CODE OF PRACTICE FOR THE CARE & HANDLING OF BEEF CATTLE: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

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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.

CODE OF PRACTICE FOR THE CARE & HANDLING OF BEEF CATTLE: REVIEW OF SCIENTIFIC RESEARCH ON PRIORITY ISSUES

Beef Code of Practice Scientists' Committee
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REPORT INTRODUCTION

The specific task and goal of the Scientists' Committee is not to create a document that includes recommendations, but to review and relay the relevant scientific information to the Code Development Committee in their work towards revising and drafting the new codes.

1. PAINFUL PROCEDURES

INTRODUCTION

In this section on dehorning, castration and branding we aimed to report only on the scientific literature relating to beef cattle. However, much of the relevant research has been conducted on dairy cattle and/or under dairy management conditions. This distinction is important when evaluating research findings for two reasons. First, beef cattle and dairy cattle differ genetically and behaviourally and second, the handling and management systems for beef production are markedly different from dairy production. Despite these differences, there is little reason to suspect that dehorning, castration and branding do not cause pain and distress in beef cattle regardless of age. These differences mean that care is required in interpreting how specific research findings in dairy cattle relate to beef cattle. These comparisons are useful to assist in identifying gaps in scientific knowledge and future research needs for beef cattle.

DEHORNING

Conclusions:

1. **Dehorning causes pain and distress at any age.**
2. **Use of homozygous polled sires avoids the need for dehorning and has not been shown to affect productivity.**
3. **Animals dehorned at younger ages heal more quickly than those dehorned at older ages.**
4. **Local anesthetic makes calves easier to handle during the dehorning procedure.**
5. **Local anesthetic administered alone diminishes pain during the dehorning procedure but does not mitigate post-procedure pain.**
6. **A combination of local anesthetic and analgesia will mitigate pain during and after dehorning.**

The horns of beef cattle are routinely removed to decrease the risk of injuries to workers and other animals, and to minimize carcass bruising. Horns begin as buds within the skin of the poll and at approximately 2 months of age the buds become attached to the frontal bone (American Veterinary Medical Association [AVMA], 2010). As described by the AVMA (2010), disbudding involves destroying the horn-producing cells of the bud without opening the frontal sinus. Chemical and hot-iron disbudding methods destroy the horn-producing cells, whereas physical methods of disbudding excise them. Dehorning is the removal of the horns after they have formed from the horn bud. Physical methods of dehorning include the use of embryotomy wire, guillotine shears, or dehorning knives, saws, spoons, cups, or tubes.

There is a potential difference in what the animal experiences before and after horn buds attach, and some research studies distinguish between disbudding and dehorning. However, among cattle breeds there is significant variation in animal age at horn bud attachment, and therefore using animal age to distinguish between disbudding or dehorning is not accurate. The distinction between disbudding and dehorning is rarely made in the literature reviewed and therefore, we will use the term dehorning to represent both, but caution readers that age is a critical factor.

There is strong scientific evidence that all methods of dehorning cause pain. This has been shown in numerous studies that have measured physiological stress responses such as plasma cortisol and heart rate and behavioural responses (Duffield et al., 2010; Faulkner & Weary, 2000; Graf & Senn, 1999; Grøndahl-Nielsen et al., 1999; Heinrich et al., 2009; McMeekan et al., 1998a, b; Mellor et al., 2002; Morisse et al., 1995; Petrie et al., 1996; Schwartzkopf-Genswein et al., 2005; Stewart et al., 2009; Stilwell et al., 2008, 2009, 2010; Sutherland et al., 2002; Sylvester et al., 1998a, 2004; Vickers et al., 2005). Dehorning is recognized as a painful procedure by veterinarians (AVMA, 2010; Hewson et al., 2007), the Canadian Council on Animal Care (CCAC), the agency overseeing use of animals in science (CCAC, 2009) and Canadian dairy farmers (National Farm Animal Care Council [NFACC], 2009). Risks become greater in dehorning older animals with larger horns. Extra care must be taken due to the creation of large open sinuses, the increased risk of infection, blood loss and, in extreme situations, death.

Use of polled sires: Using homozygous polled (genetically hornless) sires is an alternative to dehorning, and polled cattle are present in all commonly used beef breeds in Canada (Goonewardene et al., 1999a, b; Prayaga, 2007; Stookey & Goonewardene, 1996). Horns are inherited as an autosomal recessive gene with polled as the dominant condition so polled calves can be produced from horned cows reliably by breeding to a polled bull that is homozygous for the polled condition (Long & Gregory, 1978). Various performance measures have been studied to determine if a difference exists between polled and horned cattle. One study found horned and polled crossbred lines from various beef breeds were no different in live weight, fertility and mortality rates (Frisch et al., 1980). Polled German Simmental cattle were no different from their horned counterparts in growth, carcass yield, carcass composition, health and reproductive performance (Lange, 1989). Comparisons from 578 Charolais bulls and 1,860 Hereford bulls in Alberta and Saskatchewan found polled Hereford bulls to have higher average daily gain and polled Charolais bulls were fatter at the end of the test period. No differences were found in scrotal measurements or adjusted yearly weight (Stookey & Goonewardene, 1996).

In comparisons of three beef synthetic lines there were no differences between horned and polled cattle in birth weight, weaning weight, pre and post average daily gain, carcass weight and carcass characteristics (Goonewardene et al., 1999b). In the same study there were no differences between horned and polled cattle in reproductive traits such as pregnancy rates, dystocia scores, cow weights or cow condition scores (Goonewardene et al., 1999b). Therefore, no real differences have been shown to exist between polled and horned beef breeds in average daily gain, adjusted yearly weight, scrotal measurements, back fat thickness, carcass yield, carcass composition, health, reproductive performance, fertility, mortality rates, dystocia scores, cow weights or cow condition scores.

Age of animal at dehorning: There is limited research comparing the effects of dehorning at different ages. One study examined the impact of dehorning at 4, 7, 19 or 30 months on live weight gain compared to polled cattle over a 6 week period and no clear differences in performance between age groups were found (Loxton et al., 1982). However, frontal sinus wounds healed within 4 weeks in animals dehorned at 4 and 7 months of age, but required over 6 weeks in animals dehorned at 19 or 30 months of age (Loxton et al., 1982). Goonewardene and Hand (1991) compared the growth rates of feedlot calves dehorned 6 weeks after auction purchase with those of calves dehorned prior to auction purchase (and therefore at a younger age) or born polled (n=507). In the 14 days after dehorning, they found the growth rates of calves dehorned at the feedlot (318.9±36.5kg) were 30% lower than in calves dehorned prior to auction purchase or born polled, and 4.5% lower in the 106 days after dehorning. This evidence shows that animals dehorned at a younger age heal more quickly than when dehorned as older animals. However, there is no behavioural or physiological evidence regarding whether it is more or less painful at different ages, and this is an area needing further investigation.

Pain mitigation: There is currently no standardized method of mitigating the pain of dehorning in beef cattle. All of the research on dehorning pain mitigation has been done on dairy cattle breeds and/or management conditions. However, the literature provides some information that may serve to guide producers as they work with their veterinarians to design a strategy for their particular conditions.

Use of local anesthetic alone: Use of anesthetic[1] alone controls acute pain at the time when hot-iron dehorning is carried out and makes the animals easier to handle during the dehorning procedure (likely due to decreased sensitivity to pain) (Graf & Senn, 1999; Grøndahl-Nielsen et al., 1999). However, once the anesthetic wears off, a rise in cortisol and/or behaviours indicative of pain are seen (in dairy: Duffield et al., 2010; Graf & Senn, 1999; Grøndahl-Nielsen et al., 1999; Heinrich et al., 2009; Morisse et al., 1995; Petrie et al., 1996; Stewart et al., 2009). A similar delay in cortisol rise and/or performance of pain-indicating behaviours was seen with scoop dehorning plus anesthetic (in dairy: McMeekan et al., 1998a, b, 1999; Mellor et al., 2002; Petrie et al., 1996; Sutherland et al., 2002; Sylvester et al., 1998b; 2004).

When local anesthetic was used with caustic paste dehorning of 4-week old calves one study observed a decreased cortisol response, but found it had no effect on behavioural changes observed during the first 4 hours after treatment compared to calves without anesthetics (Morisse et al., 1995). Another study assessing the effect of anesthesia (lidocaine nerve block) on caustic paste dehorning of one-month-old calves found calves had lower cortisol concentrations and fewer head-shaking and head-rubbing behaviours at the time of application than calves dehorned with no anesthesia (Stilwell et al., 2009). However, an increase in head-shaking and head-rubbing behaviours was seen in the treated calves 3 hours post-application of caustic paste, consistent with lidocaine wearing off. Therefore, use of anesthetic alone during dehorning makes calves easier to handle and diminishes pain during the dehorning procedure but does not mitigate post-procedure pain (see review by Stafford & Mellor, 2011).

[1] A local anesthetic (e.g. lidocaine) produces anesthesia and the loss of sensation and pain by paralyzing sensory nerve endings or nerve fibers at the site of application.

Use of analgesia alone: Few studies have examined the effects of analgesia[2] alone in controlling dehorning pain. One study reported that the calves treated with the analgesic ketoprofen, a non-steroidal anti-inflammatory drug (NSAID) had plasma cortisol return to control concentrations more quickly than in untreated 3 to 4-month-old calves dehorned by scoop (McMeekan et al., 1998b). When the NSAID flunixin meglumine was used alone it was not sufficient to control the pain of caustic-paste dehorning (Stilwell et al., 2008). In this experiment, flunixin meglumine was injected into 1-month-old calves, five of which were injected at 5 minutes and five injected at 60 minutes before dehorning (with 10 control animals who did not receive analgesia) (Stilwell et al. 2008). They found no difference in cortisol concentrations and performance of head-shaking and hind-limb scratching between calves dehorned with and without analgesia. Similarly, using xylazine (a sedative and mild analgesic) alone did not eliminate performance of ear-flicking and head-shaking behaviours after hot iron dehorning of 1-month-old calves (as compared to calves dehorned with xylazine and anesthesia and sham-dehorned calves) (Stafford et al., 2003; Stilwell et al., 2008). These authors concluded that xylazine's analgesic effect is insufficient for the first 40 minutes post-procedure.

Use of drug combinations: Local anesthetic is effective at reducing pain caused by the hot-iron procedure but this effect wears off several hours later. Many studies show that use of an NSAID analgesic in combination with anesthetic can reduce pain once the anesthetic wears off. For example, Faulkner and Weary (2000) administered sedative (xylazine) and anesthetic to 4 to 8-week-old calves prior to hot-iron dehorning. In addition, some calves received analgesia (ketoprofen) before dehorning and 2 and 7 hours afterwards. They found that ketoprofen treatment reduced head-shaking and ear-flicking behaviour in the 24 hours after hot-iron dehorning. Milligan et al. (2004) found a significant difference in cortisol concentrations from the time of dehorning until 3 hours after in 2-week-old calves hot-iron dehorned with ketoprofen and analgesia. However, in contrast to Faulkner and Weary (2000), no differences in ear-flicking and head-shaking were observed, although the authors note that this may be due to differences in experimental methodology. Milligan et al. (2004) used a butane, rather than an electric dehorner and they also dehorned younger calves.

Duffield et al. (2010) found that the administration of ketoprofen in combination with local anesthetic reduced the amount of ear-flicking, head-shaking and head-rubbing in 4 to 8-week-old calves dehorned with a hot-iron (in comparison with anesthesia-only controls). Two studies found that the combination of local anesthetic and the analgesic meloxicam reduced physiological responses to hot-iron dehorning in 1-month-old (Stewart et al., 2009) and 6 to12-week-old (Heinrich et al., 2009) calves. Another study found 1-month-old calves dehorned by hot-iron showed fewer ear, head, and leg movements when a combination of local anesthetic and xylazine were used (compared to treatment with xylazine alone) (Stilwell et al., 2010).

The behaviour (lying, grazing, tail-shaking and ear-flicking) of 3 to 4-month-old calves dehorned by scoop after both a local anesthetic and analgesic had been administered was similar to non-dehorned calves (McMeekan et al., 1999). However, within 6 hours post-dehorning, tail-shaking

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[2] An analgesic is a substance which reduces or ameliorates the sensation of pain. This includes non-steroidal anti-inflammatory drugs (NSAIDs) which are anti-inflammatory agents that reduce fever and inflammation and provide varying degrees of analgesia. Examples of analgesic drugs are carprofen, flunixin meglumine, ketoprofen, meloxicam and xylazine.

and ear-flicking behaviours in calves dehorned with local anesthetic and analgesic started to increase (McMeekan et al., 1999). The combination of local anesthesia and analgesia has also been shown to reduce the pain from caustic paste dehorning. For example, local anesthesia and flunixin meglumine were found to decrease cortisol concentrations and head-shaking and head-rubbing behaviours in caustic paste dehorning in 1-month-old dairy calves (Stilwell et al., 2009).

Overall there is conclusive evidence that the use of a combination of local anesthetic and analgesia can be used to control pain during and after dehorning (see review by Stafford & Mellor, 2011)**.**

Future research: The few studies that have investigated beef calves' responses to dehorning have focussed on performance. Beef cattle may show different behavioural responses to dehorning than dairy cattle due to temperament differences and fear responses to handling and restraint. These differences could influence their response to dehorning, but until a comparative study between beef and dairy calves shows otherwise, there is no reason to assume that beef calves would perceive the pain or benefit from pain mitigation any differently than dairy calves at any age.

