CODE OF PRACTICE FOR THE CARE AND HANDLING OF DAIRY CATTLE: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

March 2009

Dairy Code of Practice Scientists' Committee

Jeffrey Rushen B. Sc. (Hons), Ph. D (Co-Chair)
Research Scientist, Pacific Agri-Food Research Centre, Agassiz, BC
Agriculture and Agri-Food Canada

Daniel M. Weary, B. Sc., M. Sc. D.Phil (Co-Chair)
Professor, NSERC Industrial Research Chair in Animal Welfare
Faculty of Land and Food Systems, The University of British Columbia

Valerie Smid DVM
Clinical Veterinarian, University of Manitoba

Kees Plaizier, Ph. D.
Associate Professor, Dairy Production and Management
Department of Animal Science, University of Manitoba

Christiane Girard agr., M. Sc., Ph. D.
Dairy and Swine Research and Development Centre, Sherbrooke Que
Agriculture and Agri-Food Canada

Michael Hall, Dairy Code Development Committee Chair (ex officio)
Dairy Farmers of Canada

NATIONAL FARM ANIMAL CARE COUNCIL
CONSEIL NATIONAL POUR LE SOIN DES ANIMAUX D'ÉLEVAGE

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Excerpt from Scientists' Committee Terms of Reference

Background

It is widely accepted that animal welfare codes, guidelines, standards or legislation should take advantage of the best available knowledge. This knowledge is often generated from the scientific literature, hence the term "science-based".

In re-establishing a Code of Practice development process, NFACC recognized the need for a more formal means of integrating scientific input into the Code of Practice process. A Scientists' Committee review of priority animal welfare issues for the species being addressed will provide valuable information to the Code Development Committee in developing or revising a Code of Practice. As the Scientists' Committee report is publicly available, the transparency and credibility of the Code process and the recommendations within are enhanced.

For each Code of Practice being developed or revised, NFACC will identify a Scientists' Committee. This committee will consist of 4-6 scientists familiar with research on the care and management of the animals under consideration. NFACC will request one or two nominations from each of 1) Canadian Veterinary Medical Association, 2) Canadian Society of Animal Science, and 3) Canadian Chapter of the International Society for Applied Ethology.

Purpose & Goals

The Scientists' Committee will develop a report synthesizing the results of research relating to key animal welfare issues, as identified by the Scientists' Committee and the Code Development Committee. The report will be used by the Code Development Committee in drafting a Code of Practice for the species in question.

The full Terms of Reference for the Scientists' Committee can be found within the NFACC Development Process for Codes of Practice for the Care and Handling of Farm Animals, available at www.nfacc.ca/code-development-process#appendixc.

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1. LAMENESS

SETTING TARGETS

Conclusions:

1. **Estimates of obvious or severe lameness are likely to be fairly reliable regardless of the particular gait scoring system used.**
2. **An animal welfare standard based on a maximum prevalence of 5-10% for obvious or severe lameness, or of 5-10% for sole ulcers and 10-20% of digital dermatitis are realistic targets.**
3. **Meeting these targets requires training in detecting lameness and hoof lesions.**

Lameness among dairy cows is widely recognized as one of the most serious (and costly) animal welfare issues for lactating dairy cows. To control lameness on a farm, many aspects of housing and management must be maintained correctly. Since a great deal of variation exists between farms, different producers can achieve success in different ways. This makes the prevalence of lameness an efficient outcome-based indicator; it shows the adequacy of housing and management on that farm. By specifying the standard in terms of the desired outcome (a low prevalence of lameness) it is not necessary to specify in detail the particular inputs (the housing or management conditions that are required), and allows some flexibility in how to achieve this goal.

Recently, some dairy standards have incorporated measures of prevalence (or incidence) of lameness (Whay et al. 2003). The new CCAC guidelines for the use of farm animals in research or teaching recommend that the prevalence of lameness be kept below 10%. Similarly, in her welfare audit for dairy farms, Grandin recommends 10% prevalence as a cut-off point for the proportion of cows with an obvious limp (Grandin 2007).

In order for the 10% prevalence value to be useful, identifying lameness accurately is necessary. However, research in the US and the UK shows that dairy producers substantially underestimate lameness in their herds (Wells et al. 1995, Whay et al. 2003, Espejo et al. 2006). This demonstrates the importance of improved training in lameness detection.

Methods of assessing prevalence: To use the prevalence of lameness as an outcome-based animal welfare standard, we need reliable and valid measures that can be applied on farm. The two most common options are to assess lameness directly by gait scoring and to assess aspects of hoof disease (especially sole ulcers and dermatitis) that are common causes of lameness. An outcome-based standard could then be defined either in terms of the maximum acceptable prevalence of lameness or the maximum acceptable prevalence of hoof disease. The advantage of gait scoring is that this can be done frequently and with relative ease by the producer, although accurate scoring requires training. Dermatitis can often be recognized in the parlour, but the presence of hoof lesions can only be determined when the hooves are trimmed.

Lameness assessment: A number of gait scoring methods are available and several have been used on-farm in North America.

The system developed by Sprecher et al. (1997) is probably the most well-known and relies on subjective assessments of the degree of arched back, short strides, cow favouring one limb, and a reluctance to bear weight. This system has recently been used to assess the prevalence of lameness on 50 dairy farms in Minnesota, with a fair degree of reliability (good agreement between different observers; Espejo et al. 2006). However, detection of hoof lesions by this system is not confirmed; there is a heavy reliance on the presence of an arched back, and this is not a reliable method of detecting hoof lesions when used alone (Cramer 2007).

The system devised by Cook (2003) uses a 4 point scale to subjectively assess walking speed, stride length, favouring of a limb, reluctance to bear weight and arched back. This system has reasonable sensitivity and specificity for detecting sole lesions. For example, a cow given a score of 3 or more has a 71% chance of having a hoof lesion, while a cow given a score of less than 3 has only a 40% chance (Cramer 2007). This gait scoring system has recently been used to assess the prevalence of lameness on 38 dairy farms in Ontario (Cramer 2007) and 30 farms in Wisconsin (Cook 2003).

The gait scoring system devised by Flower and Weary (2006) relies on 7 changes in gait: asymmetric stepping, a reluctance to bear weight, rear leg abduction/adduction, tracking up, head bobbing, joint flexion, and arched back. This gait scoring system has been found to have a good level of agreement between different observers and to be accurate at detecting cows with sole ulcers (Flower and Weary 2006, Flower et al. 2007, Rushen et al. 2008). For example, in two studies, the overall gait score was able to correctly classify 22 out of 24 cows (Flower and Weary 2006) and 12 out of 17 cows (Flower et al. 2007) as being with or without a sole ulcer.

Unfortunately, no studies have directly compared these different gait scoring systems. In general, these gait-scoring systems rely on similar features in gait to detect lameness, so there may be little difference among these scoring systems in categorizing cows, especially in cases of moderate and severe lameness. Flower and Weary (2006) noted that an assessment of the reluctance to bear weight (which effectively defines limping and which is a common element of the three gait scoring systems) was as good as the overall gait score at classifying cows into those with or without sole ulcers. Therefore, recording the prevalence of obviously lame cows (those with an obvious limp) would seem to be the most reliable method, if the particular gait scoring system is not defined.

<u>Setting a realistic target for lameness prevalence.</u> The lower the prevalence of lameness, the better, and no lameness is best of all. However, to set animal welfare standards in terms of the prevalence it is necessary to set a cut-off level that is realistic: the majority of Canadian dairy farmers should be able to meet the target. Recently, studies have reported prevalences of lameness in Ontario (Cramer 2007), BC (Ito et al. per comm.), Wisconsin (Cook 2003) and Minnesota (Espejo et al. 2007), and of hoof lesions in Ontario (Cramer 2007). The results of these studies (Table 1) allow us to estimate how many farms in Canada have different levels of prevalence.

Data from the studies suggest a conservative target for the prevalence of obviously or severely lame cows would be the 50th percentile, which is likely to be somewhere in the range of 3-6% prevalence. This corresponds roughly to the prevalence of sole ulcers of 5% (Cramer 2007). Half of the dairy farms in Canada are probably already meeting this target. A more liberal target would be a prevalence of 10%, which would be met by more than three-quarters of Canadian farms.

It is essential to remember that these figures refer to the prevalence of severe lameness. The prevalence of all cases of lameness is likely to be much higher, between 20-50%. There could be 3-10 times as many mildly lame cows within a herd as there are severely lame cows, depending on the criterion for deciding whether a cow is mildly lame or not. However, while there is likely to be good agreement as to whether or not a cow is severely lame, there is more disagreement over whether or not a cow is only mildly lame: agreement over the prevalence of severely lame cows is good (e.g. the 50th percentile ranges from 3-6%), but the estimate for the prevalence of overall lameness varies from 45% (Cook 2003) to 24% (Espejo et al. 2006). The latter likely reflects differences in the criterion used to decide whether or not a cow is mildly lame.

<u>Hoof lesions and dermatitis.</u> Many cases of lameness in dairy cows involve lesions in the hoof. Many types of lesions that vary greatly in size and severity can affect the hooves of dairy cows; however, there is little agreement about how best to classify or score lesions. In general, the prevalence of hoof lesions is greater than the prevalence of lameness (see Tables 1 and 2). Sole ulcers are the most consistently associated with lameness (e.g. Flower and Weary 2006; Flower et al. 2007); fortunately, sole ulcers can be consistently identified after trimming.

Cramer (2007) also provides data on the prevalence of various hoof lesions on 180 dairy farms in Ontario (Table 2). The most common hoof lesions in free-stalls were digital dermatitis, sole hemorrhages and sole ulcers; in tie stalls Cramer found digital dermatitis, sole hemorrhages and heel horn erosion. Agreement between scorers was highest when identifying digital dermatitis and sole ulcers and lowest when identifying sole hemorrhages and heel horn erosion.

In a survey of 20 free-stall herds in BC, Bell (2004) found that the mean prevalence of digital dermatitis was 15.2% which corresponds with the figure found by Cramer (2007).

If prevalence targets were set to 5% for sole ulcers and of 10% for digital dermatitis, adherence would be seen in over 50% of current tie-stall farms and more than 25% of free-stall farms. Adherence would increase to 75% (tie-stall farms) and 50% (free-stall farms) if the prevalence targets were set to 10% for sole ulcers and of 20% for digital dermatitis.

Table 1: Estimates of the 25th, 50th and 75th percentiles for the prevalence (%) of severe lameness from the studies of Cook (2003) in Wisconsin, Cramer (2007) in Ontario, Espejo et al. (2007) in Minnesota, and Ito et al. (personal communication) in British Columbia. The 25th percentile represents the prevalence below which the best 25% of farms lie. The 50th percentile is the prevalence below which the best 50% of farms lie and the 75th percentile is the prevalence below which the best 75% of farms lie.

Percentile	Cook 2003[1] 30 farms in Wisconsin	Cramer 2007[1] 38 farms in Ontario	Espejo et al. 2007[2] 50 farms in Minnesota	Ito et al. (per comm.)[3] 43 farms in B.C.
25th	0	1.3	2.6	2.8
50th	3.0	4.7	6.0	6.0
75th	5.0	Not given	8.3	9.4
Maximum prevalence recorded (%)	12.0 – 16.0	19.0	20.0	25.5

1. based on % of cows with a score of 4 in the gait scoring system of Cook (2003).
2. based on % of cows having a score of 4 or 5 in the gait scoring system of Sprecher (1997).
3. based on % of 'high-producing' cows having a score of 4 or 5 in the gait scoring system of Flower and Weary (2006).

Table 2 shows the 25th, 50th and 75th percentile for the prevalence (%) of sole ulcers and digital dermatitis based on data of Cramer (2007).

	Prevalence of Sole ulcers (%)		Prevalence of Digital dermatitis (%)	
Percentile	Free stall	Tie stalls	Free stalls	Tie stall
25th	4.4	0	9.4	0
50th	9.0	3.8	18.0	4.8
75th	16.8	7.3	38.9	15.0

References

Bell, E. (2004). Description of claw horn lesions and associated risk factors in dairy cattle in the lower Fraser Valley, British Columbia. M.Sc. Thesis. Vancouver, BC: The University of British Columbia.

Cook, N. B. (2003). Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. *Journal of the American Veterinary Medical Association, 223*, 1324-1328.

Cramer, G. (2007). Quantification of foot lesions and an evaluation of early detection methods for lameness in Ontario dairy farms. DVSc Thesis. Guelph, ON: The University of Guelph.

Espejo, L. A., Endres, M. I., & Salfer, J. A. (2006). Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. *Journal of Dairy Science, 89*, 3052-3058.

Flower, F. C., de Passillé, A. M., Weary, D. M., Sanderson, D. J., & Rushen, J. (2007). Softer, higher-friction flooring improves gait of cows with and without sole ulcers. *Journal of Dairy Science*, *90*, 1235-1242.

Flower, F. C., & Weary, D. M. (2006). Effect of hoof pathologies on subjective assessments of dairy cow gait. *Journal of Dairy Science, 89*, 139-146.

Grandin, T. (2007). Outline of cow welfare critical control points for dairies. 7 October 2008. <http://www.grandin.com/cow.welfare.ccp.html>

Rushen, J., de Passillé, A. M., von Keyserlingk, M. A. G., & Weary, D. M. (2008). The welfare of cattle. *Animal Welfare Vol. 5*. Berlin: Springer Verlag.

Sprecher, D. J., Hostetler, D. E., & Kaneene, J. B. (1997). A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. *Theriogenology, 47*, 1179-1187.

Whay, H. R., Main, D. C. J., Green, L. E., & Webster, A. J. F. (2003). Assessment of the welfare of dairy cattle using animal-based measurements : Direct observations and investigation of farm records. *The Veterinary Record, 153*, 197-202.

Wells, S. J., Trent, A. M., Marsh, W. E., Williamson, N. B., & Robinson, R. A. (1995). Some risk factors associated with clinical lameness in dairy herds in Minnesota and Wisconsin. *Veterinary Record, 136*, 537-540.

2. CALF HEALTH AND WELFARE

CALVING AREA

Conclusions:

1. **Calves are vulnerable to infection from pathogens in the calving area.**
2. **Risk of infection is reduced by calving in a clean area, without exposure to feces and other herd mates.**

Cows are especially active in the hours before calving, so factors affecting the comfort of the calving area are especially important. For example, Huzzey et al. (2005) found an 80% increase in the number of standing bouts during the day before calving, likely due to the discomfort associated with calving. Thus, addressing maternity pen design may positively benefit cow comfort. In particular, the stall surface is known to affect comfort when changing positions (see section on cow housing).

Calving in an area that allows farm workers to supervise calving and intervene if necessary may provide some benefits. However, because of their undeveloped immune system, newborn calves are highly susceptible to infectious diseases, and the risk of infection is increased in enclosed areas. In the US, the risk of various calf diseases (diarrhea, respiratory problems, etc.) in beef herds is higher when calving takes place in a confined area, such as a pen, shed or dry lot, compared to calving on pasture (Sanderson et al. 2000). In dairy herds, diarrhea (Frank and Kaneene 1993), respiratory problems (Svensson et al. 2003), and the risk of Salmonella infections (Losinger et al. 1995) is lower when calving in individual calving pens versus group settings. In maternity areas, removal of soiled bedding can also help reduce the incidence of diarrhea (Frank and Kaneene 1993).

References

Frank, N. A., & Kaneene, J. B. (1993). Management risk factors associated with calf diarrhea in Michigan dairy herds. *Journal of Dairy Science, 76*, 1313-1323.

Huzzey, J. M., von Keyserlingk, M. A. G., & D. M. Weary. (2005). Changes in feeding, drinking, and standing behavior of dairy cows during the transition period. *Journal of Dairy Science*, *88*, 2454-2461.

Losinger, W. C., Wells, S. J., Garber, L. P., Hurd, H. S., & Thomas, L. A. (1995). Management factors related to salmonella shedding by dairy heifers. *Journal of Dairy Science, 78*, 2464-2472.

Sanderson, M. W., & Dargatz, D. A. (2000). Risk factors for high herd level calf morbidity risk from birth to weaning in beef herds in the USA. *Preventive Veterinary Medicine, 44*, 97-106.

Svensson, C., Lundborg, K., Emanuelson, U., & Olsson, S. O. (2003). Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine*, *58*, 179-197.

COW-CALF SEPARATION

Conclusions:

1. **Allowing the calf to stay with the cow can have beneficial effects for both, including improved health and as well increased natural cow-calf interactions.**
2. **Continued housing with the dam can present health risks for the calf depending upon the level of hygiene and whether supplementary colostrum is provided.**
3. **Separation of the cow and calf results in a pronounced behavioural and physiological response, especially if cow and calf have had the opportunity to bond.**
4. **Methods of reducing separation distress include early separation and two-step weaning.**

Cow health may be improved by allowing the calf to suckle. Suckling has been reported to reduce the risk of retained fetal membranes (Krohn et al. 1990) and of the risk of mastitis (Krohn et al. 1999).

Calf mortality is generally lower in beef cow-calf systems than in dairy systems where the calf is separated at birth (Rushen et al. 2008). Although these differences in mortality could be due to a number of factors, these results do indicate that the presence of the cow need not place the calves' health at risk. This is evidenced by the lowest calf morbidity being noted in dairy systems that keep calves with the cow (Svensson et al. 2003).

Continued contact with the cow allows for continued suckling. There may be positive effects of continued colostrum intake in the days after birth. For example, Weary and Chua (2000) found that calves kept with cows for 4 days had fewer bouts of diarrhoea during the first three weeks of life than calves separated earlier, despite the fact that all calves were bottle-fed colostrum within 24 hours of birth. This difference may be due to local effects of colostrum in the gut wall after absorption of immunoglobulin (Ig) (Godden et al. 2008). Calves allowed to suckle dams for several weeks after birth achieve greater daily weight gains than calves reared conventionally (Flower & Weary 2003), in part because they suckle more frequently and drink more milk.

However, in circumstances where hygiene is poor, the best solution may be to remove the calf as soon as possible. Under these conditions the length of time calves remain with their dams after birth increases the risk of diarrhea; in such cases, calves that were separated from their dams more than one hour after birth, were 39% more likely to develop diarrhea (Trotz-Williams et al. 2007) and had an increased risk of inadequate colostral-derived immunity (Trotz-Williams et al. 2008). Quigley et al. (1994) found that the prevalence of Cryptosporidium was higher in calves that had been allowed to nurse their dams, than in calves of the same age that had been separated from their dams before they could nurse.

If calves and cows are kept together for a period of time, they can develop a bond which can cause some distress when they are separated. Lidfors (1996) compared cow responses when calves were separated either immediately or after 4 days; when calves were older, cows responded more to separation by increased activity and vocalizations, and by decreasing rumination. Weary and Chua (2000) recorded the behaviour of calves separated from their dams 6 h, 1 day, or 4 days after birth, and found that the behavioural responses of both the cow and calf increased in relation to calf age at separation. Moreover, Flower and Weary (2001) found that cows separated from their calves at two weeks of age also showed stronger vocal and behavioural responses than those separated after just 1 day. Thus the distress response to separation can be reduced by separating the cow from the calf in the first few hours after birth.

If cows and calves are allowed prolonged contact a strong bond will form, but the response to separation can be reduced if the process consists of two distinct steps. Beef calves showed almost no response when they were prevented from suckling so long as they had continued social contact with the dam. Once the calf has reduced their dependency on milk (after several days without access to the udder), cow and calf could be separated with little distress response (Haley et al. 2005). Thus, encouraging the young to achieve more nutritional independence would seem to be the best method of reducing the response to separation from the dam when this eventually occurs.

References

Flower, F. & Weary, D. (2001). Effects of early separation on the dairy cow and calf: 2. Separation at 1 day and 2 weeks after birth. *Applied Animal Behaviour Science, 70,* 275-284.

Flower, F., & Weary, D. M. (2003). The effects of early separation of the dairy cow and calf. *Animal Welfare, 12,* 339-348.

Godden, S. 2008. Colostrum management for dairy calves. *Veterinary Clinics Food Animal Practice, 24,* 19-39.

Haley, D. B., Bailey, D. W., & Stookey, J. M. (2005). The effects of weaning beef calves in two stages on their behavior and growth rate. *Journal of Animal Science, 83,* 2205-2214.

Krohn, C., Jonasen, B., & Munksgaard, L. (1990). Cow–calf relations. 2: The effect of 0 vs. 5 days suckling on behaviour, milk production and udder health of cows in different stabling. *Report No. 678.* Foulum, Denmark: National Institute of Animal Science.

Krohn, C., Foldager, J., & Mogensen, L. (1999). Long-term effect of colostrum feeding methods on behaviour in female dairy calves. *Acta Agriculturae Scandinavica (Section A — Animal Science), 49,* 57-64.

Lidfors, L. (1996). Behavioural effects of separating the dairy calf immediately or 4 days post-partum. *Applied Animal Behaviour Science, 49,* 269-283.

Quigley, J. D., Martin K. R., Bemis, D. A., Potgieter, L.N.D., Reinemeyer, C. R., Rohrbach, B. W., Dowlen, H. H., and Lamar, K. C. (1994). Effects of Housing and Colostrum Feeding on the Prevalence of Selected Infectious Organisms in Feces of Jersey Calves. *Journal of Dairy Science 77*, 3124-3131

Rushen, J., de Passillé, A. M., von Keyserlingk, M. A. G., Weary, D. M. (2008). The welfare of cattle. *Animal Welfare, Vol. 5*. Berlin: Springer Verlag.

Svensson, C., Lundborg, K., Emanuelson, U., & Olsson, S. (2003). Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine, 58,* 179-197.

Trotz-Williams, L. A., Martin, S. W., Leslie, K. E., Duffield, T., Nydam, D. V., & Peregrine, A. S. (2007). Calf-level risk factors for neonatal diarrhea and shedding of Cryptosporidium parvum in Ontario dairy calves. *Preventive Veterinary Medicine, 82,* 12-28.

Trotz-Williams, L. A., Leslie, K. E., & Peregrine, A. S. (2008). Passive immunity in Ontario dairy calves and investigation of its association with calf management practices. *Journal of Dairy Science, 91,* 3840-3849.

Weary, D. M. & Chua, B. (2000). Effects of early separation on the dairy cow and calf. 1. Separation at 6 h, 1 day and 4 days after birth. *Applied Animal Behaviour Science, 69,* 177-188.

COLOSTRUM

Conclusions:

1. **The quality, amount and timing of colostrum given to calves have major impacts on their welfare.**
2. **Many dairy calves in Canada continue to suffer from inadequate colostral-derived immunity.**
3. **Adequate passive immunity is best ensured by allowing the calves to drink at least 4L of good quality colostrum within 12h, with the first meal occurring less than 6h after birth.**
4. **The timing of first colostrum is particularly important since calves' ability to absorb colostrum is reduced 6-8h after birth.**
5. **Supplemental colostrum feeding is required even when calves are allowed to suckle from the cow.**
6. **The quality of colostrum varies greatly between cows but can be estimated with a colostrometer.**
7. **Poor hygiene during colostrum collection and storage can result in bacterial contamination, reducing absorption of Ig.**
8. **Measuring Ig concentration in the blood is an effective way of ensuring good colostrum management practices.**

Colostrum feeding has an important influence on the health and welfare of calves (Davis and Drakely 1998). The importance of an adequate intake of colostrum has long been known but surveys continue to report that large numbers of dairy calves still receive either inadequate or marginal levels (USDA 2002, McGuirk and Collins 2004). Between 25% and 38% of dairy calves in Ontario suffer from failed passive transfer of immunoglobulins from colostrum (Wallace et al. 2006, Trotz-Williams et al. 2008). Colostrum contains antibodies, known as immunoglobulins (Ig), which are large glycoprotein molecules that constitute the main protection against diseases. The immunoglobulins contained in colostrum are absorbed into the calf's blood (passive transfer). The immunoglobulins obtained in this way protect the calf until its own immune system becomes fully functional at around 3 to 6 wks of age (Franklin 2004). Many types of Ig exist, but IgG provides most of the immunity against pathogens a calf to which a calf would be exposed. Therefore, for the purpose of this review, Ig and IgG are used interchangeably.

The ability of the calf to defend itself against infectious diseases is directly related to the amount (L), quality (Ig level and hygiene), and timing of colostrum intake. The result of inadequate colostrum intake is a low concentration of circulating Ig in the blood of the calf, a condition known as 'failure of passive transfer' (FPT). FPT can be defined as a calf's blood-serum concentration of IgG less than 10.0 g/L (McGuirk and Collins 2004).

