DISSERTATION

DAIRY COW MANAGEMENT AND WELFARE: PRACTICES ON DAIRY OPERATIONS IN THE UNITED STATES THAT MAY IMPACT DAIRY COW WELFARE, LAMENESS, AND BEEF QUALITY ASSURANCE

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ABSTRACT

DAIRY COW MANAGEMENT AND WELFARE: PRACTICES ON DAIRY OPERATIONS IN THE UNITED STATES THAT MAY IMPACT DAIRY COW WELFARE, LAMENESS, AND BEEF QUALITY ASSURANCE

Consumers are becoming increasingly concerned with where their food is coming from, and they are looking for evidence that the animals raised in agriculture are not suffering in the process. Dairy cows are handled very frequently, and therefore animal handling has the potential to greatly impact the welfare of dairy cows. The purpose of this PhD program was to investigate which management practices were in place on dairy operations in the US that may impact dairy cow welfare, lameness, and beef quality assurance.

A large portion of this PhD program included working with USDA’s National Animal Health Monitoring System (NAHMS) Dairy 2014 study, which surveyed dairy operations in the US to gather information concerning the health and management of dairy cattle. A goal of this survey was to describe management practices that are in place on US dairy operations that may impact dairy cow welfare, including a comparison between organic and non-organic operations. The objectives of this portion were to: 1) describe housing and management practices on US dairy operations that impact dairy cow welfare, and 2) identify changes in housing and management practices on US dairy operations that impact dairy cow welfare from the NAHMS 2007 Dairy study to the NAHMS 2014 Dairy study.

The results from this survey highlight different aspects of dairy management that can be modified to improve dairy cow welfare. Expanding educational efforts, aimed at both dairy owners and personnel, can help to ensure that information presented in scientific literature

reaches dairy producers, where it can be applied on the farm. Stressing the benefits of certain management practices on dairy cow welfare, such as installing rubber matting over concrete or having standard operating procedures in place for handling nonambulatory cows, can help to ensure that dairy producers have the knowledge and tools necessary to provide their cows with the best possible care.

The objective of the second part of the NAHMS dairy 2014 study was to determine the association between different housing and management practices and the prevalence of lameness, hock lesions, and thin cows on US dairy operations. The prevalence of lameness and hock lesions in the current study was lower than prevalence levels previously reported. Despite the relatively low prevalence estimates found, many associations were identified between dairy operation characteristics and the prevalence of lameness, hock lesions, and thin cows on US dairy operations. Large dairy operations had fewer lame cows than medium operations. Operations that housed cows on pasture had fewer lame cows than operations that housed cows in freestall or tie-stall barns, and fewer severely lame cows than those that housed cows in open/dry lots or freestall barns. Hock lesions were associated with housing type, with open/dry lots having a lower percentage of cows with hock lesions than the other housing types. Using sand as a bedding material for lactating dairy cows was protective against hock lesions, with the prevalence being lower than on operations that used straw/hay/corn cobs or sawdust/wood products. Additionally, dairy operations that used a nutritionist to balance rations for lactating dairy cows had a fewer thin cows than those where the dairy owner or other personnel balanced rations. The results from this study highlight different management practices on dairy operations that can be implemented to impact the prevalence of lameness, hock lesions, and thin cows on dairy operations in the US.

Lameness in dairy cattle is usually identified by judging the locomotion of dairy cows and assigning a score to the cow based on different characteristics of the animal's gait. There are multiple scoring systems that can be used to score dairy cow locomotion, which differ by the number of categories in each system and the classification of each category. A portion of this PhD program included a study involving dairy industry experts throughout the US and dairy farm personnel in Colorado, investigating reliability and agreement among three different locomotion scoring systems and which system participants preferred to use and why. The objectives of this study were: 1) determine differences in intra- and interrater reliability among three different locomotion scoring systems for dairy cows; and 2) gather information pertaining to user preference among the three locomotion scoring systems.

Results from this study indicate that intra- and interrater reliability and agreement vary among the 3-, 4-, and 5-point locomotion scoring systems, with agreement decreasing and reliability increasing as the number of categories increase. Intra- and interrater reliability and agreement was improved for those who had previous experience with locomotion scoring dairy cows, compared to those that had no experience, highlighting the importance of increased exposure for improving reliability and agreement among the three systems. Participants overwhelmingly preferred the 3-point locomotion scoring system to the other two, although intra- and interrater performance was lower for this system than the other two. Future work, increasing the exposure of those in the dairy industry to the 3-point system should allow this system to be utilized in the industry with improved success.

Beef quality assurance (BQA) and dairy cow welfare are intimately related, with many practices that benefit one also benefiting the other. Implementation of a dairy BQA program has the potential to markedly improve the welfare of dairy cows and quality of carcasses from

market cows. The objectives of this study were to: 1) evaluate the effect of on-farm BQA training on welfare- and BQA-related traits in dairy cows, including locomotion score (LS) and BCS, 2) determine what practices were in place on dairy farms than may impact dairy cow welfare and BQA, and 3) determine if on-farm dairy BQA training has an effect on dairy worker knowledge of BQA and welfare-related practices.

Implementation of an on-farm BQA training has the potential to positively impact dairy cow welfare and BQA practices. Results from this pilot study are encouraging and worth investigating further. Although not significant, a substantial numerical difference was found in the prevalence of lame and severely lame cows between dairies that received training in BQA practices and those that did not. Additionally, improvement in dairy worker knowledge suggests that BQA training programs have the potential to positively influence the dairy industry. Educating dairy owners and employees on proper BQA and welfare-related practices could potentially result in improved handling and management of dairy cows, as well as the quality of cull cows that are being sent to market. Further research, including a larger sample size and follow-up visits to gauge employee knowledge retention and changes in behavior, is needed to investigate the long-term effect of on-farm BQA training on dairy worker knowledge and management practices.

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TABLE OF CONTENTS

CHAPTER I: LITERATURE REVIEW

DAIRY COW WELFARE

Consumers are becoming increasingly concerned with where their food is coming from (Rushen et al., 2008), and they are looking for evidence that the livestock raised in animal agriculture are not suffering in the process. Within the past decade more research studies emphasizing dairy cow welfare have been conducted, with a literature search from 2005-2014 bringing up 72 articles with the term "dairy cow welfare" in the title (Google Scholar, 2015); a substantial increase from the 17 articles found during the preceding 10 years. Not only has dairy cow welfare caught the attention of consumers and researchers alike, it has also been noticed by animal welfare groups, including the Humane Society of the United States (HSUS), and People for the Ethical Treatment of Animals (PETA). The increased attention to welfare, by consumers, researchers, activists and the dairy industry itself has resulted in an increase in dairy cow welfare monitoring and auditing programs in the United States to allow the industry to police itself (USDA, 2015), such as the National Dairy FARM Program (NMPF, 2013).

What is animal welfare?

The term welfare itself seems so simple, yet it is quite complex. The simple dictionary definition of the word is the state of doing well, especially in respect to good fortune, happiness, well-being, or prosperity (Merriam-Webster, 2015). While it may be difficult to relate prosperity and good fortune to animal welfare, the underlying principles still apply. It has been suggested that animal welfare covers three main ethical concerns: 1) animals should lead natural lives, 2) animals should feel well, and 3) animals should function well (Fraser et al., 1997). Additionally, the Five Freedoms of Animal Welfare were designed to protect farm animals from unnecessary suffering and to promote good animal welfare (FAWC, 2009), and address both physical and mental suffering.

<u>The Five Freedoms:</u>

1. Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain health and vigor
2. Freedom from discomfort – by providing a suitable environment including shelter and a comfortable resting place
3. Freedom from pain, injury and disease – by prevention and rapid diagnosis and treatment of disease
4. Freedom to express normal behavior – by providing sufficient space, proper facilities and company of the animal's own kind
5. Freedom from fear and distress – by ensuring conditions which avoid mental suffering

The main concern in animal agriculture is when welfare is compromised as a result of the production practices and systems that are in place in a certain industry. Areas of concern include (Webster, 2001):

1. Hunger or acute metabolic disease – through improper feeding and/or breeding
2. Chronic discomfort – through bad housing, loss of condition etc.
3. Chronic pain or restricted movement – due to distortion of body shape or function
4. Increased disease – through overwhelming exposure to pathogens, pollutants, and/or diminished immunity
5. Chronic anxiety or frustration – through improper housing, stockmanship, or social contact between animals
6. Metabolic of physical exhaustion – due to prolonged, excessive productivity

All of the above recommendations and guidelines are centered on preserving the animal's physical and mental well-being.

There are many different management practices that can impact dairy cow welfare. These practices include: animal handling (Hemsworth et al., 1989, 1995), lameness prevention and management (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012), pain mitigation during surgical procedures (Faulkner and Weary, 2000; Bergman et al., 2014) housing management (Rushen, 2001; Regula et al., 2004), employee training (Waiblinger et al., 2002), culling and mortality (Thomsen and Houe, 2006; McConnell et al., 2008), nonambulatory cow management (Cox et al., 1998; Burton et al., 2009), and euthanasia practices (Thomsen et al., 2004; Shearer, 2008).

Animal Handling

Dairy cows are handled very frequently, and therefore animal handling has the potential to greatly impact the welfare of dairy cows. All lactating cows are milked an average of 2 to 3 times per day (USDA, 2008) and, with the exception of dairies that use robotic milking units, they will interact with their human handlers during each milking. Additional handling opportunities include breeding on dairies that employ artificial insemination, routine herd health checks, and administration of vaccinations and medications (Lindahl et al., 2013). Each of these interactions has the potential to impact dairy cow welfare, either positively or negatively, as a result of how the interaction was carried out by the stockperson and perceived by the animal.