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CASTRATION

Conclusions:

1. **All methods of castration cause pain and distress at any age.**
2. **The trauma caused by castration increases as the testes grow bigger, so castration at a younger age results in quicker healing and causes less pain and distress overall.**
3. **Animals castrated at younger ages show lower declines in growth rate post-procedure.**
4. **Anesthesia-alone has been shown to decrease but not eliminate calves' immediate pain responses to castration. However, anesthesia does not control longer-term post-operative pain.**
5. **Longer-term pain from castration can be diminished with the use of analgesics.**
6. **Current research suggests that wound healing is fastest with surgical methods while rubber band castration can cause a delay in wound healing.**
7. **Various methods for pain control have been described in the scientific literature. Although not always possible to eliminate pain, medication strategies to minimize the pain from castration exist.**

Castration of male beef cattle is done to prevent unwanted pregnancies, decrease the level of testosterone, to reduce aggression and improve ease of handling, and improve the palatability of the meat. The most common methods of castration of beef cattle in Canada include: surgery to remove the testicles, crushing of the spermatic cord and vessels providing blood supply to the testicles (burdizzo) or by constricting the tissues that supply blood to the testes (rubber rings or bands).

There is strong scientific evidence that all methods of castration cause pain and distress in cattle of all ages (Coetzee, 2011; Rault et al., 2011). This has been shown in numerous studies that measure physiological stress responses such as plasma cortisol and heart rate (in beef cattle: González et al., 2010; Stookey et al., 2000; Thüer et al., 2007; in dairy cattle: Boesch et al., 2008; Stilwell et al., 2008; Ting et al., 2003a, b; Warnock et al., 2012) and studies of behavioural responses (in beef cattle: Currah et al., 2009; González et al., 2010; Stookey et al., 2000; Thuer et al., 2007; in dairy cattle: Boesch et al., 2008; Marti et al., 2010; Schwartzkopf-Genswein et al., 2005; Stilwell et al., 2008; Ting et al., 2003a, b). Castration is also recognized as a painful procedure by the Canadian Council on Animal Care (CCAC, 2009) and Canadian dairy farmers (National Farm Animal Care Council [NFACC], 2009). The pain of castration can often be long-lasting: the performance of pain-related behaviours has been observed up to 3 months after rubber ring castration with and without local anesthesia (Thüer et al., 2007).

Age of animal at castration: Castration is painful at any age. However, the trauma of castration increases with the size of the testicles being removed. Calves castrated at a younger age also experience lower declines in growth rate post-castration than those castrated at older ages (Bretschneider, 2005). For example, beef calves castrated surgically or by rubber band at 14 months of age were so negatively affected by the procedure that steers castrated at 9 months of age caught up to them in weight, effectively erasing any growth benefit from the extended exposure to testosterone (Fisher et al., 2001). Similarly, González et al. (2010) compared the growth rates for 42 days post-castration of calves surgically castrated at 34 days of age and calves castrated with rubber bands at 6 to 8 months of age. They found poorer growth rates for calves castrated at 6 to 8 months of age compared with those of previously castrated animals. Therefore, younger calves show less evidence of overall pain and distress during castration (in beef cattle: Bretschneider, 2005; King et al., 1991; Robertson et al., 1994; in dairy cattle: Boesch et al., 2008; Ting et al., 2005).

Pain mitigation: There is currently no standardized method of mitigating the pain of castration in beef cattle. The cattle and management conditions in the research on castration pain mitigation are a mixture of dairy and beef. However, the literature provides useful information that may help guide beef producers as they work with their veterinarians to design a strategy for their specific operation.

Use of local anesthesia alone: Anesthesia-alone has a short-term pain mitigation effect following surgical castration, regardless of the route of administration (i.e. epidural or local anesthesia). For example, sexually mature beef bulls surgically castrated without anesthetic exerted considerably more force against the headgate, and exhibited a greater drop in heart rate than surgically castrated bulls that received an epidural anesthetic (Stookey et al., 2000). Adequate sedation using xylazine as an epidural can be achieved to block the pain associated with surgical castration of mature beef bulls (Caulkett et al., 1993), but the skill set and drugs required to deliver an epidural block may be restricted to veterinarians.

Another study compared differences in stride length between 3-month-old beef calves surgically castrated with, and without epidural lidocaine and found no differences 4 hours post-procedure (Currah et al., 2009). Using a local anesthetic 15 minutes before castration was shown to reduce peak cortisol concentrations by 23% in 5-month-old surgically castrated dairy calves (Fisher et al., 1996). However, it did not significantly reduce total cortisol release over the 10 hours following castration as compared to non-medicated, castrated controls. Earley and Crowe (2002) compared 5-month-old dairy bulls to calves castrated surgically, with or without local anesthetic. They found that using anesthetic reduced peak cortisol concentrations in castrated animals to the same level as intact controls. However, the total cortisol response for castration-alone and castration-and-local anesthesia calves was greater than for intact control calves. In addition, surgically castrated 4 to 6-month-old beef calves that received intravenous xylazine had a reduced cortisol response 60 minutes post-castration compared to calves castrated with no medication (Coetzee et al., 2010).

Anesthetic treatment did not reduce peak cortisol concentrations or total cortisol release for 3 to 4-week-old calves castrated with rubber bands compared to controls castrated without anesthetics (Thüer et al., 2007). However, in the first 2 hours post-castration the number of abnormal postures observed in these calves was significantly greater after rubber band castration without anesthetic, compared to control calves and calves with rubber band castration with local anesthesia. In the remainder of the three month observation period, rubber band castrated calves with and without anesthesia showed a significantly greater proportion of abnormal postures than control calves (Thüer et al., 2007). However, Stafford et al. (2002) injected a local anesthetic into the distal pole of each testis and into the scrotal cavity and waited 20 minutes before applying a rubber ring. They found there was no significant response in cortisol for the next 8 hours, suggesting a complete absence of pain from the rubber ring procedure when used in conjunction with a local anesthetic. The exceptional long lasting effect of the local anesthetic (normally it is only 2 hours) may have been due to the inability of the local anesthetic to escape past the ring and be metabolized. This treatment may successfully block all sensation of pain, but the wait-time post-injection, the ergonomics and human safety of injecting the testes and scrotum may need refinement.

Some studies have examined the effect of administering anesthesia prior to burdizzo castration. Comparisons between 5.5-month-old anesthetized and non-anesthetized dairy calves found that injection of local anesthetic 15 minutes before castration reduced peak cortisol concentrations by 15.6% but did not significantly reduce total cortisol release over the 10 hours following castration (Fisher et al., 1996). Another study reported that local anesthetic and caudal epidural anesthetic both reduced peak and mean plasma cortisol concentrations associated with burdizzo castration in 13-month-old calves but doubled the time to peak cortisol concentration (peaked at 1.5 hour after castration in all treatments and returned to control levels by day 3) (Ting et al., 2003b). They also found that total abnormal lying and standing behaviour was higher in non-anesthetized castrates and in animals castrated with a local anesthetic in the first 6 hours after castration while animals treated with an epidural anesthetic did not differ from non-castrated control animals (Ting et al., 2003b).

Thüer et al. (2007) found that local anesthetic reduced peak cortisol concentration and total cortisol release compared to control levels in 3 to 4-week-old beef calves castrated by the burdizzo method. However, in the first 2 hours post-castration the number of abnormal postures observed was significantly greater after burdizzo castration (with and without local anesthetic) compared to control calves. Stilwell et al. (2008) found burdizzo castration of 5 to 6-month-old dairy calves with and without epidural lidocaine had significant increases in plasma cortisol concentration at 6, 24 and 48 hours after castration, compared with baseline values. In this study no significant differences in pain-related behaviours (gait alterations) were observed between anesthetized and non-anesthetized groups. Boesch et al. (2008) observed less struggling during the castration procedure and lower peak cortisol and smaller total cortisol response than castration-only control calves when anesthesia was used during burdizzo castration of 2 to 7-day-old dairy calves.

Overall, use of anesthesia-alone at the time of the procedure has been shown to decrease but not eliminate calves' immediate pain (measured by physiological and behavioural parameters) due to castration. Use of anesthetics alone reduces the intensity of the cortisol response at the time of castration, but does not reduce total cortisol release. Also, anesthesia used alone does not contribute to control of post-operative pain (see review by Coetzee, 2011).

Use of analgesia alone: Longer term pain from castration can be diminished with the use of non-steroidal anti-inflammatory analgesics (NSAIDs) such as ketoprofen. For example, Early and Crowe (2002) found that ketoprofen alone was more effective in alleviating inflammatory stress from surgical castration (as measured by total cortisol and other physiological parameters) than local anesthetic alone in dairy calves). Similarly for burdizzo castration, Ting et al. (2003b) found that total cortisol response was lower 6 hours post-castration, and that fewer abnormal postures were observed for dairy calves treated with ketoprofen compared to non-medicated calves and calves treated with anesthesia-only. There is also evidence to suggest that the use of NSAIDs at the time of castration may decrease calf morbidity. One study on the effect of providing oral meloxicam to feedlot beef calves just prior to surgical castration found that treated calves had a lower incidence of bovine respiratory disease (BRD) than control calves castrated with no analgesia (n=145; 8 to 10 months of age) (Coetzee et al., 2012).

Use of drug combinations: The use of some drug combinations seemed to have short-term pain mitigation effects for calves castrated surgically. Early and Crowe's (2002) study on surgical castration in 5-month-old dairy calves found the time to peak cortisol concentrations was longer for calves receiving ketamine-and-local anesthetic than for calves receiving only ketamine or no medication. A study on surgical castration in beef calves aged 2 to 3 months found that animals receiving the combination of epidural lidocaine and flunixin meglumine had smaller decreases in stride length for up to 8 hours after castration when compared to calves that received anesthesia-alone or no medication (Currah et al., 2009). However, this effect was not seen at 24 hours post-castration and the authors concluded that the analgesic effect had worn off. A study on surgical castration of 4 to 6-month-old beef calves found that xylazine administered intravenously in combination with ketamine analgesic resulted in lower cortisol responses 60 minutes post-castration compared to castration with xylazine-alone and no medication (Coetzee et al., 2010). Medicated calves also demonstrated "attitude that was unchanged from pre-manipulation behavior" compared to calves castrated with no medication (Coetzee et al., 2010).

For rubber ring or band castration the administration of drug combinations at the time of castration does not appear to reduce the performance of pain-related behaviours in the days and weeks post-castration. One study administered lidocaine and flunixin meglumine just prior to rubber band castration of 3-month-old dairy calves. During days 3 to 14 post-castration they observed more abnormal standing and head-turning in castrated calves than non-castrated controls (although physiological parameters [serum cortisol, haptoglobin concentrations, rectal temperature and humoral immunity] were not different) (Marti et al., 2010). A study on rubber band castration of 6 to 8-month-old beef bulls found that the combination of xylazine and flunixin meglumine reduced the acute cortisol response at 1 and 2 hours post-procedure (González et al., 2010). However, reduced lying time, feeding activity and "step length" was observed for 6 weeks post-castration in both the medicated and non-medicated groups when compared to non-castrated controls.

One study assessed the effect of anesthesia-plus-analgesia in burdizzo castration. It compared the effect of epidural lidocaine-with-flunixin meglumine and epidural lidocaine-with-carprofen on burdizzo castration of 5 to 6-month-old dairy calves (Stilwell et al., 2008). At 6 hours post-procedure, non-medicated control calves had higher plasma cortisol concentrations, compared with baseline values and both treatment groups; at 24 hours, epidural-and-carprofen calves had lower plasma cortisol concentrations compared with control calves (Stilwell et al., 2008). At 48 hours epidural-and-carprofen calves had cortisol concentrations that were similar to baseline values and lower than epidural-and-flunixin meglumine and anesthesia-alone calves. In addition, at 24 and 48 hours post-castration, epidural-and-carprofen calves were first to arrive at the feed trough and exhibited fewer pain-related behaviours (gait alterations) than other groups.

Combinations of local anesthesia and analgesia can eliminate pain-induced behaviour and physiological responses during castration (see review by Coetzee, 2011). This is particularly evident when castration is done by surgical or burdizzo methods, however, the drug combinations that have been studied to date do not appear to diminish longer-term pain associated with rubber band castration.

Comparing castration methods: Factors to weigh when comparing different methods of castration include: the acute pain experienced at the time of the procedure, the post-procedural pain, the duration of pain, rate of wound healing, whether the pain can be managed, and the distress caused by restraint. Recent research shows greater initial pain responses following surgical castration at 230 days of age but delayed pain emerging at 3 to 4 weeks after application of the rubber band associated with sloughing the scrotum and wound healing following castration with a rubber band (González et al., 2012). Methods that produce fast-healing wounds with fewer complications are preferable and research suggests that wound healing is fastest with surgical methods, whether performed at 2-4 months of age (Stafford et al., 2002) or at sexual maturity (Stookey et al., 2000). In contrast, rubber band castration was found to cause a delay in wound healing: one study reported that just 6 of 50 calves banded at sexual maturity had their scrotums fall off 28 days post-castration by rubber band, and as long as the scrotum was attached there was a weeping wound at the site where the live tissue met the band and necrotic tissue (Stookey et al., 2000). Another study found that calves banded at 230 days of age showed the greatest amount of inflammation 3 to 4 weeks after banding when the testicles drop off, and this led to an open wound (González et al., 2010). Similarly, Warnock et al. (2012) reported that a prolonged inflammatory response (higher plasma haptoglobin concentrations 15 days post-castration) was observed in 200-day old calves banded versus those surgically castrated. In addition, a study on inflammation found that castration by rubber banding at 12 months of age caused more inflammatory-associated gene expression changes to the epididymis and scrotum than castration by burdizzo (Pang et al., 2009). However, the same study also found burdizzo castration caused more severe acute inflammatory responses in the testis and epididymis than banding (Pang et al., 2009).