A number of studies have documented the close association between inadequate colostrum intake, FPT and increased mortality or morbidity of both beef and dairy calves (Rea et al. 1996, Filteau et al. 2003, Dewell et al. 2006). According to Wells et al. (1996), 31% of calf deaths during the first 3 weeks of life could have been prevented if colostrum feeding had been adequate. Even where death is avoided, there can be long term effects of an inadequate colostrum intake; calves with FPT have lower body weights 6 months later (Dewell et al. 2006). Colostrum derived antibodies can remain active for many months (Munoz-Zanzi et al. 2002). Clearly, an inadequate intake of colostrum and too low levels of Ig in the blood represent a major risk factor for poor welfare of newborn calves.

Factors that influence the passive transfer of Ig from colostrum to the calf have been well documented (Weaver et al. 2000, McGuirk and Collins 2004). There are two main factors that limit passive transfer:

1) The calf's capacity to absorb Ig is gradually lost within the first 24 hours of life (Weaver et al. 2000). The transfer of Ig across the gut epithelium of the calf is optimal in the first 4 hours and decreases after 12 hours after birth (Weaver et al. 2000). Even a 30-minute delay has been found to reduce the concentration of Ig in the calf (Rajala and Castrén 1995). Many farms in Quebec and Ontario do not give colostrum within 6 hours of birth (Vasseur et al. 2006, 2007; Trotz-Williams et al. 2008). Furthermore, a low-level of calving surveillance at night means that the age at which calves are first given colostrum may be underestimated (Vasseur et al. 2006, 2007).

2) The amount of Ig in the colostrum varies with age, parity, health, and other factors such as the nutrition of the pregnant cow (Quigley and Drewry 1998). Colostrum must be tested for quality since a litre can contain less than 20 to more than 100 mg/ml of IgG (Gay, 1994 as cited by Davis and Drackely 2003). Colostrum quality can be tested using a colostrometer (e.g., Kruuse Colostrum Densimeter).

The recommendations for colostrum feeding, according to Davis and Drackely (based on their critical review of the literature) are: 1. The calf must ingest its first meal of colostrum before 6 hours postpartum, preferably before 2 hours; 2. The Ig content of the colostrum must be of high quality (over 50mg/ml) and; 3. The calf must receive 4 liters of good quality colostrum. Many farms in Ontario and Quebec continue to give less than this recommended amount (Vasseur et al. 2006, 2007, Trotz-Williams et al. 2008).

One way to verify the adequacy of colostrum management practices is to examine the blood levels of Ig in the calf at 24 to 48 hrs after colostrum feeding. About 2% of US dairy farmers report that they routinely test Ig levels in the calves' blood (USDA 2007). Kits to test blood levels at the farm are available (e.g., Midland Quick Test Kit).

Some recent surveys report high levels of bacterial contamination of colostrum fed to dairy calves (e.g., Stewart et al. 2005, Fecteau et al. 2002); this may be detrimental as indirect evidence suggests that bacterial contamination of colostrum may interfere with Ig absorption in the calf (Hagman et al. 2006, Terre and Bach 2008). Heat-treatment can be used to treat contaminated colostrum. Pasteurizing colostrum has been found to significantly increase blood IgG levels in day-old calves, and also improve their IgG absorption efficiency (Johnson et al.

2007). Clearly the degree of hygiene associated with the collection and storage of colostrum can have an important impact on the effectiveness of colostrum.

Most beef cattle obtain their colostrum through suckling their mother and many dairy farmers also leave the calf with the cow for a period of time to allow it to suckle colostrum (Trotz-Williams et al. 2008). Unfortunately, this is not a reliable way of ensuring adequate colostrum intake. Franklin et al. (2003) compared calves that were allowed to suckle freely from their mothers to calves that were removed from their mothers and fed colostrum by bottle. The concentrations of serum proteins (a way of estimating Ig content) were lower in the nursed calves. This reflects a combination of factors, such as differences between cows in the Ig content of colostrum as well as differences between calves in their success at suckling. When dairy calves were left with the cow for 24 hours, almost half were found to suffer from FPT (Wesselink et al. 1999); similarly, Trotz-Williams et al. (2008) reported that leaving the calf with the cow for more than 3 hours doubled the risk of FPT. Inadequate intake of colostrum during suckling has been noted to cause FPT in beef calves as well (Filteau et al. 2003). It has been suggested that as a result of the low colostrum intake, calves that obtain their colostrum only by suckling suffer from a higher incidence of diarrheoa (Svensson et al. 2003). Some hand feeding of colostrum therefore is essential to ensure the welfare of the calves.

In summary, within 6 hours of birth, calves must receive at least 4 litres of good quality colostrum (i.e. at least 50mg/ml of Ig). This colostrum must be clean and fed in a clean environment to avoid bacterial contamination, which is a real danger for calves because they have little immune protection at birth.

References

Davis, C. L., & Drackley, J. K. (1998). *The Development, Nutrition, and Management of the Young Calf.* Ames, IA: Iowa State University Press.

Dewell, R. D., Hungerford, L. L., Keen, J. E., Laegreid, W. W., Griffin, D. D., Rupp, G. P., & Grotelueschen, D. M. (2006). Association of neonatal serum immunoglobulin G1 concentration with health and performance in beef calves. *Journal of the American Veterinary Medical Association, 228,* 914-921.

Fecteau, G., Baillargeon, P., Higgins, R., Paré, J., & Fortin, M. (2002). Bacterial contamination of colostrum fed to newborn calves in Québec dairy herds. *Canadian Veterinary Journal, 43,* 523-527.

Filteau, V., Bouchard, E., Fecteau, G., Dutil, L., & DuTremblay, D. (2003). Health status and risk factors associated with failure of passive transfer of immunity in newborn beef calves in Quebec. *Canadian Veterinary Journal, 44,* 907-913.

Franklin, S. T. (2004). Enhancing immunity of the calf. *Official Proceedings of the Thirty-Ninth Annual Pacific Northwest Animal Nutrition Conference* (pp. 1-7). Seattle, WA.

Franklin, S. T., Amaral-Phillips, D. M., Jackson, J. A., & Campbell, A. A. (2003). Health and performance of Holstein calves that suckled or were hand- fed colostrum and were fed one of three physical forms of starter. *Journal of Dairy Science, 86,* 2145-2156.

Hagman, D., Godden, S., Johnson, J., Molitor, & Ames, T. (2006). Effect of feeding heat-treated colostrum on serum immunoglobulin G concentration in dairy calves. *Journal of Dairy Science*, *89*(Suppl. 1), 414.

Johnson, J. L., Godden, S. M., Molitor, T., Ames, T., & Hagman, D. (2007). Effects of feeding heat-treated colostrum on passive transfer of immune and nutritional parameters in neonatal dairy calves. *Journal of Dairy Science, 90,* 5189-5198.

Kehoe, S. I., Jayaro, B. M., & Heinrichs, A. J. (2007). A survey of bovine colostrum composition and colostrum management practices on Pennsylvania dairy farms. *Journal of Dairy Science, 90*, 4108-4116.

McGuirk, S. M., & Collins, M. (2004). Managing the production, storage, and delivery of colostrum. *Veterinary Clinics of North America: Food Animal Practice*, *20*, 593-603.

Munoz-Zanzi, C. A., Thurmond, M. C., Johnson, W. O., & Hietala, S. K. (2002). Predicted ages of dairy calves when colostrum-derived bovine viral diarrhea virus antibodies would no longer offer protection against disease or interfere with vaccination. *Journal of the American Veterinary Medical Association, 221*, 678-685.

Quigley, J. D., & Drewry, J. J. (1998). Nutrient and immunity transfer from cow to calf precalving. *Journal of Dairy Science, 81*, 2779-2790.

Rea, D. E., Tyler, J. W., Hancock, D. D., Besser, T. E., Wilson, L., Krytenberg, D. S., & Sanders, S. G. (1996). Prediction of calf mortality by use of tests for passive transfer of colostral immunoglobulin. *Journal of the American Veterinary Medical Association, 208*, 2047-2049.

Rajala, P., & Castrén, H. (1995). Serum immunoglobulin concentrations and health of dairy calves in two management systems from birth to 12 weeks of age. *Journal of Dairy Science, 78*, 2737-2744.

Stewart, S., Godden, S., Bey, R., Rapnicki, P., Fetrow, J., Farnsworth, R., Scanlon, M., Arnold Y., Clow, L.,Mueller, K., & Ferrouillet, C. (2005). Preventing bacterial contamination and proliferation during the harvest, storage, and feeding of fresh bovine colostrum. *Journal of Dairy Science, 88*, 2571-2578.

Svensson, C., Lundborg, K., Emanuelson, U., & Olsson, S. O. (2003). Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine, 58*, 179-197.

Terre, M., & Bach, A. (2008). Relationship between total microbial colostrum contamination and IgG absorption in newborn dairy calves. *Journal of Dairy Science*, *91*(E-Suppl.1), 193.

Trotz-Williams, L. A., Leslie, K. E., & Peregrine, A. S. (2008). Passive immunity in Ontario dairy calves and investigation of its association with calf management practices. *Journal of Dairy Science*, *91*, 3840-3849.

USDA. (2002). *Part I: Reference of dairy health and management in the United States*. No. N377.1202). Fort Collins, Colorado: National Animal Health Monitoring System, United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services.

USDA. (2007). NAHMS Dairy 2007, Part I: *Reference of dairy cattle health and management practices in the United States*. Fort Collins, Colorado: National Animal Health Monitoring System, United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services.

Vasseur, E., Pellerin, D., Rushen, J., de Passille, A. M., Cue, R., Lefebvre, D. (2006). Premier portrait québécois des conditions d'élevage et du bien-être des génisses. In 30e Symposium sur les bovins laitier. CRAAQ, Quebec, 2-22.

Vasseur, E., Borderas, F., Cue, R., Lefebvre, D., Pellerin, D., Rushen, J. P., Wade, K., & de Passillé, A. M. B. (2007). Calf rearing practices: First step in the development of a welfare monitoring System. *Proceedings of the 41st International Congress of the ISAE.* Merida, Mexico. 241 (Abstr.).

Wallace, M. M., Jarvie, B. D., Perkins, N. R., & Leslie, K. E. (2006). A comparison of serum harvesting methods and type of refractometer for determining total solids to estimate failure of passive transfer in calves. *Canadian Veterinary Journal, 47*, 573-575.

Weaver, D. M., Tyler, J. W., vanMetre, D. C., Hostetler, D. E., & Barrington, G. M. (2000). Passive transfer of colostral immunoglobulins in calves. *Journal of Veterinary Internal Medicine, 14*, 569-577.

Wesselink, R., Stafford, K. J., Mellor, D. J., Todd, S., & Gregory, N. G. (1999). Colostrum intake by dairy calves. *New Zealand Veterinary Journal, 47*, 31-34.

Wells, S. J., Garber, L. P., & Hill, G. W. (1996). Health status of preweaned dairy heifers in the United States. *Preventive Veterinary Medicine, 29*, 185-199.

MILK FEEDING

Conclusions:

1. **Dairy calves are motivated to consume large amounts of whole milk (for example, Holstein calves will drink in excess of 8 L/d).**
2. **Feeding only 4 L/d of milk does not allow the calf to meet its nutritional requirements for maintenance, growth and development.**
3. **Calves benefit especially from higher milk intakes during the first 4 weeks of life when their ability to digest solid feed is limited.**
4. **Higher milk intakes by calves are not associated with increased diarrhoea or other health problems.**
5. **Gradually reducing milk intake can reduce welfare problems at weaning.**
6. **Calves are highly motivated to suck. Providing milk via a teat or providing a dry-teat after milk feeding helps to satisfy this motivation, stimulates production of higher levels of digestive hormones, promotes rest and prevents abnormal behaviours such as cross-sucking and sucking on pen fixtures.**
7. **Group feeding systems need to be managed to reduce competition between calves.**

How much milk? The welfare of milk-fed calves depends on how much milk they drink. Extensively reared calves can die from insufficient milk intake (Mellor and Stafford 2004), and calves fed low volumes of milk often lose or fail to gain weight during the first weeks of life (Hammon et al. 2002, Jasper and Weary 2002).

In some cases, the problems of hand-fed fed calves arise from the quality of the milk or milk replacer they are fed (Godden et al. 2005). Whole milk has a higher protein, fat and digestible energy content, as well as a better balance of nutrients than some commercial milk replacers (Davis and Drackley 1998).

Milk-fed dairy calves are often fed only a small amount of milk (4 – 5 L/d), substantially less than what they drink during nursing or when milk is available ad libitum (Jasper and Weary 2002, Hammon et al. 2002, Hepola 2003). For example, de Passillé and Rushen (2006) showed that Holstein dairy calves allowed to nurse from their mothers drank 6-14 L/d. Low amounts of milk do not adequately decrease feeding motivation, and probably leave the calves feeling hungry (Hammon et al. 2002, Jensen and Holm 2003, de Paula Vieira et al. 2008).

Recent studies (Appleby et al. 2001, Diaz et al. 2001, Jasper and Weary 2002, Khan et al. 2007) have shown that the growth rates of calves can be greatly increased by feeding higher amounts of milk. Higher amounts of milk can help reduce the weight loss in the days after birth that can occur among calves fed small amounts of milk (Hammon et al. 2002). These improved weight gains are also associated with improved feed conversion efficiency (Diaz et al. 2001, Van Amburgh and Drackley 2005). With sufficient levels of milk intake, growth rates of ~1 kg/d can occur for Holstein calves especially during the first weeks of life (Hammon et al. 2002), a period when conventionally milk fed calves show little weight gain (~0.4-0.5 kg/d) and when health risks are high. During the first weeks of life, solid feed intake is very low, regardless of the amount of milk fed or amount of grain provided, so these young calves appear unable to increase their intakes of solids sufficiently to compensate for inadequate milk intake.

The optimal amount of milk will vary with a number of factors, as for example, under cold conditions, energy requirements increase as the calves need this energy to generate body heat (Schrama et al. 1993).

Feeding large amounts of milk to calves can improve the efficiency of automated milk feeding systems. Calves fed the conventional small amounts of milk visit the feeder very often, but usually do not receive any milk (de Paula Vieiera et al. 2007). This increases the time that the feeder is occupied. Competition at the feeder is also increased (de Paula Vieiera et al. 2007).

Abrupt changes in diet, use of poor quality milk or milk replacer, and force feeding of milk are all associated with health risks for the calf, including diarrhea. However, there is no evidence that high milk intake poses any health risk in well-managed systems (Appleby et al. 2001, Jasper and Weary 2002, Chua et al. 2002, Diaz et al. 2001, Hammon et al. 2002). In fact, Khan et al. (2007) recently showed that feeding calves higher quantities of milk actually reduced the incidence of diarrhoea. One recent study has reported increased health risks with feeding higher levels of milk replacer (Quigley et al., 2006), but this likely resulted from methodological problems in the study (Borderas et al. 2007).

However, where calves are fed large amounts of milk, abrupt weaning off milk may lead to welfare problems (EFSA 2006). In such cases, gradual or step-down weaning may be preferable (Khan et al. 2007).

In response to the welfare concern that calves fed restricted milk amounts are hungry, a growing body of research has focused on determining the effects of feeding more milk as well as exploring alternative feeding systems that allow calves to express a more natural sucking behaviour.

How to feed milk? Calves are typically provided milk from a bucket and thus are unable to perform their natural sucking behaviour. Calves can also be fed milk through a teat, allowing the calves to suck. Teat-based milk feeding systems vary from simple arrangements where calves drink from teat bottle or buckets fitted with a teat, through feeding stations with multiple teats connected to a milk reservoir, to computer-controlled feeders.

Research has documented a number of potential advantages to allowing calves to suck for their milk. First, sucking behaviour itself appears to contribute to satiety (Rushen and de Passillé 1995) and influences the secretion of insulin and CCK, hormones that have been shown to be important for digestive function (de Passillé et al. 1993, Lupoli et al. 2001). Calves that suck for their milk have been shown to lie down sooner and sleep for longer than calves drinking from a bucket (Veissier et al. 2002, Hanninen et al. 2008). There is some evidence that heart rates are also lower among teat-fed calves (Veissier et al. 2002). Second, when compared with bucket feeding, sucking milk through a teat has also been shown to reduce non-nutritive sucking (sucking on parts of the pen, etc.), partly because the overall feeding time is increased (Appleby et al. 2001). A smaller teat orifice to reduce the flow rate of milk also reduces non-nutritive sucking in dairy calves (Haley et al. 1998). Where it is not possible to feed milk through a teat, allowing the calves to suck a dry teat after the milk meal can have similar effects (de Passillé et al. 1993, de Passillé and Rushen 2006).

Computer-controlled milk and grain feeding systems were developed in the early 1980s and are now widely available. Caring for group-housed calves on an automated milk feeding system requires less labour than when calves are housed individually (Kung et al. 1997, de Passillé et al. 2004), helping to offset the capital costs of the machines. Automated-feeding systems facilitate the distribution of the total daily milk intake into small meals throughout the day, allowing a greater amount of milk to be fed without requiring the calf to drink a large amount at each meal. The pattern of drinking by the calves more closely resembles that seen during normal nursings (Senn et al. 2000). These systems can monitor the number and timing of visits, and the amount of milk consumed by each calf.

One study reported a lower incidence of disease among calves fed with an automated milk feeding system (Kung et al. 1997). Although other studies have reported higher mortality and morbidity, this is likely because farmers tend to increase the size of the groups when these feeders are used (Svensson et al. 2003, Svensson and Liberg 2006). Certainly the way automatic feeders (or any group feeding systems) are managed can greatly influence their impact on calf welfare. Too many calves for the number of teats available increases social competition between calves for teats and can reduce milk intake (von Keyserlingk et al. 2004, Jensen 2004). Furthermore, open introduction into a group, milk consumption does decrease temporarily (O’Driscoll et al. 2006), while the calf adjusts to its new social environment. When multiple teats are provided, the impact of social competition can be lessened by placing long barriers between teats, reducing the chance that quick-feeding calves will displace slower ones (Jensen et al. 2008).

Teat feeding can have advantages, but feeding systems need to be managed to avoid competition by keeping group size small, ensuring good hygiene, carefully managing the introduction of new calves, increasing the ratio of teats to calves, and feeding higher milk volumes.

References

Appleby, M. C., Weary, D. M., & Chua, B. (2001). Performance and feeding behavior of calves on ad-libitum milk from artificial teats. *Applied Animal Behaviour Science, 74,* 191-201.

Borderas, F., von Keyserlingk, M. A. G., Rushen, J., de Passillé, A. M., van Amburg, M., & Weary, D. M. (2007). The effects of force-feeding sick dairy calves: A comment on Quigley et al. (2006). *Journal of Dairy Science, 90,* 3567-3568.

Chua, B., Coenen, E., van Delen, J., & Weary, D. M. (2002). Effects of pair versus individual housing on the behavior and performance of dairy calves. *Journal of Dairy Science, 85,* 360-364.

Davis, C.L., & Drackley, J. K. (1998). *The Development, Nutrition, and Management of the Young Calf.* Ames, IA: Iowa State University Press.

de Passillé, A. M., Christopherson, R., & Rushen, J. (1993). Non-nutritive sucking by the calf and postprandial secretion of insulin, CCK and gastrin. *Physiology & Behavior, 54,* 1069-1073.

de Passillé, A. M., Rushen, J., & Weary, D. M. (2004). Designing good environments and management for calves. Advances in Dairy Technology, 16, 75-89. *Proceedings of the 2004 Western Canadian Dairy Seminar*. Edmonton: University of Alberta.

de Passillé, A. M. B., & Rushen, J. (2006). Calves' behaviour during nursing is affected by feeding motivation and milk availability. *Applied Animal Behaviour Science*, *101,* 264-275.

de Paula Vieira, A., Guesdon, V., de Passillé, A. M., von Keyserlingk, M. A. G., & Weary, D. M. (2008). Behavioural indicators of hunger in dairy calves. *Applied Animal Behaviour Science, 109,* 180-189.

Diaz, M. C., van Amburgh, M. E., Smith, J. M., Kelsey, J. M., & Hutten, E. L. (2001). Composition of growth of holstein calves fed milk replacer from birth to 105-kilogram body weight. *Journal of Dairy Science, 84,* 830–842.

EFSA. (2006). The EFSA Journal. Opinion on "The risks of poor welfare in intensive calf farming systems. An update of the Scientific Veterinary Committee Report on the Welfare of Calves." *EFSA-Q-2005-014, 366,* 1-36.

Godden, S. M., Fetrow, J. P., Feirtag, J. M., Green, L. R., & Wells, S. J. (2005). Economic analysis of feeding pasteurized nonsaleable milk versus conventional milk replacer to dairy calves. *Journal of the American Veterinary Medical Association, 226,* 1547-1554.

Haley, D. B., Rushen, J., Duncan, I., Widowski, T., & de Passillé, A. M. B. (1998). Effects of resistance to milk flow and the provision of hay on non-nutritive sucking by dairy calves. *Journal of Dairy Science, 81,* 2165-2172.

Hammon, H. M., Schiessler, G., Nussbaum, A., & Blum, J. W. (2002). Feed intake patterns, growth performance, and metabolic and endocrine traits in calves fed unlimited amounts of colostrum and milk by automate, starting in the neonatal period. *Journal of Dairy Science, 85,* 3352-3362.

Hänninen, L., Mäkelä, J. P., Rushen, J., de Passillé, A. M., & Saloniemi, H. (2008). Assessing sleep state in calves through electrophysiological and behavioural recordings: A preliminary study. *Applied Animal Behaviour Science, 111,* 235-250.

Hepola, H. (2003). Milk feeding systems for dairy calves in groups: Effects on feed intake growth and health. *Applied Animal Behaviour Science, 80,* 233-243.

Jasper, J., & Weary, D. M. (2002). Effects of ad libitum milk intake on dairy calves. *Journal of Dairy Science, 85,* 3054-3058.

Jensen, M. B. (2004). Computer-controlled milk feeding of dairy calves: The effects of number of calves per feeder and number of milk portions on use of feeder and social behavior. *Journal of Dairy Science, 87,* 3428-3438.

Jensen, M. B., & Holm, L. (2003). The effect of milk flow rate and milk allowance on feeding related behaviour in dairy calves fed by computer controlled milk feeders. *Applied Animal Behaviour Science, 82,* 87-100.

Jensen, M.B., de Passille, A. M., von Keyserlingk, M. A. G., & Rushen, J. (2008). A barrier can reduce competition over teats in pair-housed milk-fed calves. *Journal of Dairy Science, 91,* 1607-1613.

Khan, M. A., Lee, H. J., Lee, W. S., Kim, H. S., Ki, K. S., Hur, T. Y., Suh, G. H., Kang, S. J., & Choi, Y. J. (2007). Structural growth, rumen development, and metabolic and immune responses of holstein male calves fed milk through step-down and conventional methods. *Journal of Dairy Science, 90,* 3376-3387.

Kung, L., Demarco, S. J., Siebenson, L. N., Joyner, E., Haenlein, G. F. W., & Morris, R. M. (1997). An evaluation of two management systems for rearing calves fed milk replacer. *Journal of Dairy Science, 80,* 2529-2533.

Lupoli, B., Johansson, B., Uvnas-Moberg, K., & Svennersten-Sjaunja, K. (2001). Effect of suckling on the release of oxytocin, prolactin, cortisol, gastrin, cholecystokinin, somatostatin and insulin in dairy cows and their calves. *Journal of Dairy Research, 68,* 175-187.

Mellor, D. J., & Stafford, K. J. (2004). Animal welfare implications of neonatal mortality and morbidity in farm animals. *The Veterinary Journal, 168,* 118-133.

O'Driscoll, K., von Keyserlingk, M. A. G., & Weary, D. M. (2006). Effects of mixing on drinking and competitive behavior of dairy calves. *Journal of Dairy Science, 89,* 229-233.

Rushen, J., & de Passillé, A. M. (1995). The motivation of non-nutritive sucking in calves, Bos taurus. *Animal Behaviour, 49,* 1503-1510.

Schrama, J. W., Arieli, A., Brandsma, H. A., Luiting, P., & Verstegen, M. W. (1993). Thermal requirements of young calves during standing and lying. *Journal of Animal Science, 71,* 3285-3292.

Senn, M., Gross-Luem, S., Leuenberger, H., & Langhans, W. (2000). Meal patterns and meal-induced metabolic changes in calves fed milk ad lib. *Physiology & Behavior, 70,* 189-195.