An important factor when working with dairy cows is to understand which interactions are perceived by the animal as negative, and which are perceived as positive. Multiple aversion studies have been conducted investigating dairy cattle's response and preference for different handling methods. When comparing the amount of time and effort required to move cows through a handling facility, cows that were accustomed to being hit or shouted at when they reached the end of the facility took more time and required more force than cows that received food, were brushed, or received no treatment (Pajor et al., 2000). This same study showed that cows that were either shouted at or were shocked when they reached the end of the facility took longer to finish the course and required more force to do so than control cows. Another study by Pajor et al (2003) used a Y-maze to compare dairy cow preferences for different handling methods. After an adaptation period cows were able to learn which direction would result in which handling method, and their preference could be ascertained. Dairy cows preferred gentle talking or no talking over being shouted at, which is to be expected. A surprising find in this study was the lack of preference for cows to be shouted at over being hit, or to be shouted at over being shocked with an electric prod, suggesting that cows perceive being yelled at as negatively as they perceive being hit and shocked. Additionally, the experimenters found that cows showed no preference for being stroked and talked to softly over no interaction, suggesting that while humans may believe cows to enjoy this interaction, cows may not actually perceive it as positive or have a preference for it.

The attitudes of animal handlers, whether it be towards their job or towards dairy cows themselves, can greatly impact their interactions with the animals, and as a result animal welfare. Waiblinger et al. (2002) administered a survey to dairy personnel to gather information pertaining to their general attitude towards milking cows and working with them. Participants were determined to have positive attitudes towards cows if they agreed with statements such as "Cows enjoy being stroked by humans" and "Cows are aware of being talked to," while they were categorized as having negative attitudes towards cows if they agreed with statements such as "Cows are often nervous" and "Cows are difficult to handle." The authors found a positive association between positive attitudes of stockpeople towards cows and multiple positive behaviors when interacting with cows, including patience when moving and milking cows, warning cows prior to attaching milking units, and contact with cows while caring for them. This same study found an association between negative attitudes towards cows and punishing cows while milking them as well as increased use of kicking restraints during milking. A similar study, which utilized a questionnaire to gauge stockperson attitudes towards working with dairy cows (Breuer et al., 2000), showed that the attitudes of stockpeople were correlated with cow avoidance behavior in the milking parlor, with cows expressing an increase in flinching, stepping, and kicking when being milked by people with negative attitudes towards dairy cows. Another study that also used survey results to assess the personality and attitudes of stockpeople (Hanna et al., 2009) determined that people who were more agreeable and conscientious were also more empathetic, patient, content at work and held fewer negative beliefs about cows.

Human attitudes towards dairy cows are usually based on past experiences, and as with behaviors, can be changed through training and intervention. When comparing farms that had received training aimed at improving the attitude and behavior of stockpeople towards cows and farms that had not received training, dairy personnel behaviors were found to differ between treatment groups (Hemsworth et al., 2002). Stockpeople on the farms that had received the training participated in fewer negative and forceful interactions than those on farms that did not receive the training. Additionally, the attitude of dairy cow handlers seemed to be improved as a result of the training, with 69% of personnel reporting an improvement in their attitudes towards handling dairy cows, and 85% stating they experienced improvement in their behavior towards cows. By providing dairy personnel with information and educational opportunities related to the importance of stockperson-dairy cow interactions, an improvement in the behavior of those in charge of handling dairy cows is possible, resulting in improved dairy cow welfare on farms where cows come into contact with humans on a daily basis. Training programs that are designed to increase dairy worker knowledge about the impact of rough handling and stress on milk production can improve the attitudes of stockpeople bringing cows to the parlor and milking the cows. Hemsworth et al (2002) found that milk production was greater on farms that had received training aimed at improving dairy worker behavior towards cows than on farms that did not receive the training. Educational efforts aimed at informing dairy personnel about how their behavior towards dairy cows not only has an effect on the stress and behavior of dairy cows, but on the profitability of the dairy operation as a whole, has the potential to positively impact dairy cow welfare.

Interactions that occur between dairy cows and their handlers can impact dairy cow behavior and productivity. The flight distance or zone is defined as a cow's safety area, and can be determined by the distance between a cow and a slowly approaching person at the moment that the cow moves away from the person (Grandin, 2010). The cow moves away from the person once it begins to feel threatened, and the moment when she starts moving away varies greatly among animals based on previous experience with humans. Hemsworth et al. (2002) found that the type of interaction between cows and stockpeople was correlated with flight distance, with negative interactions being positively correlated with flight distance (increasing negative interactions resulted in increased flight distance) while positive interactions were negatively correlated with flight distance. Cows that experienced negative interactions with their handlers were hesitant to approach the experimenters, while those with positive interactions did not show as much hesitation. Similar results were reported by Munksgaard et al (2001) who found that after repeated exposure the distance between cows and aversive handlers increased while it decreased between cows and gentle handlers. Breuer et al (2000) found that the amount of time that cows are willing to spend within close proximity of handlers (within 3m) is positively correlated with milk yield and milk fat.

Multiple studies have illustrated the impact of rough handling, both when bringing cows to the parlor and during the milking process, on milk production. The handling of cows in the milking parlor has the potential to not only impact the stress that animals feel during the milking, but it can also greatly affect milk production. The process of milk letdown can be greatly affected when cows experience stress, inhibiting oxytocin release, thus resulting in an increase in residual milk and corresponding decrease in production (Bruckmaier et al., 1993; Rushen et al., 2001). In the presence of an aversive handler, dairy cows experienced an increase in residual milk compared to when they were in the presence of a gentle handler or no handler (Rushen et al., 1999). Breuer et al. (2000) examined the relationship between different stockperson behaviors and milk parameters, such as yield, percent protein, and percent fat. Both stockperson behavior and negative tactile interactions when bringing cows into the milking parlor from their home pen were negatively correlated with the production variables yield, protein and fat. Additionally, loud or harsh vocalizations and negative tactile interactions when bringing cows into and out of the parlor were negatively correlated with milk yield.

Pain

There are different surgical procedures that are carried out in the dairy industry that are known to cause pain in dairy animals. While benefits of some of these practices, such as dehorning, are well known, others, such as tail-docking, are questionable and have no scientific basis in terms of benefits to animal health, welfare and milk quality. Regardless of the necessity of the procedure, the use of pain management can mitigate some of the negative effects of the process. Whether or not a dairy farmer provides pain management may be dependent on their personal attitude towards dairy animals. If dairy personnel view dairy cows as a production unit rather than an individual animal that has the capacity to feel pain, then it is possible they have little empathy towards the cows, and as a result the animal's welfare may suffer (Bateson, 1991). It has been found, however, that the majority of dairy producers do believe that dairy cows have the ability to feel pain. In a study investigating dairy farmer's attitudes and empathy towards animals, the majority agreed that animals have the ability to feel pain just as humans do (Kielland et al., 2010); however, 13% of farmers disagreed and 2% totally disagreed with that statement. While that study did not investigate pain management tools used on participating dairy operations, it is unlikely that farmers would provide pain management to animals when they did not believe that they could feel pain.

Pain behaviors have been studied extensively, concluding that dairy animals do in fact experience pain. Examples of this include head shaking and ear flicking after dehorning (Faulkner and Weary, 2000), or tail licking by calves that have had their tails banded (Eicher et al., 2000). Additionally, avoidance behavior during hot iron dehorning (Grøndahl-Nielson et al., 1999) or vocalizations during branding (Watts and Stookey, 1999) indicate that the animals are experiencing pain during these procedures. Anesthesia and analgesia are available for use to reduce the pain and discomfort associated with surgical procedures on dairy animals. Studies investigating dehorning procedures in dairy calves have shown that pain mitigation, including sedatives, local blocks, and post-procedural pain medications are effective at controlling pain (Faulkner and Weary, 2000; Vickers et al., 2005). Application of a local block requires additional handling and restraint, and is painful as well (although less so than hot-iron branding), which can result in increased stress to the calves (Weary et al., 2006). The costs and benefits of using anesthesia and analgesia need to be weighed in order to determine which option is best for the animal, as not all facilities and management systems allow for the easy application of pain mitigation. With the understanding that dairy cattle are able to experience pain, it is the dairy producers' responsibility to prevent pain whenever possible, as well as reduce or alleviate pain when they can.

Tail docking is a procedure that was introduced as a way to reduce the risk of mastitis on dairy farms, with the hypothesis being that the udder of cows with docked tails would be cleaner than those with tails (Stull et al., 2002). Multiple studies have been conducted and failed to prove this hypothesis to be true. A study involving 297 dairy operations in the US found that cows on operations that performed tail docking were actually dirtier than those on operations that did not dock tails (Lombard et al., 2010). While the procedure itself appears to cause little acute pain (Rushen et al., 2008), there are many behavioral and long term effects have the potential to impact dairy cow welfare. Chronic pain, as a result of neuroma formation, has the potential to elicit a response similar to phantom limb pain experienced in humans following amputation (Eicher et al., 2006). Additionally, tail-docking removes a dairy cow's natural fly-swatter, resulting in increased fly avoidance behavior such as increased tail movement and leg stomping (Matthews et al., 1995). An additional reason given for tail-docking is dairy worker comfort and safety. The idea is that removal of the tail will prevent dairy workers from being hit in the face with a feces and urine soaked tail during the milking process (Stull et al., 2002). There are management practices that can be employed to alleviate this concern, such as trimming the switch (Matthews et al., 1995) or installing a butt plate in the parlor preventing the tail from reaching dairy personnel while milking (Smith et al., 1991). Research has failed to support the practice of tail-docking, making many wonder why almost half of the operations surveyed in the NAHMS Dairy 2007 study had cows with docked tails (USDA, 2007). By eliminating tail docking, a procedure that is not necessary, dairy producers could reduce the negative effects that the process has on dairy cow welfare and on the image of the dairy industry to its consumers.