At present, there is not enough scientific evidence to definitively conclude that one method of castration is preferable to another. Greater pain at the time of castration may be caused by some methods. For example, Stookey et al. (2000) observed a greater behavioural response at the time of the procedure in sexually mature bulls castrated surgically compared to rubber band. However, the performance of pain-related behaviours has been observed for long periods of time following rubber band castration. For example, González et al. (2010) observed that animals band castrated at approximately 230 days of age exhibited signs of chronic pain 6 weeks after banding. Similarly, the performance of pain-related behaviours has been observed 14 days (Marti et al., 2010) and 3 months (Thüer et al., 2007) following rubber band castration, with and without the administration of pain medication at the time of band application. There is no research that specifically examines the impact of distress caused by restraint.

Immunological castration has been accomplished by using a vaccine designed to cause the animal to build antibodies that attack its own gonadotropin-releasing hormone (GnRH), thereby interfering with luteinizing hormone (LH) release and sexual maturation. This technique is currently not approved for use in Canada, nor has research been conducted on its welfare implications. However, it could circumvent the need for castration using more conventional methods.

Future research: As there is currently not enough scientific evidence to definitively conclude that one method of castration is preferable to another, this is an area needing further investigation. In addition, continued research on practical methods to 1) mitigate pain and 2) encourage wound healing is warranted. Research to examine welfare implications at various ages is lacking, especially research at very young ages. Finally, research that specifically examines the impact of distress caused by restraint is also needed.

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BRANDING AND ANIMAL IDENTIFICATION

Conclusions:

1. **Both freeze branding and hot-iron branding cause pain and distress in cattle.**
2. **Freeze branding causes less acute pain at the time of the procedure than hot-iron branding.**
3. **Newer methods to identify cattle that are less invasive or non-invasive are becoming available.**
4. **Practical methods to decrease pain at branding are currently lacking.**

Branding of beef cattle in Canada occurs for two reasons: 1) to provide a permanent, visual means of establishing ownership and 2) to permit export of cattle for feedlot or breeding purposes to the United States (US) (US regulations require Canadian animals to be identified with either a tattoo bearing the letters "CAN" inside the left ear or a “CAN” brand on the right hip). However, brands are not used as means of identifying individual animals in cases of reportable disease outbreaks or to trace animal movement from farm-to-farm or farm-to-slaughter. Instead, beef cattle within Canada are required by law to have a Canadian Cattle Identification Agency (CCIA) ear tag for these purposes (CCIA, 2010).

There are two methods of branding: 1) by using a hot-iron to burn the skin and create scar tissue on which no hair will grow and 2) using an iron that has been cooled in either liquid nitrogen or a combination of dry ice and alcohol to destroy the melanocytes within the hair follicle, causing the hair to grow back white (termed “freeze branding”). In order to carry out either branding procedure cattle must be physically restrained and operators must be properly trained. Both methods of branding cause pain and distress (Lay et al., 1992a, b, c; Schwartzkopf-Genswein et al., 1997a, b, c, 1998; Schwartzkopf-Genswein & Stookey, 1997; Watts & Stookey, 1999). However, the research indicates that hot-iron branding appears to cause more acute pain than freeze-branding (Lay et al., 1992a, b, c; Schwartzkopf-Genswein et al., 1997a, b, c, 1998; Schwartzkopf-Genswein & Stookey, 1997). There is no research on practical methods to mitigate pain to cattle during branding.

Other methods of identification: There is a small body of research available on less invasive and non-invasive methods to identify cattle. Less invasive cattle identification methods include ear tags or brisket tags with electronic identifiers (i.e. barcodes or radio-frequency identification devices [RFID]), hair de-pigmenting compounds, injectable or intra-ruminal transponders, and biometric methods (Gonzales Barron et al., 2009; Stanford et al., 2001). As mentioned, ear tags with RFID are currently used as part of CCIA identification of cattle. At present, the retention rate of cattle ear tags is less than 100% and the tags can be purposely removed and so are of limited use in proving ownership. To generate baseline data on ear tag retention in Canada, various long term trials using commercially available ear tags are underway, but to date no results have been published (personal communication, P. Laronde, CCIA, May 24, 2011). There is no research on the retention rate or animal welfare implications of brisket tags. The application of hair de-pigmenting compounds has been investigated as an alternative to branding. Of eight compounds tested, none produced permanent loss of colour in the hair of cattle (Schwartzkopf et al., 1994).

Electronic transponders have also been developed for use in animal identification. These can be injected into the body, for example at the ear base, but problems have occurred with the transponders migrating to other locations in the body and/or not being located and removed at slaughter. Therefore these have not been approved by US regulators due to the risk of the transponders entering the food chain (Gonzales Barron et al., 2009). Intra-ruminal boluses have been used as another way to permanently identify cattle with electronic transponders. One study found these boluses were retained in the rumen over several months and had a 100% read success rate (McAllister et al., 2000). Similarly, a European Union study on transponder readability found fewer reading failures occurred with ruminal boluses (0.28%) than electronic ear tags (2.32%) or injectable transponders (1.05%) (Gonzales Barron et al., 2009). Disadvantages associated with boluses include difficulties and death occurring when administering the bolus to calves younger than 4 weeks (Gonzales Barron et al., 2009), retrieval of boluses at slaughterhouse (Gonzales Barron et al., 2009; McAllister et al., 2000), and changes to reticuloruminal mucosa, rumination patterns, and the growth and metabolic activity of ruminal bacteria (Antonini et al., 2006). Rumen boluses with transponders are currently used as part of cattle identification programs in Australia (producers can choose to use RFID boluses or ear tags but must also use brands) and Botswana (boluses used in addition to brands) (Bowling et al., 2008).

The most animal welfare-friendly identification methods may be non-invasive ones such as biometric identifiers. These are "any measurable, robust and distinctive physical, anatomical or molecular trait that can be used to uniquely identify or verify the claimed identity of an animal" (Gonzales Barron et al., 2009, p.205). Biometric markers that have been studied in relation to animal identification include retinal vascular pattern, iris pattern, muzzle pattern recognition, facial recognition, and DNA finger printing (Gonzales Barron et al., 2009; Shanahan et al., 2009). The uniqueness of retinal vascular patterns and usefulness of these as a form of cattle identification has been the subject of some research. Visual matching of retinal images (i.e. unaided by software) was found to be more easily done in cattle as compared to sheep, and required 15-45 seconds to capture one retinal image (Gonzales Barron et al., 2009). Limitations of identification using retinal vascular patterns include loss of the unique identifier (i.e. the vascular pattern) if the eye is damaged and at slaughter after exsanguination (personal communication, P. Laronde, CCIA, May 24, 2011).

Other biometric identification methods are still in the research stage. Iris recognition technology as a means of animal identification has been studied in horses. One study found that accurate recognition is possible but complicated by the difficulty of capturing a good digital image of the iris (Suzaki et al., 2001). Muzzle pattern recognition relies on the uniqueness of oval, rounded or irregular structures spread over the muzzle, similar to fingerprints in humans (Gonzales Barron et al., 2009). Historically these have been obtained by ink prints of the muzzle and therefore are currently not practical for beef cattle identification. However, procedures for digital imaging of the muzzle and software-aided image analysis are being investigated by some researchers (Gonzales Barron et al., 2009). The adaptation of human facial recognition software to use in animals and use of DNA finger-printing methods are also in the research stage.

Future research: Research needs include the investigation of practical methods to mitigate pain during branding. Research on non-invasive methods of cattle identification, such as the biometric methods described above, is also needed to develop these options into practical alternatives.

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2. FEEDLOT HEALTH & MORBIDITY

BOVINE RESPIRATORY DISEASE (BRD)

Conclusions:

1. **BRD is a disease with a range of negative effects on normal behaviour and welfare. As the disease progresses, it can lead to chronic debilitating conditions or death. The control and treatment of BRD is necessary to ensure beef cattle welfare.**
2. **Multiple sources of animals resulting in mixing of animals from different backgrounds increases risk of BRD.**
3. **Preconditioning calves before arrival at feedlot decreases morbidity due to BRD. Preconditioning usually includes vaccination, dehorning, castration and weaning several weeks prior to transport.**
4. **Vaccination either as part of a preconditioning program or upon arrival at the feedlot decreases the incidence of BRD.**
5. **In calves that are at high risk of developing BRD, metaphylaxis upon arrival at the feedlot decreases morbidity due to BRD.**
6. **Early identification and prompt treatment of sick calves decreases chronicity and mortality due to BRD.**

Bovine respiratory disease (BRD) (also referred to as undifferentiated bovine respiratory disease [UBRD], undifferentiated fever and shipping fever) is a multi-factorial respiratory infection. It is caused by interactions between the host animal, the environment and pathogens (viral and bacterial) (Booker et al., 2008).

BRD is a leading cause of morbidity in the beef industry. From their examination of data from five studies conducted between 1997 and 2003, Booker et al. (2008) reported that in western Canada, approximately 10% to 30% of auction market-derived calves were treated for BRD with a case fatality rate of 5 to 10%. A 15-year United States (US) study on the feedlot records of 18,112 calves from a closed animal system (i.e. all calves from the same location) found that the average annual BRD incidence was 17% (range 4.6 to 43.8%) (Snowder et al., 2006). The National Animal Health Monitoring System (NAHMS) 1999 survey of US feedlots found that 14.4% of feedlot cattle develop BRD (United States Department of Agriculture [USDA], 2000). However, detecting cattle affected by BRD is difficult. For example, Schneider et al. (2009) found 8.17% of 5,976 cattle were diagnosed with symptoms of BRD, while in a subset of 1,665 cattle, lung lesions were observed after slaughter in 61.9%, although not all lesions were necessarily indicative of undetected BRD. In addition to the more immediate negative welfare implications of the illness itself on the welfare of individual animals (e.g., feeling sick, feeling in pain), associated changes in behaviour such as reduced feed or water intake may also lead to other negative consequences such as the animal subsequently feeling hungry (Aubert, 1999; Hart, 1988; Johnson, 2002; Millman, 2007).

Evaluation of the scientific information related to BRD necessarily includes examination of findings from the veterinary literature. However, detailed review of the pathogenesis of BRD, the clinical veterinary research and accepted veterinary conclusions is beyond the scope of this committee to evaluate. Therefore, we have cited review articles from the veterinary literature in place of original research to support generally accepted veterinary conclusions.

Risk factors: The Canadian beef industry is structured such that a large number of cow-calf producers (67,300) supply a much smaller number of intensively managed feedlots (2,775 feedlots) (Statistics Canada, 2011). This necessitates transportation of calves to auction barns for sale or directly to feedlots. Therefore, calves arrive at the feedlot from many different cow-calf producers and often vary in weaning method, age and immunological background. In addition, they will have had different exposure to commingling, transport stressors, weather and dust. These factors have all been associated with increased morbidity due to BRD, however, there is not clear evidence that any one factor is the most important. Instead, the available evidence points to the additive or perhaps even synergistic effect of many factors contributing to BRD morbidity (Taylor et al., 2010a).

A recent epidemiological review of the predisposing factors for BRD determined that lighter-weight cattle, which are mostly younger, are at greater risk for BRD, but that the association has not been consistent (Taylor et al., 2010a) and it may be related to how recently they have been weaned. Immune status has been identified as a risk factor for BRD; several sero-epidemiological studies have shown a relationship between immune status to certain pathogens and the risk of contracting BRD (Booker et al., 1999; O'Conner et al., 2001a, b). Sex of the animal is also a risk factor, with steers having a higher incidence of BRD than heifers (20 versus 14%) (Snowder et al., 2006).

The type of weaning method used is also a risk factor for BRD. Some cow-calf producers separate calves from dams and transport them to the feedlot on the day of separation. Others separate calves from dams but do not transport them for several weeks, a method that disconnects weaning from introduction to the feedlot. The number of days post-weaning before transport was found to be a factor in morbidity at the feedlot (Boyles et al., 2007; Step et al., 2008) and will be discussed in greater detail below.

Multiple sources of animals resulting in mixing of animals from different backgrounds increases risk of BRD (Step et al., 2008; Edwards, 2010). There is a positive linear relationship between mixing of calves from truckloads from different sources and morbidity due to transport (Ribble et al., 1995). Feedlot pens composed of calves from a greater number of sources have a higher risk factor than pens comprised of cattle from fewer sources (Ribble et al., 1995). Transportation contributes additional stressors. A study on the effects of pre-haul management and transport duration on beef calf welfare during the feedlot receiving period found that the decrease between pre-transport weight and weight upon arrival at feedlot (shrink) was greater for calves transported for 15 hours as compared to 12.7 hours (Schwartzkopf-Genswein et al., 2007). A review of predisposing factors to BRD also found evidence of a link between sudden and extreme changes in weather and increased BRD (Taylor et al., 2010a). Although dust has been proposed as an environmental factor that affects the incidence of BRD, this has not been clearly demonstrated in the literature (Taylor et al., 2010a).

Prevention and control: Feedlot morbidity and mortality due to BRD can be reduced by prevention practices carried out by the cow-calf producer (preconditioning and vaccination) and by the feedlot operator (vaccination, metaphylaxis and management practices). At the feedlot, strategies for preventing BRD include categorizing animals as low risk or high risk and following different receiving protocols based on risk category. Assignment of risk category typically depends on the source of the calves and management practices of the cow-calf producer, if known.