Svensson, C., Lundborg, K., Emanuelson, U., & Olsson, S. O. (2003). Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine, 58,* 179-197.

Svensson, C., & Liberg, P. (2006). The effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. *Preventive Veterinary Medicine, 73,* 43-53.

Quigley J. D., Wolfe, T. A., & Elsasser, T. H. (2006). Effects of Additional Milk Replacer Feeding on Calf Health, Growth, and Selected Blood Metabolites in Calves. *Journal of Dairy Science, 89,* 207-216.

van Amburgh, M., & Drackley, J. (2005). Current perspectives on the energy and protein requirements of the pre-weaned calf. In: Garnsworthy, P.C. (Ed.), *Calf and Heifer Rearing: Principles of Rearing the Modern Dairy Heifer from Calf to Calving* (pp. 67-82). Nottingham: Nottingham University Press.

Veissier, I., de Passillé, A. M. B., Després, G., Rushen, J., Charpentier, I., Ramirez de la Fe, A. R., & Pradel, P. (2002). Does nutritive and non-nutritive sucking reduce other oral behaviours and stimulate rest in calves? *Journal of Animal Science, 80,* 2574-2587.

von Keyserlingk, M. A. G., Brusius, L., & Weary, D. M. (2004). Competition for teats and feeding behavior by group-housed dairy calves. *Journal of Dairy Science, 87,* 4190-4194.

CALF HOUSING

Housing for Unweaned Calves

Conclusions:

1. **Housing calves individually or in small groups (less than about 7-10 calves) can reduce the transmission of infectious diseases.**
2. **Housing calves in larger groups increases the risk of infectious diseases.**
3. **Behavioural problems associated with group housing, including competition and cross-sucking, can be controlled with appropriate management.**
4. **Calves are social animals and motivated to seek the company of other calves.**
5. **Limited access to space provides fewer opportunities for physical exercise and can restrict resting postures in calves.**

Individual housing of calves is common; in the U.S. 58% of dairy farms keep unweaned heifers in individual pens or hutches (USDA 2002). In the countries of the EU, individual housing for calves over 8 weeks of age was effectively banned. The recent European Food Safety Authority Scientific Opinion (EFSA 2006) concluded that: “Where calves cannot be kept with their mother, the system where welfare is best is in groups with a bedded area and an adequate space allowance”.

As reviewed in the sections below, individual housing is reported to benefit calves because the transmission of infectious diseases is reduced as physical contact is minimized. Individual housing also facilitates the detection of clinical signs of illness by the farm staff, reduces aggression among calves as well as competition over resources such as feed. Individual housing has also potential disadvantages. Most obviously, the limited physical space that is usually provided denies calves most forms of social contact and movement.

Most of the research assessing the advantages and disadvantages of individual housing in calves is on veal calves, and is only indirectly relevant to dairy calves. Furthermore, research on housing is often not easy to interpret. Often comparisons are made between housing systems that differ in many respects, such as the use of bedding, indoor vs. outdoor housing, space allowance, etc. Important variables, such as the quality of the ventilation are often not reported in these studies compromising the interpretation of the results.

Individual versus group housing – effects on calf health: Although individual housing is often recommended as a means of reducing disease transmission, research on this topic has produced conflicting results. For example, Webster et al. (1985a) examined 14 veal farms that bought in male dairy calves for veal production. The mortality rate reported in the study (up to 16 weeks of age) was higher for the group-housed calves (3.8%) than for the individually housed ones (1.7%). When compared to individually housed calves, the same study reported a higher incidence of respiratory diseases in group housed veal calves that had been brought in from other farms. In contrast, when other farms were examined, dairy replacement calves that had been born on the farm and housed in either groups or individual pens showed similar incidence of respiratory diseases. This suggests that either the effect of group housing on morbidity was specific to the types of group management used in veal production, or that there was some interaction between the use of group housing and the bringing in of calves from other farms.

The incidence of gastro-intestinal (GI) disorders showed similar complexity. During weeks 0-2 the probability of having calves with GI disorders was higher for farms that group housed veal calves (71% of farms) than for farms that individually housed the calves (29% of farms). However, this difference had disappeared by 6-10 weeks. For farms with farm-born dairy calves, the same difference was apparent, but only for the farms that fed warm milk. Farms that group housed the calves but fed them cold, acidified milk had the same, low incidence of GI problems as farms that individually housed the calves. Furthermore, from 2-6 weeks the situation was the reverse; the incidence of GI tract disorders was higher on farms that used individual housing.

Together, these results suggest that health problems associated with group housing of veal calves may be specific to the management practices adopted on the farm such as the type of diet provided to the calves. More recent studies of veal calves reared in modern group housing tend to report very good health status and similar or improved growth rates compared to individual housing (Andrighetto et al. 1999, Xiccato et al. 2002).

Several large-scale epidemiological studies have failed to show a clear advantage of housing calves individually. The incidence of infectious diseases caused by E. coli O157 (Rugbjerg et al. 2003), Salmonella spp. (Losinger et al. 1995), and Cryptosporidium parvum (Mohammed et al. 1999) is not increased with group housing. Actually, health problems in group housed calves increase only when group size is large. For example, a large scale study of 1685 dairy farms in the US showed that when more than six calves are kept in a group, calf mortality is increased (>6%), when compared to farms that housed calves in individual pens. However, farms that housed 6 or less calves per group had similar mortality rates to the farms that housed calves individually (Losinger and Heinrichs 1997). Svensson and Liberg (2006) found some evidence that calf mortality was lowest among calves housed in small groups compared to large groups or individual housing. The detrimental effect of housing calves in larger groups was also shown in a study of 122 dairy farms in Sweden (Svensson et al. 2003). The farms were classified according to whether the unweaned calves were kept individually, in smaller groups (3-8 calves fed milk manually) or larger groups (fed with an automatic milk dispenser). The incidence of diarrhoea did not differ markedly between the type of housing, although severe cases of diarrhoea (loss of weight or suppression of appetite for 2d or more) were higher for calves housed in larger groups. Similarly, the reported cases for respiratory disorders were twice as high for calves housed in larger groups when compared to calves housed in smaller groups or in individual pens. There is also evidence that calves housed in small groups grow much faster, when compared to those housed either in larger groups (smallest weight gains) or individually (intermediate gains). Svensson and Liberg (2006) reported a higher risk of respiratory disease and lower growth rates among calves housed in groups of 12-18 compared to calves housed in groups of 6-9. In conclusion, these large-scale epidemiological studies throw doubt on the claim that individual housing of unweaned calves is advantageous for their health, although they do indicate that health of calves housed in larger groups (more than 6-9 animals) is compromised.

To overcome potential confounding effects of epidemiological studies, smaller scale studies have isolated the effects of group housing by controlling for feeding or management. Hänninen et al. (2003) and Chua et al. (2002) examined the health and growth of calves kept either in individual or group pens (with either two or four calves), but which were fed and managed identically. None of these studies found a difference in growth rates and Hänninen et al. (2003) found that the incidence of diarrhoea was actually lower in the group housed calves.

The type of pen is likely to have little effect in the transmission of infectious diseases as pathogens responsible for causing enteric diseases can be transported through the air (Wathes et al. 1988). In addition, some physical contact between calves still occurs at the end or top of pens or through slatted partitions. Thus, proper management of housing systems (cleanliness, adequate ventilation, feeding), as well as calf immunity, are likely more important than the housing system when preventing infectious diseases. Maintaining stable groups of calves in an “all-in all-out” system rather than having dynamic groups can greatly reduce the incidence of illness (Pedersen et al. in press). Thus, these studies show that unweaned calves can be kept in small groups without increased health problems, providing that housing, feeding and management are appropriate.

Individual versus group housing -- behavioural effects: The most obvious behavioural effects of individual housing are the lack of social interactions, and the limited ability of calves to move. The latter will depend on the size of the space available, but generally calves kept in groups have a larger total area available, even when the space per animal is the same. The individual housing typically used in dairy production often does not allow sufficient room for the animal to run or jump. On the other hand, individual housing will reduce the incidence of aggressive behaviour and competition over resources such as feed, and can prevent cross-sucking.

Social behaviour: Webster et al. (1985b) and Chua et al. (2002) report that group or pair-housed calves spent about 1-2% of the time engaged in social contacts. Earlier research showed that unweaned calves that had been reared individually show more exploration of unfamiliar calves when they are given the opportunity to make social contact (Dellmeier et al. 1985). More recent research has replicated this finding and has attempted to unravel the motivational changes that underlie this effect. Jensen et al. (1997) kept calves either in single pens or group pens for 3 months. The calves were then subjected to an “open-field” test with an unfamiliar calf. Individually housed calves had higher heart rates and showed longer latencies to approach the unfamiliar calf suggesting that these calves were more fearful. Other research has indicated that individual housing of dairy heifers reduced their ability to compete within groups later on life (Broom and Leaver 1978). Veissier et al. (1994) examined calves housed individually or in a group of eight animals until 14 weeks of age. At 14 weeks, all animals were placed in groups with unfamiliar animals. During the 2h after mixing calves that had been individually housed showed more aggression (and less positive social behaviour such as playing or grooming) than the group-housed calves. However, when the mixing was repeated 5 weeks later, no differences were found. Individual rearing may reduce the calf’s ability to cope with strange animals during initial encounters. When moved to a novel environment, the presence of a familiar calf reduced the number of vocalizations and allowed a higher exploration of the pen, when compared to calves that were moved alone (Færevik et al. 2006).

Locomotion: Young, growing animals need exercise and there is considerable evidence from humans and laboratory animals that insufficient exercise can affect growth and health. Controlled studies have shown that individually housed animals do tend to move less than grouped animals. Chua et al. (2002) compared individually housed calves and calves housed in pairs. The paired calves moved twice as much as the individually housed calves (1.43% vs. 0.64% of the day) despite the fact that the space allowance per animal was the same in each housing type (2.04m^2/animal). Hänninen et al. (2003) compared individually housed calves (1.2m^2/calf) with grouped housed animals (4 calves with 8m^2/calf) and found more movements among the group housed calves (5.4% vs. 3.5%).

Unfortunately, the research that has examined locomotion in young calves does not provide enough information to enable us to draw firm conclusions about how the type of housing impacts the calves' ability to move around. The space provided may not be adequately described by the number of square metres per animal. For example, we suggest that calves are more likely to run and jump when housed in a long narrow space than they are in a square enclosure of the same dimensions. Calves may also have a greater incentive to move in some environments – for example on pasture calves may move to access fresh grass, shade or social companions.

<u>What are the likely consequences for animal welfare of a reduced time spent moving?</u>
Individually housed calves will show more locomotion, especially running and jumping, when given the opportunity to do so (Dantzer et al. 1983, Dellmeier et al. 1985) suggesting that they are motivated to perform these behaviours. The most likely long-term effects on calf development would be poorer bone, muscle and cardiovascular condition. We know little about the importance of exercise for the health of growing calves, but there is a large body of research showing the health benefits of exercise on other species. For example, piglets kept in larger pens have significantly better bone growth than those kept in smaller environments (Blanaru et al. 2004). The effect that the housing environment of the calf has on later health of the cow needs more study.

Cross-sucking and aggression: One possible behavioural advantage of individual housing is that it does not allow cross-sucking among calves. Cross-sucking can occur at a high frequency among group-housed, pre-weaned calves, although several studies have now shown that calves can be kept in groups with only a very low incidence of cross-sucking (reviewed in Rushen et al. 2008). In any case, the incidence of cross-sucking appears to be more related to the way that the animals are fed and can be controlled easily by appropriate feeding techniques. In general, individual housing is not necessary to prevent cross-sucking between calves.

Aggression also seems uncommon among pre-weaned calves (e.g., Webster et al. 1985b, Veissier et al. 2001) and its incidence would not seem sufficient to justify individual housing. However, group housed calves may still displace each other from important resources, such as a favoured resting location or feed (see von Keyserlingk et al. 2004).

Dimensions of individual housing for calves: Although space availability can affect both veal calves and dairy replacement heifers, research to date has focused largely on the veal crate. Individual housing normally limits the calves' ability to walk or run, and it seems unlikely that under commercial conditions individual pens will ever be large enough to allow full expression of such behaviours. Hence, much of the research has focused simply on whether the individual pens are large enough to allow the animals to comfortably lie down. Calves lie down in a variety of postures, with the head supported by the neck or resting on the ground or body, and with the legs extended or not. The most common criticism regarding traditional veal crates is that their small size does not allow older calves, to lie down with their legs outstretched. This is limited not so much by the actual area of the crate but by its width. Veal calves housed in the traditional narrow crates appear to lie down as long as calves kept in group pens but are less likely to lie down with the legs extended (de Wilt 1985, Le Neindre 1993, Stull and McDonough 1994, Andrighetto et al. 1999) or flat on their sides (Webster et al. 1985b), lying postures linked to thermoregulation, as calves need to lose considerable metabolic heat. Crated calves were also reported to spend less time lying with their heads turned back over their bodies (de Wilt 1985). Such posture may be important for calves to sleep properly. When calves are prevented from adopting specific sleeping postures, REM sleep may be affected (Hänninen 2008).

Researchers have tried to determine what size of crate is necessary to allow the calves to adopt their normal resting postures. Detailed observations of the amount of space taken by calves when resting suggest that in order to lie with legs outstretched, calves weighing 70-210 kg require 60-75 cm width (van Putten 1982, van Putten and Elshof 1982), and calves weighing 170 kg to 300 kg require crates 80-95 cm wide (Ketelaar-de-Lauwere and Smits 1991). Webster et al. (1985a) also concluded that calves weighing more than 100 kg should be kept in crates at least 85 cm wide. Tennessen and Whitney (1990) report that for 4-month-old calves (135 kg), 60 cm is the average width required to lie with the head turned back, although some calves require up to 70 cm. However, Andrighetto et al. (1999) observed that calves in 60 cm wide crates spent as much time lying (with their head laid back on their bodies), as did group housed calves.

Other work has indicated that even the larger of these sizes may be inadequate. Le Neindre (1993) noted that calves spent less time resting with all legs bent when kept in 65 vs. 55 cm crates at 13 weeks of age, but this difference disappeared at 17 weeks of age. At this age, time spent resting with all legs bent was only reduced when calves were 1.1 m in width. Wilson et al. (1999) also noted that increasing the width of the crate from 56 cm to 76 cm did not affect the amount of time spent in various lying postures, although calves in 56 cm wide crates could not stretch one or more legs while lying down.

It seems that for veal calves to adopt their normal resting postures throughout the growth phase, crates need to be at least 1 m wide. Small crates seem to have little effect on the growth of the calves. Van Putten and Elshof (1982) cite data indicating reduced weight gains when crates were 55 cm wide but no differences between crates 60, 65 and 70 cm wide. Terosky et al. (1997) found no growth differences for calves kept in crates that were 56, 66, or 76 cm wide. Either there is no effect of crate size, or all of the sizes studied were too small.

As a rough guide to the size of individual pens, EFSA (2006) concluded that the minimum size for individual pens should be as follows: the width at least the height of the calf at its withers, and the length 110% of the length of the calf (measured from the tip of its nose when standing to the caudal edge of the tuber ischium (pin bone). Much of the difficulty in assessing the effect of crate size upon the welfare of calves comes from the lack of information on why calves adopt the resting postures that they do. Although there are good reasons for assuming that some postures are important for thermoregulation or for the different phases of sleep, more research is needed on the functions of rest and sleep in calves, and the role of resting position in promoting adequate rest.

Bedding and flooring: Traditionally, calves were provided with some sort of organic material for bedding, usually straw, but the recent trend is to reduce the use of such bedding, primarily because of labour costs involved in cleaning and because of concerns about hygiene. For example, dirty bedding can increase the incidence of diarrhoea (Frank and Kaneene 1993) and of Cryptosporidiosis (Mohammed et al. 1999). In some cases, animals are kept on bare concrete or wooden floors, usually slatted to allow the drainage of urine and feces. Unfortunately, few studies have examined the necessity for bedding for calves. Webster et al. (1985a) reported that 20% of veal calves kept on wooden slats had cut, swollen or bruised knees, and far fewer injuries were observed on calves kept at pasture or on straw bedding. Deep bedding has been found to be associated with a reduced risk of Cryptosporidium infection (Brook et al. 2008). Hänninen et al. (2005) found no difference in growth rates or in the amount of time spent lying down between calves kept in individual pens with solid concrete floors or soft rubber mats. Nor did the type of flooring appear to affect measures of the HPA axis activity or secretion of growth hormone (Hänninen et al. 2006). The importance of the softness of flooring probably depends on the weight of the animals: the lighter weight of young calves may explain why concrete or wooden flooring do not have the same negative effects for calves as they do for adult cattle. However, a clean dry surface will still be important, and the thermal protection of bedding may be especially important for young calves kept in cool conditions.

Outdoor versus indoor housing: A few studies that have compared indoor and outdoor housing. Unfortunately, variation in the design of indoor housing systems and differences in management among systems makes it difficult to conclude much about their relative advantages. In recent years, North American dairy producers have adopted outdoor hutches for dairy calves, and this is now the most common type of outdoor housing for dairy calves in the U.S. (USDA 2002). Some studies have reported reduced disease and mortality and improved growth of dairy calves in outdoor hutches compared to indoor individual pens (McKnight 1978, Quigley et al. 1994, Fiems et al. 2002). However, one of these studies (McKnight 1978) actually found lower growth in hutch housed calves during winter months, and other work (Jorgenson et al. 1970, Friend et al. 1985, Frank and Kaneene 1993) has found no advantage of hutches on health and growth rates. Another study (Kung et al. 1997) found higher morbidity (measured by days of medication) in dairy calves kept in hutches compared to group-housed calves indoors.

References

Andrighetto, I., Gottardo, F., Andreoli, D., & Cozzi, G. (1999). Effect of type of housing on veal calf growth performance, behaviour and meat quality. *Livestock Production Science, 57,* 137-145.

Blanaru, J. L., Kohut, J. R., Fitzpatrick-Wong, S. C., & Weiler, H. A. (2004). Dose response of bone mass to dietary arachidonic acid in piglets fed cow milk-based formula. *The American Journal of Clinical Nutrition, 79,* 139-147.

Brook, E., Hart, C. A., French, N., & Christley, R. (2008). Prevalence and risk factors for Cryptosporidium spp. infection in young calves. *Veterinary Parasitology, 152,* 46-52.

Broom, D. M., & Leaver, J. D. (1978). Effects of group-rearing or partial isolation on later social behaviour of calves. *Animal Behaviour, 26,* 1255-1263.

Chua, B., Coenen, E., van Delen, J., & Weary, D. M. (2002). Effects of pair versus individual housing on the behavior and performance of dairy calves. *Journal of Dairy Science, 85,* 360-364.

Dantzer, R., Mormède, P., Bluthé, R. M., & Soissons, J. (1983). The effect of different housing conditions on behavioural and adrenocortical reactions in veal calves. *Reproduction and Nutrition Development, 23,* 501-508.

Dellmeier, G. R., Friend, T. H., & Gbur, E. E. (1985). Comparison of four methods of calf confinement. II. *Behavior. Journal of Animal Science, 60,* 1102-1109.

de Wilt, J.G. (1985). Behaviour and welfare of veal calves in relation to husbandry systems. Thesis, Institute of Agricultural Engineering, Wageningen, NL.

EFSA. (2006). The EFSA Journal. Opinion on "The risks of poor welfare in intensive calf farming systems. An update of the Scientific Veterinary Committee Report on the Welfare of Calves." *EFSA-Q-2005-014, 366,* 1-36.

Fiems, L. O., De Campeneere, S., De Boever, J. L., & Vanacker, J. M. (2002). Performance of double-muscled bulls affected by grazing or restricted indoor feed intake during the growing period followed by finishing up to two different slaughter weights. *Livestock Production Science, 77,* 35-43.

Færevik, G., Jensen, M. B., & Bøe, K. E. (2006). Dairy calves social preferences and the significance of a companion animal during separation from the group. *Applied Animal Behaviour Science, 99,* 205-221.

Frank, N. A., & Kaneene, J. B. (1993). Management risk factors associated with calf diarrhea in Michigan dairy herds. *Journal of Dairy Science, 76,* 1313-1323.

Friend, T. H., Dellmeier, G. R., & Gbur, E. E. (1985). Comparison of four methods of calf confinement. I. Physiology. *Journal of Animal Science, 60,* 1095-1101.

Hänninen, L., Hepola, H., Rushen, J., de Passillé, A. M., Pursiainen, P., Tuure, V. M., Syrjälä-Qvist, L., Pyykkönen, M., & Saloniemi, H. (2003). Resting behaviour, growth and diarrhoea incidence rate of young dairy calves housed individually or in groups in warm or cold buildings. *Acta Agriculturae Scandinavica, Section A, Animal Science, 53,* 21-28.

Hänninen, L., de Passillé, A. M., & Rushen, J. (2005). The effect of flooring type and social grouping on the rest and growth of dairy calves. *Applied Animal Behaviour Science, 91,* 193-204.

Hänninen, L., Løvendahl, P., de Passillé, A. M., & Rushen, J. (2006). The effect of floor type or relocation on calves' pulsatile growth hormone and cortisol secretion. *Acta Agriculturae Scandinavia, Section A, Animal Science, 56,* 99-108.

Hänninen, L., Mäkelä, J. P., Rushen, J., de Passillé, A. M., & Saloniemi, H. (2008). Assessing sleep state in calves through electrophysiological and behavioural recordings: A preliminary study. *Applied Animal Behaviour Science, 111,* 235-250.

Jensen, M. B., Vestergaard, K. S., Krohn, C. C., & Munksgaard, L. (1997). Effect of single versus group housing and space allowance on responses of calves during open-field tests. *Applied Animal Behaviour Science, 54,* 109-121.

Jorgenson, L. J., Jorgensen, N. A., Schingoethe, D. J., & Owens, M. J. (1970). Indoor versus outdoor calf rearing at three weaning ages. *Journal of Dairy Science, 53,* 813-816.

Ketelaar-de Lauwere, C. C., & Smits, A. C. (1991). Spatial requirements of individually housed veal calves of 175 to 300 kg. In: Metz, J.H.M., Groenestein, C.M. (Eds.), *New Trends in Veal Calf Production* (pp. 49-53). Wageningen, NL: EAAP Publication no. 52.

Kung, Jr, L., Demarco, S., Siebenson, L. N., Joyner, E., Haenlein, G. F. W., & Morris, R. M. (1997). An evaluation of two management systems for rearing calves fed milk replacer. *Journal of Dairy Science, 80,* 2529-2533.

Le Neindre, P. (1993). Evaluating housing systems for veal calves. *Journal of Animal Science, 71,* 1345-1354.

Losinger, W. C., & Heinrichs, A. J. (1997). Management practices associated with high mortality among preweaned dairy heifers. *Journal of Dairy Research, 64,* 1-11.

Losinger, W. C., Wells, S. J., Garber, L. P., & Hurd, H. S. (1995). Management factors related to Salmonella shedding by dairy heifers. *Journal of Dairy Science, 78,* 2464-2472.

McKnight, D. R. (1978). Performance of newborn dairy calves in hutch housing. Canadian *Journal of Animal Science, 58,* 517-520.

Mohammed, H. O., Wade, S. E., & Schaaf, S. (1999). Risk factors associated with Cryptosporidium parvum infection in dairy cattle in southeastern New York State. *Veterinary Parasitology, 83,* 1-13.

Pedersen, R.E., Sørensen, J.T., Skjøth, F., Hindhede, J., & Nielsen, T.R. (In Press). How milk-fed dairy calves perform in stable versus dynamic groups. *Livestock Science, In Press* doi:10.1016/j.livsci.2008.06.007.

Quigley, J. D., Martin K. R., Bemis, D. A., Potgieter, L.N.D., Reinemeyer, C. R., Rohrbach, B. W., Dowlen, H. H., and Lamar, K. C. (1994). Effects of Housing and Colostrum Feeding on the Prevalence of Selected Infectious Organisms in Feces of Jersey Calves. *Journal of Dairy Science 77,* 3124-3131.

Rugbjerg, H., Nielsen, E. M., & Andersen, J. S. (2003). Risk factors associated with faecal shedding of verocytotoxin-producing Escherichia coli O157 in eight known-infected Danish dairy herds. *Preventive Veterinary Medicine, 58,* 101-113.

Rushen, J., de Passillé, A. M., von Keyserlingk, M. A. G., & Weary, D. M. (2008). The welfare of cattle. *Animal Welfare Vol. 5.* Berlin: Springer Verlag.