Housing

There are many different types of housing systems used in the US dairy industry, including pasture, open/dry lots, tie stall or stanchion barns, and freestall barns. In addition to multiple housing systems, many different flooring types are available, such as smooth concrete, grooved concrete, slatted concrete, rubber belting/mats, dirt, and pasture. With all of these options available it can be difficult to determine the best housing-flooring combination to protect the welfare of dairy animals. The housing and flooring systems used generally depends on the type and size of the dairy farm. Dairy cows on an organic operation are required to be on pasture for the entire grazing period (a minimum of 120 days) and have year-round access to the outdoors (NOP, 2014), while non-organic dairies have no such requirements. The USDA found that tie stalls were common to small dairies (2010), with 53.4% of operations using them, while medium and large dairies were more likely to use free-stalls (76.8 and 73.7%, respectively). As dairy farms are becoming larger, a shift away from tie-stall and stanchion barns is occurring, and dairy producers are opting for modernization and increased efficiency, resulting in more free-stall barns (Bewley et al., 2001), compost bedded barns (Barberg et al., 2007, Lobeck et al., 2011), and cross-ventilated barns (Lobeck et al., 2011) being constructed on dairy operations in the US. There are benefits and risks where dairy cow welfare is concerned for all of the housing types listed.

Pasture-based systems – Results from the last national dairy survey (USDA, 2007) reported that 49.4% of operations allowed lactating cows on pasture at some point throughout the year, although only 9.9% used pasture as they primary housing type for lactating cows. As there are few areas in the country where pasture access is a viable option all year long, it is not surprising that few operations use pasture as the primary housing type. There are many aspects about pasture that promote dairy cow welfare, including the ability of cows to graze (Krohn et al., 1992; Phillips, 2002), a comfortable place to rest (Charlton et al., 2013), and benefits to hoof health (Wells et al., 1999). There is also the potential for the welfare of cows on pasture to suffer, with cows housed on pasture being at an increased risk of pests and parasites (Sato et al., 2005), lacking adequate shelter during inclement weather, and having reduced BCS compared to other housing types, especially during the spring and fall when the quality of forage is low (Fontanell et al., 2005; Sato et al., 2005).

Tie-stall barns – Tie-stall barns provide dairy cows with a place that is protected from the elements to lie down, eat and drink, with minimal competition for feeding (Rushen et al., 2008). The most obvious concern for welfare is the restricted movement of cows housed in this system, especially when cows are not allowed out for daily exercise. Every aspect of tie-stall has to be considered to prevent compromising dairy cow welfare, such as appropriate size for adult dairy cows and adequate lunge space to allow for cows to easily stand up and lie down. Since cows in tie-stall facilities both stand and rest in the same spot, the base material needs to be designed to promote comfort and prevent injury. Rubber mattresses or mats over concrete provide increased compressibility and comfort to cows when compared to concrete, and promote increased lying times for dairy cows (Haley et al., 2001). Rubber mattresses alone may not be enough to provide adequate comfort. A study by Tucker and Weary (2004) showed that cows housed on mattress stalls prefer stalls that are heavily bedded with sawdust over those with no bedding, as evidenced by an increase in the amount of time cows spent lying down and the number of times cows changed position on the deep bedded stalls. Another potential problem of tie-stall barns is the increased risk of injuries, most specifically hock lesions and swollen knees (Rushen et al., 2008). When comparing cows housed on concrete versus those housed on rubber mats, the cows housed on concrete had an increase in swelling of the knees and hocks when compared to those housed on rubber mats (Rushen et al., 2007), as a result of the physical impact incurred when rising and lying down on concrete.

Open/dry lots – Open or dry lot housing is an inexpensive option for dairy operations to use for lactating and dry cows. The most basic design is similar to that of a feedlot pen, with cows housed together in an open lot surrounded by fencing. Farms may choose to provide a wind break, which may or may not be permanent (e.g. stacked straw bales versus a constructed wall), and/or a shade or shelter to provide protection from the sun and precipitation. When compared to freestalls or tie-stalls, cows housed in appropriately stocked open lots have more freedom of movement and choice of where to lie down (Haley et al., 1999; Fregonesi and Leaver, 2001), and show more play behaviors, which is an indicator of good welfare. On farms that do not choose to install a windbreak or shade structure, the welfare of dairy cows can be compromised. Providing shelter to farm animals is a requirement in many welfare monitoring programs (NMPF, 2013), and as dairy cows are sensitive to heat stress (Rushen et al., 2008), providing shade during the summer is important for ensuring the welfare of dairy cows. Even on operations that provide a shelter for cows, the majority of the open lot is unprotected from rain and snow, which increases the risk of dairy cows laying on wet bedding and therefore their risk of mastitis (Fregonesi and Leaver, 2001). Housing dairy cows in an environment that increases their risk of disease, such as mastitis, is a welfare concern.

Freestall barns – Freestall barns get their name because while cows are housed in stalls, they have the freedom to move around within the pen and choose which stall to rest in. Freestall barns are becoming more common in the U.S due to dairy produces trying to decrease labor and increase efficiency (Bewley et al., 2001), as all cows in a specific pen are fed the same ration and generally managed the same way, and machinery can be used to clean the alleyways. The number of freestall barns has increased from 30.8% of operations using them as their primary housing system for lactating dairy cows in 2001 (USDA, 2002) to 41.4% of operations using them in 2006 (USDA, 2007). Freestall barns allow protection for dairy cows from weather extremes, and producers can choose to install heat abatement methods such as fans and sprinklers to help prevent heat stress. Some freestall facilities allow cows access to the outside, while others keep cows confined within the barn at all times when not milking.

The primary flooring type used in freestall barns is concrete, which is an unforgiving and abrasive surface (Cook et al., 2004; Vokey et al., 2001). Previous studies have indicated that increased time spent on concrete may result in an increased prevalence of lameness due to claw horn lesions (Greenough and Vermunt, 1991; Cook et al., 2004; and Haskell et al., 2006), and white line disease (Cook et al., 2004). Additionally, the unyielding nature of concrete may exacerbate lameness and contribute to an imbalance in claw growth between the medial and lateral claws (Vokey et al., 2001). A study investigating the difference in lameness scores between cows housed in freestalls and those housed in straw yards found that cows housed on straw yards had lower lameness scores than those housed in freestalls (Haskell et al., 2006). The same study found that farms where cows were confined throughout the year (zero-grazing farms) had higher lameness scores than those where cows were allowed to graze. Similarly, cows housed in compost-bedded barns had a lower prevalence of lameness than cows housed in freestall barns (Lobeck et al., 2011). These findings suggest that cows benefit when they are allowed a break from concrete, as indicated by the reduction in lameness seen in straw yards, compost barns, and grazing systems.

Bedding Material

Bedding material and amount can have an effect on dairy cow welfare, by impacting lameness, udder health, and injuries such as hock lesions. Mastitis causing bacteria, such as *Klebsiella* spp., and *Streptococcus* spp., have been shown to be present at higher levels on the teat ends of cows housed on sawdust when compared to cows housed on sand bedding (Zdanowicz et al., 2004). Additionally, studies have shown that deeply bedded stalls decrease the prevalence of hock lesions. In a survey of 297 freestall operations in the US (Lombard et al., 2010), operations that used rubber mats or mattresses had a higher percentage of cows with severe hock lesions than operations that used sand as the stall base. Similar results were found in multiple studies (Weary and Taszkun, 2000; Lobeck et al., 2011), with rubber mats or mattresses resulting in an increase in hock lesions when compared to sand bedded stalls.

Employee training

As dairy operations get larger, the need for competent personnel to carry out the daily tasks on a dairy operation is critical to the success of the enterprise as well as the welfare of the cattle. Understanding how to properly handle dairy cattle not only ensures human safety, but animal safety as well. Although dairy cows are used to being handled on a daily basis, they still can be worked like other types of livestock, by manipulating their flight zones and point of balance (Albright and Arave, 1997; Grandin, 1999, 2000, 2010). While these concepts may be well known to those who have experience working with livestock, many workers on large dairy operations are migrant workers who may have little to no previous experience working with dairy cows (von Essen and McCurdy, 1998; Román-Muniz et al., 2006). Simple training programs, either on-the-job or via classroom training, can educate dairy workers on the proper way to manipulate the cow's flight zone or point of balance to get the animal to move where they want them to, without making physical contact with the cow (Grandin, 1999, 2000, 2010). Proper use of the flight zone and point of balance allow people to easily direct cattle where to go, with little stress on either the animal or the handler. When dairy personnel are not educated on the flight zone they are more likely to encroach on it when handling cows, such as when bringing cows to the parlor for milking. When cows are not able to reestablish their safety zone (i.e. flight zone) they are likely to experience increased stress and may even be at an increased risk of injury by trying to get away from the handler when they are prevented from doing so (such as when in a crowd of cattle). Proper handling of dairy cows greatly reduces the stress experienced by dairy cows during the process, as well as the stress and frustration of the employees handling the cattle, which can benefit the welfare of dairy cows by improving the human-animal interaction on dairy operations, as well as farm profitability (Waiblinger et al., 2002).