Studies of weaning strategies show that keeping calves at home after weaning lowers feedlot morbidity compared with weaning and transporting on the same day, but the results have not always been consistent. For example, a study on 178-day-old beef calves (n=280) found that just 15% of calves weaned in a pasture 30-days prior to transport required treatment for respiratory disease compared to 28% for calves weaned on the day of transport (Boyles et al., 2007). However, this same study found higher morbidity in the weaned and kept-at-home in a drylot group, suggesting pasture is preferable to a drylot after weaning. A study on different preconditioning strategies found calves (n=509) that were weaned and then retained on the ranch for 45 days prior to transport to a feedlot had a 5.9% BRD morbidity rate compared to 35.1% for calves that were weaned and immediately transported to a feedlot and 41.9% for weaned, auction-purchased calves with unknown health backgrounds and 38% for calves weaned in a drylot 30 days prior to transport (Step et al., 2008). A more detailed review of the animal welfare implications of weaning methods is contained elsewhere in this report.

Preconditioning refers to combinations of management practices imposed by cow-calf producers prior to transport to improve the health status of calves. Typically, preconditioned calves are categorized as low risk for BRD upon arrival at the feedlot. Generally in preconditioning programs the following procedures have been carried out on calves prior to transport: weaning at least 30 to 45 days prior to transport, vaccination (clostridial bacterin and respiratory viruses), treatment with anthelmintic, castration, dehorning (when necessary) and introduction to feedbunks and water troughs (Duff & Gaylean, 2007; Schwartzkopf-Genswein et al., 2007; Taylor et al., 2010b).

Different aspects of preconditioning have been shown to effect morbidity at the feedlot. One study found that preconditioning had a significant effect on morbidity rates (morbidity defined as at least one hospital visit) (Roeber et al., 2001). Morbidity rates of 34.7, 36.7 and 77.3% were observed for two different preconditioning programs and auction-barn calves respectively (study n=273) (Roeber et al., 2001). Common features between the preconditioning programs were that calves were: 1) owned by the seller for at least 27 days; 2) dehorned and castrated; 3) vaccinated with clostridial and viral vaccines; 4) ear tagged; and 5) accompanied by their 'processing records'. Schwartzkopf-Genswein et al. (2007) found that in the feedlot receiving period (30 days), dry matter intake (DMI) was higher for calves that were preconditioned prior to transport versus calves transported directly after weaning.

Vaccination either as part of a preconditioning program or upon arrival at the feedlot decreases the incidence of BRD (Griffin, 2010). A study on calves at Ontario feedlots found that vaccinated and conditioned calves were less likely to receive treatment for BRD during the first 28 days in the feedlot (Macartney et al., 2003). Another study examined the role of vaccination in precondition programs and found that serum antibodies to certain pathogens detected at entry to the feedlot were related to morbidity at the feedlot in the 417 cattle from 24 herds (Fulton et al., 2002). A review of BRD preventive measures concluded that timing of vaccinations is critical to vaccination success and that it should be done three weeks or more prior to transport (Taylor et al., 2010b). This evidence shows that preconditioning calves before arrival at the feedlot decreases the incidence of BRD and preconditioning should include vaccination, dehorning, castration, and weaning followed by an approximate 45 day interval before transport to the feedlot.

Metaphylaxis is the timely mass medication of a group of animals to minimize expected disease outbreak (Edwards, 2010). Typically, metaphylaxis is only used in the receiving protocols for calves that are categorized as high risk for BRD. Veterinary reviews of the evidence for metaphylaxis of cattle on arrival at the feedlot with injectable, long-acting antibiotics have found that it decreases morbidity due to BRD (Nickell & White, 2010; Taylor et al. 2010b). For example, one study (three trials, n= 150, 150 and 148 calves) of metaphylactic injectable antibiotics administered upon calves' arrival at the feedlot decreased the incidence of morbidity by 43% (animals exhibiting nasal discharge, coughing, and depression were considered morbid) (Daniels et al., 2000). In another study, groups of calves that received antimicrobial injections upon arrival at the feedlot were less likely (0.64 times as likely) to be treated for BRD than groups that did not (Macartney et al., 2003).

Similarly, meta-analyses have found that metaphylaxis decreases morbidity due to BRD (Van Donkersgoed, 1992; Wellman & O'Connor, 2007; Wileman et al., 2009). For example, a meta-analysis of the effects of metaphylaxis with any antimicrobial upon arrival at the feedlot found the morbidity rate was 29% compared with 55% for untreated animals (Wileman et al., 2009). The timing of treatment (before or after shipment) may not be critical. One study found that pre-shipping antibiotic (Tilmicosin phosphate) administration programs are not more effective at decreasing the incidence of BRD than medication upon arrival at the feedlot (Duff et al., 2000). There is some evidence to support the addition of antibiotics to the feed as a method of administering antimicrobials, but it is not conclusive (Van Donkersgoed, 1992).

Management practices at the feedlot contribute to the control of BRD; in particular, early identification and removal of sick animals helps control the spread of the disease (Griffin, 2010). For example, a study on the calf records of a US feedlot concluded that BRD can be controlled by decreasing pathogen transmission between animals with management practices such as removing affected animals from pens and avoiding crowding (Snowder et al., 2006).

Manipulation of the nutritional content of receiving diets does not decrease morbidity due to BRD (Duff & Gaylean, 2007; Taylor et al., 2010b). In one study, no significant differences in morbidity related to varying levels of concentrate were found (Fluharty & Loerch, 1996). Similarly, another study found a lower percentage of BRD pathogens in nasal swabs of calves fed a high energy diet compared to those fed a lower energy ration, but no significant association between diet and BRD morbidity (Berry et al., 2004).

Research regarding the effectiveness of other BRD-prevention management practices is inconclusive. For example, the use of "trainer animals" to decrease stress in newly arrived calves has had mixed results. Loerch and Fluharty (2000) found that trainer steers had a significant effect on eating behaviour of newly received calves, but health and performance benefits were variable. Gibb et al. (2000) found trainer cows did not improve calf health, time spent at the feed bunk, or performance of newly received calves. Some studies have suggested that behavioural observations may assist in detecting animals with BRD, for example, observations of feeding bouts (Sowell et al., 1999). However, a study on drinking and feeding behaviour of newly received feedlot cattle found that drinking and feeding behaviour is highly variable between individuals (Buhman et al., 2000).

Future research: Preconditioning programs limit morbidity and mortality from BRD however, due to the industry structure and cost recovery (issues unrelated to the efficacy of preconditioning), they are not widely used. Therefore, research to examine how the barriers to implementation may be overcome would be useful. In addition, further research to determine the optimal timing for preconditioning procedures, to define which preconditioning components are most important and to examine the synergism between multiple stressors will provide information to develop cost-effective programs that benefit all segments of the beef industry. This will encourage industry acceptance and promote change. Research is also needed to improve methods of early detection of sick cattle so that timely treatment can minimize the effects of the disease and to clarify the role of pain in BRD and whether pain medication is needed.

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LAMENESS

Conclusions:

1. **Lameness results in pain and reduces the ability of cattle to access feed and water.**

2. **The main causes of lameness in feedlot cattle are foot rot, toe tip necrosis, laminitis, injuries and infectious arthritis.**

3. **An increased incidence of infectious lameness is associated with pen conditions that affect skin integrity, in particular wet or muddy conditions. An increased incidence of foot rot has also been associated with extremely dry pasture conditions.**

4. **An important cause of infectious arthritis is the bacterium *Mycoplasma bovis* which is also associated with bovine respiratory disease (BRD). Therefore, BRD preventative measures also contribute to the prevention of lameness.**

5. **Proper facility design can help to prevent some forms of lameness and physical injuries. Low stress handling that minimizes slips and falls reduces lameness cases caused by physical injuries.**

Lameness has a significant effect on the welfare of cattle because it results in pain and reduces the ability of cattle to move and therefore to access feed and water. The main causes of lameness in feedlot cattle are: foot rot, toe tip necrosis, laminitis, injuries and infectious arthritis. This section will review foot rot, toe tip necrosis, injuries and infectious arthritis due to *Mycoplasma bovis*. Laminitis is discussed later in this report in the section on *Nutritional Diseases Associated with High Concentrate Feeding* (see below).

In the United States (US) lameness accounted for 16% of all feedlot health problems in surveys of Kansas and Oklahoma feedlots (Griffin et al., 1993). The US National Market Cow and Bull Beef Quality Audit-1999 reported that lameness was observed in slaughterhouse holding pens in 31.4% of the cattle audited (n=3,969) (Roeber et al., 2001). This included 14.5% of cattle with elongated and/or cracked hooves or minor arthritis; 2.7% with structural incorrectness or foot rot; 13.4% were stifled, arthritic, and/or had a broken leg; and 0.8% were disabled or non-ambulatory. Data on the prevalence of lameness in Canadian feedlots is not available and there has been no recent data published in the US.

Foot rot: Foot rot (pododermatitis, interdigital necrobacillosis) refers to infection and inflammation of the interdigital tissue of the toes, the coronary bands, and heels (Stokka et al., 2001). The main causative bacteria are *Fusobacterium necrophorum* and *Bacteroides melaninogenicus* (Tibbetts et al., 2006).

Toe tip necrosis: Toe tip necrosis is characterized by necrosis of the distal part of the third phalanx (P3) bone in the foot, typically of the hind limb. It is hypothesized to be caused by trauma.

Injuries: Injuries, for example, sprains and fractures (musculoskeletal) and lacerations, are a common cause of feedlot lameness. These can often result from being ridden by other steers as is seen in the buller steer syndrome (Stokka et al., 2001).

Infectious arthritis due to Mycoplasma bovis: Infections of the joint with bacteria from the group called 'mycoplasmas' result in arthritis with associated lameness. *Mycoplasma bovis* is the most pathogenic of these and the species most associated with joint infections (Stokka et al., 2001). *Mycoplasma bovis* is also a cause of bovine respiratory disease (BRD) and animals that are lame from arthritis are also often sick from BRD (Caswell et al., 2010).

Risk factors*:* Increased incidence of infectious lameness is associated with pen conditions that affect skin integrity, in particular wet or muddy conditions (Bergsten, 1997). An increased incidence of foot rot has also been associated with extremely dry pasture conditions (Bergsten, 1997)**.** Compromise of the interdigital epithelial barrier (i.e. skin and claws) by rough or sharp objects such as rocks, frozen pen surfaces and chronic exposure to moisture are risk factors for foot rot (Stokka et al., 2001). A study on the records of 7,100 steers found 469 were diagnosed with a single foot rot incident and found that foot rot occurred more in "growing" and "finishing" than in "starter" phases of feedlot operations. In addition, steers diagnosed with foot rot gained weight more slowly and needed more days on feed to reach slaughter weight (Tibbetts et al., 2006).

Stokka and coworkers' (2001) review of feedlot lameness concluded that facility design flaws, slick surfaces that cause animals to slip, and protruding objects that have sharp edges all contribute to physical injuries. Human handling can also affect whether cattle slip and fall and is a risk factor for lameness due to physical injuries (Grandin, 1988; Stokka et al., 2001). In addition, the buller steer syndrome is associated with lameness-related injuries (Stokka et al., 2001; Taylor et al., 1997).

There is limited comprehensive research on beef cattle lameness in feedlots with concrete or slatted floors. However, claw health appears better for beef cattle kept in straw yards or deep litter rather than on slatted floors (e.g. Murphy et al., 1987; Tessitore et al., 2009). Somers et al. (2003) observed a greater number of claw disorders in dairy cattle housed on concrete and slatted floors when compared to dairy cattle housed in a straw yard, with no difference in number of claw disorders found between concrete and slatted floors, so it is possible that the same increase in lameness for beef cattle kept on concrete may occur.

Lameness due to infectious arthritis is often preceded by a "significant amount of BRD in calves" (Stokka et al., 2001). A study on the correlation between sickness and buller steer syndrome in a Western Canadian feedlot found that buller steers were significantly more likely to get sick and die than other steers (Taylor et al., 1997). Lameness may also be a risk factor to becoming a buller steer, but additional research is required on this topic.

Prevention and control: Pen management, landscaping and drainage are important for creating optimal pen conditions to prevent foot rot. This includes pen cleaning, removal of sharp objects such as rocks, use of materials that promote drainage, and building mounds of soil for cattle to stand and lie on (Stokka et al., 2001). A *Fusobacterium necrophorum v*accine trial in Western Canada (conducted without co-administration of antibiotics) found the effect of the vaccine was moderated by diet; the vaccine lowered the incidence of foot rot when a higher forage diet was fed ad libitum in the backgrounding period (Checkley et al., 2005). The vaccine had no effect on the incidence of foot rot when cattle were provided with a limit-fed grain diet during the backgrounding period (Checkley et al., 2005). Lameness caused by infectious arthritis may be reduced by measures taken to prevent BRD (Taylor et al., 1997).

Lameness due to physical injuries can be prevented by good handling practices and facility design. These include immediate removal of animals with buller injuries from the pen and the use of 'buller cages' (protected areas within pens) to prevent animals from being excessively ridden by one another (Stokka et al., 2001).

Stress-indicating behavioural responses and physical injuries are also more prevalent in cattle that have had negative handling experiences (Breuer et al., 2003; Hemsworth et al., 2000; Lensink et al., 2001). Regular gentle handling counteracts some of these undesirable effects (Hemsworth et al., 2002; Lensink et al., 2000a, b). Therefore, training stockpersons in low stress handling may reduce lameness.

Future research: Research is needed to more fully understand the risk factors, prevalence, characteristics, and management of lameness in Canadian feedlots. More research is also needed to understand the cause of toe tip necrosis. In addition, research into the frequency of pen cleaning required to prevent foot rot as well as economic analysis of the benefits of pen cleaning is needed.

