Ruminants*, Orlando, 2002

Wandel H, Jungbluth T, Benz B: Cow comfort in losse house systems. p313 *Proc 12th Int Symp Lameness in Ruminants*, Orlando, 2002

Warnick LD, Janssen D, Guard CL, Grohn YT: The effect of lameness on milk production in dairy cows. *J Dairy Sci.* 84: 1988-1997

Weary DM and Taszkun I: Hock lesions and freestall design. *J Dairy Sci* 83: 697-702, 2000

Webster AJF: Effects of housing and two forage diets on the development of claw horn lesions in dairy cows at first calving and in first lactation. *The Vet J* 162: 56-65, 2001

Wells SJ, Trent AM, Marsh WE, Williamson NB, Robinson RA: Some risk factors associated with clinical lameness in dairy herds in Minnesota and Wisconsin. *Vet Rec*136: 537-540, 1995.

Wierenga HK and Hopster H: The significance of cubicles for the behaviour of dairy cows. *Appl Anim Behav Sci* 26: 309-337, 1990.