Stull, C. L., & McDonough, S. P. (1994). Multidisciplinary approach to evaluating welfare of veal calves in commercial facilities. *Journal of Animal Science, 72,* 2518-2524.

Svensson, C., Lundborg, K., Emanuelson, U., & Olsson, S. O. (2003). Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine, 58,* 179-197.

Svensson, C., & Liberg, P. (2006). Effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. *Preventive Veterinary Medicine, 73*, 43-53.

Tennessen, T., & Whitney, D. (1990). Estimating animal space needs with video image analysis. *Canadian Journal of Animal Science, 70,* 1183.

Terosky, T. L., Wilson, L. L., Stull, C. L., & Stricklin, W. R. (1997). Effects of individual housing design and size on special-fed Holstein veal calf growth performance, haematology, and carcass characteristics. *Journal of Animal Science*, *75,* 1697–1703.

USDA. (2002). *Reference of Dairy Cattle Health and Health Management Practices in the United States: Part III*. NAHMS.

van Putten, G. (1982). Welfare in veal calf units. *Veterinary Record, 111,* 437-440.

van Putten, G., & Elshof, W. J. (1982). Inharmonious behaviour of veal calves. In *Disturbed Behaviour in Farm Animals* (pp. 61-71). Stuttgart : Verlag Eugen.

Veissier, I., Gesmier, V., Le Neindre, P., Gautier, J.Y., & Bertrand, G. (1994). The effects of rearing in individual crates on subsequent social behaviour of veal calves. *Applied Animal Behaviour Science, 41,* 199-210.

Veissier, I., Boissy, A., de Passillé, A. M., Rushen, J., van Reenen, C. G., Roussel, S., Andanson, S., & Pradel, P. (2001). Calves responses to repeated social regrouping and relocation. *Journal of Animal Science, 79,* 2580-2593.

von Keyserlingk, M. A. G., Brusius, L., & Weary, D. M. (2004). Competition for teats and feeding behavior by group-housed dairy calves. *Journal of Dairy Science, 87,* 4190-4194.

Wathes, C. M., Zaidan, W. A., Pearson, G. R., Hinton, M., & Todd, N. (1988). Aerosol infection of calves and mice with Salmonella typhimurium. *Veterinary Record*, *123,* 590-594.

Webster, A. J. F., Saville, C., & Church, B. M. (1985a). The effect of different rearing systems on the development of calf behaviour. *British Veterinary Journal*, *141*, 249-265.

Webster A. J. F., Saville, C., Church, B. M., Gnanasakthy, A., & Moss, R. (1985b). Some effects of different rearing systems on health, cleanliness and injury in calves. *British Veterinary Journal*, *141,* 472-483.

Wilson, L. L., Terosky, T. L., Stull, C. L., & Stricklin, W. R. (1999). Effects of individual housing design and size on behaviour and stress indicators of special-fed Holstein veal calves. *Journal of Animal Science, 77,* 1341-1347.

Xiccato, G., Trocino, A., Queaque, P. I., Sartori, A., & Carazzolo, A. (2002). Rearing veal calves with respect to animal welfare: effects of group housing and solid feed supplementation on growth performance and meat quality. *Livestock Production Science, 75*, 269-280.

3. SURGICAL INTERVENTIONS

DEHORNING

Conclusions:

1. **Dehorning is painful for all calves, but is best performed at younger ages.**
2. **Use of polled sires avoids the need for dehorning.**
3. **A combination of sedatives, local anaesthetics and analgesics can be used to control the distress due to the procedure and the pain during and after dehorning.**
4. **Dehorning procedures require careful training. For example over application of caustic paste or the hot-iron can cause serious injuries to the calf.**

The horns of intensively-managed dairy cattle increase the risk of injuries to workers and other animals (Meischke et al. 1974) so horns are typically removed. Dairy farmers (Hoe and Ruegg 2006) and veterinarians (Hewson et al. 2007) recognize that dehorning causes pain. Fortunately, a large body of scientific research has now identified dehorning methods and interventions can be used to reduce pain (see Stafford and Mellor 2005 for a review).

The developing horns of cattle 3 months of age or older are normally removed surgically using a number of techniques (scooping, shearing and sawing), and physiological responses indicate that all these procedures are painful (Sylvester et al. 1998). Dehorning of older animals can lead to a setback in weight gain that can be detected more than 100 days after dehorning (Goonewardene and Hand 1991). Although no research we are aware of has specifically compared dehorning older heifers and calves, it seems clear that this procedure is less invasive if performed at younger ages (before 3 months of age). If older animals must be dehorned, research shows that both a sedative and a local nerve block are required to control pain during the procedure (Lepková et al. 2007). The research reviewed below also indicates that adult animals would very likely benefit from analgesics to control post-operative pain.

For younger animals, horn buds of calves are typically removed using a caustic paste or a hot iron. There is again good evidence that both methods are painful (Morisse et al. 1995, Stilwell et al. 2008), but most of the studies on the pain of dehorning and how it can be reduced have focused on hot-iron dehorning. This procedure is known to cause an immediate behavioural response, including tail wagging, head movements, tripping and rearing (Graf and Senn 1999), as well as post-operative pain indicated by head rubbing, head shaking and ear flicking (McMeekan et al. 1999) and increased levels of circulating corticosteroids in the hours following the procedure (Doherty et al. 2007). It is well known that local analgesics can reduce the pain caused by the burn injury, but local aesthetic alone does not adequate provide adequate post-operative pain relief (Stafford and Mellor 2005). The most popular local anaesthetic, lidocaine, is effective for 2 to 3 hours after administration (McMeekan et al. 1998), and calves treated with local anaesthetic actually experience higher plasma cortisol levels than untreated animals after the local anaesthetic loses its effectiveness (Graf and Senn 1999, McMeekan et al. 1998, Petrie et al. 1996). However, the use of NSAIDs (such as ketoprofen), in addition to a local anaesthetic, can keep plasma cortisol and behavioural responses close to baseline levels in the hours that follow dehorning (Stafford and Mellor 2005; Milligan et al, 2004).

A second consideration is that animals respond to both the pain of the procedure and to the physical restraint. Calves dehorned using a local anaesthetic still require restraint, and calves must also be restrained while the local anaesthetic is administered. The use of a sedative (such as xylazine) can essentially eliminate calf response to the administration of the local anaesthetic and the need for physical restraint during the administration of the local anaesthetic and during dehorning (Grøndahl-Nielsen et al. 1999). Thus a combination of sedative, local anaesthetic and a NSAID reduces the response to the pain both during dehorning and in the hours that follow.

One common alternative to hot-iron dehorning is using caustic paste to cause a chemical burn. This method of dehorning is painful, but as described by Vickers et al. (2005) this pain is easier to control. Much of the pain due to caustic paste dehorning can be controlled using only the sedative and mild analgesic xylazine. If xylazine is not used, a local anaesthetic is necessary to control pain (Stilwell et al. 2008). Both caustic paste and hot-iron dehorning require careful training; over-application of either method can cause serious injuries to the calf.

One alternative to dehorning for many breeds of cattle is to breed cows to polled (genetically hornless) sires (Prayaga 2007). Horns are inherited as an autosomal recessive gene with polled as the dominant condition (Long and Gregory 1978), making it easy to produce polled calves from horned cows reliably. Recent molecular biological research has begun to identify the genes involved (Prayaga 2007). The quality of many polled beef sires is similar to that for horned animals and there is no evidence that polled cattle have lower productivity (Prayaga 2007). For example, Goonewardene et al. (1999a, 1999b) found no differences between horned and polled cattle in birth weight, weaning weight, carcass weight, carcass characteristics, pregnancy rates, dystocia scores, cow weights, and cow condition scores. Unfortunately, dairy producers still have only a relatively small selection of polled sires available. This is an obvious area for continued development by companies that sell cattle genetics, as the use of polled sires saves a chore for the producer, and provides an easy way of avoiding what is obviously a painful procedure for the calf.

References

Doherty, T. J, Kattesh, H. G., Adcock, R. J., Welborn, M. G., Saxton, A. M., Morrow, J. L., & Dailey, J. W. (2007). Effects of a concentrated lidocaine solution on the acute phase stress response to dehorning in dairy calves. *Journal of Dairy Science, 90,* 4232-4239.

Goonewardene, L. A., & Hand, R. K. (1991). Studies on dehorning steers in Alberta feedlots. *Canadian Journal of Animal Science, 71*, 1249-1252.

Goonewardene L. A., Pang, H., Berg, R. T., & Price, M. A. (1999a). A comparison of reproductive and growth traits of horned and polled cattle in three synthetic beef lines. *Canadian Journal of Animal Science, 79,* 123-127.

Goonewardene L. A., Price, M. A., Liu, M. F., Berg, R. T., & Erichsen, C. M. (1999b). A study of growth and carcass traits in dehorned and polled composite bulls. *Canadian Journal of Animal Science, 79,* 383-385.

Graf, B., & Senn, M. (1999). Behavioural and physiological responses of calves to dehorning by heat cauterisation with or without local anaesthesia. *Applied Animal Behaviour Science, 62,* 153-171.

Grøndahl-Nielsen, C., Simonsen, H. B., Damkjer Lund, J., & Hesselholt, M. (1999). Behavioural, endocrine and cardiac responses in young calves undergoing dehorning without and with use of sedation and analgesia. *The Veterinary Journal 158,* 14-20.

Hewson, C. J., Dohoo, I. R., Lemke, K. A., & Barkema, H. W. (2007). Factors affecting Canadian veterinarians' use of analgesics when dehorning beef and dairy calves. *Canadian Veterinarian Journal, 48*, 1129-1136.

Hoe, F. G. H., & Ruegg, P. L. (2006). Opinions and practices of Wisconsin dairy producers about biosecurity and animal well-being. *Journal of Dairy Science, 89,* 2297-2308.

Lepková, R., Sterc, J., Vecerek, V., Doubek, J., Kruzíková, K., & Bedánová, I. (2007). Stress responses in adult cattle due to surgical dehorning using three different types of anaesthesia. *Berliner und Munchener Tierarztliche Wochenschrift, 120,* 465-469.

Long C. R., & Gregory, K. E. (1978). Inheritance of the horned, scurred and polled condition in cattle. *Journal of Heredity, 69,* 395-400.

McMeekan, C. M., Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N., & Gregory, N. G. (1998). Effects of regional analgesia and/or a non-steriodal anti-inflammatory analgesic on the acute cortisol response to dehorning in calves. *Research in Veterinary Science, 64,* 147-150.

McMeekan, C. M, Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N., & Gregory, N. G. (1999). Effects of a local anaesthetic and a non-steroidal anti-inflammatory analgesic on the behavioural responses of calves to dehorning *New Zealand Veterinary Journal, 47,* 92-96.

Meischke, H. R. C., Ramsay, W. R., & Shaw, F. D. (1974). The effect of horns on bruising cattle. *Australian Veterinary Journal, 50*, 432-434.

Milligan, B.N., Duffield, T., Lissemore, K. 2004. The utility of ketoprofen for alleviating pain following dehorning in young dairy calves. *Canadian Veterinary Journal, 45,* 140-143.

Morisse, J. P, Cotte, J. P, & Huonnic, D. (1995). Effect of dehorning on behavior and plasma-cortisol responses in young calves. *Applied Animal Behaviour Science, 43,* 239-247.

Petrie, N. J., Mellor, D. J., Stafford, K. J., Bruce, R. A., & Ward, R. N. (1996). Cortisol responses of calves to two methods of disbudding used with or without local anaesthetic. *New Zealand Veterinary Journal, 44,* 9-14.

Prayaga, K. C. (2007). Genetic options to replace dehorning in beef cattle - A review. *Australian Journal of Agricultural Research, 58,* 1-8.

Stafford, K. J., & Mellor, D. J. (2005). Dehorning and disbudding distress and its alleviation in calves. *Veterinary Journal, 169,* 337-349.

Stilwell, G., de Carvalho, R. C., Lima, M. S., & Broom, D. M. (2008). Effect of caustic paste disbudding, using local anaesthesia with and without analgesia, on behaviour and cortisol in calves. *Applied Animal Behaviour Science, In Press,* doi:10.1016/j.applanim.2008.06.008.

Sylvester, S. P., Stafford, K. J., Mellor, D. J., & Ward, R. N. (1998). Acute cortisol responses of calves to four methods of dehorning by amputation. *Australian Veterinary Journal, 76,* 123-126.

Vickers, K. J., Niel, L., Kiehlbauch, L. M., & Weary, D. M. (2005). Calf response to caustic paste and hot-iron dehorning using sedation with and without local anesthetic. *Journal of Dairy Science, 88,* 1454-1459.

TAIL-DOCKING

Conclusions:

1. **Tail docking does not improve cleanliness or udder health.**
2. **Tail docking can cause some immediate pain, puts cows at risk for post-operative infections and the formation of painful neuromas, and reduces the cow's ability to naturally control flies.**

Cows use their tails as a natural fly swat, and with each swat, the tail comes into contact with the rest of the body. When the tail becomes contaminated with faeces containing pathogens, it can contaminate other areas of the cow's body, perhaps increasing the risk of udder infections, and the tail becomes more of a threat to milkers and others who work with the cows. For these reasons the practice of tail-docking dairy cattle gained popularity in the 1980s and 1990s.

Dairy farmers vary in when and how they perform this procedure (Barnett et al. 1999, Stull et al. 2002). For example, docking is sometimes done using elastic rings that restrict blood flow and kill the distal portion of the tail and sometimes using a docking iron that both cuts the tail and cauterizes the stump (see Tom et al. 2002b for comparison).

Numerous studies have examined the pain due to tail docking in dairy cattle. The procedure likely causes some pain but there is little evidence that this is severe or prolonged, as shown by a variety of behavioural, physiological and immune measures of both calves and adult cows (Petrie et al. 1996, Eicher et al. 2000, Eicher et al. 2001, Tom et al. 2002a, Tom et al. 2002b). There is no clear evidence that anaesthetics are necessary or that tail docking calves is preferable to docking adult cows (Tom et al. 2002a, Tom et al. 2002b). In calves, evidence of acute pain is sometimes apparent when rubber rings are used rather than a hot docking iron (Petrie et al. 1995, Tom et al. 2002a), but even here the effect is small.

Tail docking has clear long lasting negative effects on welfare. Sectioning the nerves in the tails of both young calves and adult cattle results in neuroma formation (Lunam et al. 2002), which can result in chronic pain, similar to the phantom pain felt following limb amputation (Eicher et al. 2006). In addition, docked cows have more flies on them and show more fly avoidance behaviours (Eicher et al. 2001). Docking can also lead to serious post-operative infections including tetanus and gangrene (Stull et al. 2002).

Some producers choose to dock tails because they believe that this improves working conditions for the milker (Petrie et al. 1996), but this issue is becoming less relevant as most modern milking parlours prevent contact with the tail (Stull et al. 2002). The idea that intact tails are a health risk for milkers has long been discredited (Mackintosh et al. 1982). A common alternative to tail docking in dairy cows is switch trimming. In a study comparing docking, switch trimming and intact tails, the proportion of flies on the rear quarters of switch-trimmed cows was intermediate between cows with intact or docked tails. A compromise for milking personnel comfort might be achieved by trimming the switch in the spring (when the tail was more likely to be dirty) and allowing it to grow back over the summer (when fly numbers are highest) (Stull et al. 2004).

In contrast to the beliefs of many dairy farmers (Barnett et al. 1999), multiple large-scale, controlled experiments have now shown that docking tails provides no systematic advantage in terms of cow cleanliness or udder health (Schreiner and Ruegg 2002, Tucker et al. 2001). Only one smaller scale study reported an increase in cleanliness, and no study has found improved udder health in docked cows (Eicher et al. 2001). The study by Schreiner and Ruegg, for example, found no differences in cleanliness, somatic cell counts or bacterial cultures of mastitis causing pathogens from docked and undocked cattle on 9 commercial dairies. The 2007 NAHMS survey showed that farms that tail dock their cows actually have *more* problems with cow cleanliness than do farm with cows that have their tails intact.

Given the obvious disadvantages to the cow, especially the reduced ability to control flies (Eicher et al. 2001), and the lack of any effects in terms of improved hygiene, there seems little justification for continuing this procedure.

References

Barnett, J. L., Coleman, G. J., Hemsworth, P. H., Newman, E. A., Fewings-Hall, S., & Ziini, C. (1999). Tail docking and beliefs about the practice in the Victorian dairy industry. *Australian Veterinary Journal, 77*, 742-747.

Eicher, S. D., Morrow-Tesch, J. L., Albright, J. L., Dailey, J. W., Young, C. R., & Stanker, L. H. (2000). Tail-docking influences on behavioral, immunological, and endocrine responses in dairy heifers. *Journal of Dairy Science, 83*, 1456-1462.

Eicher, S. D., Morrow-Tesch, J. L., Albright, J. L., & Williams, R. E. (2001). Tail-docking alters fly numbers, fly-avoidance behaviors, and cleanliness, but not physiological measures. *Journal of Dairy Science*, *84*, 1822-1828.

Eicher, S. D., Cheng, H. W., Sorrells, A. D., & Schutz, M. M. (2006). Short communication: Behavioral and physiological indicators of sensitivity or chronic pain following tail docking. *Journal of Dairy Science*, *89*, 3047-3051.

Lunam, C. A, de Passillé, A. M., & Rushen, J. (2002). Neuroma formation following tail docking of dairy calves. *Journal of Dairy Science, 85*(Suppl. 1), 371.

Mackintosh, C. G., Schollum, L. M., Blackmore, D. K., & Marshall, R. B. (1982). Epidemiology of leptospirosis in dairy farm workers in the Manawatu, part II: A case-control study of high and low risk farms. *New Zealand Veterinary Journal, 30*, 73-76.

Petrie, N. J., Stafford, K. J., Mellor, D. J, Bruce, R. A., & Ward, R. N. (1995). The behaviour of calves tail docked with a rubber ring used with or without local anaesthesia. *Proceedings of the New Zealand Society of Animal Production, 55*, 58-60.

Petrie, N. J., Stafford, K. J., Mellor, D. J., Bruce, R. A., & Ward, R. N. (1996). Cortisol responses of calves to two methods of tail docking used with or without local anaesthetic. *New Zealand Veterinary Journal, 44*, 4-8.

Schreiner, D. A., & Ruegg, P. L. (2002). Effects of tail docking on milk quality and cow cleanliness. *Journal of Dairy Science, 85*, 2503-2511.

Stull, C. L., Payne, M. A., Berry, S. L., & Hullinger, P. J. (2002). Evaluation of the scientific justification for tail docking in dairy cattle. *Journal of the American Veterinary Medical Association, 202*, 1298-1303.

Stull, C. L., Payne, M. A., Berry, S. L., & Hullinger, P. J. (2004). Tail docking in dairy cattle. 7 October 2008. <http://www.vetmed.ucdavis.edu/vetext/INF-AN/Tail-Docking-Dairy.pdf>

Tom, E. M., Duncan, I. J. H., Widowski, T. M., Bateman, K. G., & Leslie, K. E. (2002a). Effects of tail docking using a rubber ring with or without anesthetic on behavior and production of lactating cows. *Journal of Dairy Science*, *85*, 2257-2265.

Tom, E. M., Rushen, J., Duncan, I. J. H., & de Passillé, A. M. (2002b). Behavioural, health and cortisol responses of young calves to tail docking using a rubber ring or docking iron *Canadian Journal of Animal Science*, *82*, 1-9.

Tucker, C. B., Fraser, D., & Weary, D. M. (2001). Tail docking dairy cattle: Effects on cow cleanliness and udder health. *Journal of Dairy Science*, *84*, 84-87.

BRANDING

Conclusions:

1. **Freeze branding and hot-iron branding are both painful for cattle.**
2. **There is some evidence that freeze branding maybe somewhat less painful than hot iron branding.**

All cattle within Canada are required by law to be marked with National Livestock Identification for Dairy (NLID) tags. Branding is not required but a small proportion of dairy farmers still choose to brand their animals. Like dehorning, branding involves at least three distinct welfare issues: stress due to restraining the animal before and during the procedure, the immediate pain during branding, and post-operative pain that can occur in the hours following the procedure. Research to date has focussed on the second of these three issues, although some data is also available to assess post-operative pain.

Cattle are typically branded using a hot iron (heated electrically or over fire) that burns the skin and creates scar tissue on which no hair will grow. One alternative method is freeze branding with an iron that has been cooled in liquid nitrogen or a combination of dry ice and alcohol. The freeze brand works by killing the cells that pigment the hair, such that white hair grows from the area that has been branded. It seems clear from all the research completed to date that both methods are painful, but freeze banding consistently results in a lower pain response than hot-iron branding (Lay et al. 1992 a, Lay et al. 1992b, Schwartzkopf-Genswein et al. 1997a, Schwartzkopf-Genswein et al. 1997b, Schwartzkopf-Genswein et al. 1998, Watts and Stookey 1999). In addition to the direct injury cause by the brand, branding can also increases the risk of skin infections and disease (Yeruham et al. 1996).

Beef cattle respond to branding by vocalizing, kicking, flicking their tails, falling in the chute, and making avoidance or escape movements; these have been characterized using subjective scores, as well as objective methods. For instance, Schwartzkopf-Genswein et al. (1998) quantified the head movements of cattle during branding; compared to freeze branding, hot-iron branded cattle were found to have increased amount, speed and distance of head movements. In another study, Schwartzkopf-Genswein et al. (1997a) evaluated the post-operative inflammatory responses to branding using infrared thermography. Both freeze and hot-iron branding resulted in a pronounced inflammatory response, with skin temperature almost 2 ºC higher than baseline and differences persisting throughout the 7 days of post-procedural monitoring. However, this inflammatory response was greater and persisted longer for cattle that were hot-iron branded compared to their freeze branded counterparts.

One obvious gap in the research on branding is lack of attention paid to finding practical methods of pain mitigation. Given that the work on hot-iron dehorning has resulted in successful treatment methods, this seems like a useful area to pursue. More generally, researchers and the cattle industry need to work to develop and adopt modern methods of identifying cattle that do not involve injuring the animal.

References

Lay, D. C., Friend, T. H., Bowers, C. L., Grissom, K. K., & Jenkins, O. C. (1992a). A comparative physiological and behavioral study of freeze and hot-iron branding using dairy cows. *Journal of Animal Science, 70,* 1121-1125.

Lay, D. C., Friend, T. H., Bowers, C. L., Grissom, K. K., & Jenkins, O. C. (1992b). Behavioral and physiological effects of freeze or hot-iron branding on crossbred cattle. *Journal of Animal Science, 70*, 330-336.

Schwartzkopf-Genswein, K. S., Stookey, J. M., de Passillé, A. M., & Rushen, J. (1997a). Comparison of hot-iron and freeze branding on cortisol levels and pain sensitivity in beef cattle. *Canadian Journal of Animal Science, 77*, 369-374.

Schwartzkopf-Genswein, K. S., Stookey, J. M., & Welford, R. (1997b). Behavior of cattle during hot-iron and freeze branding and the effects on subsequent handling ease. *Journal of Animal Science*, *75,* 2064-2072.

Schwartzkopf-Genswein, K. S., Stookey, J. M., Crowe, T. G., & Genswein, B. M. (1998). Comparison of image analysis, exertion force, and behavior measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding. *Journal of Animal Science, 76*, 972-979.

Watts, J. M., & Stookey, J. M. (1999). Effects of restraint and branding on rates and acoustic parameters of vocalization in beef cattle. *Applied Animal Behaviour Science, 62*, 125-135.

Yeruham, I., Perl, S., & Nyska, A. (1996). Skin tumours in cattle and sheep after freeze- or heat-branding. *Journal of Comparative Pathology, 114*, 101-106.

CASTRATION

Conclusions:

1. **All methods of castration cause pain and distress.**
2. **This response can be reduced by the use of sedatives, anesthetics, and analgesics.**
3. **Stress due to castration is less evident when performed on younger animals.**
4. **The burdizzo method may be less painful than either surgery or constricting rings.**

Of all the routine surgical procedures performed on cattle, one of the most ancient and best researched is castration. The effects of castration on the welfare of cattle have been reviewed by Stafford and Mellor (2005) and Bretschneider (2005). Below we provide a brief review of some of the key issues and research in this area.

As with other procedures that can be accomplished using several techniques, research on castration has tended to focus on comparisons of procedures. The most common methods are those in which the testicles are either removed (surgery), killed by crushing (Burdizzo) or by constricting (rubber rings or latex bands) the tissues that supply blood to the testes. There are several variations on the surgical method including: 1) whether the scrotum is simply incised to allow extraction of the testes or if the bottom of the scrotum is removed, and 2) if the spermatic cord is cut versus tearing it by pulling on the testicle. All methods of castration are known to cause pain, but the evidence reviewed below indicates that the constriction methods (rubber ring and latex band) are most problematic.