Dairy personnel are the first line of defense for the health and welfare of the animals on dairy operations, and proper training not only ensures that they handle the animals appropriately, but also that they have the knowledge to adequately identify cows that are sick, . Inadequate employee training has been blamed for increased sick cows and deaths on large dairies (McConnell et al., 2008). Multiple studies have shown that training programs can be used to improve participant knowledge and performance when working with cows and carrying out tasks on the dairy operation. One study investigating the effect of training on correctly scoring dairy cows using locomotion scoring found that training improved the agreement between non-experienced and experienced scorers (March et al., 2007). Similarly, Hemsworth et al (2002) found that a training program aimed at improving dairy worker attitudes towards working with dairy cattle succeeded in improving their impression of working with the animals (even if it did not change their impression of the animal itself). Despite the evidence showing the efficacy of training on increasing dairy worker knowledge and behavior, many dairy operations still fail to provide their employees with training opportunities (Bergman et al., 2014).

Body Condition Score

Body condition scores (BCS) are used to gauge the amount of fat on a dairy cow, with low values representing under-conditioned or emaciated cows, and high values representing over-conditioned or obese animals (Wildman et al., 1982; Ferguson et al., 1994). There is concern from the public that the welfare of under-conditioned dairy cows is compromised (Roche et al., 2009), while multiple studies suggest that the health of over-conditioned dairy cows may suffer (Markusfeld, 1985; Gillund et al., 2001). Over-conditioned cows are at an increased risk of metabolic diseases following calving, including milk fever (Roche and Berry, 2006), and ketosis (Gillund et al., 2001; Ingvartsen, 2006). In contrast, a study by Hoedemaker et al (2009) illustrated an association between BCS and lameness, with thin animals more likely to be lame. This study was unable to determine, however, if the low BCS was a cause or a result of lameness. Dry matter intake is affected by production and stage of lactation (Gallo, 1996), with it decreasing in early lactation and recovering in mid-lactation. Throughout the transition period, the goal is to maintain a BCS between 2.5 and 3.5 (Heuer et al., 1999), with cows outside of that range considered too thin or fat. The public concern for thin animals is likely anthropomorphic, with many perceiving an under-conditioned dairy cow is suffering from malnutrition (Roche et al., 2009), and as a result may feel hungry, tired, or sick (Webster, 2005). While it is difficult to validate these statements scientifically, multiple studies have illustrated that thin cows, with a negative energy balance, have reduced reproductive success (Butler and Smith, 1989; Markusfeld et al., 1997; Beam and Butler, 1999), suggesting that cows are suffering from physiological abnormalities as a result of being under-conditioned. While there is a concern for the welfare of thin cows, the majority of dairy cows are within the suggested range of 2.5 to 3.5. Dechow et al. (2001) reported the mean body condition score of cows just prior to calving to be between 3.06 and 3.18 (differing by number of lactations) prior to calving, which decreased to a low of 2.81 to 2.87 at peak milk production. Another study investigating the association between BCS and different milk production traits reported the mean BCS of first lactation heifers to be 2.78 (Loker et al., 2012). While the mean for both of these studies suggest that the majority of cows fall in the suggested range, there are likely to be cows that fall below the threshold of 2.5, indicating that there are cows within the dairy industry that are considered too thin.

Nonambulatory Dairy Cow Management

Nonambulatory cows are commonly referred to as "downer cows" and are animals that are unable or willing to stand. The definition of a nonambulatory cow differs among sources, including a cow that is unable to stand or walk without assistance for any length of time (Green et al., 2008) and animals that are recumbent for 12 or more hours and are unable or unwilling to stand (Fenwick et al., 1986; Smith et al., 1997). Nonambulatory dairy cows become a welfare concern after prolonged recumbency, which can result in pressure ischemia and associated neuropathies (Cox et al., 1998; Burton et al., 2009). There are multiple techniques that dairy operations can employ to assist nonambulatory cattle to stand, preventing or slowing the progression of neuromuscular injury (Burton et al., 2009). Such techniques include: hip lifters, slings, and flotation tanks (Cox et al., 1998; Burton et al., 2009). With the majority of dairy operations in the US (78%) reporting at least one nonambulatory cow annually during the last NAHMS Dairy study (USDA, 2007), the impact for dairy cow welfare is substantial. Large dairy operations are at an increased risk of having nonambulatory cattle than smaller herds (Green et al., 2008), which is to be expected as the probability of having at least one nonambulatory animal increases when more animals are present. This same study found that cows in later lactation had an increased recovery rate when compared to cows with fewer lactations (10.1% first lactation, 17.7% lactation 2 - 4, and 22.2% ≥ 5 lactations); also, a smaller percentage of cows with a BCS < 2.5 recovered compared to cows with a BCS ≥ 2.5 (8.1% versus 16.6%); and a greater percentage of cows that were nonambulatory for less than 24 hours recovered than cows that were nonambulatory for greater than 24 hours (32.9% versus 8.2%). This last result is an important indicator of welfare for nonambulatory cows, as their prognosis decreased significantly the longer they had been nonambulatory. Euthanasia is usually the most humane option for these cows, in order to prevent prolonged suffering

Culling and Mortality

Culling can be described as selecting cows to be removed from the herd and replacing them, usually with a first lactation heifer (Hadley et al., 2006). It is a practice employed to improve the herd by removing the older, less productive individuals and replacing them with animals that have improved genetic potential. Optimum culling rates for profitability have been estimated between 19 and 30% (Rogers et al., 1988; Bauer et al., 1993; Stott, 1994; Bascom and Young, 1998; Hadley et al., 2006). Actual culling rates tend to be higher than this. In the Northeast it was estimated that the average cull rate is 34%; for upper Midwest DHIA herds in 2001 it was reported at 38%; a study examining the DHI records for 5 Upper Midwest states and 5 Northeast states found the average culling rate to be 35.1%; finally, a survey of New Mexico dairies found the average culling rate to be 33% (Bascom and Young, 1998; Rogers et al., 2004; Hadley et al., 2006;). Culling of dairy cows can be classified as either voluntary or involuntary (Gröhn et al., 1998; Rajala-Shultz and Gröhn, 1999; Hadley et al., 2006). Voluntary culling refers to cows chosen by the owner or herd manager to be removed from the herd, generally due to low milk production or an excess of animals, while involuntary culling represents animals removed from the herd for reasons outside of the owner or herd manager's control, such as illness, injury, infertility, or death. The most common reasons for culling cows have historically been reproductive problems, mastitis, and low production (Bascom and Young, 1998; Lehenbauer and Oltjen, 1998; Groenendaal et al., 2004; Hadley et al., 2006).

Dairy cow mortality has been gradually increasing over the years, with national estimates increasing from 3.8% in 1996 (USDA, 1996), to 4.8% in 2002 (USDA, 2002), and to 5.7% in 2007 (USDA, 2007). In the NAHMS dairy 2007 study the reasons given for dairy cow mortality included lameness or injury (20%), mastitis (16.5%), calving problems (15.2%), unknown reasons (15.0%), and respiratory problems (11.3%; USDA, 2007). McConnell et al. (2008) demonstrated that a higher mortality rate was associated with herd size, region, and milk production, with operations with more than 355 cows, operations in the West, Midwest, and Southeast, and operations with an increased RHA being associated with increased levels of mortality. Additionally, this study determined that dairy operations with a moderate to high percentage of lameness had an increased mortality rate when compared with operations that had a low level.

Culling and mortality can be considered an indicator of the welfare of cows on a dairy farm, as increased removal and death rates may be able to highlight areas of concern on a specific operation. For example, increased culling of lame cows may indicate that a farm has a lameness problem (Sogstad et al., 2007). Also, farms that have an increased cull or death rate within the first 50 days in milk (DIM) are likely to have issues with transition cow management and the subsequent health of fresh cows (McConnell et al., 2008). The timing of culling can also have an impact on the welfare of dairy cows. Timely culling decisions reduce the incidence of weak and under-conditioned cows, which are at an increased chance of becoming nonambulatory during transport to slaughter (White and Moore, 2009). Timely culling also prevents undue suffering for sick cows with a poor prognosis. The decision to treat or cull a cow is quite complex and often considers a cow's milk production, age, reproductive status, and history with a specific illness (Gröhn et al., 1998). Regardless of the production indices involved in the decision to treat or cull a cow, the cow's welfare should always be a consideration, most specifically the risks of the cow suffering and her chances of recovery (Shearer, 2008).

Euthanasia

The process and timing of euthanasia has implications for dairy cow welfare mainly because of the consequences of improper euthanasia techniques, or delayed or non-existent euthanasia for terminal cattle. Humane euthanasia is often necessary on dairy operations to prevent prolonged suffering of dairy cows from an illness or injury that cannot be treated (Thomsen et al., 2004). Diseases and illnesses where euthanasia may be indicated include: fractures, calving related injuries, advanced ocular neoplasia, and diseases with a poor prognosis (Shearer, 2008). Allowing cows to die unassisted raises ethical questions and seriously compromises dairy cow welfare (Thomsen et al., 2004). A survey of dairy operations in Wisconsin found that small herds were less likely to euthanize sick cows than larger herds (Hoe and Ruegg, 2006). Similar results were found by Thomsen and Sørensen (2009) who surveyed dairy operations in Denmark and determined that the odds of a cow being euthanized increased with increasing herd size, and increasing milk yield, with the authors concluding that operations with increased euthanasia were likely well managed and therefore more likely to have standard operating procedures in place for euthanizing seriously ill cows.

The ultimate goal of euthanasia is a humane death for the animal (AABP, 2013). There are essentially two options for effective euthanasia in the dairy industry: gunshot and captive bolt (Shearer, 2008). Multiple studies have reported that gunshot is the leading method used by dairy producers for euthanizing dairy cows (Hoe and Ruegg, 2006; Adams et al., 2014), which when conducted properly is an effective and humane method. The use of captive bolt requires a secondary method to ensure death, such as exsanguination, pithing, or injection of potassium chloride or magnesium sulfate (AABP, 2013), which may explain why it's not commonly used on dairy operations. Euthanasia should be conducted to minimize the pain and stress experienced by the animal, with training of individuals to ensure adequate euthanasia techniques (Shearer, 2008). The AABP maintains up-to-date information regarding proper euthanasia techniques, including landmarks for the correct location of the gunshot or captive bolt, as well as indicators that death has been achieved (AABP, 2013). Following these guidelines helps to ensure that euthanasia is carried out in a humane manner.