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NUTRITIONAL DISEASES ASSOCIATED WITH HIGH CONCENTRATE FEEDING

Conclusions:

1. **Nutritional diseases can have a range of negative effects on normal behaviour and welfare. As they progress, they can lead to chronic debilitating conditions or death. The control and treatment of nutritional diseases is necessary to ensure beef cattle welfare.**
2. **Forage of effective particle length in the diet reduces the risk of sub-acute and acute ruminal acidosis.**
3. **Acidosis in the feedlot is most likely to occur during transition from a forage-based diet to a grain-based (high concentrate) diet.**
4. **Gradual shifts from high forage to high concentrate diets allow for healthy populations of ruminal microbes to develop and for the ruminal epithelium to adapt; generally it takes 3 to 4 weeks to adapt to high concentrate diets.**
5. **Feeding ionophores, such as monensin, minimizes sub-acute acidosis.**
6. **Antibiotics in the feed decreases the incidence of liver abscesses.**

Nutritional diseases associated with high concentrate feeding include acidosis, liver abscesses and laminitis. In most cases acidosis is the predisposing factor with liver abscesses and laminitis occurring secondary to acidosis (Gaylean & Rivera, 2003; Nagaraja & Lechtenberg, 2007b; Nocek, 1997). Acidosis occurs when the rate of acid production in the rumen exceeds the rate for acid removal, resulting in low ruminal pH (Owens et al., 1998; Penner et al., 2009). Two forms of acidosis have been identified in the literature: clinical, or acute, acidosis is often defined to occur when the pH drops below 5.0 and sub-clinical acidosis or sub-acute ruminal acidosis (SARA) is often defined to occur in feedlot cattle when ruminal pH is less than 5.8 for greater than 12 hours per day (Schwartzkopf-Genswein et al., 2003).

Acidosis is the result of a complex interaction among meal patterns and quantity, diet fermentability, ruminal microorganisms and mechanisms of acid removal by the animal (Schwartzkopf-Genswein et al., 2003). Acute acidosis causes overt illness and is potentially fatal in cattle, while animals with SARA may not appear sick but have reduced or variable feed intake and weight gain (Owens et al., 1998). Rumenitis is a common consequence of SARA commencing with parakeratosis (thickening of the stratum corneum of the rumen mucosa) which occurs as a consequence of increased lactate production causing mucosal lesions that serve as an entry point for bacteria. Embolic spread to the liver results in liver abscesses (Nagaraja & Lechtenberg, 2007b) and lameness in cattle due to laminitis and associated hoof lesions (Cook et al., 2004; Nordlund et al., 2004). In addition to the more immediate negative welfare implications of the illness itself on the welfare of individual animals (e.g., feeling sick, feeling in pain), associated changes in behaviour such as reduced feed or water intake may also lead to other negative consequences such as the animal subsequently feeling hungry (Aubert, 1999; González et al., 2012; Hart, 1988; Johnson, 2002; Millman, 2007).

Laminitis is a generic term that refers to inflammation of the connective tissue (corium) located between the pedal bone and hoof horn. This can lead to white line hemorrhages, sole ulcers and formation of ridges on the hoof wall (Hendry et al., 1997). The proposed link between acidosis and laminitis is that acidosis causes damage to the surface of the rumen wall that allows bacteria and bacterial toxins to enter the portal circulation (Gozho et al., 2005; Nocek, 1997) which can result the inflammation of the corium. It should be noted that acidosis does not always result in cattle laminitis (Donovan et al., 2004; Momcilovic et al., 2000) and other factors such as environment appear to alter the susceptibility of cattle to acidosis induced laminitis (Cook et al., 2004).

Data describing the prevalence of acidosis is not available, however the prevalence of liver abscesses in feedlots ranges from 12-32% (Nagaraja & Lechtenberg, 2007a). In a Canadian beef quality audit, 14% of livers were condemned and approximately 64% of the liver losses were due to abscesses (Van Donkersgoed et al., 2001). A United States (US) audit found the incidence of liver condemnation was 24.7% with 54.2% of these due to abscesses (Garcia et al., 2008).

Risk factors: The main risk factors for acidosis are: the amounts and fermentability of concentrate and fibre in the diet; the level of feed intake; the length of time to adapt to high concentrate feeding; feeding behaviour of the animals and; ability of the animals to cope with high levels of acid production. The proportions of concentrate and fibre in the diet influence rumen pH. High levels of concentrate (i.e. fermentable carbohydrates) can lead to prolonged periods of lowered rumen pH (Fulton et al., 1979). It also increases the production of volatile fatty acids (VFAs). Increasing the concentrate content of diets reduces chewing, saliva production, and rumen buffering, and combined with the increase in VFA production, reduces rumen pH (Goad et al., 1998). The rate and extent of ruminal digestion of various concentrates depends on particle size, moisture content, storage, and processing (grinding, steam-flaking, or chemical treatment) and these factors can all have a major influence on ruminal degradability and availability (Theurer, 1986). Particle length of forage especially affects digestion. For example, increasing particle length increases time spent ruminating and chewing (Campbell et al., 1992; Yang & Beauchemin, 2006, 2007) and rumen pH increases with increased particle length (Yang & Beauchemin, 2007).

The length of time allotted for newly received feedlot cattle to adapt to high concentrate feeding is critical. Both sub-clinical and clinical acidosis can be induced by abrupt diet changes from a diet containing a low proportion of concentrate to one containing a high proportion of concentrate (Bevans et al., 2005; Nagaraja & Titgemeyer, 2007; Owens et al., 1998; Schwartzkopf-Genswein et al., 2003).

Feeding behaviour has also been associated with acidosis. When rumen pH is low, cattle generally eat less (Schwartzkopf-Genswein et al., 2003). Feed intake has a large effect on rumen ecology during the transition from a forage-based to grain-based diet as occurs at the feedlot (Schwartzkopf-Genswein et al., 2003). However, animals show individual differences in their susceptibility to developing acidosis due to the stability of their microbe population, their feed preference and selectivity at the bunk and consumption rate (Gibb et al., 1998; González et al., 2012; Schwartzkopf-Genswein et al., 2003, 2011).

There are additional risk factors for acidosis including the development of hindgut acidosis (Gressley et al., 2011) and non-dietary physiological factors such as capacity for fermentation acid absorption, epithelial molecular level adaptation and epithelial proliferation (Penner et al., 2011). These are areas for future research.

Prevention and control: Feeding adequate amounts of fibre in the diet reduces the risk of cattle developing acidosis (Nagaraja & Lechtenberg, 2007a). Fibre dilutes the fermentability of the diet, increases cattle salivary secretion and increases ruminal motility which may help to stabilize ruminal pH (Schwartzkopf-Genswein et al., 2003).

Feeding ionophores such as monensin minimizes subacute acidosis in feedlot cattle by manipulating the ruminal fermentation and feeding behaviour of cattle fed high concentrate diets (González et al., 2012; Nagaraja & Lechtenberg, 2007a). Monensin has been shown to improve feed efficiency (Goodrich et al., 1984; Richardson et al., 1976), reduce feed intake variation (Burrin et al., 1988; Stock et al., 1995) and increase the ruminal pH of cattle fed high concentrate diets (Burrin & Britton, 1986; Nagaraja et al., 1981). Erickson et al. (2003) examined whether dietary monensin concentration altered cattle and ruminal responses to clean bunk management systems (i.e. when all feed delivered to a pen is meant to be consumed daily, with bunks being empty for a period of time prior to the next feeding). They found that meal size, pH change, and pH variance were lower ($P<0.10$) for steers fed monensin with clean bunk management compared to steers fed monensin with ad libitum bunk management, but increasing concentrations above currently approved levels (i.e. greater than 36.7mg/kg) had little additional effect (Erickson et al., 2003). Feed additives including buffers (e.g. sodium bicarbonate, seaweed) and direct fed microbials (e.g. yeast cultures and bacteria [*Enterococcus*, *Lactobacillus*]) may be beneficial in controlling acidosis in cattle however, the effects can be variable (Enemark, 2008).

Feeding strategies can help cattle adapt to high concentrate diets. Microflora require 10 to 14 days to establish in the rumen (Schwartzkopf-Genswein et al., 2003). The time required for cattle to transition to a high concentrate diet without causing them to go “off-feed” is not well defined, but most feedlot nutritionists and experienced cattle feeders allow at least 3 to 4 weeks for adaptation (Vasconcelos & Galyean, 2007). If 14 days or less time are allotted to the transition period it generally results in decreased performance during adaptation or over the entire feeding period compared with longer adaptation periods (Brown et al., 2006).

The dietary transition period is also essential to allow for the adaptation of the ruminal epithelium, thereby increasing the absorptive capacity for VFA and leading to increased secretion of bicarbonate (Penner et al., 2011). Absorption of VFA and secretion of bicarbonate by the ruminal epithelium both contribute to the stabilization of ruminal pH (Aschenbach et al., 2011). Various studies have examined the effect of fluctuations in feed delivery. One study compared the feeding behaviour and performance of feedlot steers (n=234, initial body weight approximately 310kg) fed at a constant or varied feeding time. They found that the risk of subclinical acidosis was increased when feed delivery fluctuated, however growth was not impaired (Schwartzkopf-Genswein et al., 2004). Another study examined the effects of feeding a high concentrate diet once, twice, three and four times per day on four Holstein heifers (body weight approximately 385kg). Feeding a high concentrate diet once daily in noncompetitive social conditions did not cause ruminal acidosis, but feeding twice daily resulted in a smaller range of ruminal pH values (González et al., 2009). In addition, delaying the time of day of feeding (in Holstein beef heifers weighing approximately 134kg) did not increase the risk of ruminal acidosis (González et al., 2009). This was because changes in feeding behaviour that caused pH to increase (more straw eaten, smaller first meal size) and increased stress response due to feed delay as measured by salivary cortisol, resulted in reduced appetite (measured by decreased concentrate intake, increases straw intake, smaller meal size). Therefore available evidence suggests that variation in feeding times does not significantly increase the risk of developing acidosis.

Some studies have shown that cattle can self-select feed components without increasing risk of sub-clinical acidosis. For example, Moya et al. (2011) found that cattle fed barley grain and corn silage separately selected a diet that was similar to conventional total mixed ration with no signs of acidosis. However, this was in an experimental setting and has not yet been demonstrated in a commercial feedlot. In addition, no correlation was found between free choice sodium bicarbonate intake and ruminal pH indicating that cattle did not self-select sodium bicarbonate to help prevent ruminal acidosis (Paton et al., 2006). However, mixing sodium bicarbonate into the ration reduced the number of long bouts of ruminal acidosis, which may decrease the negative consequences of ruminal acidosis on feed digestion (Paton et al., 2006).

A meta-analysis of feeding trials found that feeding an antibiotic decreases the incidence of liver abscesses in feedlot cattle (Wileman et al., 2009). Similarly, Nagaraja and Lechtenberg (2007b) concluded feeding antibiotics decreases the incidence of liver abscesses by 40 to 70% and increases weight gain.

Future research: Research is needed to define the prevalence of acidosis in Canadian feedlots and to further define how ruminal pH influences animal welfare, such as whether acidosis and/or sub-clinical acidosis are painful for cattle. Also needed is continued research to: 1) identify optimal feedlot transition strategies; 2) identify differences in feeding behaviour, ruminal physiology, metabolism and genetics that lead to individual variations in susceptibility to acidosis; and 3) determine which diets produce the best weight gain and carcass with the least digestive upset. Economic analysis to compare the cost of reduced final weight to the cost of nutritional diseases associated with high concentrate feeding (i.e. drug treatment costs and carcass value losses) is also needed.

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3. WEANING METHODS

Conclusions:

1. **The management practice of weaning causes distress to both the cow and the calf as evidenced by behavioural changes and increased morbidity.**
2. **Regardless of the method, calves that are weaned and immediately transported to the feedlot (which exposes calves to stress from transport, mixing, and change of diet) have higher morbidity rates and decreased weight gain, compared to calves weaned and left at home.**
3. **Two-stage weaning (nose-flap) causes less distress to the calf compared to other weaning methods, as evidenced by fewer behavioural changes and improved calf growth.**
4. **A majority of studies have found that weaning cows and calves with fence-line contact causes less distress than weaning by abruptly and remotely separating cows and calves.**

Weaning is the process of eliminating milk from the calf's diet (Weary et al., 2008). Under natural conditions, a cow's milk output is understood to decrease gradually over several months. A study on natural weaning in zebu cattle (*Bos indicus*) found that calves were approximately 7 to 14 months of age when natural weaning occurred (Reinhardt & Reinhardt, 1981). Under conventional beef production, calves are artificially weaned at 6 to 8 months of age (United States Department of Agriculture [USDA], 2008a).

Weaning causes distress to both the cow and the calf. The loss of social contact between cow and calf is distressful for both of them and the loss of milk is additionally distressful for the calf (Enríquez et al., 2011; Weary et al., 2008). Newly weaned calves are also at an increased risk for getting sick, in particular when other stressors are added, for example, transportation and commingling with unfamiliar calves (Edwards, 2010). Research assessing how weaning affects the welfare of calves has used measures of health (i.e. morbidity and mortality) and changes in behaviour that are reflective of the emotional state of the animals (i.e. changes in the amount of vocalizing, time spent feeding, lying and walking).

Weaning methods: Most weaning methods use some form of separation of the cow and calf which terminates nursing. Abrupt weaning is a form of weaning that removes the calf completely from physical and visual contact with the dam. Fence-line weaning is a variation of abrupt weaning where calves are separated from their dams and placed in an adjacent pen or pasture so that auditory and visual contact is maintained. Two-stage weaning is done in two stages. First nursing is prevented by placing a nose-flap on the calf. In the second stage, the nose-flap is removed and the cow and calf are separated. In this method calves are weaned in the presence of their dam during the period when they wear the nose-flap.