Pain Assessment Methods: Early scientific assessments of castration centred on production effects. Production measures will, at best, be indirectly related to the pain. Assessing the effects of castration using production parameters is complicated because of the role of testosterone in mediating growth; however, production measures are still worthy of attention, in part because they can allow us to identify win-win solutions that provide economic benefits to producers and welfare benefits to their animals. One major problem with studies of weight gain is that cattle can vary greatly in body weight *depending* upon the last time they last ate, drank, defecated or urinated. Previous work has indicated that all methods of castration can cause reductions in weight gains with this being most pronounced when older animals are castrated (e.g., Bretschneider 2005). Some studies have reported differences among castration methods in the magnitude of growth check that results. For example, Knight et al. (2000) found that cattle castrated with latex bands showed a greater setback in growth than did those that were castrated surgically. However, Bretschneider's (2005) review showed that most studies did not find such a difference.

A more directly relevant parameter for assessing castration effects is that related to wound healing and complications associated with the procedure. All else being equal, methods producing wounds that heal quickly, and that are less prone to post-surgical infections and complications should be preferred by veterinarians, producers, and the cattle. Intuitively the 'bloodless' methods of Burdizzo and ring castration might be considered superior in this regard, but the scientific evidence suggests that tissue trauma actually heals most quickly with surgical castration. For example, Stafford et al. (2002) reported that wounds from surgery were completely healed within 28 days, while healing continued more than 7 weeks after the rubber ring procedure.

Studies attempting to directly assess pain have used both physiological and behavioural measures, with physiological studies focusing on plasma cortisol. In some situations, plasma cortisol has proven to be a valid indicator of pain; levels are lower following castration with the local anesthetic lidocaine than following castration without a local block (Fisher et al. 1996; Thuer et al. 2007). However, cortisol will also respond to other stressors potentially masking pain effects. For example, separation from the cow results in a pronounced cortisol response, such that calves that are separated and castrated cannot be distinguished from those that are simply separated and not castrated (King et al. 1991). For this reason many of the well designed studies using physiological responses to assess pain have been on individually housed cattle. All methods of castration appear to cause a pronounced cortisol response, with this being greatest for older animals (Bretschneider 2005). However, the relative ranking of measures varies depending upon the way cortisol is interpreted (e.g. peak response, duration above baseline). One way of integrating these measures is to consider the area under the response curve, and by this measure the Burdizzo method seems slightly better than surgical or ring methods (Stafford et al. 2002). Interestingly, the cortisol response to the surgical methods in which the spermatic cord is cut (rather than torn by traction) is highly variable, suggesting that some ways of performing this procedure may be less painful than others.

Because of the time course of the response, behavioural responses may be better able to distinguish between the distress due to restraint and separation from herdmates versus pain due to castration, and also distinguish between the immediate effects of the procedure, and longer-term, post-operative pain. However, the physical restraint can also make it difficult for calves to express certain behaviours, and for observers to properly quantify these responses. Unfortunately, relatively little behavioural data is available to address pain due to castration in cattle. Fell et al. (1986) showed that during castration calves struggle and kick with the hind legs, but this response is more evident during surgical castration than during the placement of a rubber ring. In the hours that follow castration all methods cause behavioural change although the nature of these changes can vary with method. As Stafford and Mellor (2005) argue, there are no clear differences that can allow us to conclude which procedures cause more or less pain.

Impact of Age: A number of studies show that this pain is likely reduced when the procedure is performed at younger ages. For example, Ting et al. (2005) reported that the cortisol response to the Burdizzo procedure is greater when applied at 5 months of age than when applied at younger ages. Restraint is also easier with younger animals, so all procedures requiring restraint are best performed at younger ages. However, castration results in a pronounced physiological and behavioural pain response at all ages, so performing the procedure at a young age should not be considered as sufficient to eliminate pain – methods are still needed to control or prevent the pain.

Pain Mitigation: As with other invasive procedures, pain mitigation strategies should consider distress due to restraint, the immediate pain associated with the procedure, and post-operative pain. As described for dehorning (see Surgical Interventions: Dehorning), drugs such as xylazine can be used to sedate calves, facilitating the procedure and removing the need for any physical restraint. Xylazine has the added advantage of providing some analgesic effect. Experiments on cattle have shown that this can effectively prevent the immediate pain due to the procedure (e.g., Ting et al. 2003), but this study used epidural application, a procedure that is unlikely to be practical on many commercial farms. New work is needed to determine if intra-muscular injections of xylazine or other drugs of this class (alpha-2 agonists) can be used to both sedate the calf and provide adequate analgesia for the procedure, as has been used for caustic paste dehorning of young calves.

Local anaesthetics (such as lidoicaine) are normally effective at mitigating, but not necessarily eliminating, the immediate pain due to castration (e.g. Thuer et al. 2007). Stafford and Mellor (2005) show that local anaesthesia much reduces the cortisol response caused by rubber-ring or latex-band castration, but needs to be combined with a systemic analgesic such as the non-steroidal anti-inflammatory drug ketoprofen to eliminate the cortisol response to Burdizzo or surgical castration. When used alone, ketoprofen sometimes reduces the cortisol response to Burdizzo or surgical castration but may need to be accompanied by local anaesthesia to eliminate the pain-induced behaviour seen during the castration process itself. Hudson et al. (2008) studied local infiltration of local anaesthetic in the skin of the distal scrotum (surgical castration) and over the neck of the scrotum to provide analgesia to the spermatic cord (surgical and Burdizzo castrations).

Earley and Crowe (2002) determined the effects of IV ketoprofen, alone or with local anesthesia (lidocaine injected into each testis) during castration on cortisol, immune and acute phase responses of Friesian calves. Surgical castration induced a significant elevation in cortisol secretion; the rise in cortisol was reduced to control levels by the administration of ketoprofen but not local anaesthetic. Systemic analgesia using ketoprofen is more effective than local anesthesia during castration to alleviate the associated stress response (Earley and Crowe 2002).

Barrett (2004) noted the cortisol response to surgical castration, either by traction on the spermatic cord or via the use of an emasculator, was diminished in calves given local anaesthetic, and eliminated in calves given a combination of local anaesthetic and ketoprofen. He found the rise in cortisol following surgical castration was reduced to control levels following administration of ketoprofen but was not altered by administration of local anaesthetic. It was concluded that systemic analgesia using ketoprofen was more effective than local anaesthesia during castration. Ketoprofen is an effective method of alleviating acute inflammatory stress in surgical castration and is more effective than local anaesthetic, or an epidural of xylazine and lidocaine in reducing inflammatory responses associated with burdizzo castration.

Unfortunately, administering the drug requires extra restraint for the animal. Lidocaine should be administered several minutes before the procedure is performed, meaning either a prolonged period of restraint, or capturing and restraining the animal twice: first to administer the local and again to perform the procedure.

Regardless of how we control the immediate pain, castration will cause pain that extends for the hours and sometimes days that follow. This pain can be treated; however, practicality becomes more difficult the longer the pain persists. As described for other procedures like dehorning, NSAIDs are effective for treating pain following all of the castration methods described above (Stafford et al. 2002). Responses in plasma cortisol, acute-phase proteins, immune function, feed intake, growth and behaviour were compared by Ting et al. (2003) when 11-month-old, 300 kg bulls were surgically castrated without analgesia or with administration of ketoprofen. Ketoprofen reduced the cortisol response to castration but there was no advantage to splitting the pre-operative dose or to administering a second dose 24 hours post-operatively. More research is needed to examine possible longer-term mitigation strategies for post-op pain.

All methods of castration cause pain but this can be reduced through the appropriate use of local anaesthetics and longer lasting analgesics.

References

Barrett, D. C. (2004). Non-steroidal anti-inflammatory drugs in cattle - Should we use them more? *Cattle Practice*, *12*, 69-73.

Bretschneider, G. (2005). Effects of age and method of castration on performance and stress response of beef male cattle: A review. *Livestock Production Science, 97,* 89-100.

Earley, B., & Crowe, M. A. (2002). Effects of ketoprofen alone or in combination with local anesthesia during the castration of bull calves on plasma cortisol, immunological, and inflammatory responses. *Journal of Animal Science*, *80*, 1044-1052.

Fell, L. R., Wells, R., & Shutt, D. A. (1986). Stress in calves castrated surgically or by the application of rubber rings. *Australian Veterinary Journal, 63*, 16-18.

Fisher, A. D., Crowe, M. A., Alonso de la Varga, M. E., & Enright, W. J. (1996). Effect of castration method and the provision of local anesthesia on plasma cortisol, scrotal circumference, growth, and feed intake of bull calves. *Journal of Animal Science*, *74*, 2336-2343.

Hudson, C., Whay, H., & Huxley, J. (2008). Recognition and management of pain in cattle. *In Practice, 30*, 126-134.

King, B. D., Cohen, R. D. H., Guenther, C. L., & Janzen, E. D. (1991). The effect of age and method of castration on plasma-cortisol in beef-calves. *Canadian Journal of Animal Science*, *71*, 257-263.

Knight, T. W., Cosgrove, G. P., Death, A. F., Anderson, C. B., & Fisher, A. D. (2000). Effect of method of castrating bulls on their growth rate and liveweight. *New Zealand Journal of Agricultural Research*, *43*, 187-192.

Stafford, K. J., Mellor, D. J., Todd, S. E., Bruce, R. A., & Ward, R. N. (2002). Effects of local anaesthesia or local anaesthesia plus a non-steroidal anti-inflammatory drug on the acute cortisol response of calves to five different methods of castration. *Research in Veterinary Science*, *73*, 61-70.

Stafford, K. J., & Mellor, D. J. (2005). The welfare significance of the castration of cattle: A review. *New Zealand Veterinary Journal, 53*, 271-278.

Thüer, S., Mellema, S., Doherr, M.G., Wechsler, B., Nuss, K., Steiner, A. 2007.Effect of local anaesthesia on short- and long-term pain induced by two bloodless castration methods in calves. *Veterinary Journal, 173*, 333-342.

Ting, S. T. L., Earley, B., & Crowe, M. A. (2003). Effect of repeated ketoprofen administration during surgical castration of bulls on cortisol, immunological function, feed intake, growth, and behavior. *Journal of Animal Science, 81*, 1253-1264.

Ting, S. T. L., Earley, B., Veissier, I., Gupta, S., & Crowe, M. A. (2005). Effects of age of Holstein-friesian calves on plasma cortisol, acute-phase proteins, immunological function, scrotal measurements and growth in response to burdizzo castration. *Animal Science, 80*, 377-386.

PAIN RELIEF DURING AND AFTER SURGICAL PROCEDURES

Conclusions:

1. **All surgeries are likely to be painful.**

2. A combination of treatments, including analgesics and anesthetics can greatly reduce this pain.

The use of analgesics on farm animals is low for reasons that include fear of residues, legislation, cost, tradition, and lack of knowledge about their use (Stafford et al. 2006).

Pre-emptive analgesia is preferable to reactive analgesia when conducting surgical procedures, reducing or preventing hyperalgesia, allodynia, or wind-up. The most effective analgesia is often provided using a combination of agents that act on different pathways. For example, the use of an epidural containing local anaesthetic and xylazine, combined with a systemic nonsteroidal anti-inflammatory drug (NSAID), provides appropriate analgesia in cases of dystocia (Hudson et al. 2008).

Non-steroidal anti-inflammatory drugs (NSAIDs) such as flunixin, meglumine, tolfenamic acid, ketoprofen, carprofen, and meloxicam are indicated for diseases likely to be associated with pain in cattle include respiratory disease, mastitis, periparturiem inflammatory conditions such as metritis, and inflammatory limb lesions such as joint ill, sole ulceration, and white line disease (Barrett 2004). Traumatic insults and physiological states such as parturition may also be expected to result in the animal experiencing pain, as will surgical procedures such as laparotomy, foot surgery, castration, disbudding, and dehorning.

References

Barrett, D. C. (2004). Non-steroidal anti-inflammatory drugs in cattle - Should we use them more? *Cattle Practice, 12*, 69-73.

Hudson, C., Whay, H., & Huxley, J. (2008). Recognition and management of pain in cattle. *In Practice, 30*, 126-134.

Stafford, K. J., Chambers, J. P., & Mellor, D. J. (2006). The alleviation of pain in cattle: A review. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 1*, 1-7.

4. FEED MANAGEMENT & NUTRITION

FEED BUNK MANAGEMENT AND PROVISION OF APPROPRIATE FEED BUNK SPACE

Conclusions:

1. **Most feeding activity occurs around the time of fresh feed delivery and when cows return from milking.**
2. **Stocking densities at the feed bunk that prevent all cows from feeding at one time increase aggressive competition and keep subordinate cows away from feed.**
3. **Vulnerable cows (i.e., sick, lame, and transition cows) should be provided with feed bunk space in excess of 60 cm to increase feeding activity.**
4. **Physical barriers, including head lockers and feed stalls, can help reduce competition at the feed bunk and increase feeding time, particularly for subordinate cows.**
5. **Frequent delivery of feed reduces the amount of feed sorting and improves access to feed during peak feeding periods.**

Dairy cattle synchronize their behavior such that cows housed in a group prefer to feed at the same time (DeVries et al. 2003). Increasing the frequency of feed delivery to group-housed cows increases feeding time, especially during peak feeding periods when fresh feed is provided, and reduces the degree of feed sorting (DeVries et al. 2005).

There are several aspects of the feeding environment that affect the cow’s ability to access feed, including the amount of available feed bunk space per animal and the physical design of the feeding area. Therefore, if feeding space is limited so that not all cows can feed at the same time, increased competition among cows at the feeder may occur, preventing access to feed during peak-feeding times, especially for subordinate cows.

When feed bunk space is reduced, increases in aggressive behavior limit the ability of some cows to access feed at times when feeding motivation is high, such as when fresh feed is delivered or upon return from the parlour (DeVries and von Keyserlingk 2005). DeVries et al. (2004) showed that when cows had access to more feed bunk space (100 versus 50 cm/cow) there was at least 60% more space between animals and 57% fewer aggressive interactions while feeding. These changes in spacing and aggressive behaviour in turn allowed cows to increase feeding activity by 24%. This effect was strongest for subordinate animals.

Competition and feeding behaviour can also be strongly impacted by the physical design of the feeding area. One of the most obvious features is the physical barrier that separates the cow and the feed. Different feed barriers are all designed with the intention of allowing cows access to feed, but some allow for a higher frequency of aggressive interactions at the feed bunk. Endres et al. (2005) compared post-and-rail versus headlock feed line barriers on the feeding and social behaviour of dairy cows. During periods of peak feeding activity (within 90 min of fresh feed delivery), subordinate cows that had lower feeding times relative to group mates when using the post-and-rail barrier, displayed similar feeding times to group mates when using the headlock barrier. There were also 21% fewer displacements at the feed bunk when cows accessed feed by the headlock barrier compared to the post-and-rail barrier. These results suggest that using a headlock barrier reduces aggression at the feed bunk and improves access to feed for socially subordinate cows.

Huzzey et al. (2006) examined how stocking density and feed barrier design interact. Cows were tested with the barriers described above but using stocking densities of 0.81, 0.61, 0.41 and 0.21 m/cow (corresponding to 1.33, 1.00, 0.67 and 0.33 headlocks/cow). There was less aggressive behaviour with the headlock barrier compared to the post and rail barrier. As well, regardless of barrier type, feeding time decreased and inactive standing increased as stocking density at the feed bunk increased. Cows were displaced more often from the feeding area when the stocking density was increased, and this effect was greater for cows using the post-and-rail feed barrier. Subordinate cows were displaced more often with the post-and-rail barrier design, particularly at high stocking densities. Overstocking the feed bunk will decrease time spent at the feed bunk and increase competition, resulting in poor feed access.

The addition of partitions (feed stalls) between the bodies of adjacent cows can provide additional protection while feeding and allows for improved access to feed (DeVries and von Keyserlingk 2006). When animals had access to more space, particularly with the feed stalls, there were far fewer displacements while feeding. Further, subordinate cows benefited the most from this reduction in displacements. Reduced aggression at the feed bunk allowed cows to increase their daily feeding time and reduce the time they spent standing in the feeding area while not feeding; the latter is especially important because increases in inactive standing have been linked to increased risk for lameness.

References

DeVries, T. J, von Keyserlingk, M. A. G., & Beauchemin, K. A. (2003). Diurnal feeding pattern of lactating dairy cows. *Journal of Dairy Science, 86*, 4079-4082.

DeVries, T. J., von Keyserlingk, M. A. G., & Weary, D. M. (2004). Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed lactating dairy cows. *Journal of Dairy Science, 87*, 1432-1438.

DeVries, T. J., & von Keyserlingk, M. A. G. (2005) Time of fresh feed delivery affects the feeding and lying patterns of dairy cows. *Journal of Dairy Science, 88*, 625-631.

DeVries, T. J., M. A. G. von Keyserlingk, M. A. G., & Beauchemin, K. A. 2005. Frequency of feed delivery affects the behavior of lactating dairy cows. *Journal of Dairy Science, 88*, 3553-3562.

DeVries, T. J., & von Keyserlingk, M. A. G. (2006). Feed stalls affect the social and feeding behavior of lactating dairy cows. *Journal of Dairy Science, 89*, 3522-3531.

Endres, M. I., DeVries, T. J., von Keyserlingk, M. A. G., & Weary, D. M. (2005). Effect of feed barrier design on the behavior of loose-housed lactating dairy cows. *Journal of Dairy Science, 88*, 2377-2380.

Grant, R. J., & Albright, J. L. (2001). Effect of animal grouping on feeding behavior and intake of dairy cattle. *Journal of Dairy Science, 84*(Suppl. 1), 156-163.

Huzzey, J. M., DeVries, T. J., Valois, P., & von Keyserlingk, M. A. G. (2006). Stocking density and feed barrier design affect feeding and social behavior of dairy cattle. *Journal of Dairy Science, 89*, 126-133.

GROUPING

Conclusions:

1. **In loose-housing, regrouping can have short-term negative effects on milk production.**
2. **Regrouping has negative consequences on lying, feeding and social behaviour.**
3. **Aggressive interactions are most frequent immediately after regrouping.**

Dairy cattle are frequently regrouped, often 4 or 5 times in a single lactation. Some regrouping is probably unavoidable. Reasons for regrouping include the maintenance of similar groups in terms of milk yield or stage of lactation.

There is evidence that regrouping has negative consequences on both behaviour and production. When cows are regrouped they re-establish social relationships using non-physical and physical interactions (Lamb 1975, Kondo and Hurnik 1990). Von Keyserlingk et al. (2008) monitored cows before and after they were placed into a new social group and found that after regrouping, cows spent less time eating and less time lying down.

Social competition is greatest at the feed bunk (Val-Laillet et al. 2008) and can negatively affect feeding behaviour, particularly for subordinate cows (DeVries et al. 2004, Huzzey et al. 2006). The number of aggressive interactions is most frequent immediately after regrouping (Kondo and Hurnik 1990, Brakel and Leis 1976), with regrouped cows being more often displaced from the feeding area by other cows; furthermore, regrouped cows are less likely to be groomed by a pen mate (von Keyserlingk et al. 2008).

Several researchers have noted a short-term decrease in milk yield of cows that were mixed into a new social group (Brakel and Leis 1976, Hasegawa et al. 1997, von Keyserlingk et al. 2008), possibly as a result of increased competitive interactions at the feed bunk. Others studies report no change in milk yield (Clark et al. 1977, Sowerby and Polan 1978).

References

Brakel, W. J., & Leis, R. A. (1976). Impact of social disorganization on behavior, milk yield, and body weight of dairy cows. *Journal of Dairy Science, 59*, 716-721.

Clark, P. W., Ricketts, E., & Krause, G. F. (1977). Effect on milk yield of moving cows from group to group. *Journal of Dairy Science, 60*, 769-772.

DeVries, T. J., von Keyserlingk, M. A. G., & Weary, D. M. (2004). Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed lactating dairy cows. *Journal of Dairy Science, 87*, 1432-1438.

Hasegawa, N., Nishiwaki, A., Sugawara, K., & Ito, I. (1997). The effects of social exchange between two groups of lactating primiparous heifers on milk production, dominance order, behavior and adrenocortical response. *Applied Animal Behaviour Science, 51*, 15-27.

Huzzey, J. M., DeVries, T. J., Valois, P., & von Keyserlingk, M. A. G. (2006). Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. *Journal of Dairy Science*, *89*, 126-133.

Kondo, S., & Hurnick, J. F. (1990). Stabilization of social hierarchy in dairy cows. *Applied Animal Behaviour Science, 27*, 287-297.

Lamb, R. C. (1975). Relationship between cow behavior patterns and management systems to reduce stress. *Journal of Dairy Science, 59*, 1630-1636.

Sowerby, M. E., & Polan, C. E. (1978). Milk production responses to shifting cows between intrabred groups. *Journal of Dairy Science*, *61*, 155-160.

Val-Laillet, D., Veira, D. M., & von Keyserlingk, M. A. G. (2008). Short communication: Dominance in freestall-housed dairy cattle is dependent upon resource. *Journal of Dairy Science*, *91*, 3922-3926.

Von Keyserlingk, M. A. G., Olenick, D., & Weary, D. M. (2008). Acute behavioral effects of regrouping dairy cows. *Journal of Dairy Science, 91*, 1011-1016.

NUTRITION AND TRANSITION COW HEALTH

Conclusions:

1. **The risks of inadequate feed intake are especially severe during the transition period and can lead to ketosis and fatty liver.**
2. **Increasing energy density of the diets by feeding additional grain or using dietary supplements of fat are not successful strategies to prevent fatty liver.**
3. **Extremely thin or over-conditioned cows should be avoided.**
4. **Propylene glycol and rumen-protected choline are the most promising feed additives for the prevention of ketosis and fatty liver.**
5. **The key to preventing milk fever is to prevent metabolic alkalosis using forage low in potassium or by feeding anions to induce mild acidosis to close-up dry cows.**

The onset of lactation and its concomitant increase in nutrient demands require metabolic adaptation. Cows that are not provided with adequate nutrition during the period of transition from gestation to lactation are highly vulnerable to both metabolic and infectious diseases. These health disorders can have a major impact on the dairy cow, reducing milk production, reducing reproductive performance, and shortening the life expectancy.

Ketosis and fatty liver: In early lactation most high yielding dairy cows are in negative energy balance. Depending of the severity and duration of the negative energy balance, ketosis and fatty liver (steatosis) can occur.

The symptoms of ketosis include high concentrations of non-esterified fatty acids (NEFA) and ketone bodies and low concentrations of glucose in the blood. The ketones produced by the cow have a characteristic sweet "sickly" smell, which may be detected on the cow's breath and the milk. Symptoms of ketosis also include loss of appetite, decreased rumen motility, weight loss, and lower milk yield. Fatty liver is usually associated with other metabolic disorders such as milk fever, ketosis, and mastitis and its symptoms include depression of appetite and overall depression.

The degree of reduction in feed intake around calving is related to the severity of fatty liver immediately after calving (Grummer et al. 2004). Therefore to prevent ketosis, feed intake in the days immediately before and after calving needs to be maintained (Goff 2006). Hence, management practices that increase feed intake in transition cows help to prevent fatty liver (Grummer et al. 2004).

Extremely thin or over-conditioned cows should be avoided. Thin cows (body condition score < 3 on a scale of 1 to 5) can be fed additional energy during the dry period to replenish condition. However, over-conditioned cows (body condition score >4) at drying-off should not be feed restricted. Adequate stocking densities and feeding management may help to reduce the changes in dry matter intake during the transition period (see Housing section).

There is no strong evidence that increasing the energy content of the diets after calving, by feeding additional grain (high levels of non forage carbohydrates), or using dietary supplements of fat are successful strategies to prevent fatty liver (Grummer 2008).