Organic versus Non-organic

Not only do management practices differ between individual dairy operations, they can vary greatly between types of dairy operations. For example, organic operations are not allowed to use antimicrobials and reproductive hormones (NOP, 2014), and they rely more heavily on grazing than non-organic dairies (Sato et al., 2005). With many consumers preferring to see cows on pasture grazing rather than housed in a barn, they have begun to believe that the welfare of cows and the quality of the milk produced on organic dairy operations is superior to that of their non-organic counterparts, contributing to the increase in organic milk production (Sundrum, 2001). There are benefits to both types of production, with multiple studies illustrating differences between the two. A study comparing organic and non-organic herds in Norway

(Hardeng and Edge, 2001) reported that organic cows were older than non-organic cows, and organic cows had lower odds of being diagnosed with ketosis, mastitis, and milk fever. The authors did note though that the reduction in milk yield on organic operations may be responsible for the decrease in the incidence of milk fever. Another study also found that cows on organic operations were older than cows on non-organic operations (Ahlman et al., 2011), consequently resulting in lower replacement rates in organic herds.

One study reported that many herd health problems are the same for both organic and non-organic herds (Krutzinna et al., 1996), with farmers for both operation types listing mastitis, fertility, and hoof diseases as the leading health problems. Since organic operations are not allowed to treat dairy animals with antimicrobials (USDA, 2010), it would be expected that the majority would administer vaccines in order to maximize disease prevention. This was not found when comparing organic and non-organic operations in New York, Oregon, and Wisconsin, where 97% of non-organic no-graze farms administered vaccinations to adult cows, compared to 64% of organic operations (Stiglbauer, 2013). While many people believe cows that have access to pasture are healthier than those that do not, multiple studies have actually failed to find a difference. A Danish study comparing sole disorders between organic and non-organic herds found no significant difference between herd types (Vaarst et al., 1998). Similarly, Sato et al. (2005) found no difference in the prevalence of lameness between organic and non-organic farms. This same study also found that cows on organic farms were actually thinner during the spring than those on non-organic farms, and they had a higher parasite burden than their non-organic counterparts. Similarly, organic farmers in Sweden reportedly have a greater problem with parasite infections than non-organic farmers do (Svensson et al., 2000), suggesting that the increased access to pasture puts organic dairy cows at a greater risk of being infected with internal and external parasites. The prevalence of hock lesions was lower on organic farms than non-organic when comparing operations in New York, Oregon, and Wisconsin (Bergman et al., 2014), suggesting that there are benefits to dairy cow welfare on organic operations. This benefit is not likely due to pasture access alone, as non-organic grazing farms in the same study had a greater prevalence of hock lesions than organic operations, although both organic and non-organic grazing operations had fewer lesions than non-grazing non-organic farms did.

Multiple studies have been conducted to determine whether differences exist between the quality of milk produced on organic and non-organic farms. Sato et al (2005) compared different milk quality indicators between the two farm types and concluded that there was no difference in clinical mastitis, bulk tank somatic cell count (SCC), and sanitation between the types of dairies. Similarly, Stiglbauer et al (2013) found no differences in milking procedures between organic and non-organic herds, or differences in bulk tank SCC. Results from these two studies suggest that milk quality does not differ between the two production types.

DAIRY COW LAMENESS

Lameness is a leading welfare concern in the dairy industry, mainly due to the fact that lame animals are in pain (Rushen et al., 2007; O'Callaghan et al., 2003). The average prevalence of lameness on dairies in the US is reported to range from 20 to 55% (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012), indicating that roughly a quarter to half of dairy cows in the US are in pain. There are many causes of lameness, including infectious agents, and lesions due to metabolic or physical injury to the hoof (Rushen et al., 2008). All of these causes can be impacted by various management practices, including housing, handling, sanitation, and lameness identification and treatment.

Risk Factors of Dairy Cow Lameness

There are many external risk factors that can contribute to dairy cow lameness in the US. The environment that dairy cows are housed in can vary greatly between dairy operations, and can have a significant impact on the prevalence of lameness. Additionally, on-farm lameness management practices can determine the severity and prognosis of lameness depending on the preventive and management practices in place. Finally, dairy cow handling has been suggested to be a substantial contributor to the prevalence of lameness on dairy farms.

Environment – There are many different components of a dairy cow's environment that can have an effect on their chances of becoming lame. A dairy cow's environment should be designed to promote cow comfort and health, and therefore limit injury and suffering. While it is unlikely that any housing system was designed to result in injury to dairy cows, there are some systems that are associated with higher levels of lameness than others. Multiple studies have illustrated the benefits of softer flooring surfaces on dairy cow lameness. Cows housed in compost barns in the US have illustrated low levels of lameness, with an average of 7.8% of cows housed in compost bedded pack barns in Minnesota (Barberg et al., 2007) being clinically lame (LS $\geq$ 3; Sprecher et al., 1997). Another study reported the prevalence of lameness in compost bedded barns to be 4.4% (Lobeck et al., 2011), which was substantially lower than what was found in cross-ventilated (13.1%) and non-ventilated (15.9%) freestall barns. A study comparing freestall housed herds that allowed dairy cows to graze part time and those that housed cows year round found that those that had access to pasture had a lower prevalence of lameness (17%) compared to those that did not (39%; Haskell et al., 2006). Similarly, a study investigating risk factors for lameness in New England found that access to pasture during the dry period was associated with a lower prevalence of lameness (Chapinal et al., 2013). Somers et al (2003) found that cows housed on straw yards had a lower level of claw disorders when compared to cows housed on concrete (42.5% versus 81%, respectively).

As dairy farms in the US get larger, more operations are housing cows in freestall barns with concrete flooring for more efficient use of labor and resources (Bewley et al., 2001), resulting in more cows subjected to concrete flooring. Concrete is an abrasive surface with no compressibility, which has been associated with increased lameness in dairy cows. Concrete flooring results in excessive wear of the claw, contributing to poor heel height, toe ulceration, and white line disease (Cook, 2006). The concussive and unyielding nature of concrete can contribute to increased lameness (Haskell et al., 2006) and increased incidence of thin soles, bruising, and sole ulcers (Blowey, 2005). Rubber flooring in the feed alley and transfer lanes is becoming more widely used in the US dairy industry in an attempt to reduce the time cows have to stand on concrete (Cook et al., 2004). Multiple studies have investigated the use of rubber over concrete with promising results. A study looking at dairy operations in California found that rubber in the walkway to the milking parlor was associated with a reduction in lameness (Chapinal et al., 2013), with the authors suggesting that the rubber provides more secure footing and is more comfortable to walk on than concrete. Similarly, Vanegas et al (2006) found that cows housed on concrete were 5 times as likely to be diagnosed as lame than those that were housed on rubber.

The type and depth of bedding material can have an influence on dairy cow lameness. Deep sand bedding in freestall barns has been shown to reduce lameness in dairy cows, with herds in Wisconsin using deep sand bedding having a significantly lower prevalence of lameness when compared to herds using mattress stalls (Cook, 2013). Similar results were seen when comparing sand stalls to non-sand stalls (Cook, 2003), and sand bedded stalls to sawdust bedded stalls (Chapinal et al., 2013). The benefit of sand bedding is believed to be related to its ability to conform to a cow's body and to provide cushion, improving the ability of cows to lie down and get up (Cook, 2003 and 2013). A study by Vokey et al (2001) compared the effects of different alley and stall surfaces and concluded that rubber alleys in combination with sand bedded stalls performed the best when considering claw lesion score compared to the other treatment groups (rubber alley and concrete stall; concrete alley and concrete stall; concrete alley and sand stall; rubber alley and mattress stall), highlighting the importance of considering both alley surface and bedding materials when designing housing facilities for dairy cows. In instances where stall comfort is compromised, such as when there is inadequate bedding, rubber matting in alleys is not recommended as it may actually promote standing and be detrimental to hoof health (Cook et al., 2004).

The maintenance of the walking surfaces that dairy cows have access to is an important contributor to different infectious forms of lameness. Clean and dry surfaces reduce the chances of infectious causes of lameness such as digital dermatitis, and hoof rot (Cook, 2006; Mülling et al., 2006). Digital dermatitis, or hairy heel wart, is characterized by lesions on the soft tissues just about the claw of the rear foot that are wart-like and have been known to resemble strawberries or raspberries in appearance (Epperson, 2005), although lesions may be present in the interdigital space on the front side of the hoof as well. Hoof rot begins with inflammation between the claws of the hoof, which can spread to the adjacent coronary band and even into the underlying joints and tendons (AHDB, 2014). Both digital dermatitis and hoof rot are associated with the presence of environmental bacteria (Maas, 2009; Greenough, 2012), which thrive in wet and dirty environments and can spread easily between cows in improperly maintained housing environments. Cows that are housed in wet conditions or manure slurry are at an increased risk of digital dermatitis and foot rot (Nordlund et al., 2004). Even in the absence of the bacteria responsible for the above infectious types of lameness, the integrity of a cows hoof is compromised when they are routinely subjected to wet conditions, resulting in increased susceptibility to injury and lameness (Blowey, 2005; Mülling et al., 2006).