Calves can be provided with supplementary concentrate feed (creep-feeding) prior to using any weaning method. In addition, there are some post-weaning management options that may contribute to maintaining the health of the calves, including whether calves are transported and mixed with calves from other farms immediately following weaning, or whether they are kept and preconditioned for a period of time prior to transport to the feedlot (see Table 1). Although data on the proportion of Canadian calves that are weaned and transported immediately is not available, in a survey from 2007, 49.8% of calves in the United States (US) were reported as being transported immediately at the time of separation of the cows and calves (USDA, 2008b).

Table 1: Beef cattle weaning methods and post-weaning management options

Weaning method	Description of weaning procedure	Reference	Options available after pairs separated		
			Keep at home	Transport Immediately	Precondition for sale
Abrupt	Cows and calves are separated; no physical or visual contact possible	Arthington et al. (2008)	✓	✓	✓
Fence-line	Cows and calves are separated by fence; have visual and auditory contact	Price et al. (2003)	**n/a**	**n/a**	✓
Two-stage	Stage One; Calves wear nose-flaps (5-7 days) to prevent nursing. Stage Two; nose flaps removed and cow-calf pairs separated	Haley et al. (2005)	✓	✓	✓

Effects of weaning-and-transporting versus weaning-and-keeping at home: Several studies have assessed the effects of post-weaning management options on abruptly weaned calves. Physiological measurements indicate that calves abruptly weaned kept at home are less stressed. For example, cortisol concentrations measured upon arrival at a Western Canadian feedlot were lower among calves that were abruptly weaned and kept at home for a period of time, compared to calves that were transported to the feedlot the same day they were abruptly weaned (n=174; average 153 days old) (Schwartzkopf-Genswein et al., 2007). One study found that on days 15 and 22 at the feedlot, concentrations of acute phase proteins (a stress marker) were lower in abruptly-and-early-weaned beef calves (age 70 to 90 days) that were kept at home, compared to calves abruptly weaned at age 7 months and transported the same day (Arthington et al., 2008). This effect was likely due to the preconditioning and the additional time calves spent at home prior to transport to the feedlot and was likely not related to the age at weaning. However, no effects of post-weaning management on physiological stress biomarkers were observed when Burke et al. (2009) compared abruptly weaned beef calves to fence-line weaned calves (which by definition had been kept at home post-weaning) (total study animals n=36; 221 days of age).

Growth is also affected by whether calves are kept at home following weaning. During the feedlot receiving period, overall average daily gain (ADG) was significantly greater for abruptly-and-early weaned (age 70 to 90 days) beef calves kept on pasture, compared to calves 7 months of age that were abruptly weaned and transported the same day (Arthington et al., 2008). Average dry matter intake (DMI) was significantly greater for calves kept at home with access to concentrate for 45 to 53 days prior to transporting, compared to creep-fed calves that were transported on the day of abrupt weaning (Arthington et al., 2008).

Keeping calves at home following weaning has been shown to lower feedlot morbidity, possibly because it delays exposure to the multiple stressors they encounter during transportation to the feedlot (i.e. commingling, dust, time off feed and water). One study conducted during the feedlot receiving period (n=280; 175 days-of-age), found only 15% of beef calves that were fence-line weaned and kept on pasture for 30 days were treated for respiratory disease compared with 28% of the calves that were abruptly weaned and transported to the feedlot the very same day (Boyles et al., 2007). Another study also found receiving period (42 days) morbidity was lower for abruptly weaned-and-kept-at-home (45 days) beef calves, compared to calves transported on the day of abrupt weaning (5.9% versus 35% morbidity; 8 months of age at weaning) (Step et al., 2008).

These results have not always been consistent, which suggests farm level management practices may also be important. One study found no differences in morbidity rate between abruptly weaned-and-kept at home calves and abruptly weaned-and-transported same day calves (n=174; animals transported directly from ranch to feedlot), however in this study the retention periods were relatively short (13 and 29 days) compared to other studies that kept calves for a longer period prior to shipping (Schwartzkopf-Genswein et al., 2007). In addition, Boyles et al. (2007) found higher morbidity in the abruptly weaned-and-kept at home for 30 days in a drylot group compared with the abruptly weaned-and-transported same day group (38% versus 28%; all animals transported directly from ranch to feedlot). This suggests that it may be preferable to keep weaned calves on pasture rather than a drylot.

However, the balance of experimental findings combined with epidemiological data show that regardless of method, calves that are weaned and kept at home, and not transported to the feedlot for 30-45 days have less morbidity and greater weight gain than calves weaned and immediately transported.

Effects of abrupt and fence-line weaning on calves: Several studies have assessed behavioural responses to abrupt and fence-line weaning methods. Typically, fewer distress-related behavioural responses have been observed when fence-line weaning is used. One study on beef calves (n=100; average 213 days-of-age) found calves that were fence-line weaned for 7 days vocalized less and spent more time grazing and eating hay in the two weeks following separation, than abruptly weaned calves (Price et al., 2003). Similarly, after separation from their dams, fence-line weaned beef calves spent more time eating and less time with their jaws idle (i.e. not eating and not attempting to suckle other calves) compared to abruptly weaned calves (Boland et al., 2008). Benefits from fence-line weaning in the form of decreased behavioural responses have also been observed in foals (McCall et al., 1985) and elk (Haigh et al., 1997), suggesting the visual presence of the dam during the weaning period may be beneficial for multiple mammalian species.

The only study which contradicts these consistent results compared the behavioural responses of abruptly weaned versus fence-line weaned beef calves (n=48; average 181 days-of-age) and found fence-line calves vocalized more, and played, ruminated and walked less than abruptly weaned calves (Enríquez et al., 2010). The authors concluded that fence-line weaning causes more distress, and upset the animals over a longer time period than abrupt weaning. These results may be different because the duration of the fence-line treatment was 17 days; longer than the 7 days used in previous studies that found behavioural benefits to fence-line weaning (Boland et al., 2008; Price et al., 2003). The majority of studies (across several species) show that fence-line weaning results in fewer behavioural signs of distress for the weaned offspring. However, these results suggest there is still more work to be done to fully understand the factors that influence the response of beef cattle to fence-line weaning.

The effect of abrupt weaning methods on calf growth is less clear. One study showed fence-line weaned beef calves had a 95% greater weight gain in the two weeks following separation than abruptly weaned calves (Price et al., 2003). However, other studies did not find differences in post-separation weight gain between abruptly weaned and fence-line weaned beef calves (Landa, 2011; Boyles et al., 2007). These mixed results suggest that other factors, including the location of weaning (i.e. on pasture or in drylot), may have some impact on post-weaning weight gain.

The effect of using “trainer” adult animals to minimize post-weaning distress has also been evaluated. Loerch and Fluharty (2000) tested the effect of the presence of unfamiliar trainer cows and steers in the pens with newly weaned feedlot beef calves (n=819). They found that in the presence of trainer adult animals, a greater percentage of newly arrived calves started eating from the feedbunk compared to calves without a trainer animal, but health and performance benefits were not consistent. In contrast, another study concluded that the use of trainer cows that were unfamiliar to the calves did not improve health, time spent at the feed bunk, or growth of newly weaned calves (n=1,846) (Gibb et al., 2000). These studies suggest there are no clear benefits to using trainer cows as a way to minimize the distress associated with abrupt weaning and same day transport to the feedlot.

Effects of two-stage weaning on calves: A few studies have evaluated the behavioural and growth responses to two-stage weaning (nose-flaps). One found beef calves (n=190; average 187 days-of-age) weaned using the two-stage method for 3 or 14 days vocalized and walked less when separated from their dams compared to calves weaned abruptly (Haley et al., 2005). However, preventing nursing for the longer duration of time (14 days) had no noticeable beneficial effects on the behaviour response to separation. Therefore a time period of at least 3 days and less than 14 days is preferred (Haley, 2006). Another study found that prior to separation from their dams, beef calves (n=108; average 220 days-of-age; stage one treatment for 7 days) weaned using the two-stage method spent less time eating, and more time with their jaws idle while with their dams (i.e. not eating and not attempting to suckle) compared to abruptly weaned and fence-line weaned calves (Boland et al., 2008). However, after separation from the dam, the two-stage calves spent significantly more time eating and less time idling and walking than abruptly weaned calves. Benefits from two-stage weaning in the form of decreased behavioural responses have also been observed in dairy calves weaned from their dams at 5 weeks of age (Haley, 2006) and dairy calves weaned from foster cows at 10 weeks-of-age (Loberg et al., 2008). Just one study concluded that two-stage weaned beef calves (stage one treatment for 17 days) did not have behavioural advantages over abruptly weaned calves (Enríquez et al., 2010).

Studies show that in the week following separation from their dams, two-stage calves gain more weight than abruptly weaned calves (Haley et al., 2005). This advantage has been maintained over a longer period of time in some trials (6.5 weeks), but this has not been a consistent finding in every trial (Haley et al., 2005). Further investigation and refinement of the two-stage weaning process, perhaps related to feeding, could help more producers maximize the potential benefits to be gained by using two-stage weaning. A graduate thesis by Campistol (2010) also compared the weight changes of two-stage weaned calves using two different cow-calf separation methods. One group of calves were two-staged weaned and then completely separated from their dams while the other group was two-staged weaned and then separated with a fence-line. Although this study has yet to pass the process of peer review, they found that calves given fence-line contact as the second phase of two-stage weaning lost more weight in comparison to two-stage weaned calves that were completely separated from their dam in stage two.

The balance of evidence shows that two-stage weaning causes less behavioural distress to the calf and thus has an important beneficial welfare effect on calves over abrupt separation weaning. However, the effect of different weaning methods on calf growth rate is not consistent.

Effects of weaning on cows: Behavioural responses show that certain conditions can affect the distress cows experience when separated from their calves. For example, dairy cows with visual and auditory contact with their calves vocalized, sniffed, and placed their heads outside the pen more frequently compared to cows without any sensory contact with their calves (Stěhulová et al., 2008). In addition, multiparous beef cows were more responsive to separation from their calf, exhibiting more frequent contact and contact-seeking behaviour than inexperienced heifers (Price et al., 1986; Ungerfeld et al., 2011). One study observed negative changes in physiological and immunological stress response markers of beef cows in the days following abrupt weaning (Lynch et al., 2010).

Some evidence suggests that two-stage weaning decreases cow distress. Haley (2006) observed that beef cows whose calves were weaned by the two-stage method called less, walked less and spent more time eating than cows whose calves were abruptly weaned. Similarly, other research found that foster dairy cows vocalized and walked less, and held their heads out of the pens less frequently with two-stage weaning compared to abrupt weaning (Loberg et al., 2007). In addition, heart rates of the two-stage weaned cows were less variable in the two hours following separation compared to the abrupt weaned cows (Loberg et al., 2007). However, another study found that before separation, cows with two-stage weaned calves spent less time eating and more time idling compared to cows with fence-line weaned calves (Boland et al., 2008). These authors reported that these cows appeared to be “distracted” from grazing by the calves’ suckling attempts.

Research in dairy cows has observed a pronounced behavioural response to drying-off (ending lactation). The reasons for these behaviour changes shown by dairy cows are not clear and some of the behaviour changes may be the result of changes made to the quality and quantity of feed provided at that time and/or pain caused by having a full udder (von Keyserlingk & Weary, 2007). For cows that do not become pregnant, lactation can proceed much longer. It is not known how cessation of lactation affects beef cattle. However, one study found that after two-stage weaning, the body weight of beef calves from low-milk-yield cows increased more than the weight of calves from high-milk-yield cows, suggesting milk production may have some influence of the “ease of weaning” and post weaning growth (Hötzel et al., 2010). The behavioural responses between these two groups of calves did not differ.

Future research: Research is needed to determine the effect of weaning strategies on calf health, in particular the influence of weaning method on the incidence of bovine respiratory disease (BRD) at the feedlot, and the effect of different weaning strategies on calf growth rate. New techniques in assessing cognitive and emotional responses to management procedures may help improve our understanding of animal welfare in relation to weaning. Research is also needed to clarify the interaction of weaning method on cow health and welfare, including: 1) reproductive health; 2) udder health (e.g. development of mastitis); and 3) the effect of parity and annual distress from weaning, on cow welfare.

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4. ENVIRONMENTAL & HOUSING CONDITIONS FOR BEEF CATTLE

INTRODUCTION

This section reports on environmental and housing conditions for beef cattle on cow-calf operations and in feedlots. As of January 1, 2011 there were 67,300 cow-calf operations, 11,525 cow-calf backgrounding operations and 2,775 feeding operations in Canada (Statistics Canada, 2011). In cow-calf operations the animals are typically housed outdoors on rangeland; shelter may either be manmade or naturally occurring, such as stands of trees and/or shrubs. Feedlot cattle may either be housed on dirt, in open outdoor pens, particularly in Western Canada, or inside in covered barns on concrete or slatted floors in Eastern Canada.

About half of the scientific literature relevant to environmental and housing effects on beef cattle welfare has been conducted on dairy cattle and/or under dairy management conditions. This distinction is important when evaluating research findings for two reasons. First, beef and dairy cattle differ genetically, phenotypically (i.e. hair coat cover) and behaviourally, plus the handling and management systems for beef production are markedly different from dairy production. In addition, the effects of weather on cattle have been shown to vary with breed (Gaughan et al., 2010; Schwartzkopf-Genswein et al., 2003). These differences mean that care is required in interpreting how specific research findings in dairy cattle relate to beef cattle. However, comparisons are useful to assist in identifying gaps in scientific knowledge and future research needs for beef cattle.