Utilization of feed additives, such as propylene glycol and rumen-protected choline, in order to reduce adipose lipolysis or to enhance hepatic VLDL can prevent ketosis and fatty liver (Grummer 2008). Propylene glycol is a glucose precursor. Oral drenches of this feed additive at doses around 400 mL per day for a few days around calving increases plasma insulin and glucose, and decreases NEFA and ketone bodies (Nielsen and Ingvartsen 2004). Propylene glycol has proven effective for the prevention of fatty liver by reducing fatty acid mobilization from adipose tissue and oral drenching appears more effective than feeding (Grummer 2008). Choline has the potential to enhance exportation of hepatic VLDL secretion (Grummer 2008). The microbial population in the rumen quickly degrades dietary choline. Therefore, choline must be protected from ruminal degradation (Atkins et al. 1998). Positive effects on ketosis incidence and lipid transport have been reported when rumen-protected choline is fed to dry and fresh cows (Goff 2006). Cooke et al. (2007) showed that cows fed 15 g of choline/day in a ruminally-protected form had significantly reduced plasma NEFA concentrations and liver triglyceride concentrations. In conclusion, propylene glycol and rumen-protected choline are the most promising feed additives for the prevention of ketosis and fatty liver.

Milk fever: In early lactation, calcium can leave the blood to support milk production faster than calcium can be replaced from the diet, skeletal calcium stores, and renal conservation of calcium. This will cause calcium homeostatic mechanisms, which normally maintain blood calcium concentration, to fail and causes blood calcium concentrations to fall (Curtis et al. 1983). Most cows are able to cope with the developing hypocalcemia, and have only a minor decline in blood calcium. The inability to maintain sufficient concentrations of calcium in the blood to support milk production, muscle, and nerve function can cause hypocalcemia, more commonly known as milk fever.

Clinical signs of milk fever are sunken eyes, cold ears and skin, lethargy, decreased dry matter intake, sluggishness, lack of interest in feed, dilated pupils, retained placenta, constipation, weakness, uncoordinated gait and difficulty standing. Calcium is necessary for nerve and muscle functions, such as contractions of smooth muscles (including those responsible for abomasal contraction and closure of the teat sphincter) and skeletal muscle. Inadequate blood calcium concentrations disable muscle contractions which can result in a cow that is unable to stand (Goff 2006, Goff 2008). Moreover, when a cow is unable to stand, the pressure exerted by the massive weight of the cow can cause a ‘crush syndrome’ effect on the down side appendages in as little as 4 hours. This causes ischemia of the muscles and nerves, and is followed by necrosis of these tissues resulting in the downer cow syndrome (Goff 2008). Sub-clinical hypocalcemia reduces feed intake, ruminal and intestinal motility, productivity, and increases susceptibility to other metabolic and infectious disease, such as ketosis, retained placenta, displaced abomasum, and mastitis (Goff 2006, Goff 2008, Curtis et al. 1983, Houe et al. 2001, Ducusin et al. 2003). Dairy cows that develop milk fever (clinical hypocalcemia) at parturition are eight times more likely to suffer from mastitis in the subsequent lactation (Mulligan and Doherty 2008).

There are several risk factors associated with milk fever, including age, breed, body condition and low blood magnesium concentration. However, milk fever is mostly related to metabolic alkalosis (alkaline blood) which is a result of a high cation anion difference (DCAD) in the diet of dry cows in last weeks before calving (the close-up period), which is mainly due to high potassium in the diet (NRC 2001, Goff 2008).

In order to reduce the risk of milk fever, it is important to prevent metabolic alkalosis in close-up dry cows (NRC 2001). A good indicator of blood pH is the pH of the urine. For optimal control of subclinical hypocalcemia the average urine pH should be between 6.2 and 6.8, and between 5.8 and 6.3 for close-up Holstein and Jersey cows respectively (Goff 2008). The urine pH target for the final week before calving must be increased by about 0.5 units (Goff 2008).

For prevention of metabolic acidosis, the following adjustments are recommended:
1. Reducing dietary potassium by using plant species low in K concentration. Corn silage is often used to reduce the DCAD (Beede et al. 1992). Timothy grass has a lower DCAD than other cool season grass species (Tremblay et al. 2006). Growing timothy on low-potassium soils combined with application of chloride fertilizer can effectively further lower the DCAD of timothy grass (Pelletier et al. 2007). Feeding timothy hay, grown as described previously, before calving has been demonstrated to be an effective means of decreasing the dietary cation-anion difference and obtaining a lower urine pH (Charbonneau et al. 2008).
2. Adding Anions to Induce Mild (Compensated) Metabolic Acidosis. Block (1984) showed that close-up dry cows consuming a diet with added anions had no milk fever and produced nearly 7% more milk in the subsequent lactation. Addition of anions such as ammonium, calcium, magnesium salts of chloride and sulfate, chloride salts, and hydrochloric acid to the dry cow ration in small increments until proper urine pH is achieved could prevent milk fever (Ender et al. 1971, Block 1984).

References

Atkins, K. B., Erdman, R. A., & Vandersall, J. H. (1998). Dietary choline effects on milk yield and duodenal choline flow in dairy cattle. *Journal of Dairy Science, 71,* 109-116.

Beede, D. K., Sanchez, W. K., & Wang, C. (1992). Macrominerals. In: Van Horn, H.H., Wilcox, C.J. (Eds.), *Large Dairy Herd Management* (pp. 272-286). Gainsville, FL: University of Florida.

Block, E. (1984). Manipulating dietary anions and cations for prepartum dairy cows to reduce incidence of milk fever. *Journal of Dairy Science, 67,* 2939-2948.

Charbonneau, E., Chouinard, P. Y., Tremblay, G. F., Allard, G., & Pellerin, D. (2008). Hay to Reduce Dietary Cation-Anion Difference for Dry Dairy Cows. *Journal of Dairy Science, 91,* 1585-1596.

Cooke, R. R., Silva Del Rio, N., Caraviello, D. Z., Bertics, S. J., Ramos, M. H., & Grummer, R. R. (2007). Supplemental choline for prevention and alleviation of fatty liver in dairy cattle. *Journal of Dairy Science, 90*, 2413-2418.

Curtis, C. R., Erb, E. H., & Sniffen, C. J. (1983). Association of parturient hypocalcemia with eight periparturient disorders in Holstein cows. *Journal of American Veterinary Medical Association, 183,* 559.

Ducusin, R. J., Uzuka, Y., Satoh, E., Otani, M., Nishimura, M., Tanabe, S., & Sarashina, T. (2003). Effects of extracellular Ca2+ on phagocytosis and intracellular Ca2+ concentrations in polymorphonuclear leukocytes of postpartum dairy cows. *Research in Veterinary Science, 75,* 27-32.

Ender, F., Dishington, I. W., & Helgebostad, A. (1971). Calcium balance studies in dairy cows under experimental induction and prevention of hypocalcaemic paresis puerperalis. *Z. Tierphysiol. Tierernahr. Futtermittelkd. 28*, 233-256.

Goff, J. P. (2006). Major advances in our understanding of nutritional influences on bovine health. *Journal of Dairy Science*, *89,* 1292-1301.

Goff, J. P. (2008). The monitoring, prevention, and treatment of milk fever and subclinical hypocalcemia in dairy cows. *The Veterinary Journal, 176,* 50-57.

Grummer, R. R., Mashek, D. G., & Hayirli, A. (2004). Dry matter intake and energy balance in the transition period. In: Cook, N.B., Nordlund, K.V. (Eds.), *Managing the Transition Cow to Optimize Health and Productivity* (pp. 447-470). Philadelphia, PA: Veterinary Clinics of North America, W.B. Saunders Co.

Grummer, R. R. (2008). Nutritional and management strategies for the prevention of fatty liver in dairy cattle. *The Veterinary Journal*, *176,* 10-20.

Houe, H., Ostergaard, S., Thilsing-Hansen, T., Jorgensen, R. L., Larsen, T. , Sorensen, J. T., Agger, J. F., & Blom, J. Y. (2001). Milk fever and subclinical hypocalcemia – an evaluation of parameters on incidence risk, diagnosis, risk factors and biological effects as input for a decision support system for disease control. *Acta Veterinaria Scandinavica, 42,* 1-29.

Mulligan, F. J., & Doherty, M. L. (2008). Production diseases: A major health, welfare and economic problem on dairy farms. *The Veterinary Journal*, *176*, 1-2.

National Research Council (NRC). (2001). *Nutrient Requirements of Dairy Cattle.* 7th rev. ed. Washington, DC: National Academies Press.

Nielsen, N. I., & Ingvartsen, K. L. (2004). Propylene glycol for dairy cows. A review of the metabolism of propylene glycol and its effects on physiological parameters, feed intake, milk production and risk of ketosis. *Animal Feed Science Technology, 115*, 191-213.

Pelletier, S., Bélanger, G., Tremblay, G. F., Seguin, P., Drapeau, R., & Allard, G. (2007). Dietary cation–anion difference of Timothy (Phleum pratense L.) as influenced by application of chloride and nitrogen fertilizer. *Grass Forage Science, 62,* 66-77.

Tremblay, G. F., Brassard, H., Bélanger, G., Seguin, P., Drapeau, R., Brégard, A., Michaud, R., & Allard, G. (2006). Dietary Cation Anion Difference of Five Cool-Season Grasses. *Agriculture Journal*, *98*, 339-348.

NUTRITION AND RUMINAL ACIDOSIS

Conclusions

1. **Diets that are high in forage reduce the risk of sub-acute and acute ruminal acidosis.**
2. **Cows fed high concentrate diets are at risk of sub-acute ruminal acidosis (SARA), but this risk can be reduced by ensuring that the diet contains sufficient coarse (physically effective) fiber, by feeding total mixed rations, and by avoiding sorting.**
3. **Shifts from high forage to high-energy diets should be done gradually to allow for healthy populations of ruminal microbes to develop.**
4. **Dietary buffers and alkalinizing agents have been shown to be effective, but caution should be taken with using them continuously.**
5. **Biotin levels may be impacted by acidic conditions in the rumen, so supplementation may be beneficial for improving hoof health.**

When high concentrate diets are fed, and pH fluctuates for longer periods, acidosis results. Sub-acute ruminal acidosis (SARA) is characterized by prolonged periods of pH 5.6 or lower each day (Kleen et al. 2003). When pH drops below 5.0, acute ruminal acidosis occurs.

In response to increasing energy requirements at certain periods in the lactation cycle (i.e. the first 3 weeks after calving as well as peak lactation 10 to 14 weeks after calving), the energy content of rations is often increased. Use of high levels of fermentable carbohydrates can lead to prolonged periods of lowered pH (Fulton et al. 1979, Stone 2004). Lowered pH is also associated with highly variable ration intake and meal patterns (i.e., “slug-feeding” in heat stressed cows -- Mallonée et al. 1985).

In the dry off period, cows are shifted to high forage rations that are less energy dense (1.28 NE_L Mcal/kg) and are higher in neutral detergent fiber (45–50% NDF) than the lactation ration. In response, bacterial populations shift towards fiber digesting, rather than starch digesting microbes (Yokoyama and Johnson 1988), and bacteria capable of converting lactate (a by-product of starch fermentation and digestion) decline. The impact of this shift is felt when the cow is returned to a high-energy diet. A further effect of the diet shift is a reduction in the papillae length reducing the absorptive capacity of the rumen (Van Soest 1994). Positively, the higher fiber content increases saliva production via increased chewing (Beauchemin et al. 2008). Inorganic buffers such as sodium bicarbonate contained in saliva contribute to the neutralization of the organic acids produced during ruminal fermentation (Church 1988); this in turn prevents the rumen pH from decreasing (Goff 2006).

If the rumen pH stays within the 6.0 to 5.6 range, the fermentative capacity and growth rates of major lactic acid-producing bacteria and lactic acid-utilizing bacteria will remain balanced. However, when cows calve and are shifted quickly onto diets containing much higher starch contents amounts of highly fermentable starches, the production of volatile fatty acids (VFAs) increases dramatically (Burrin and Britton 1986, Britton and Stock 1989, Oetzel et al. 1999).

Increasing the concentrate content of diets reduces chewing, saliva production, and rumen buffering, which combined with the increase in VFA production, reduces rumen pH (Goad et al. 1998, Enemark et al. 2002).

As ruminal pH decreases, the microbes that aid fiber digestion decline in numbers. Conversely, starch-digesting bacteria proliferate, producing increased levels of lactate. Therefore, what results is a low pH environment where fiber-digesting capacities are minimized, and where lactate producing bacteria outnumber lactate-converting bacteria. Both these factors contribute to a continued decrease in pH. As the rumen environment becomes more acidic, inflammation of the rumen wall can occur, which reduces acid absorption. If the pH stays below 5.6 for more than a few hours each day, SARA occurs (Kleen et al. 2003, Stone 2004, Gozho et al. 2005).

Symptoms: Symptoms of SARA are subtle (Nocek 1997), the major clinical symptom is reduced or inconsistent DMI (Garrett 1996, Kleen et al. 2003, Oetzel 2003). Other associated indications include decreased efficiency of milk production (Nocek 1997, Stone 2004), body weight loss or poor body condition score (Oetzel 2000), bright yellow feces (Kleen et al. 2003), foamy feces (Nordlund et al. 2004), diarrhea (Nordlund et al. 1995, Oetzel 2000), milk fat depression (Nordlund et al. 1995, Oetzel 2000), caudal vena cava syndrome (Nordlund et al. 1995), pathogen infiltration in the rumen (Nocek 1997, Stone 2004), abscessed liver and/or lungs, abomasal displacement/ulceration (Olson 1991), ruminitis (Enemark 2008), immunosuppression (Kleen et al. 2003) inflammation (Plaizier et al., 2008) and laminitis (Oetzel 2000, Enemark et al. 2002). Acute ruminal acidosis may impair physiological functions and cause death (Nocek 1997), however if caught in time, can be treated directly.

Diagnosis: Lowered milk fat content is frequently used as an indicator of SARA (Mertens 1997, De Brabander et al. 2002). For instance, sudden drops in the average fat percentage by 1 or 2% have been linked to low levels of coarse fiber in the feed; such feed has been linked with to increased incidence of SARA. Diagnostic tests for SARA include collection of rumen fluid samples via stomach tubing or ruminal cannulation (Nocek 1997) and rumenocentesis. Other diagnostic methods currently being developed include measurement of urine acidity as well as continuous measurement of rumen pH. A positive connection has been established between rumen pH and urine pH (Roby et al. 1987, Fürll 1994). Assessment of the renal net acid-base excretion, determined by urine titration, is claimed to be more accurate than pH determination (Fürll 1994) and may therefore be considered as a monitoring tool for metabolic acidosis in cattle. However, recent studies (Gakhar et al. 2008) were not able to demonstrate a relationship between rumen pH depression, urine pH, and net acid-base excretion.

More information is needed in order to develop accurate physiological diagnostics such as milk, urine, blood, feces, or dietary characteristics to diagnose SARA (Nocek 1997).

Feed Components:
<u>Physically effective fiber.</u> Physically effective neutral detergent fiber (peNDF) relates to the physical characteristics of a feed and is an indication of the potential of a feed to stimulate chewing. Long forage particles in the diet promote chewing, salivary secretion and increased rumination time; these increase the flow of salivary buffers into the rumen. Thus, particle length of forages and the amount of fiber in the diet can have a significant impact on ruminal pH. In

addition, long forage fiber creates a floating mat in the rumen (Mertens 1997), which stimulates contractions of the rumen. Contractions promote VFA removal via fluid absorption and passage. Furthermore, since fiber is more slowly digested than non-structural carbohydrates (NSC), including fiber in the diet slows the rate of feed digestion in the rumen, thereby reducing the amount of VFA produced directly after a meal. Therefore, adding coarse forage to the diet not only increases chewing time and saliva secretion, but it evens out VFA production throughout the entire day increasing ruminal pH.

The intent of grain processing is to increase starch availability in the rumen while avoiding digestive disturbances. The rate and extent of ruminal digestion of various feedstuffs depends on particle size, moisture content, storage, and processing (grinding, steam-flaking, or chemical treatment); these factors can all have a major influence on ruminal degradability and availability (Nocek and Tamminga 1991, Theurer 1986). Therefore, when formulating diets for increased ruminal starch digestion, it is essential to supply adequate physically effective neutral detergent fiber (peNDF) to minimize the incidence of ruminal acidosis.

<u>Nonstructural carbohydrates (NSC) in the ration:</u> Non-structural carbohydrates (NSC) are the sugars (grasses and legumes), starches (typically via concentrates) and pectins that make up a large part of the energy component in feeds. NSC represents the plant cell contents that have faster digestion rates than cell wall components. This means cows utilize these energy sources more efficiently than fibrous, low-energy components; however, the fast digestion rates can result in pH declines. In response to this, Dirksen et al. (1985) and Dirksen (1989) recommended gradually increasing NSC levels over a 5-week period during the pre- and post-calving time periods. However, gradually increasing NSC levels has not always proved effective (Pennner et al. 2007). This time period should be adjusted according to how quickly a specific NSC ferments. Different ingredients ferment at different rates; wheat, barley, and oats all ferment quite quickly, whereas corn and sorghum have slower fermentation rates (Herrera-Saldana et al. 1990). More time should be allotted when introducing highly fermentable NSC components.

When cows consume TMR, rate of NSC consumption is moderated due to simultaneous consumption of fiber and concentrates. The forage encourages increased chewing and salivation, thereby increasing ruminal-buffering capacity of the highly fermentable NSC. Feeding of NSC components separately from forages as well as feeding them in a few larger meals has been shown to negatively impact the incidence of sole hemorrhages (Bergsten 1994), as well as the stability of ruminal pH (Kaufmann et al. 1980).

<u>Formulating Diets.</u> NRC (2001) recommends a minimum of 25% NDF in the diet, with 75% of this fiber coming from forage sources (i.e., 19% NDF from forages). The amount of NDF from forage sources can be decreased to as low at 15% if total dietary NDF is increased and the non-fiber carbohydrate levels (usually about 85-90% starch) are lowered from 44% to 36%. These recommendations are based on diets containing alfalfa or corn silage and dry ground corn grain as the starch source. When more highly fermentable sources of grain are used (e.g., barley, high moisture and flaked corn), a minimum of 21 to 23% NDF from forages and a maximum of 38% non-fiber carbohydrates (or 33% starch) is recommended. Beauchemin et al. (1991) recommended 34% of dietary DM ad NDF for barley based diets. Minimum fiber recommendations assume that the silages are coarsely chopped.

Heinrichs and Kononoff (2002) recommended at least 40% of feed particles of dietary ingredients in total mixed rations (TMRs) be longer than 8 mm and less than 19mm. It is recommended that this be increased 1 – 3 percent in early lactation in order to help minimize the incidence of SARA (Stone 2004). It has also been suggested that adding a small amount of straw (less than 0.5 kg/d) into the TMR may stimulate chewing behaviour (Stone 2004).

Microadditives. Monensin and lasalocid have been used to prevent lactic acidosis (Nagaraja et al. 1981). These ionophores inhibit the growth of lactate-producing bacteria (Mutsvangwa et al. 2002); as such, they may be beneficial for use during the transition from low energy diets to higher energy diets, or in cows demonstrating highly variable feeding patterns due to periods of stress. However, it is not likely to help increase pH caused by high ruminal VFAs.

Dietary buffers.It has been recommended that ruminal acidosis can be controlled by supplementing the ration with buffering agents such as sodium bicarbonate or alkalinizing agents such as magnesium oxide (Goff 2008, Garry 2002). However, literature also suggests that such agents should not be used regularly to compensate for sub-optimal feed management Enemark (2008), rather as a treatment during an acute SARA incident. The following are recommended doses (g/day) of various buffers added to the feed rations of lactating cows (Hutjens 1991); Sodium bicarbonate (110–225), Sodium sesquicarbonate (110–225), Magnesium oxide (50–90), Sodium bentonite (110–454), Calcium carbonate (115–180), Potassium carbonate (270–410). Normally, a single buffer is used but combinations of several buffers are possible, and have been noted for positive impacts on milk yield, fat percentage, and DMI (Hutjens 1991).

Effects of SARA on biotin availability and hoof health: Biotin, a water-soluble B vitamin, is essential for proper hoof quality and structure (Mülling et al. 1999). It is also required nutrient for several species of rumen cellulolytic and saccharolytic bacteria (Baldwin and Allison 1983). Biotin is naturally present in plants and thus in the diets fed to dairy cows. For biotin, in opposition to other B-vitamin, ruminants rely mostly on dietary intake. Biotin is not synthesized in significant amounts in the rumen (Santschi et al. 2005, Schwab et al. 2006, Lebzien et al. 2006). However, this vitamin might be destroyed or used at the same rate as it is produced, suggesting no apparent synthesis, as reported by Frigg et al. (1993). In vitro acidic rumen conditions can reduce biotin synthesis (Da Costa Gomez et al. 1998). It has also been shown that biotin synthesis by rumen organisms in continuous culture is reduced by increased proportions of grain in the ration (Abel et al. 2001). Hence, feeding high grain diets may exacerbate the need for supplemental biotin in high producing dairy cows. Biotin deficiency leads primarily to changes in epidermal structures such as skin, hair, and claws (Kolb et al. 1999, Mülling et al. 1999).

Although biotin deficiency does not occur in ruminants under conditions normally encountered on Canadian dairy farms, there is mounting evidence from clinical field studies that administration of supplemental dietary biotin has a positive influence on hoof and claw quality (Geyer and Schulze 1994, Schmid 1995, Josseck et al. 1995, Zenker et al. 1995, Geyer 1998, Green et al. 2000). Results from histological and biochemical studies have indicated that there are improvements in the inter- and intracellular ultrastructure of horn as a result of dietary biotin supplementation (Hochstetter 1998). Biotin supplementation has also been reported to increase the rate of lesion healing in cows. Lischer et al. (1996) and Koller (1998) found a positive influence on the structure and quality of new horn during the healing process of sole ulcers. Studies have shown feeding 20 mg biotin per cow per day results in a reduced incidence of several of the most common hoof disorders including sole ulcer, white line disease, sandcracks, and digital dermatitis.

References

Abel, H. J., Immig, I., DaCosta Gomez, C., & Steinberg, W. (2001). Research note: Effect of increasing dietary concentrate levels on microbial biotin metabolism in the artificial rumen simulation system (RUSITEC). *Archives of Animal Nutrition, 55,* 371-376.

Baldwin, R. L., & Allison, M. J. (1983). Rumen metabolism. *Journal of Animal Science, 57*(Supp. 2), 461-477.

Beauchemin, K. A. (1991). Effects of dietary neutral detergent fiber concentration and alfalfa hay quality on chewing, rumen function, and milk production of dairy cows. *Journal of Dairy Science, 74,* 3140-3151.

Beauchemin, K. A., Eriksen, L. P., Nørgaard, P., & Rode, L. M. (2008). *Short Communication:* Salivary Secretion during Meals in Lactating Dairy Cattle. *Journal of Dairy Science, 91,* 2077-2081.

Bergsten, C. (1994). Hemorrhages of the sole horn of dairy cows as a retrospective indicator of laminitis: An epidemiological study. *Acta Veterinaria Scandinavica, 35,* 55.

Britton, R., & Stock, R. (1989). Acidosis: A continual problem in cattle fed high grain diets. In *Proc. Cornell Nutrition Conference for Feed Manufacturers* (pp. 9-15). Ithaca, NY: Cornell University.

Burrin, D. G., & Britton, R. A. (1986). Response to monensin in cattle during subacute acidosis. *Journal of Animal Science, 63,* 888–893.

Church, D.C. (1988). Salivary function and production. In Church, D.C. (Ed.), *The Ruminant Animal, Digestive Physiology and Nutrition* (pp. 117-124). Englewood Cliffs, NJ: Prentice Hall.

Da Costa Gomez, C., Al Masri, M., Steinberg, W., & Abel, H. J. (1998). Effect of varying hay/barley proportions on microbial Biotin metabolism in the rumen simulating fermenter Rusitec. *Proc. Soc. Nut. Phys., 7*(Abstr.), 30.

De Brabander, D. L., De Boever, J. L., Vanacker, J. M., & Geerts, N. E. (2002). Evaluation and effects of physical structure in dairy cattle nutrition. In: *Proceedings of the 22nd World Buiatrics Congress* (pp. 182-197). Hanover.

Dirksen, G., Liebich, H. G., & Mayer, E. (1985). Adaptive changes of the ruminal mucosa and their functional and clinical significance. *The Bovine Practitioner, 20,* 116–120.

Dirksen, G. (1989). Rumen function and disorders related to production disease. In: *Proc. VII Int. Conf. Dis. Farm Animals,* (pp. 350-361). Ithaca, NY: Cornell University Press.

Enemark, J. M. D., Jørgensen, R. J.,& Enemark, P. S. (2002). Rumen acidosis with special emphasis on diagnostic aspects of subclinical rumen acidosis: A review. *Veterinarija ir Zootechnika, 20,* 16-29.