Management – How dairy cows are managed, both prior to and after being diagnosed as lame, is important to the prevalence of lameness on a dairy farm. Routine hoof trimming promotes even growth (Blowey, 2005), balances the weight load on the lateral and medial claw (Mülling et al., 2006), and promotes early identification and prevention of foot problems. Hoof care programs that incorporate scheduled trimmings either once or twice per lactation have shown to benefit dairy cow lameness (Manske, 2002). Improper hoof trimming can be more detrimental than no hoof trimming though, resulting in thin soles that predispose the cow to injury (Blowey, 2005; Bell et al., 2009) or transmission of infectious causes of lameness (Mülling et al., 2006).

Lameness monitoring programs promote the early identification and treatment of lame cows, improving the prognosis and decreasing the duration and treatment costs associated with lameness (Gundelach et al., 2013). A study investigating different risk factors associated with lameness (Bell et al., 2009) determined inadequate detection and treatment of lameness to be the greatest hazard associated with severe lameness. Gundelach et al (2013) found that increased vigilance for dairy cow lameness resulted in the earlier detection and treatment of lame cows and reduced the duration and prevalence of lameness. Similarly, Clarkson et al. (1996) reported that the prevalence of lameness on dairies where farmers were trained to identify the early stages of lameness was lower than on operations that did not identify lameness until it was more progressed.

Adequately maintained hoof baths can be an excellent tool for the prevention of infectious forms of lameness in dairy cows. Location of the footbath is important to ensure that all cows pass through the bath, and the proper size (length and depth) ensures that all of the cow's feet have adequate contact with the solution (Blowey, 2005). Additionally, foot baths need to be cleaned frequently to ensure proper concentrations of the agent being used (Bell et al., 2009). Proper use of foot baths has been associated with decreased prevalence of clinical lameness (Chapinal et al., 2013) by decreasing infectious forms of lameness.

Dairy cow handling – How cows are handled has been shown to have an impact on dairy cow lameness. As dairy cows are handled on a daily basis, the risk of lameness attributed to improper handling is high. Cows that are pushed too hard, or rushed along an alleyway or track, have been found to have a greater incidence of lameness than those that are allowed to walk at their own speed (Clarkson and Ward, 1991). It is believed that cows that are pushed too hard are unable to see their footing and as a result may experience more injury and bruising than they otherwise would have experienced if allowed to walk at their own pace (Blower, 2005). Similar results were found in a study investigating lameness in New Zealand (Chesterton et al., 1989), where the prevalence of lameness was associated with the patience of the farmer handling the cows. Additionally, pushing cows too hard can result in a lack of space and conflict between cows, which can lead to sudden or irregular movements, all of which has the potential to impact dairy cow lameness (Mülling et al., 2006).

Locomotion Scoring Systems

Many different locomotion scoring systems exist that are used to identify lame cows. The number of categories differs among systems, and each looks at different postures and gait characteristics. Gait characteristics that are generally included are: amount of weight the cow is willing to bear on one or more limbs; the presence or absence of an arch in the animals back; stride length; head movements; fluidity or rhythm of movement, and walking speed (DairyNZ, 2014). Cows that are lame on one limb will likely try to maximize the amount of time spent on a sound limb while limiting the amount of time spent on the affected limb (Whay, 2002), which is easy to identify when the animal has an obvious limp, but is also identifiable by a shortened stride length. Arching of the back has been associated with pain and lameness in dairy cattle (Sprecher et al., 1997). Lame cows may have an obvious head bob as they use this movement to help direct weight away from the affected limb (Whay, 2002); with front limb lameness cows bobbing their head up while they're bearing weight on the affected limb, while with rear lameness they may bob their head down while placing weight on the lame foot. Cows that are sound tend to walk with smooth easy movements and at the same pace of the rest of the herd (or a brisk walking human; DairyNZ, 2014); in contrast lame cows walk with abnormal gaits and have trouble maintaining pace with the rest of the herd and will likely be towards the end of the group.

There are a couple of different 3-point systems, which break lame cows into two different groups. The National Dairy FARM program (NMPF, 2013) advocates a 3-point system because they are simpler than other systems. The FARM program emphasizes how the cow places weight on all of her limbs, with a category 1 representing a sound cow that walks with a "healthy gait", category 2 representing a cow that favors a limb while walking, and category 3 representing a severely lame cow that tries to avoid bearing weight on one or more limbs. The most recent NAHMS Dairy survey (USDA, 2014) developed a 3-point system to estimate the prevalence of lameness on dairy operations in the US, with the goal being ease of use as multiple people would be responsible for scoring the cows. The system was similar to that of the FARM program, with a score 1 representing a sound cow with no gait abnormality, score 2 representing a mildly/moderately lame cow with an abnormal gait but the affected limb was not obvious, and score 3 defined as a severely lame cow that was hesitant to bear weight on one or more limbs. The biggest difference when compared to the FARM program's 3-point system is that a cow that is obviously favoring a limb is considered severely lame, while cows that have a gait abnormality (e.g. uneven gait or head bob) but the affected limb is not obvious would be scored a 2. A study conducted in the Netherlands (Amory et al., 2006) used a 3-point system that was based off of the 5-point system developed by Sprecher et al. (1997; discussed below), in which a score 1 was the same as a score 1 in the 5-point system, a score 2 represented a mildly/moderately lame cow and combined scores 2 and 3 from the 5-point system, and score 3 represented a lame/severely lame cow and combined scores 4 and 5 from the 5-point system.

Four point systems are more common in other parts of the world, although some are used in the US. A system used in the UK assesses the dairy cow's ability to move easily (AHDB, 2015), and ranges from 0 to 3. A score 0 represents a cow with good mobility that walks with a flat back and has an even weight-bearing rhythm on all feet; a cow scored with a 1 has imperfect mobility and walks with uneven steps or shortened strides, but the affected limb(s) is (are) not easily identifiable; score 2 represents a cow with impaired mobility that walks with shortened strides and uneven weight bearing and the affected limb is identifiable; score 3 represents a cow with severely impaired mobility that has all of the signs of a score 2 cow but is also unable to walk as fast as the rest of the herd. A similar system is available in New Zealand (DairyNZ, 2014), based on six indicators of lameness: walking speed, walking rhythm, stride length and foot placement, weight bearing, back alignment, and head position. The definitions of the different categories are as follows: a cow with a lameness score of 0 is considered normal; a lameness score 1 represents a cows that is showing the early signs of lameness including shorter steps and uneven stride lengths; a cow with a lameness score of 2 is moderately lame with a shortened stride length and uneven weight bearing on a limb that is easily identifiable; a lameness score 3 represents a severely lame cow that favors one or more limbs with shortened strides, an obvious head bob, and potentially arched back that cannot keep up with the rest of the herd. Another system developed by Stokes et al. (2008) is similar to the two listed above and focuses on walking speed, and is as follows: score 0 represents a sound cow that walks confidently with even weight bearing; score 1 represents a cow with imperfect locomotion that may walk cautiously due to tenderness, may not track up, with no obvious limp; score 2 represents a lame cow with an obvious limp or an arched back with no change in walking speed; score 3 represents a severely lame cow that shows obvious signs of limb pain and cannot walk as fast as the rest of the herd. Vokey et al. (2001) used a 4-point scoring system to gauge the effect of freestall surfaces on dairy cow lameness. The scoring system categorized score 1 cows as those with a normal gait; score 2 cows as those with some gait asymmetry, compromised walking speed, slight abduction/adduction, with no obvious head bob; score 3 cows as those with asymmetric gait, shortened stride length, some reluctance to move, and limping with an obvious head bob; score 4 cows as those with severe gait asymmetry with very deliberate steps, extreme reluctance or inability to bear weight on one or more limbs, reduced walking speed, and obvious back arch. Cook (2003) developed a 4-point system that is a hybrid of the scale proposed by Wells et al. (1993), modified to use the back arch proposed by Sprecher et al. (1997). The system is as follows: score 1 represents a sound cow that walks rapidly with long strides and a level back; score 2 cows have slight lameness and walk with slower, shorter strides with an arched back, but stand with a flat back with no obvious affected limb; score 3 represents cows that are considered moderately lame that walk with deliberate and shortened steps, have difficulty turning, and stand with an arched back and favoring the affected limb; score 4 cows are severely lame and walk very slowly with frequent rests due to the partially weight bearing limb, have extreme difficulty turning, and stand and walk with an arched back.

There are multiple 5-point locomotion scoring systems that are currently used in research and in the US dairy industry. One of the most common ones was developed by Sprecher et al. (1997), and focuses on the arch of the cows back to categorize lameness. According to this scoring system a lameness score 1 represents a normal cow that stands and walks with a level back; a score 2 is a mildly lame cow that stands with a flat back, but arches her back when walking; a score 3 represents a moderately lame cow that stands and walks with an arched back, with shortened stride lengths; a score 4 cow is considered lame with an obvious arch in the back at all times and the favoring of one or more limbs; a score 5 cow is considered severely lame and in addition to the characteristics of a score 4 cow, is extremely reluctant to bear weight on one or more limbs. A simpler 5-point scoring system, based off of the system developed by Sprecher et al. (1997) was developed by Winckler and Willen (2001). The system categorizes cows as follows: a lameness score of 1 represents a cow with a normal gait; a score 2 represents a cow with an uneven gait; lameness score 3 describes cows with a short striding gait with one limb; cows with a score of 4 have a short striding gait with more than one limb and are hesitant to bear weight on one limb; and lameness score 5 describes cows with a strong reluctance or inability to put weight on two or more limbs. Another common system used in research concerning dairy cow lameness was developed by Flower and Weary (2006), which uses a numerical rating system (NRS) that, like the other systems, ranges from sound to severely lame. A cow with a

NRS 1 walks with smooth and fluid movement, with a flat back, symmetrical gait, and equal weight bearing on all legs; a NRS 2 cow has imperfect locomotion but her ability to move freely is not diminished, with a mildly arched back, slightly asymmetric gait, and with all legs equally bearing weight; a NRS 3 represents a cow whose ability to move freely has diminished, with an arched back, asymmetric gait, signs of joint stiffness, and a slight limp; a cow with a NRS of 4 is not able to move freely, with an obvious back arch, asymmetric gait, slight head bob, stiff joints and hesitant strides, and reluctant (but able) to bear weight on one or more limbs; the movement of a cow with NRS 5 is severely restricted, and is characterized by an extremely arched back, obvious head bob, asymmetric gait, obvious joint stiffness with very hesitant strides, and the inability to bear weight on one or more limbs.