MUD—EFFECT ON HEALTH AND WELFARE

Conclusions:

1. **Excessive mud is a risk factor for lameness, injury and hoof-related disease, such as foot rot, resulting in pain and decreased performance.**

2. **Mud build-up on the hide causes an increase in heat loss, which has a negative effect on an animal trying to keep warm in cold weather.**

3. **Muddy pen conditions that cause difficulty walking decrease weight gain and lying time.**

4. **Pen designs that slope and ensure drainage away from feeding and bedded areas help control mud.**

5. **Pen designs that include earthen and/or bedded mounds provide a place for cattle to lie down away from mud.**

Muddy conditions at the feedlot are a concern for cattle health and welfare. The 1998-1999 Canadian Beef Quality Audit found that 43% of beef cattle had mud or manure on the hide at time of slaughter (Van Donkersgoed et al., 2001). Similarly, the 2005 United States (US) National Beef Quality Audit found that just 25.8% of animals had no mud or manure on their bodies at slaughter. The remaining animals had mud or manure on legs (61.4%), belly (55.9%), side (22.6%), and top-line (10.0%) (Garcia et al., 2008).

In outdoor feedlots, muddy pen conditions can cause lameness and injury because mud creates slippery conditions. Muddy pens also increase occurrence of foot rot as chronic exposure to moisture compromises the interdigital epithelial barrier (i.e. skin and claws) (Stokka et al., 2001). Mud makes locomotion more difficult (Degen & Young, 1993). One study found that cattle spend more energy when walking in muddy conditions compared with walking on smooth ground (1.03 versus 0.80J/m/kg) (Dijkman & Lawrence, 1997).

Mud may also act as a medium for heat loss, since wet hair decreases the effectiveness of insulation leading to a higher metabolic rate. Degen and Young (1993) studied the rate of metabolic heat production of cold-adapted beef steers (n=4; age 5 years) under simulated mud and rain conditions. To simulate mud, the effect of standing in water at two different air temperatures was measured. To simulate mud-and-rain conditions they measured the effect of cattle standing in water and being sprayed with water at two different air temperatures. At 0°C air temperature, steers standing in 50cm of water had a higher rate of heat production than steers standing in 0cm of water (443 and 373kJ/kg per day respectively). The study also found that steers standing in 50cm of water and sprayed by water increased their rate of heat production by 39 to 56% compared to control steers (standing in 0cm of water) and steers standing in 50cm of water without water spraying. Although growth was not measured in this study, the diversion of energy to maintain body temperature would result in less energy being available for growth.

Another study found that the weight gain of feedlot steers decreased by 35% and that feed intake per pound of gain was increased by 25% when animals were housed under muddy conditions compared to a concrete pen (winter and spring in Davis, California; no temperature data provided) (Morrison et al., 1970). No difference was found between physiological measures, immune competence and adrenal efficiency of beef cattle in two feedlot treatments (dry, firm pen surface versus wet, muddy pen surface; New South Wales, Australia; n=42) (Wilson et al., 2002).

Mud in outdoor, unpaved feedlot areas can be decreased by pen designs with drainage features, for example, a 4 to 8% slope away from feeding and bedded areas (British Columbia Ministry of Agriculture, Food and Fisheries, 2002). Pen designs that include earthen and/or bedded mounds provide a place for cattle to lie down away from mud and supplying bedding provides animals with a place to lie down away from any mud (Mader, 2003). There is evidence to suggest that cattle lying behaviour is affected by mud. A study on dairy cattle housed in outdoor yards found cattle spent less time lying when the ground was muddy compared to a wood-chipped yard and a concrete yard (Fisher et al., 2003).

Mud by itself is not an issue for beef cattle housed indoors. However when mixed with manure, final mud scores (a subjective evaluation of the amount of soil and manure adhering to the hair coat of the animals) were found to be greater for steers housed in an outdoor open-lot system compared with those from an indoor hoop-barn system (Honeyman et al., 2010).

Future research: Research to date is limited. Therefore a wide range of questions examining the relationship between mud and cattle welfare are required. This includes research to define what conditions constitute excessive mud and to clearly describe the effect of excessive mud on cattle health and welfare.

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EXTREME WEATHER CONDITIONS—COLD

Conclusions:

1. **Cold weather increases the amount of energy required for growth, maintenance and to maintain body temperature in cattle housed outdoors.**

2. **Cattle will use available shelters (man-made or natural) and derive a welfare benefit from using shelters to thermoregulate and moderate effects of precipitation and wind.**

3. **Cattle housed outdoors are able to acclimate to colder conditions as the winter season advances, but will have increasing energy demands as temperatures drop.**

4. **Wet, newborn calves have less ability to tolerate cold than an animal that is dry and older. Providing shelter at calving in winter decreases newborn calf mortality**.

5. **When water sources are frozen, pastured cattle may use clean, powdery snow that can be easily taken in with the tongue as a water source without negative effects on health. However, the effects on behaviour and welfare have not been studied.**

6. **Cattle housed outdoors and indoors in winter prefer to lie on bedded areas.**

Cold weather increases the amount of energy cattle require for growth, maintenance and to maintain body temperature (Delfino & Mathison, 1991; Webster, 1970). Cold climatic conditions during winter months can diminish cattle welfare and even cause death (Mader, 2003). Calving in extreme cold can lead to hypothermia in newborn calves. For example, a study on calf mortality at 73 Colorado cow-calf operations found that 12.2% of newborn calf deaths were due to hypothermia (Wittum et al., 1993).

Pastured cattle: Beef cows in Canada are sometimes kept on pasture for periods during the winter and may or may not have access to protection from elements (wind, precipitation). When protection, or shelter, is available it can be provided by either natural or man-made structures. Windbreak designs with 15 to 30% porosity (amount of open spaces) cause snow to build-up in shallow drifts (rather than deep drifts) providing greater protection from wind and snow compared to solid windbreaks or those with higher porosity (Brandle, 2004; Curtis, 1983).

The rate of intake of pastured beef cows is minimally affected by winter temperatures and wind but is decreased by precipitation. For beef cows, the biggest welfare problem is not the acute sensation of cold but the chronic consequences of failure to maintain energy balance (i.e. progressive starvation). For this reason it is important to monitor cows on poor quality feed during cold weather and supplement their diet with additional grain or good quality forage (Alberta Agriculture and Rural Development, 2008). Several studies in Montana, United States (US) have found that the grazing behaviour of pastured beef cows in winter is unaltered by colder temperatures (range of 8 to -26°C) (Beverlin et al., 1989; Dunn et al., 1988; Prescott et al., 1994) or wind velocity (Olson & Wallender, 2002). For example, a study that measured daily grazing time found cattle maintained consistent total grazing time despite fluctuating daily temperatures (Dunn et al., 1988). Another study found daily time spent grazing decreased with changes in ambient or wind-chill temperature but the magnitude of response was small (<0.01

hour per day per °C deviation) (Beverlin et al., 1989). However, a study on the influence of winter weather in Sweden on pastured beef cows found that during winter precipitation (rain, hail, snow) cows were found to feed 25% less than when there was no precipitation (Graunke et al., 2011).

Windbreak shelters alter how cattle use a pasture although the evidence suggests that it may not affect their physiology. One study on the physiological responses of Montana beef cows to a windbreak shelter during cold conditions (temperature range -8°C to 7°C over two winters) found no difference in body condition scores (BCS) and cell-mediated immune responses between cows with a windbreak and cows without one when measured at the end of each winter (Olson et al., 2000).

Houseal and Olson (1995) observed that pastured beef cows in Montana selected microclimates (with natural shelter from forest trees, land formation, hills) with temperatures above the Lower Critical Temperature (LCT) of -23°C for grazing and resting. The animals remained in these areas when the temperature in other pasture microclimates stayed below the LCT. These authors concluded that the availability of the higher temperature microclimates may allow cattle to continue grazing for longer. In contrast, variation in wind chill temperatures, a measure combining temperature, wind speed and solar radiation, were not found to have a significant impact on the use of sheltered areas by beef cows (Graunke et al., 2011).

Shelter use is influenced by winter precipitation (rain, hail, snow). Beef cows were 2.7 times more likely to seek shelter in a forest compared to periods with dry weather and spent 25% less time lying during precipitation compared to no precipitation (Graunke et al., 2011).

Tolerance to cold is age dependent and very young calves (especially wet, newborn calves) have much less ability to tolerate cold than an animal that is dried off and older (Carstens, 1994). Therefore, one cause of hypothermia in healthy, newborn calves is exposure to extreme cold at calving (Carstens, 1994; Mellor & Stafford, 2004). Healthy newborns may become hypothermic within 15 to 30 minutes of birth and die within hours if the intensity of the cold causes excessive heat loss (Carstens, 1994; Mellor & Stafford, 2004). Providing shelter can greatly decrease newborn calf mortality when calving in winter months. For example, a study in Ontario of the effect of providing shelter for shorthorn cows at calving and for 7 days post-calving found calf mortality decreased from 50% to 8%, compared with calves born in an open lot (Jordan et al., 1969). Following the newborn period, the dry hair coat of 2 week old calves provides 65% to 75% of total thermal insulation and the effect of access to shelter becomes less significant (Carstens, 1994).

These studies show that access to windbreak shelters alters aspects of pastured cattle behaviour, suggesting that cattle derive a welfare benefit by using available shelters to thermoregulate and moderate the effects of precipitation and wind.

During periods of extreme cold when water sources are frozen, pastured cattle may use loose snow as a water source without negative effects on health including loss of body condition or subcutaneous fat; changes in metabolic heat production; or calf birth and weaning weights of their calves (Degen & Young, 1990; Young & Degen, 1991).

However, in both studies a delay between the time the cows were first denied water and when they began to consume snow was observed (although duration of delay was not reported) (Degen & Young, 1990; Young & Degen, 1991). An earlier study found that free-ranging beef cows began to eat snow within 2 days after water was denied (Young & Degen, 1980). Cattle also demonstrated preferences for type of snow. Clean, powdery snow that could be easily taken in with the tongue was preferred while trampled, wind-blown or crusty snow was avoided (Young & Degen, 1980, 1991).

Outdoor feedlots**:** Cattle kept outdoors appear to acclimate to cold weather as winter advances. A study on feedlot cattle in Alberta found that as the winter progressed, the maximum temperature at which shivering (muscle trembling while the animal was otherwise standing quietly) was observed changed from -9°C in November to -25°C in January, and shivering was not observed at -30°C in March (Gonyou et al., 1979). In addition, greater numbers of cattle were observed shivering in September than in December and these authors concluded that shivering is affected by acclimatization (Gonyou et al., 1979).

The time needed for core body temperature habituation to cold temperatures depends on the duration of daily cold exposure and shorter periods of cold exposure do not result in acclimatization. For example, one study found that heat production in beef cattle did not increase following 21 days of 16 hours/day of exposure to moderate (-6°C) and cold conditions (-15°C) (Bergen et al., 2001). Another found that the metabolic heat production of cattle did not increase following two durations of exposure to -20°C temperature for either 5 or 10 hours (Kennedy et al., 2005).

Interestingly, another Alberta study found that feedlot bulls modified their body orientation to stand perpendicular to the sun, increasing their exposure to solar radiation, on cold sunny days compared to warm cloudy days (53% and 31% respectively) (Gonyou & Stricklin, 1981). These authors concluded that feedlot designs that provide adequate southern exposure to the sun during winter will allow cattle to maximize the use of solar radiation to thermoregulate.

Shelters can be used to protect feedlot cattle from the combined effects of low temperatures (≤-20°C) and strong wind (>10 metres per second) (Brandle et al., 2004). The National Animal Health Monitoring System (NAHMS) 1999 survey of US feedlots found that approximately 83% of small feed lots compared to 43.4% of large feed lots provided wind breaks in at least some pens (United States Department of Agriculture [USDA], 2000) (similar data is not available for Canada).

A study on the effect of providing wind shelters for feedlot cattle in winter found no differences in physiological measures associated with production (Mader et al., 1997). There are no studies assessing welfare benefits of providing shelter for beef cattle in outdoor feedlots in cold weather. However, evidence from studies of dairy cattle in New Zealand suggests that access to shelter provides welfare benefits cattle in outdoor feedlots. For example, one study compared the indoor and outdoor behaviour of "thin" dairy cows (BCS 4 out of 10) and "over-conditioned" dairy cows (BCS 9) (Tucker et al., 2007). It found that cows spent more time standing, particularly with their head down, when outside than when inside, especially the "thin" cows ("thin": 1227 versus 769 minutes/24 hour total standing time; "over-conditioned": 1173 versus 676 minutes/24 hour total standing time) (Tucker et al., 2007). Similarly, another study found that dairy cows in New Zealand spent a greater proportion of time standing in wind-and-rain conditions than when indoors (0.62 versus 0.29 proportion of time) and less time lying down (0.21 versus 0.51) (Webster et al., 2008). This study, which used simulated wind and rain conditions with mean air temperature 3.4°C and windspeed 7.1km/h, also found that outdoor cattle spent slightly less time eating compared to those housed indoors (mean air temperature 4.7°C, no wind) (Webster et al., 2008).

When they did lie, dairy cows housed outdoors were more likely to spend time in lying and standing postures that reduced the amount of surface area exposed to rain and wind compared to when they were kept inside (Tucker et al., 2007). When outside, cows were less likely to lie with their head rested against their flank or on the ground (7% versus 14% of lying time) and more likely to lie with their front legs bent and hind legs touching their body, especially if thin ("thin": 74% versus 20% lying of time; "over-conditioned": 55% versus 15% of lying time). These authors concluded that these body postures were used more by cattle housed outdoors in order to conserve body heat.

Supplying bedding in a feedlot provides animals with a place to lie down away from mud and wet ground and this can improve feed efficiency (Mader, 2003). In a study on housing systems for growing dairy bulls in winter in Finland, straw bedding was provided in a sheltered area. These animals were not observed to lie outside of the bedded area for the month-long behavioural observation period (temperature range approximately 0 to -20°C) (Tuomisto et al., 2009). Therefore, evidence suggests cattle housed outdoors prefer to lie in bedded areas.