Enemark, J. M. D. (2008). The monitoring, prevention and treatment of sub-acute ruminal acidosis (SARA): A review. *The Veterinary Journal, 176,* 32-43.

Frigg, M., Hartmann, D., & Straub, O. C. (1993). Biotin kinetics in serum of cattle after intravenous and oral dosing. *International Journal for Vitamin and Nutrition Research, 63,* 36-40.

Fritsche, A., Mathis, G. A., & Althaus, F. R. (1991). Pharmakologische wirkungen von biotin auf epidermiszellen. *Schweiz. Arch. Tierheilk., 133,* 277-283.

Fulton, W.R., Klopfenstein, T.J., & Britton, R.A. (1979). Adaption to high concentrate diets by beef cattle. I. Adaption to corn and wheat diets. *Journal of Animal Science, 49,* 785-791.

Fürll, M. (1994). Diagnostik und Therapie chronischer Störungen des Säure-Basen-Haushaltes (SBH) bei Rindern. *Der Praktische Tierarzt., 75,* 49-54.

Gakhar, N., Li, S., Krause, D. O., Khafipoor, E., Ominski, K., & Plaizier, J. C. (2008). Development of alternate markers for subacute ruminal acidosis (SARA). *Advances in Dairy Technology, 20,* 369-370.

Garret, E. (1996). Subacute rumen acidosis – clinical signs and diagnosis in dairy herds. *Large Animal Veterinary Rounds, 11,* 6-10.

Garry, F. B. (2002). Indigestion in ruminants. In: Smith, B.P. (Ed.), *Large Animal Internal Medicine*, third ed (pp. 722-747). St. Louis and Baltimore: Mosby.

Geyer, H., & Schulze, J. (1994). The long-term influence of biotin supplementation on hoof horn quality in horses. *Schweizer Archiv für Tierheilkunde, 136,* 137-149.

Geyer, H. (1998). The influence of biotin on horn quality of hooves and claws. *Proceedings of 10th International Symposium on Lameness in Ruminants* (pp. 192-199). Lucerne.

Goad, D. W., Goad, C. L., & Nagaraja, T. G. (1998). Ruminal microbial and fermentative changes associated with experimentally induces subacute acidosis in steers. *Journal of Animal Science, 76,* 234-241.

Goff, J. P. (2006). Major Advances in Our Understanding of Nutritional Influences on Bovine Health. *Journal of Dairy Science, 89,* 1292-1301.

Goff, J. P. (2008). The monitoring, prevention, and treatment of milk fever and subclinical hypocalcemia in dairy cows. *The Veterinary Journal, 176,* 50-57.

Gozho, G. N., Plaizier, J. C., Krause, D. O., Kennedy, A. D., & Wittenberg, K. M. (2005). Subacute ruminal acidosis induces ruminal lipopolysaccharide release and triggers an inflammatory response. *Journal of Dairy Science, 88,* 1399-1403.

Green, L. E., Hedges, V. J., O'Callaghan, C., Blowey, R. W., & Packington, A. (2000). Biotin supplementation of dairy cows ± multivariate analysis of the prospective longitudinal study. *Proceedings of 11th International Symposium on Lameness in Ruminants* (pp. 305-307). Parma.

Hall, M. B. (2002). Rumen acidosis: Carbohydrate feeding considerations. In J.K. Shearer (Ed.), *Proceedings 12th Int. Symp. on Lameness in Ruminants* (pp. 51-61). Orlando, FL.

Heinrichs, J., & Kononoff. P. (2002). Evaluating particle size of forages and TMRs using the New Penn State Forage Particle Separator. *DAS 02- 42* (p. 3). Pennsylvania State University, University Park. PA.

Herrera-Saldana, R., Gomez-Alarcon, R., Torabi, M., & Huber, J. T. (1990). Influence of synchronizing protein and starch degradation in the rumen on nutrient utilization and microbial synthesis *Journal of Dairy Science, 73,* 142-148.

Hochstetter, T. (1998). Die HornqualitaÈt der Rinderklaue unter Einfluss einer Biotinsupplementierung. Veterinary Medicine Thesis. Berlin: Free University.

Hutjens, M. F. (1991). Feed additives. *Veterinary Clinics of North America. Food Animal Practice, 7,* 525-540.

Josseck, H., Zenker, W., & Geyer, H. (1995). Hoof horn abnormalities in Lipizzaner horses and the effect of dietary biotin on macroscopic aspects of hoof horn quality. *Equine Veterinary Journal, 27,* 175-182.

Kaufmann, W., Hagemeister, H., & Dirksen, G. (1980). Adaptation to changes in dietary composition, level and frequency of feeding. In *Physiology and Metabolism of Ruminants* (pp. 65 and 587). Westport, CT: AVI Publishing Company.

Kleen, J. L., Hooijer, G. A., Rehage, J., & Noordhuizen, J. P. (2003). Subacute ruminal acidosis (SARA): A review. *Journal of Veterinary Medicine A. Physiology Pathology and Clinical Medicine, 50,* 406-414.

Kolb, E., Seehawer, J., & Steinberg, W. (1999). Significance, utilization and application of B-vitamins in ruminants. 2. Niacin, pantothenic acid, biotin, folic acid and vitamin B-12. *Der praktische Tierarzt., 80,* 207-220.

Koller, U., Lischer, C. J., Geyer, H., Ossent, P., Schulze, J., & Auer, J. A. (1998). The effect of biotin in the treatment of uncomplicated sole ulcers in cattle. A controlled study. In C. J. Lischer, and P. Ossent (Eds.), *Proc 10th Int. Symp. Lameness Ruminants* (pp. 230-232). Zurich: Dept. Vet. Surgery, University of Zurich.

Lebzien. P., Abel, H., Schröber, B., & Flachosky, G. (2006). Studies on the biotin flow at the duodenum of dairy cows fed diets with different concentrate levels and types of forages. *Archives of Animal Nutrition, 60,* 80-88.

Leonardi, C., Armentano, L. E., & Shinners, K. J. (2001). Effect of different particle size distribution of oat silage on feeding behavior and productive performance of dairy cattle. *Journal of Dairy Science, 84*(Suppl. 1), 199. (Abstr.)

Leonardi, C., & Armentano, L. E. (2003). Effect of quantity, quality and length of alfalfa hay on selective consumption by dairy cows. *Journal of Dairy Science, 86,* 557-564.

Lischer Ch. J., Hunkeler, A., Geyer, H., & Ossent, P. (1996). The effect of biotin in the treatment of uncomplicated claw lesions with exposed corium in dairy cows. Part II: The healing process in supplemented animals. In: *Proc. 9th Int. Symp. Disorders Ruminant Digit Int. Conf. Lameness Cattle* (p. 31). Rehovot, Israel: Koret School of Veterinary Medicine.

Mallonée, P. G., Beede, D. K., Collier, R. J., & Wilcox, C. J. (1985). Production and physiological responses of dairy cows to varying dietary potassium during heat stress. *Journal of Dairy Science, 68,* 1479-1487.

Martin, R. (2000). Evaluating TMR particle distribution: a series of on-farm case studies. In: *Proc. 4-State Prof. Dairy Mgmt. Seminar* (pp. 75-78). Dubuque, IA MWPS-4SD8. Ames, IA.

Mertens, D. R. (1997). Creating a system for meeting the fiber requirements of dairy cows. *Journal of Dairy Science, 80,* 1463-1481.

Mülling, C. K. W., Bragulla, H. H., Reese, S., Budras, K. D., & Steinberg, W. (1999). How structures in bovine hoof epidermis are influenced by nutritional factors. *Anatomia Histologia Embryologia Journal of Veterinary Medicine Series C. Zentralblatt Fur Veterinarmedizin Reihe C., 28,* 103-108.

Mutsvangwa, T., Walton, J. P., Plaizier, J. C., Duffield, T. F., Bagg, R., Dick, P., Vessie, G., & McBride, B. W. (2002). Effects of a monensin controlled-release capsule or premix on attenuation of subacute ruminal acidosis in dairy cows. *Journal of Dairy Science, 85,* 3454-3461.

Nagaraja, T. G., Avery, T. B., Bartley, E. E., Galitzer, S. J., & Dayton, A. D. (1981). Prevention of lactic acidosis in cattle by lasalocid or monensin. *Journal of Animal Science, 53,* 206-216.

National Research Council (NRC). 2001. *Nutrient Requirements of Dairy Cattle.* 7th rev. ed. Washington, DC: National Academies Press.

Nocek, J. E., & Tamminga, S. (1991). Site of digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. *Journal of Dairy Science, 74,* 3598.

Nocek, J. E. (1997). Bovine Acidosis: Implications on Laminitis. *Journal of Dairy Science, 80,* 1005-1028.

Nordlund, K. V., Garrett, E. F., & Oetzel, G. R. (1995). Herd-based rumenocentesis: A clinical approach to the diagnosis of subacute rumen acidosis. Compendium for continuing education for the practicing veterinarian. *Food Animals, 17,* s48-s56.

Nordlund, K. V., Cook, N. B., & Oetzel, G.R. (2004). Investigation strategies for laminitis problem herds. *Journal of Dairy Science, 87,* E27-E35.

Oetzel, G. R., Nordlund, K. V., & Garrett, E. F. (1999). Effect of ruminal pH and stage of lactation on ruminal lactate concentration in dairy cows. *Journal of Dairy Science, 82*(Suppl. 1), 38. (Abstr.)

Oetzel, G. R. (2000). Clinical aspects of ruminal acidosis in dairy cattle. In: *Proceedings of the 33rd Annual Convention of the American Association of Bovine Practitioners* (pp. 46-53). Rapid City, SD.

Oetzel, G. R. (2003). Subacute ruminal acidosis in dairy cattle. *Advances in Dairy Technology, 15*, 307-317.

O'Grady, L., Doherty, M.L., & Mulligan, F.J. (2008). Subacute ruminal acidosis (SARA) in grazing Irish dairy cows. *The Veterinary Journal, 176,* 44-49.

Olson, J. D. (1991). Relationship of nutrition to abomasal displacement and parturient paresis. *The Bovine Practitioner, 26,* 88-91.

Penner, G. B., Beauchemin, K. A., & Mutsvangwa, T. (2007). Severity of Ruminal Acidosis in Primiparous Holstein Cows During the Periparturient Period. *Journal of Dairy Science, 90,* 365-375.

Plaizier, J. C., Krause, D. O., Gozho, G. N., & McBride, B. W. (2008). Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences. *The Veterinary Journal, 176,* 21-31.

Roby, K. A., Chalupa, W., Orsini, J. A., Elser, A. H., & Kronfeld, D. S. (1987). Acid-base and electrolyte balance in dairy heifers fed forage and concentrate rations: Effects of sodium bicarbonate. *Journal of Veterinary Research, 48,* 1012-1016.

Santschi, D.E , Berthiaume, R., Matte, J. J., Mustafa, A. F., & Girard, C. L. (2005). Fate of supplementary B-vitamins in the gastrointestinal tract of dairy cows. *Journal of Dairy Science, 88,* 2043-2054.

Schmid, M. (1995). Der Einfluss von Biotin auf die Klauenhornqualität beim Rind. Veterinary Medicine Thesis. Zurich: University of Zürich.

Schwab, E. C., Schwab, C. G., Shaver, R. D., Girard, C. L., Putnam, D. E., & Whitehouse, N. L. (2006). Dietary forage and nonfiber carbohydrate contents influence B-vitamin intake, duodenal flow, and apparent ruminal synthesis in lactating cows. *Journal of Dairy Science, 89*, 174-187.

Shaver, R. D. (2002). Rumen acidosis in dairy cattle: bunk management considerations. In J. K. Shearer (Ed.), *Proc. 12th Int. Symp. on Lameness in Ruminants* (pp. 75-81). Orlando, FL.

Stone, W. C. (2004). Nutritional approaches to minimize subacute ruminal acidosis and laminitis in dairy Cattle. *Journal of Dairy Science*, *87*(E. Suppl.), E13-E26.

Theurer, C. D. (1986). Grain processing effects on starch utilization by ruminants. *Journal of Animal Science, 63,* 1649.

Yokoyama, M.T., & Johnson, K.A. (1988). Microbiology of the rumen and intestine. In D. C. Church (Ed.), *The Ruminant Animal Digestive Physiology and Nutrition* (p. 125). Prospect Heights, IL: Waveland Press.

Zenker, W., Josseck, H., & Geyer, H. (1995). Histological and physical assessment of poor hoof horn quality in Lipizzaner horses and a therapeutic trial with biotin and a placebo. *Equine Veterinary Journal, 27,* 183-191.

5. FACILITY DESIGN: STALLS, FEEDING AREAS, FLOORING, STOCKING

STALL DESIGN AND MANAGEMENT

Conclusions:

1. **The quantity and quality of bedding are the most important determinants of a comfortable lying stall. Cows strongly prefer dry lying surfaces, and lying times increase dramatically when cows are provided with a well maintained (dry and even) lying surface.**
2. **The physical structures used in stall design (stall partitions, neck and brisket barriers) all interfere with cow movements and restrict stall use. These structures are for the convenience of the producer, not the comfort of the cow. The negative effects of these structures on lying and standing can be reduced by removing barriers (such as the neck rail and brisket locator), and by providing generous space allowances.**

For specific sizing recommendations and trouble shooting, see Figure from Nordlund, K., & Cook, N. B. (2003). A Flowchart for Evaluating Dairy Cow Freestalls. Bovine Practitioner 37, 89-96).

Lying surface: A growing body of research has now demonstrated that the surface we provide for cows is one of the most important factors in designing a suitable lying area. First and foremost, the housing we provide should not cause injuries or other health risks to the cow. Although this sounds obvious, too often poor stall design leads to preventable health problems. For example, several studies have shown that cows on farms with mattresses (and little bedding) have more severe hock lesions than do cows on farms that using deep-bedded stalls (Weary and Taszkun 2000, Wechsler et al. 2000).

Cows also clearly prefer lying surfaces with more bedding, and spend more time lying down in well-bedded stalls. The effect of the amount of bedding on the time spent lying and standing has been studied in free stalls (Tucker and Weary 2004). Each stall was fitted with a geotextile mattress, and bedded with one of three levels of kiln-dried sawdust (0, 1, and 7 kg). Cows spent 1.5 h more time lying down in the heavily bedded stalls. In addition, cows spent less time standing with only the front legs in the stall when the mattresses were heavily bedded. These changes in both standing and lying behavior indicate that cows are hesitant to lie down on poorly-bedded mattresses. A more recent study has found similar results for cows housed in tie stalls (Tucker et al., 2009).

The flooring and amount and type of bedding in stalls can affect the incidence of health problems. Cows housed on mattresses also have a higher incidence of clinical lameness than those housed in deep-bedded sand stalls Cook et al. 2004, Espejo et al. 2006, Norring et al. 2008). The lying surface can also affect udder health, and many studies have now shown the advantages to cows of using sand or other inorganic bedding as a way of reducing the growth of bacteria associated with environmental mastitis (Zdanowicz et al. 2004).

Sand appears to be a promising type of bedding material. Cows prefer deep straw bedding when given a choice (Manninen et al. 2002) but this can be reduced by giving cows enough experience of sand (Norring et al. 2008). Cows may spend less time lying down with sand stalls compared to deep-bedded stalls but this may be compensated for by the reduced risk of hoof lesions (Norring et al. 2008).

Making the decision to provide a well-bedded surface is just the first step in achieving a reasonable level of cow comfort – this surface must also be properly maintained. A series of experiments has documented how the sand level declines in stalls that are not maintained, and how this decline reduces stall use by cows (Drissler et al. 2005). Sand levels in deep-bedded stalls decrease over a 10-day period, with the deepest part at the center of the stall. Lying time by cows also declines as the stall empties: every inch decline decreased lying time by about half an hour per day. Contact with concrete while lying down may explain lower lying times in deep-bedded stalls with less sand, and this concrete also affects leg health. Lesions on the point of the hock are common in deep-bedded stalls (Mowbray et al. 2003), likely due to contact with the concrete curb when stalls are not well maintained.

Another important aspect of bedding quality on stall preference and use is the moisture content of the bedding. In a recent experiment, cows were restricted to freestalls with either kiln-dried or wet sawdust bedding in two ‘no-choice’ phases of the study, followed by a free-choice phase in which cows could choose to use stalls with either wet or dry bedding (Fregonesi et al. 2007). In the no-choice phases, cows spent approximately 14 h/d lying down when provided access to dry bedding, and reduced lying time by 5 h/d when provided wet bedding. All cows showed a strong preference for the stalls with dry bedding. These results indicate that access to a dry lying surface is important to dairy cattle.

In tie stalls, the flooring of the stall is particularly important since the cow must lie and stand on the same surface. Much less work has been done on the comfort of tie stalls compared to free stalls, but cows that must rest on concrete floors have been shown to lie down for 2h less and have more swollen knees than cows which have a soft rubber mat (Haley et al. 2001, Rushen et al. 2007). Many tie-stalls in Canada are below the recommended sizes, and have been associated with a variety of injuries (Zurbrigg et al. 2005a). Little is known about the best design of tie stalls. Stall fronts with too small an opening can force the cow further back in the stall when she is lying down, thus reducing the effective size of the stall (Haley et al. 2001). The height of the tie-rail can also affect the incidence of neck lesions, which are most common if the rail is too high or too low (Zurbrigg et al. 2005b)

Stall configuration: Most indoor housing provides more than just a lying surface for the cows. Typically the space is designed to encourage the cow to lie down in a specific location, and to use the stall in such a way that feces and urine do not soil the stall. Unfortunately, most attempts to constrain how and where the cow lies down also reduce cow comfort as illustrated by the studies described below.

Although some excellent recommendations for stall dimensions are now available, too often new constructions and renovated barns fail to provide appropriate space. Several studies have shown how stall size and configuration affect standing and lying times. For example, one study tested the effect of stall width on cow behavior (Tucker et al. 2004), by proving cows access to free stalls measuring 42, 46, or 50" between partitions. Cows spent an additional 42 min/day lying in the widest stalls, likely because they had less contact with the partitions in these larger stalls. Cows also spent more time standing with all four legs in the wider stalls, reducing the time they spent standing partially (perching) or fully on the concrete flooring available elsewhere in the barn. As discussed elsewhere in this report, standing fully or partially on concrete is a risk for lameness.

Ceballos et al. (2004) provide some detailed measures of degree of displacement of various body parts when cows lie down and relate this to the body dimensions of the cows. Cows used up to 76cms (78% of back length) of forward lunge space and a total of 300 cm (300% of back length) of longitudinal space when lying down, which was more than is typically provided by current industry recommendations for stall length. Most commonly, the nose moved 60 cm during the lunge movement. Cows used up to 109 cm of lateral space (which was the equivalent of 180% of their hip width). Thus, stalls for cows should have a width of at least 180% of hip width and a length of at least 300% of back length. During the lying-down movement, the maximal lateral movement of the hip occurred at two heights: one between 95 and 135 cm, and the second less than 50 cm above the lying surface. The maximal longitudinal movements of the nose occurred 10 to 30 cm above the surface. These heights should be taken into account when positioning stall partitions. The maximum velocity of body parts was 220 cm/s, which shows that the cows could hit inappropriately-placed stall partitions and the lying surface with considerable force.

In addition to stall width, neck-rail placement is important for managing standing behavior. Both the height of the neck rail and its distance from the curb affect standing (Tucker et al. 2005); more restrictive neck-rail placements (lower and closer to the rear of the stall) prevent cows from standing fully in the stall, again increasing the time cows spend on concrete flooring elsewhere in the barn. The neck-rail is designed to 'index' the cow in the stall while she is standing, but the brisket board achieves this function while cows are lying down. Unfortunately, brisket boards also discourage stall use – cows spend 1.2 h/d less time lying down when stalls have a brisket board compared to when using stalls without this barrier (Tucker et al. 2006).

Although dirty stalls are undesirable, readers should be aware that stall cleanliness alone is a poor measure of stall design. Free stalls that have higher occupancy rates are most likely to contain feces. Thus well-used stalls require more stall maintenance, just like other equipment used on the farm.

References

Ceballos, A., Sanderson, D., Rushen, J., & Weary, D. M. (2004). Improving stall design: Use of 3-D kinematics to measure space use by cows when lying down. *Journal of Dairy Science, 87*, 2042-2050.

Cook, N. B., Bennett, T. B., & Nordlund, K. V. (2004). Effect of free stall surface on daily activity patterns in dairy cows with relevance to lameness prevalence. *Journal of Dairy Science, 87*, 2912-2922.

Drissler, M., Gaworski, M., Tucker, C. B., & Weary, D. M. (2005). Freestall maintenance: Effects on lying behavior of dairy cattle. *Journal of Dairy Science, 88,* 2381-2387.

Espejo, L. A., Endres, M. I., & Salfer, J. A. (2006). Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. *Journal of Dairy Science, 89,* 3052-3058.

Fregonesi, J. A., Viera, D. M., von Keyserlingk, M. A. G., & Weary, D. M. (2007). Effects of bedding quality on lying behaviour of dairy cows. *Journal of Dairy Science, 90,* 5468-5472.

Haley, D. B., de Passillé, A. M., & Rushen, J. (2001). Assessing cow comfort: Effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. *Applied Animal Behaviour Science, 71,* 105-117.

Manninen, E., de Passillé, A. M., Rushen, J., Norring, M., & Saloniemi, H. (2002). Preferences of dairy cows kept in unheated buildings for different kinds of cubicle flooring. *Applied Animal Behaviour Science, 75,* 281-292.

Mowbray, L., Vittie, T., & Weary, D. M. (2003). Hock lesions and free-stall design: Effects of stall surface. *Proceedings of the Fifth International Dairy Housing Conference* (pp. 288-295). St. Joseph, MI: ASAE.

Nordlund, K., & Cook, N. B. (2003). A flowchart for evaluating dairy cow freestalls. *Bovine Practitioner, 37,* 89-96.

Norring, M., Manninen, E., de Passillé, A. M., Rushen, J., Munksgaard, L., & Saloniemi, H. (2008). Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows. *Journal of Dairy Science, 91,* 570-576.

Rushen, J., Haley, D., & de Passillé, A. M. (2007). Effect of softer flooring in tie stalls on resting behavior and leg injuries of lactating cows. *Journal of Dairy Science, 90,* 3647-3651.

Tucker, C. B., & Weary, D. M. (2004). Bedding on geotextile mattresses: How much is needed to improve cow comfort? *Journal of Dairy Science, 87,* 2889-2895.

Tucker, C. B., Weary, D. M., & Fraser, D. (2004). Freestall dimensions: Effects of preferences and stall usage. *Journal of Dairy Science, 87,* 1208-1216.

Tucker, C. B., Weary, D. M., & Fraser, D. (2005). Neck-rail placement: Effect on freestall preference, usage, and cleanliness. *Journal of Dairy Science, 88,* 2730-2737.

Tucker, C. B., Zdanowicz, M., & Weary, D. M. (2006). Brisket boards reduce freestall use. *Journal of Dairy Science, 89,* 2603-2607.

Tucker, C. B., Weary,D. M., von Keyserlingk, M. A. G., & Beauchemin, K. A. (2009). Cow comfort in tie stalls: increased depth of shavings or straw bedding increases lying time *Journal of Dairy Science*, in press.

Weary, D. M., & Taszkun, I. (2000). Hock lesions and free-stall design. *Journal of Dairy Science, 83,* 697-702.

Wechsler, B., Schaub, J., Friedli, K. & Hauser, R. (2000). Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. *Applied Animal Behavior Science, 69,* 189-197.

Zdanowicz, M., Shelford, J. A., Tucker, C. B., Weary, D. M., & von Keyserlingk, M. A. G. (2004). Sand and sawdust bedding affect bacterial populations on teat ends of dairy cows housed in freestalls. *Journal of Dairy Science, 87,* 1694-1701.

Zurbrigg, K., Kelton, D., Anderson, N., & Millman, S. (2005a). Stall dimensions and the prevalence of lameness, injury, and cleanliness on 317 tie-stall dairy farms in Ontario. *Canadian Veterinary Journal, 46*, 902-909.

Zurbrigg, K., Kelton, D., Anderson, N., & Millman, S. (2005b). Tie-stall design and its relationship to lameness, injury, and cleanliness on 317 Ontario dairy farms. *Journal of Dairy Science, 88,* 3201-3210.