BEEF QUALITY ASSURANCE

While dairy cows are bred and raised for milk production, the majority end up as cull animals and enter the beef supply. Dairy cows are a substantial contributor to the US beef supply, with 3,125,000 harvested in 2013, accounting for 9.8% of all of the animals harvested for beef in the US (USDA, 2014). With the average herd culling approximately one third of their cows annually (Smith et al., 2000; Hadley et al., 2006), a good proportion of cows on each dairy operation will become beef each year. The US National Beef Quality Assurance (**BQA**) program details practices that can be carried out on an operation to ensure that beef products are of the highest quality and as safe as possible for consumers (BQA, 2012). While this program has proven successful for the beef industry, it is currently underutilized in the dairy industry. Since dairy cows are a substantial contributor to the nation's meat supply it is important that the dairy industry takes just as many precautions as the beef industry does in ensuring that their products are high quality and safe for consumers.

Multiple studies have illustrated the lack of participation in BQA programs by the dairy industry. While investigating dairy producer perceptions of BQA on Colorado dairies, Adams et al. (2014) concluded that BQA is not a priority for some dairy producers, with one producer stating "I am in the dairy industry and have cows to produce milk, not to produce beef." A survey of Pennsylvania dairy operations indicated that producers do not see an economic benefit to participating in dairy BQA programs (Tozer et al., 2005). Similar opinions were reported by Payne et al. (1999) when investigating the impacts of implementing on-farm quality assurance programs, with producers stating that the costs would likely outweigh the benefits of such a program.

Many practices that promote BQA also promote dairy cow welfare. Culling and euthanasia practices, dairy cow handling, lameness identification and management, and injection techniques all have the ability to impact both dairy cow welfare and BQA practices. Timely culling decisions reduce the incidence of weak and under-conditioned cows, which are at an increased chance of becoming nonambulatory during transport to harvest (White and Moore, 2009). Identifying which cows should be euthanized on farm rather than sent to market can help to prevent sick animals from ending up at packing plants, where they are at an increased risk of being condemned (White and Moore, 2009), as well as minimize the suffering of cows that have little chance of recovery (Thomsen et al., 2004; NCBA, 2007; Shearer and Reynolds, 2011). Many dairy producers report marketing sick animals rather than treating or euthanizing them on-farm (Ruegg, 2003), highlighting the potential for zoonotic pathogens in market dairy cattle. Historically, market dairy cattle result in more condemnations than market beef cattle), with 34 times as many cull cows being condemned compared to cattle on feed (White and Moore, 2009.

Proper dairy cow handling practices on farm and during transport ensures the welfare of animals and reduces the incidence of bruising, which can result in significant trimming of the carcass and loss to the producer (NCBA, 2007). Lameness is one of the leading welfare concerns in the dairy industry, with the average prevalence of lameness on dairies ranging from 20 to 55% (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012). Additionally, lameness is a BQA issue, with dairy cows accounting for the majority of lame cattle that are marketed each year (Ahola et al., 2011a). Severely lame cows have more difficulty navigating auction markets and slaughter facilities, and are therefore at an increased risk of becoming nonambulatory and condemned. Identification of lame cows on dairy operations has been a challenge, with many producers underestimating the prevalence of lameness on their dairy by as much as 50 to 60% (Wells et al., 1993; Whay et al., 2003). BQA promotes the early identification and treatment of lame cows (BQA, 2012), which increases the chance of recovery and reduces the risk of sending severely lame animals to harvest (Whay, 2002; Nordlund et al., 2004).

Beef quality assurance programs emphasize proper injection techniques to ensure the quality of the meat is preserved (BQA, 2012). Most medications can be administered one of four ways: intramuscularly (i.m.), intravenously (i.v.), subcutaneously (s.c), and intramammary (i.m.m). The label instructions for many medications allow either s.c. or i.m. administration. To prevent scar tissue and the formation of injection site lesions, administering medications s.c. is preferred to i.m. (Griffin et al., 1998). Additionally, administering injections in the neck region protects the quality of the meat along the rear of the cow, where higher quality cuts are located (Griffin et al., 1998; Tozer et al. 2005; Ahola and Glaze, 2009; Glaze and Chahine, 2009). Studies have also indicated that the neck region heals faster than the rump area (Li et al., 2012), providing another reason for administering injections in that location. Despite the reasons promoting proper injection techniques, injections in dairy cattle continue to be administered against BQA recommendations. In a survey of dairy producers in Idaho, 18 to 32% of respondents indicated that i.m. injections were administered in the leg of dairy cattle (Glaze and Chahine, 2009). A similar study conducted in Pennsylvania reported that 65% of i.m. injections were administered in areas other than the neck region (Tozer et al., 2005). Similarly, dairy producers in Colorado stated that while their preferred location for administering medications was the neck region, not all injections were actually administered in that location (Adams et al., 2014), suggesting that dairy producers are not concerned enough with BQA to ensure that all injections are administered according to BQA recommendations.

Practices such as these greatly compromise dairy BQA, and represent an area for improvement in the dairy industry. Historically, dairy cow carcasses have significantly more injection site lesions than beef cow carcasses (49% versus 26%, respectively), illustrating a lack of BQA practices on dairy operations (Roeber et al., 2002). Financial losses from injection site lesions have been substantial for dairy producers, with visible injection site blemishes accounting for a loss of $11.49/45.5 kg when marketing cull dairy cows at auction (Ahola et al., 2011b). Roeber et al. (2002) has actually proposed that injection site lesions result in an astonishing $9,000,000 loss to the beef and dairy industries annually. These findings suggest that besides improving animal welfare and the quality of beef produced, dairy producers would benefit financially from implementing dairy BQA practices on their operations.

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CHAPTER II: MANAGEMENT PRACTICES THAT IMPACT DAIRY COW WELFARE ON US DAIRY OPERATIONS

INTRODUCTION

Consumers are becoming increasingly concerned with where their food is coming from (Rushen et al., 2008), and they are looking for evidence that the livestock raised in animal agriculture are not suffering in the process. In addition, more research efforts emphasizing dairy cow welfare have been conducted in the past decade, with a literature search from 2005-2014 bringing up 72 articles with the term "dairy cow welfare" in the title (Google Scholar, 2015); a substantial increase from the 17 articles found during the preceding 10 years. Not only has dairy cow welfare caught the attention of consumers and researchers alike, it has also become a focus area for animal welfare groups. The increased attention to welfare, by consumers, researchers, activists, and the dairy industry itself, has resulted in an increase in dairy cow welfare monitoring and auditing programs in the US (USDA, 2015).

The term welfare itself seems so simple, yet it is quite complex. The simple dictionary definition of the word is the state of doing well, especially in respect to good fortune, happiness, well-being, or prosperity (Merriam-Webster, 2015). While it may be difficult to relate prosperity and good fortune to animal welfare, the underlying principles still apply. The main concern in animal agriculture is when welfare is compromised as a result of the production practices and systems that are in place. There are many different management practices that can impact dairy cow welfare, which include housing management (Rushen, 2001; Regula et al., 2004), animal handling (Hemsworth et al., 1995; Rushen et al., 2008), employee training (Hemsworth et al., 2002), culling and mortality (Thomsen and Houe, 2006; McConnell et al., 2008), nonambulatory cow management (Burton et al., 2009; Ahola et al., 2011), and euthanasia practices (Eicher, 2006; Thomsen and Sorensen, 2009). Multiple studies have been conducted investigating practices in different regions or states that have an impact on dairy cow welfare; however, national estimates of the US dairy industry as a whole have been lacking.

The National Animal Health Monitoring System (NAHMS) conducts national surveys to collect information on the health and management of domestic livestock species (USDA, 2014), and in 2014 a survey was conducted to collect information about the US dairy industry. Information reported here is a component of the NAHMS 2014 dairy study. The objectives of this study were to: 1) describe housing and management practices on US dairy operations that impact dairy cow welfare, and 2) identify changes in housing and management practices on US dairy operations that impact dairy cow welfare from the NAHMS 2007 Dairy study to the NAHMS 2014 Dairy study.

MATERIALS AND METHODS

The National Agricultural Statistical Service (NASS; USDA, 2013) "Cattle Report" was used to determine states for inclusion in the NAHMS Dairy 2014 study, with the goal of including states that accounted for at least 70% of dairy operations and dairy cattle in the United States. Seventeen states were chosen for inclusion in the study representing 81.3% of dairy operations and 81.2% of dairy cows in the United States. The states included in the study were: California, Colorado, Idaho, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Texas, Vermont, Virginia, Washington, and Wisconsin. NASS used a sampling frame and selected a stratified random sample of dairy operations within each state to participate in the study. Operation-level weights were provided by NASS and accounted for the selection criteria and study nonresponse. These weights were used to generate national estimates of the US dairy industry. Dairy sizes were categorized as very small (1 to 29 cows), small (30 to 99 cows), medium (100 to 499 cows), and large (500 or more cows).