Indoor feedlots: When feedlot cattle are housed indoors they do not experience the effects from cold that are seen in outdoor housed cattle. A study conducted during winter in Alberta, Canada found decreased energetic efficiency for steers housed outdoors compared to steers housed indoors (on concrete slats with no bedding) (Delfino & Mathison, 1991). However, when cattle are housed indoors there can be a build-up of excess moisture in the air if ventilation/moisture removal systems are poor (Webster, 1970).

Tuomisto and coworkers (2009), in Finland, looked at the effects of bedding with straw on dairy bulls housed in an un-insulated barn in winter (outdoor temperature range approximately 0 to -20°C). Their animals were observed to only lie on the bedded area of the barn for the month-long behavioural observation period (Tuomisto et al., 2009).

Future research: Research is needed to further assess the welfare benefits of providing shelter and bedding to outdoor housed beef cattle in Canadian production systems. In addition, research is needed to determine: 1) the effect of wide temperature and wind fluctuations on cattle during winter; 2) the relationship between body condition score, energy requirements and cold weather; 3) at what temperature and wind velocity are shelters required; 4) the impact of providing bedding during winter conditions; and 5) the welfare impact of using snow as a water source. Modelling methods and new techniques for assessing emotional responses may be beneficial to better understand how cattle respond to cold.

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EXTREME WEATHER CONDITIONS—HEAT

Conclusions:

1. **Heat is generally more stressful early in the summer season before cattle have acclimated. Cattle on pasture and in outdoor feedlots are able to acclimate to hot conditions as the summer season advances.**

2. **Factors that help predict heat stress in cattle include, temperature-humidity index (THI) and the amount of time of animals have had to acclimate to higher temperatures.**

3. **Handling cattle during periods when the THI is high increases cattle body temperature and the risk of mortality due to heat stress.**

4. **Animal respiration rate (panting) is an indicator of heat stress in cattle.**

5. **Water intake requirements for cattle increase in hot weather.**

6. **Access to shade, especially when ambient temperature and humidity are high, provides behavioural and physiological benefits to cattle housed in feedlots and on pasture, as evidenced by cattle motivation to seek shade, increased lying time and decreased panting.**

7. **Providing a shaded area is more effective at cooling feedlot cattle than misting with water.**

Cattle response to heat stress: Hot climatic conditions during summer months can increase animal heat load, resulting in decreased animal comfort, reduced performance, and sometimes death (Blackshaw & Blackshaw, 1994; Brown-Brandl et al., 2005; Mader, 2003; Nienaber & Hahn, 2007). In summertime, the body temperatures of cattle increase with increases in ambient temperature (Lefcourt & Adams, 1996).

To adapt to thermal challenge, cattle require about 3 to 4 days after the onset of heat challenge to adjust to the greater environmental heat load (Nienaber & Hahn, 2007). This is why cattle deaths usually occur on the third day of a heat wave event. During a heat wave event, one study found that tympanic temperature measurements of feedlot beef cattle mirrored changes in ambient temperatures, indicating that the animals' thermoregulatory processes were unable to maintain a constant temperature (Mader et al., 2010a).

The opportunity for night-time recovery is considered essential to cattle survival during severe heat events because cattle that do not adequately cool down at night are more likely to have higher body temperatures the following day (Nienaber & Hahn, 2007; Mader, 2010a). One study observed peaks in animal body temperatures in the late evening, after ambient temperatures had decreased, suggesting there is a considerable lag time between the peak of daytime temperatures and the relief animals experience after daytime temperatures begin to decline (Lefcourt & Adams, 1996). This means cattle can manage high summer daytime temperatures if there is a cooling off period at night. If night temperatures also remain high (as sometime occurs) then cattle will cool down properly (Lefcourt & Adams, 1996). Supplementation of sodium bicarbonate has been shown to be beneficial in reducing heat stress in lactating dairy cows (Schneider et al., 1984; Sunil Kumar et al., 2011).

During the summer in Canada, beef cattle are housed outdoors on pasture or in feedlots or indoors in feedlots. Much of the scientific literature relevant to cattle heat stress has been conducted in the Southern United States (US) where summer temperatures and humidity are generally higher than in Canada. Therefore, care is required in interpreting the relevance of these research findings to beef cattle in Canadian production systems.

Predictors of heat stress*:* The temperature-humidity index (THI) is calculated from measurements of air temperature and relative humidity to describe the combined impact of temperature and humidity (Nienaber & Hahn, 2007). Different ranges of THI are associated with four levels of livestock heat stress, called the Livestock Weather Safety Index: Normal, less than or equal to 74; Alert, 75-78; Danger, 79-83; and Emergency, greater than or equal to 84 (see Table 2).

The THI is an important factor for predicting thermal stress, but it is not completely predictive of heat stress caused by heat wave events. Heat waves are short term high-intensity hot weather patterns and have caused many cattle deaths in the US (Nienaber & Hahn, 2007). Climatological analysis of heat wave events lasting 3 days with THI greater than or equal to 79 for all hours identified that the most devastating ones occur in early summer, before animals have become acclimatized to high temperatures (Nienaber & Hahn, 2007). Heat waves occurring late summer caused fewer animal deaths. Therefore, early in the summer season even a mild heat wave could be dangerous, while late in the season a strong heat wave would be less dangerous due to acclimatization (Nienaber & Hahn, 2007).

Respiration rate, or panting, is a usual early warning of increasing heat stress in cattle as it increases above baseline when animals are trying to dissipate excess body heat (Brown-Brandl et al., 2005; Nienaber & Hahn, 2007). In a study to determine the environmental variables that corresponded to visual assessments of heat stress in feedlot cattle (i.e. panting), Mader and coworkers (2006) found that knowledge of the THI combined with windspeed and solar radiation measurements allowed for more accurate prediction of animal discomfort. THI measurements have also been related to respiration rate (see Table 2) (Nienaber & Hahn, 2007).

Table 2: Temperature-humidity index (THI) thresholds related to respiration rate (RR)

Threshold	THI	RR, breaths per minute
Normal	<74.0	<90
Alert	>74-<79	90-110
Danger	>79-<84	110-130
Emergency	>84	>130

(Reproduced from Nienaber & Hahn, 2007; assumes windspeed 0 m/s, dry-bulb temperature range 25 to 40°C, relative humidity 30 to 50%)

Although THI is the predominant index used in the beef industry, new indices are being developed that take into account factors such as wind speed, solar radiation and duration of exposure (Mader et al., 2010b; Scharf et al., 2011). However, to date these new indices have not been validated.

Pastured cattle: Pastured cattle make use of shade structures to moderate the effects of heat. A study on the shade-seeking behaviour of pastured beef cow-calf pairs conducted in Ontario found that cows with access to shade spent 18% of their time in the shaded areas (and spent more time in shade when air temperatures and the humidity index were higher) (Widowski, 2001).

Access to shade during the summer months has also been shown to affect the daily water intake of cattle, but not time spent grazing. Cows on pasture in Ontario without shade spent more time at the water trough on hot days than cows with shade but no effect on grazing time was observed (Widowski, 2001).

Outdoor feedlots: There are several management strategies and environmental modifications that can be used to minimize the effect of heat stress on feedlot cattle. Feeding cattle at dusk is a management practice that distributes the metabolic heat load and decreases one factor of heat stress (Nienaber & Hahn, 2007), plus it mimics the natural tendency for cattle to consume their largest meals at dusk. It may also decrease cattle's tendency to move around at dusk and thus generate less dust clouds. Dust, causes increased respiratory problems and may contribute to heat stress. Feeding highly digestible high-energy feed also helps to control body temperature by reducing excess heat (Nienaber & Hahn, 2007). However, a study to assess the effect of feeding the electrolyte $KHCO_3$ found it did not improve heat tolerance in feedlot cattle (Mader, 2010a).

A supply of cool, good quality water is also essential to minimize heat stress (Nienaber & Hahn, 2007). Arias and Mader (2011) found that higher daily mean ambient temperatures, higher daily minimum temperatures and higher THI increased the daily water intake of Nebraska feedlot cattle.

Heat stress can cause cattle to crowd together, possibly to reduce the level of fly annoyance or to stand in shade cast by other animals (Nienaber & Hahn, 2007). However, this behaviour can minimize airflow and decreases conductive and evaporative heat loss. Handling animals during hours of peak body temperature (mid-day to late afternoon) should also be avoided during periods where animals are at risk from heat stress (Nienaber & Hahn, 2007).

Providing shade is one environmental modification used to minimize the effect of extreme heat at feedlots. The National Animal Health Monitoring System (NAHMS) 1999 survey of US feedlots found that a greater percentage of small feedlots (1,000 - 7,999 animals) provided shade in at least some pens compared to large feedlots (>8000 animals) (39.7% compared to 21.6%) (United States Department of Agriculture [USDA], 2000).

For feedlot cattle, access to shade can affect feed intake. A study on Australian feedlot cattle during the summer months (n=126) found that providing shade increased feed efficiency compared to animals without shade (Sullivan et al., 2011). One study (n=186; Texas; Jun-Oct) found feedlot beef cattle kept entirely under shade had higher feed intake compared to unshaded cattle (Mitlöhner et al., 2002). However, another study found that beef cattle housed in outside lots with overhead shelter had similar intake to cattle in outside lots with no shelter (n=188; Iowa; April- October) (Koknaroglu et al., 2008).

Evidence also suggests that providing shade has mixed effects on growth. One study found no differences in final bodyweight (Sullivan et al., 2011). Another found that providing shade increased final body weight after 121 days compared to unshaded cattle (Mitlöhner et al., 2002). A third study on beef cattle in a South African feedlot (average daily temperatures ranged 23.2 to 31.8°C and 46 to 81% relative humidity over 36 days of study) also found shade increased final body weight of shaded cattle by 6kg over the unshaded cattle (Blaine & Nsahlai, 2011). The differences between studies are likely due to differences in the effective heat load that the cattle experienced, with greater THIs resulting in a greater need for shade.

Access to shade also affects cattle respiration rate. In feedlot cattle that were entirely shaded, respiration rate was decreased compared with unshaded cattle (Mitlöhner et al., 2001, 2002). Similarly, the amount of panting observed in cattle with access to shade was less than seen in cattle without access to shade (Sullivan et al., 2011).

Providing shade appears to improve feedlot cattle welfare. Shaded beef cattle appeared to be more comfortable and less restless than unshaded cattle. They spend significantly more time lying down (body contact with ground), less time standing (inactive, upright position), and exhibited less agonistic and bulling behaviours (Mitlöhner et al., 2002).

Sprinkling or misting feedlot cattle with water is also used to modify a hot environment and minimize the effect of extreme heat (Mader 2003). Sprinkling and misting is also used in feedlots for dust control. The NAHMS 1999 survey of US feedlots found that sprinklers or misters to keep cattle cool were provided in at least some pens on 29.3% of small feed lots and 25.4% of large feed lots (USDA, 2000).

Some evidence suggests that misting is not as effective at cooling cattle as shading. Mitlöhner and co-workers (2001) found no significant physiological or behavioural differences between unshaded-and-misted feedlot cattle compared with unshaded-and-unmisted cattle. They also found that shaded cattle had lower respiration rates and greater feed intake than unshaded-and-misted cattle. Another study showed that misting during the nighttime was more effective at cooling feedlot cattle. A comparison of day cooling versus night cooling using sprinklers and fans when ambient temperature was greater than 28°C, found night cooling lowered mean rectal temperature and respiration rate and maintained feed intake (Gaughan et al., 2008).

Misting versus spraying water can have different effects. Mist injected into the airstream to provide evaporative cooling increases humidity but reduces air temperatures. However, to achieve heat loss from animal surfaces, droplets of water must wet the hide (not mist), because it is the drying process that removes heat. Therefore, a mist applied to the animal could accumulate on the hair without wetting and actually reduce heat loss (Nienaber & Hahn, 2007).

A study on using water spray to cool animals during handling of feedlot cattle found that the body temperatures of sprayed heifers peaked sooner with a lower peak temperature than unsprayed heifers (39.55±0.03°C and 39.74±0.03°C) (Brown-Brandl et al., 2010). In addition the sprayed animals, recovered in 70.5 minutes compared to 83.2 minutes for the unsprayed animals. Sprinkling animals and pen surfaces in the mornings (before it gets too hot) is more effective than waiting until the hotter temperatures of afternoon (Davis et al., 2002).

Indoor feedlots: One study evaluated the effect of summertime housing in an open-front feedlot building on the feed intake of beef steers (n=188; Iowa; April to October) (Koknaroglu et al., 2008). Cattle housed in the open-front building had lower intake than cattle housed in outside open lots (with and without shelter). This study also showed that different environmental variables are important when explaining variations in intake between the different housing systems. For indoor feedlots, the temperature and humidity index from the previous days were important factors.

Johnson et al. (2011) compared the behaviour of steers housed in summertime in a deep-bedded hoop barn with those in an open feedlot with shelter (Iowa; August to November; average daily temperature 14.1°C). They found no significant differences in time spent at the bunk and water trough between the two types of housing.

Cattle prefer bedded flooring over concrete. Dairy bulls housed in an uninsulated barn in summer spent 74.9 ± 4.0% of their time in a straw-bedded lying area and 25.1±4.0% in the concrete floored feeding area of the barn (Tuomisto et al., 2008).

Future research: Research is needed to determine the effect of shade on cattle production and health in Canadian production systems. In addition, examination of the potential effects of climate trends and extreme weather events on Canadian cattle production and cattle welfare would be useful.

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