FLOORING

Conclusions

1. **The type and quality of flooring can have a major impact on the welfare of cows in free-stall systems.**
2. **Concrete flooring is too hard and does not provide sufficient traction when cows are walking. This increases the chance of slipping and falling and reduces the time that the cows are willing to stand and walk compared to soft, high-friction rubber floors.**
3. **Compared to straw or earth floors, concrete floors increase the chance of lameness and hoof lesions, but this effect is not always reduced by covering the floor with rubber.**
4. **Poorly maintained concrete floors increase the risk of hoof lesions.**
5. **Concrete flooring that is poorly drained and covered with slurry increases the chance of cows slipping and falling and increases the risk of dermatitis and heel horn erosion.**
6. **Slatted floors can help keep hooves dry and reduce dermatitis and heel horn erosion but can reduce the cows' mobility and may increase the pressure on cows' hooves.**

The type of flooring on which cows walk when housed indoors has been found to affect their welfare in two main ways: either by impairing locomotion, resulting in an increased risk of slipping and falling, or by increasing the risk of hoof disorders and lameness. The type of flooring also affects the overall activity of the cows but the implications of this for animal welfare are less obvious.

Effects on locomotion: The presence of slurry on floors clearly affects cow locomotion and the risk of injury. Cows avoid walking on passages covered with slurry (Phillips and Morris 2002). Slurry on the floor reduces walking speed (Phillips and Morris 2000, Rushen and de Passillé 2006) and increases the risk of slipping and increases the likelihood that people will need to intervene (Rushen and de Passillé 2006). These effects are most obvious when the cows are starting to walk, turning corners or surmounting an obstacle (Rushen and de Passillé 2006). Adding non-slip material to the floor does not necessarily reduce these effects of slurry (Rushen and de Passillé 2006). Walking areas for cows need to be kept clean and free of slurry.

Concrete does not provide the best walking surface for cows both because it is too hard (Rushen and de Passillé 2006) and because it does not provide sufficient traction (van der Tol et al. 2005). This is apparent in reduced walking speed and a greater tendency to slip and fall. Increasing the roughness of the concrete floor may increase friction but may not increase walking speed (Phillips and Morris 2001), risks more wear to the claw due to the greater abrasiveness, which can result in the softer parts of the claw carrying more weight (Telezhenko et al. 2008) and may result in greater pressure on the hoof increasing the risk of damage (Franck and De Belie 2006, Franck et al. 2008). The low friction can be reduced by adding a high-friction non-slip covering to the floor, which increases walking speed and reduces the chance of slipping (Rushen and de Passillé et al. 2006). However, better results can be achieved by adding a softer rubber floor, which increases walking speed and stride length, and generally improves the gait of the cows (Telezhenko and Bergsten 2005, Rushen and de Passillé 2006, Flower et al. 2007). Increasing the compressibility of the flooring reduces the risk of slipping more than does increasing the surface friction (Rushen and de Passillé 2006). Reducing the hardness of the floor is also likely to result in less compression of the claw as the cow walks (Schmid et al. 2008). Softer rubber flooring is a particular advantage for lame cows (Telezhenko and Bergsten 2005, Flower et al. 2007). However, rubber floors can be slippery if too hard or if they do not have sufficient surface friction.

Cows have been found to walk more slowly and with shorter strides on slatted concrete floors compared to solid concrete floors (Telezhenko and Bergsten 2005), and slatted floors can result in higher pressures on the claw (Hinterhofer et al. 2006).

Effects on lameness: A number of epidemiological surveys have found associations between the type of flooring and the occurrence of various hoof disorders or lameness (Table 1 below).

Concrete floors have been associated with an increased occurrence of lesions due to claw horn disruption (e.g. sole hemorrhages, sole ulcers, white line disorders) compared to straw yards (Frankena et al. 1992, Somers et al. 2003), while one study (Faye and Lescourret 1989) found an increased occurrence of all hoof disorders on concrete floors compared to earth floors. However, the area where the cows rest may also have been different (although this area was not described in detail in the studies), so that the difference may be due to the lying cubicles rather than the floor itself. One study (Cramer 2007) found no difference between concrete and rubber floors in the occurrence of hoof lesions. Whether the concrete floor is slatted or solid does not seem to affect the occurrence of claw horn disruption (Somers et al 2003). However, the particular physical properties of the concrete floor are of importance: lameness is more common when concrete flooring is smooth or slippery (Faull et al. 1996, Dembele et al. 2006). The occurrence of hoof lesions is affected by how well the concrete flooring is maintained: Bell (2004) found that the number of large imperfections in the floor (i.e., large cracks or holes in the concrete) could account for 15% of the difference in the number of cows with lesions in the hind lateral claws among dairy farms in the Fraser Valley of BC.

Hoof lesions associated with infection such as digital dermatitis, interdigital dermatitis and heel horn erosion appear to be associated with wet flooring (Wells et al. 1999) or with the accumulation of feces and urine on the floor since their occurrence is lower on slatted floors than solid floors and lower when a scraper is used on slatted floors (Somers et al. 2005a, Somers et al. 2005b). Borderas et al. (2004) found that claws exposed to moisture became softer and that softer horn was associated with increased heel horn erosion. Concrete flooring itself is not necessarily a risk factor for digital dermatitis but grooved concrete is associated with a greater occurrence compared to textured, smooth or slatted concrete (Wells et al. 1999).

A number of small scale experimental studies have examined whether rubber flooring provides an advantage over concrete floors, with mixed results. No studies have found a clear reduction in lesions associated with claw horn disruption such as sole hemorrhages, sole ulcers, white line separation or digital dermatitis (Vokey et al. 2001, Vanegas et al. 2006, Boyle et al. 2007). However, Vokey et al. (2001) did report some reduced lesion scores for cows that were both bedded on sand and with rubber floors compared to cows bedded with sand and with concrete floors. Furthermore, claw lesion scores tended to increase the most for cows with concrete floors and walking on concrete and increased the least for cows walking on rubber and with sand bedded stalls. Improvements in heel horn erosion have, however, been reported (Vanegas et al. 2006, Boyle et al. 2007) probably because the reduced abrasiveness of rubber results in less horn wear (Vokey et al. 2001, Vanegas et al. 2006). Vanegas et al. (2006) found a reduced occurrence of lameness among cows (n=950 cows) with rubber flooring but this was not reported in a smaller experiment (n=120 cows) by Vokey et al. (2001).

In conclusion, claw lesions associated with bacterial infections (dermatitis and heel horn erosion) are increased when floors are wet or covered in slurry. Concrete floors are associated with increased lesions, when compared to straw yards or earthen floors, but differences in resting area may confound these results. Rubber flooring does not reduce lesions due to claw horn disruption but reduces heel horn erosion and claw wear and may reduce the occurrence of lameness. Smooth and slippery concrete increases the occurrence of lameness and poorly maintained concrete increases the risk of hoof lesions.

Effects on overall activity: The type of flooring in the barn can influence the behaviour of cows in a number of ways but the relationship between these changes and the welfare of the cows is less clear. Cows clearly prefer to stand on a softer surface than concrete when eating (Tucker et al. 2006). Placing rubber flooring in front of feed bunks or in the feeding area does not increase time spent feeding or feed intake (Fregonesi et al. 2004, Tucker et al. 2006) but does increase the time spent standing in the feed area and reduces the time spent standing or lying in the lying stalls (Fregonesi et al. 2004, Tucker et al. 2006, Boyle et al. 2007, Ouweltjes 2008). The most likely explanation of this is that with concrete flooring cows are making more use of the lying stalls since concrete does not provide a sufficiently comfortable area for them to stand. Cows walk more when on rubber flooring compared to concrete flooring (Ouweltjes 2008, Platz et al. 2008) and make more visits to an automated milking system (Ouweltjes 2008). On rubber flooring, cows mount more frequently and are much less likely to slip when mounting (Platz et al. 2008).

Table 1. Epidemiological studies.

Author	**Country**	**Farms**	**Type of floor**	**Comparison**	**Variable**	**Effect noted**
Faye and Lescouret 1989	France	80	Concrete	Earth	All hoof diseases	Prevalence 19.8% on concrete versus 2.9% on earth
Frankena et al. 1992	Netherlands	123	Concrete slats	Straw yards	Sole hemorrhages	Prevalence: 44.6% on concrete versus 4.6% on straw
Faull et al. 1996	UK	37	Smoothness of concrete flooring		Incidence of lameness	Smooth floors had a higher incidence of lameness
Wells et al. 1999	USA	4516	Textured concrete	-Grooved concrete -Smooth or slatted concrete -Dirt, pasture or other	Incidence of digital dermatitis >5%	OR =1 (versus Grooved 2.7; Smooth or slatted 1.8) No difference with dirt, pasture.
"	"	"	Floor always wet	Floor usually dry	"	Farms more likely to have high incidence (54% vs 29%) but not significant when other variables included
Somers et al. 2003	Netherlands	47	Slatted concrete	Straw yards	Sole hemorrhage, sole ulcer, white line separation	Lower prevalence in straw yards
"	"	"	Solid concrete	Slatted concrete	Sole hemorrhage, sole ulcer, white line separation	No difference
Somers et al. 2005a	Netherlands	47	Solid concrete	Slatted concrete	Digital dermatitis	OR 1.19 on solid versus 1 on slatted
"	"	"	Slatted concrete	Slatted with scraper	Digital dermatitis	OR 1.00 on slatted versus 0.57 with scraper
Somers et al. 2005b	Netherlands	46	Solid concrete	Slatted concrete	Interdigital dermatitis and Heel horn erosion	OR 1.26 on solid versus 1.00 on slatted
"	"	"	Slatted concrete	Slatted with scraper	Interdigital dermatitis and Heel horn erosion	OR 1.00 on slatted versus 0.62 with scraper
Dembele et al.2006	Czech Republic	24	Slipperiness of floor	-	Lameness (any degree of limping)	Slippery floors had a higher lameness prevalence (r=0.48)
Cramer 2007	Canada	41	Concrete (solid, smooth or grooved)	Rubber	Hoof lesions	No effect of floor type

References

Bell, E. (2004). Description of claw horn lesions and associated risk factors in dairy cattle in the lower Fraser Valley, British Columbia. Masters Thesis. Vancouver, BC: The University of British Columbia.

Borderas, T. F., Pawluczuk B., de Passillé, A. M., & Rushen, J. (2004). Claw hardness of dairy cows: Relationship to water content and claw lesions. *Journal of Dairy Science, 87,* 2085-2093.

Boyle, L. A., Mee, J. F., & Kiernan, P. J. (2007). The effect of rubber versus concrete passageways in cubicle housing on claw health and reproduction of pluriparous dairy cows. *Applied Animal Behaviour Science, 106*, 1-12.

Cramer, G. (2007). Quantification of foot lesions and an evaluation of early detection methods for lameness in Ontario dairy farms. DVSc Thesis. Guelph, ON: The University of Guelph.

Dembele, I., Spinka, M., Stehulová, I., Panamá, J., & Firla, P. (2006). Factors contributing to the incidence and prevalence of lameness on Czech dairy farms. *Czech Journal of Animal Science*, *51*, 102-109.

Faull, W. B., Hughes, J. W., Clarkson, M. J., Downham, D. Y., Manson, F. J., Merritt, J. B., et al. (1996). Epidemiology of lameness in dairy cattle: The influence of cubicles and indoor and outdoor walking surfaces. *Veterinary Record, 139*, 130-136.

Faye, B., & Lescourret, F. 1989. Environmental factors associated with lameness in dairy cattle. *Preventative Veterinary Medicine, 7*, 267-287

Flower, F. C., de Passillé, A. M., Weary, D. M., Sanderson, D. J., & Rushen, J. (2007). Softer, higher-friction flooring improves gait of cows with and without sole ulcers. *Journal of Dairy Science*, *90*, 1235-1242.

Franck, A., & de Belie, N. (2006). Concrete floor-bovine claw contact pressures related to floor roughness and deformation of the claw. *Journal of Dairy Science*, *89*, 2952-2964.

Franck, A., Verhegghe, B., & de Belie, N. (2008). The effect of concrete floor roughness on bovine claws using finite element analysis. *Journal of Dairy Science, 91,* 182-192.

Frankena, K., van Keulen, K. A. S., Noordhuizen, J. P., Noordhuizen-Stassen, E. N., Gundelach, J., de Jong, D. J., & Saedt, I. (1992). A cross-sectional study into prevalence and risk factors of digital haemorrhages in female dairy calves. *Preventive Veterinary Medicine*, *14*, 1-12.

Fregonesi, J. A., Tucker, C. B., Weary, D. M., Flower, F. C., & Vittie, T. (2004). Effect of rubber flooring in front of the feed bunk on the time budgets of dairy cattle. *Journal of Dairy Science*, *87*, 1203-1207.

Hinterhofer, C., Ferguson, J. C., Apprich, V., Haider, H., & Stanek, C. (2006). Slatted floors and solid floors: Stress and strain on the bovine hoof capsule analyzed in finite element analysis. *Journal of Dairy Science, 89,* 155-162.

Ouweltjes, W. (2008). Influence of floor type on animal behaviour and milk production. *Proceedings of the 15th International Symposium and 7th Conference on lameness in Ruminants* (pp. 57-63). Kuopio, Finland 9-13th June, 2008.

Phillips, C. J. C., & Morris, I. D. (2000). The locomotion of dairy cows on concrete floors that are dry, wet, or covered with a slurry of excreta. *Journal of Dairy Science*, *83*, 1767-1772.

Phillips, C. J. C., & Morris, I. D. (2001). The locomotion of dairy cows on floor surfaces with different frictional properties. *Journal of Dairy Science*, *84*, 623-628.

Phillips, C. J. C., & Rind, M. I. (2002). The effects of social dominance on the production and behavior of grazing dairy cows offered forage supplements. *Journal of Dairy Science, 85*, 51-59.

Platz, S., Ahrens, F., Bendel, J., Meyer, H. H. D., & Erhard, M. H. (2008). What happens with cow behavior when replacing concrete slatted floor by rubber coating: A case study. *Journal of Dairy Science, 91*, 999-1004.

Rushen, J., & de Passillé, A. M. (2006). Effects of roughness and compressibility of flooring on cow locomotion. *Journal of Dairy Science*, *89*, 2965-2972.

Schmid, T., Weishaupt, M. A., Meyer, S. W., Waldern, N., von Peinen, K., & Nuss, K. (2008). High-speed cinematographic evaluation of claw-ground contact pattern of lactating cows. *The Veterinary Journal, In Press*, doi:10.1016/j.tvjl.2008.02.019

Somers, J. G. C. J., Frankena, K., Noordhuizen-Stassen, E. N., & Metz, J. H. M. (2003). Prevalence of claw disorders in dutch dairy cows exposed to several floor systems. *Journal of Dairy Science*, *86*, 2082-2093.

Somers, J. G. C. J., Frankena, K., Noordhuizen-Stassen, E. N., & Metz, J. H. M. (2005a). Risk factors for interdigital dermatitis and heel erosion in dairy cows kept in cubicle houses in The Netherlands. *Preventive Veterinary Medicine, 71,* 23-34.

Somers, J. G. C. J., Frankena, K., Noordhuizen-Stassen, E. N., & Metz, J. H. M. (2005b). Risk factors for digital dermatitis in dairy cows kept in cubicle houses in The Netherlands. *Preventive Veterinary Medicine*, *71,* 11-21.

Telezhenko, E., & Bergsten, C. (2005). Influence of floor type on the locomotion of dairy cows, *Applied Animal Behaviour Science*, *93,* 183-197.

Telezhenko, E., Bergsten, C., Magnusson, M., Ventorp, M., & Nilsson, C. (2008). Effect of different flooring systems on weight and pressure distribution on claws of dairy cows. *Journal of Dairy Science, 91*, 1874-1884.

Tucker, C. B., Zdanowicz, M., & Weary, D. M. (2006). Brisket boards reduce freestall use. *Journal of Dairy Science*, *89*, 2603-2607.

van der Tol, P. P. J., Metz, J. H. M., Noordhuizen-Stassen, E. N., Back, W., Braam, C. R., & Weijs, W. A. (2005). Frictional forces required for unrestrained locomotion in dairy cattle. *Journal of Dairy Science*, *88,* 615-624.

Vanegas, J., Overton, M., Berry, S. L., & Sischo, W. M. (2006). Effect of Rubber Flooring on Claw Health in Lactating Dairy Cows Housed in Free-Stall Barns. *Journal of Dairy Science, 89*, 4251-4258.

Vokey, F. J., Guard, C. L., Erb, H. N., & Galton, D. M. (2001). Effects of alley and stall surfaces on indices of claw and leg health in dairy cattle housed in a free-stall barn. *Journal of Dairy Science*, *84*, 2686-2699.

Wells, S. J., Garber, L. P., & Wagner, B. A. (1999). Papillomatous digital dermatitis and associated risk factors in US dairy herds. *Preventive Veterinary Medicine, 38*, 11-24.

STOCKING DENSITY

Conclusions:

1. **In loose housing systems such as free stall barns, increased density increases competition among cows for resources in the pen, including access to feed, water, and a lying stall.**
2. **Increased stocking at the stall (cow:stall ratios greater than 1) increases competition among cows, reducing lying time and increasing the time spent standing outside of the stall.**
3. **Reduced space per cow at the feed bunk also increases competitive interactions among cows, reduces bunk attendance times and increases the time spend standing waiting for access to feed.**
4. **All effects described above are most pronounced for socially subordinate cows.**

Increased stocking density can have quite different effects depending on whether it results from the addition of extra animals to a given area, or a reduction in the area available for a given number of animals. For example, in a large group of animals there are simply more individuals that need to be dealt with, leading to a greater variety in dominance relationships and more opportunity for aggressive encounters. Large groups can also place more demands on management, particularly if there is less time to devote to individual animals.

Reduced space for a fixed number of animals means than more cows are sharing the same volume of air (potentially leading to problems in air quality), and the same floor area (potentially increasing the manure slurry on the floor). In loose housing systems, increased density can result in increased competitive interactions between animals for limited resources such as access to stalls, feeder space, and drinkers. One of the most contentious issues in free-stall housing is the number of cows to house together in a pen with a fixed number of stalls and feeder space. Usually, density is expressed as the number of cows per stall (cow:stall ratio) or linear bunk space per cow.

Overstocking free stalls: Numerous studies have tested the effects of cow:stall ratio on stall use. The effects of overstocking appear to be linear, such that even low levels of overstocking reduce lying time. One recent study tested the effects over a range of cow:stall ratios ranging from 1:1 to 3:2, and found that lying time fell by approximately 20 min for every 10% increase in density (Fregonesi et al. 2007). This estimate agrees with earlier studies testing a more limited range of levels (Wierenga 1991, Winckler et al. 2003). Lying time is reduced by up to 4 h/d at a cow:stall ratio of 2.0 (Friend et al. 1979). The effects of overstocking can be larger for low-ranking cows (socially subordinate). Even with a cow:stall ratio of 1.0, low-ranking cows spend less time lying in the stalls and more time standing in the passage ways (Galindo and Broom 2000). Wierenga (1991) observed that lying times for low-ranking cows decreased by over 2.6 hours/day at a cow:stall ratio of 1.5. Leonard et al. (1996) found that the average resting time when cows were housed at a cow:stall ratio of 2.0 was 7.5 hours but that this varied between 2.7 h/d and 11.9 h/d for individual cows. The low resting times were associated with an increase in the incidence of sole haemorrhages and lameness. Galindo and Broom (2000) also noted that lameness and hoof lesions were more prevalent among cows that spent more time standing outside of the stall. Fregonesi et al. (2007) showed that the linear decline in lying times with overstocking was paralleled by a linear increase in time spent standing outside of stalls. It seems likely that even moderate levels of overstocking can increase the risk of lameness.

Cows compete directly and indirectly for access to stalls.

1) Indirect competition occurs when cows change their patterns of stall use. When there are too few stalls cows are able to adjust the times that they rest to a small degree but do not compensate fully and thus lying times are reduced in these situations (Fregonesi et al. 2007, Wierenga 1991). Impacts of altered stall use patterns can be great. For example, it is thought that the risk of intramammary infection may be reduced if cows stand after milking, as it allows for teat end closure. When stocked at a 1:1 ratio, freshly milked cows feed an average of 40 min before lying down (Fregonesi et al. 2007); conversely, overstocked cows are more likely to lie down immediately after returning from the parlour. This may impact their likelihood for developing intramammary infections.

2) Direct competition occurs when cows displace one another from the resource. At a cow to stall ratio of 1:1, cows rarely displace each other from the free stall, but the number of displacements more than doubles when the ratio exceeds 1.2:1 (Fregonesi et al. 2007). When direct competition occurs, it is typically the social subordinate animals that are most impacted.

Overstocking at the feed bunk: There are several aspects of the feeding environment that affect the cow's ability to access feed, including the amount of available feed bunk space per animal and the physical design of the feeding area. Reduced feed bunk space availability also increases direct competition in cattle (Kondo et al. 1989). As described in the Feed Management and Nutrition: Feed Bunk Management and Appropriate Space section, decreasing the available feed bunk increases aggressive interactions, decreases feeding activity, and increased the amount of inactive standing time (Huzzey et al. 2006). These effects are most strongly noticed in the subordinate cows. Furthermore, displacements resulting from head-to head or head-to-body contact are highest when no barrier is present between adjacent feeding cows; although full-body barriers are most effective (DeVries and von Keyserlingk, 2006), even simple headlock barriers do reduce displacements significantly (Huzzey et al. 2006). Clearly, overstocking the feed bunk decreases time spent at the feed bunk and increases competition, resulting in poor feed access.

The provision of more bunk space, especially when combined with feed stalls, improves access to feed and reduces competition at the feed bunk, and this effect is strongest for subordinate cows. Producers that avoid overstocking in the feeding area likely help reduce the between-cow variation in the composition of ration consumed. Under conventional systems, subordinate cows can only access the bunk after dominant cows have sorted the feed (Hosseinkhani et al. 2008). The use of a barrier that provides some physical separation between adjacent cows can reduce competition at the feed bunk. A less aggressive environment at the feed bunk may also have longer-term health benefits; cows engaged in aggressive interactions at the feed bunk are likely at higher risk for hoof health problems (Leonard et al. 1998).

References

DeVries, T. J., von Keyserlingk, M. A. G., & Beauchemin, K. A. (2005). Frequency of feed delivery affects the behavior of lactating dairy cows. *Journal of Dairy Science, 88*, 3553-3562.

DeVries, T. J., & von Keyserlingk, M. A. G. 2007. Feed Stalls Affect the Social and Feeding Behavior of Lactating Dairy Cows. *Journal of Dairy Science, 89,* 3522-3531.

Fregonesi, J. A., Tucker, C. B., & Weary, D. M. (2007). Overstocking reduces lying time in dairy cows. *Journal of Dairy Science, 90,* 3349-3354.

Friend, T. H., Gwazdauskas, F. C., & Polan, C. E. (1979). Change in adrenal response from free stall competition. *Journal of Dairy Science, 62*, 768-771.

Galindo, F., & Broom, D. M. (2000). The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. *Research in Veterinary Science, 69*, 75-79.

Hosseinkhani, A., DeVries, T. J., Proudfoot, K. L., Valizadeh, R., Veira, D. M., & von Keyserlingk, M. A. G. (2008). The Effects of Feed Bunk Competition on the Feed Sorting Behavior of Close-Up Dry Cows. *Journal of Dairy Science, 91,* 1115-1121.

Huzzey, J. M., DeVries, T. J., Valois, P., & von Keyserlingk, M. A. G. (2006). Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. *Journal of Dairy Science, 89*, 126-133.

Kondo, S., Sekine, J., Okubo, M., & Asahida, Y. (1989). The effect of group-size and space allowance on the agonistic and spacing behavior of cattle. *Applied Animal Behaviour Science, 24*, 127-135.

Leonard, F. C., O'Connell, J. M., & O'Farrell, K. J. (1996). Effect of overcrowding on claw health in first-calved Friesian heifers. *British Veterinary Journal, 152,* 459-472.

Leonard, F. C., Stienezen, I., & O'Farrell, K. J. (1998). Overcrowding at the feeding area and effects on behavior and claw health in Friesian heifers. In *Proceedings of the 10th International Symposium on Lameness in Ruminants* (pp. 40-41). Lucerne, Switzerland.

Wierenga, H. K. (1991). *Behaviour of dairy cows under modern housing conditions.* PhD Thesis. Wageningen, NL: Agricultural University.

Winckler, C., Capdeville, J., Gebresenbet, G., Horning, B., Roiha, U., Tosi, M., & Waiblinger, S. (2003). Selection of parameters for on-farm welfare-assessment protocols in cattle and buffalo. *Animal Welfare, 12*, 619-624.