NASS enumerators visited dairy operations to complete the survey with dairy producers in January 2014 (Phase I). During the same time period, operations with fewer than 30 cows were mailed a shortened version of the initial questionnaire, which consisted of a subset of questions that were applicable to very small operations. For example, dairy operations in that size category were not asked whether or not rubber belting was installed in the holding pen to the milking parlor, as it was assumed that they were not likely to milk cows in a milking parlor. In order to be eligible for the second phase, dairy operations had to have 30 or more adult cows and have completed the initial questionnaire. USDA:VS and state animal health staff visited dairy operations between March and July 2014 and completed the survey for the second phase of the study .

The survey for the first phase included 171 questions for small, medium, and large operations, with 68 questions included in the mail-in version for very small operations. The survey was used to collect information regarding dairy cow and heifer inventory, dairy type (e.g., organic, grazing, conventional), productivity, housing, preventive practices, management of nonambulatory cattle, and euthanasia practices. The survey for the second phase included 144 questions and collected information regarding milking procedures, employee training, morbidity estimates, lameness prevention and management, culling, and mortality. Both questionnaires are available on the NAHMS website (USDA, 2014). Questionnaires were designed to take no more than 2 hours to complete, and were pretested in multiple states to evaluate the validity and clarity of questions. Problematic questions were rewritten to improve validity and the ease of survey administration. NASS and USDA staff received training prior to administering the questionnaires, and manuals were constructed that could be referenced while administering the surveys, providing clarification for the terms and procedures referenced in the questionnaires. Prior to each visit, dairy owners were provided with a list of information that would be asked in the questionnaire, in order for them to gather the information prior to the visit, and to expedite the interview process.

Data from the first survey were entered and validated using SAS (version 9.4; SAS Institute Inc., Cary, NC). Once the data had been compiled from all 17 states, the entire data set was validated again by NAHMS staff to rectify any data entry mistakes and to identify potential response errors. Descriptive data were analyzed using the SAS callable program SUDAAN (RTI International, Research Triangle Park, NC), with the CROSSTAB and DESCRIPT procedures utilized for categorical and continuous data, respectively. Additionally, PROC RATIO was used to determine the proportion of cows in each herd that fit certain criteria (e.g. percentage of cows that became nonambulatory). The "chisq" statement was used in the CROSSTAB procedure, with 95% confidence intervals being constructed to determine if differences existed among herd size. The "contrast" statement was used to identify differences when using the DESCRIPT procedure.

RESULTS

Survey results: phase 1

A total of 3,500 operations were contacted to participate in the first phase, with 1,261 operations completing the survey. Of the 1,261 dairy operations, 70 were very small, 397 were small, 342 were medium, and 452 were large. The median adult cow inventory (including both dry and lactating cows) for very small herds was 16, for small operations was 57, for medium herds was 158, and for large operations was 1094. The rolling herd average (RHA) milk production in kg/cow per year increased with herd size ($P < 0.001$), and was 6,987 (95% CI = 6,283 to 7,692) for very small herds; 8,614 (95% CI = 8,393 to 8,834) for small herds; 9,846 (95% CI = 9,626 to 10,066) for medium herds; and 11,463 (95% CI = 11,327 to 11,560) for large herds. The primary housing type used for lactating dairy cows differed among herd size ($P <$ 0.001; Table 2.1), and included freestall barns, tie-stall barns, pasture, open/dry lots, multiple animal inside pen (e.g. bedded pack), and other. On dairy operations where the primary housing system was freestall barns, 49.7% provided cows access to open/dry lots, while 50.3% did not. Tie-stalls were the primary housing type used on very small and small operations, while the majority of medium and large operations housed lactating cows in freestall barns.

Table 2.1. Distribution of primary housing types used on US dairy operations during 2013 for lactating dairy cows, compared across herd size

	Herd size[1]									
	Very small		Small		Medium		Large		All operations	
Housing type	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Freestall	18.9[a]	10.4, 32.0	24.3[a]	20.4, 28.7	68.1[b]	62.9, 73.0	76.4[b]	72.7, 79.8	39.8	36.8, 42.8
Tie-stall	43.6[a]	31.2, 56.8	58.1[a]	56.3, 62.7	12.1[b]	8.8, 16.3	1.2[c]	0.4, 3.5	39.0	35.8, 42.3
Pasture	17.9[a]	10.0, 30.2	5.8[b]	4.0, 8.4	8.0[b]	5.4, 11.6	1.5[c]	0.7, 3.3	7.5	5.8, 9.7
Open/dry lot	8.6[ab]	3.5, 19.4	5.5[a]	3.8, 8.0	6.7[a]	4.5, 9.8	17.0[b]	14.4, 19.9	7.3	5.9, 9.1
Bedded pack	11.0	5.0, 22.3	6.3	4.2, 9.4	5.2	3.2, 8.4	3.9	2.3, 6.6	6.4	4.8, 8.5

[1]Very small (< 30 cows), small (30-99 cows), medium (100-499 cows), and large (≥ 500 cows)
[a-c]Different superscripts in each row indicate differences among housing type ($P < 0.05$)

The primary bedding material used for lactating dairy cows differed for different housing types ($P < 0.001$; Table 2.2). Sand was the primary bedding material used on operations using free-stall barns, and straw and/or hay was the primary bedding material used on operations housing cows in tie-stalls, on pasture, or in open lots.

Table 2.2. Distribution of primary bedding material used on US dairy operations during 2013 in different housing systems for lactating dairy cows

	Housing type											
	Free-stall		Tie-stall		Pasture		Open lot		Bedded pack		All Operations	
Bedding type	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Sand	44.0^{a}	39.5, 48.5	3.6^{b}	1.8, 6.8	5.3^{bc}	2.1, 12.5	2.3^{b}	0.8, 6.7	17.9^{c}	9.6, 30.8	21.8	19.4, 24.4
Straw/hay	14.2^{a}	10.8, 18.3	46.6^{b}	40.4, 52.9	38.9^{b}	26.0, 53.6	33.4^{bc}	23.5, 45.1	19.7^{ac}	9.7, 25.8	29.7	26.6, 33.1
Sawdust/wood products	19.0	15.7, 22.8	25.2	20.1, 31.2	10.9	4.5, 24.0	19.6	11.7, 31.2	35.7	23.1, 50.5	21.9	19.2, 24.9
Composted/ dried manure	10.1^{a}	8.6, 11.8	0.0	-	0.0	-	18.9^{b}	13.2, 26.2	4.5^{ab}	0.9, 19.3	5.9	5.2, 6.8
Rubber mats	3.0^{a}	1.6, 5.4	11.2^{b}	7.8, 15.9	1.6^{ab}	0.2, 10.3	3.4^{ab}	0.9, 12.2	4.7^{ab}	1.1, 17.7	6.2	4.6, 8.2
Mattresses	4.3^{a}	2.8, 6.6	6.9^{a}	4.3, 10.8	2.6^{ab}	0.4, 15.6	0.3^{b}	0.1, 2.0	6.3^{ab}	1.6, 21.8	5.0	3.6, 6.8
Corn cobs/ stalks	1.9^{a}	0.9, 3.8	4.3^{ab}	2.4, 7.7	0.0	-	10.1^{b}	5.0, 19.4	9.7^{ab}	3.3, 25.2	3.7	2.6, 5.4
Other	3.7	0.9, 6.1	2.2	0.9, 5.3	1.8	0.4, 8.1	3.1	1.3, 7.4	1.7	0.2, 10.8	2.9	1.9, 4.2
None	0.0	-	0.0	-	38.9^{a}	27.2, 52.1	8.8^{b}	4.5, 16.6	0.0	-	3.0	2.2, 4.0

[a-c]Different superscripts in each row indicate differences among housing type (*P* < 0.05)

The predominant flooring type for lactating cows differed according to housing type (*P* < 0.001; Table 2.3), with concrete being used on more freestall and bedded pack operations, and rubber mats over concrete being the primary flooring on tie-stall operations.

Table 2.3. Distribution of primary flooring type used on US dairy operations for lactating dairy cows during 2013, compared among different housing systems

	Housing type											
	Free-stall		Tie-stall		Pasture		Open lot		Bedded pack		All Operations	
Flooring type	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Concrete	87.8^{a}	84.8, 90.3	42.5^{b}	36.2, 49.0	20.2^{c}	11.4, 33.2	33.3^{bc}	23.7, 44.4	63.7^{b}	47.7, 77.1	1.6	58.3, 64.9
Rubber mats over concrete	5.6^{ac}	3.8, 8.2	47.2^{b}	40.8, 53.8	3.5^{ac}	0.5, 20.5	1.0^{a}	0.1, 6.4	14.9^{c}	6.5, 30.6	1.0	18.1, 24.1
Pasture	1.6^{a}	0.7, 3.8	5.4^{ac}	3.1, 9.4	63.1^{b}	48.9, 75.3	13.3^{c}	6.5, 25.1	2.9^{ac}	0.4, 17.8	7.7	6.0, 9.8
Dirt	4.3^{a}	3.4, 5.3	4.9^{a}	2.8, 8.5	11.7^{a}	5.1, 24.8	47.9^{b}	37.1, 58.8	4.7^{a}	1.0, 19.6	8.2	6.7, 9.9
Other	0.7^{a}	0.2, 2.5	0.0	-	1.5^{a}	0.2, 9.5	4.6^{a}	1.2, 16.4	13.8^{b}	6.0, 28.7	1.6	0.9, 2.8

[a-c]Different superscripts in each row indicate differences among housing type (*P* < 0.05)

Flooring type differed among herd size (*P* < 0.001). More small herds (30.3%; 95% CI = 25.8 to 35.2) used rubber mats over concrete than medium (8.2%; 95% CI = 5.5 to 11.9) and large herds (6.3%; 95% CI = 4.4 to 8.9); more medium herds (79.4%; 95% CI = 74.6 to 83.5) used concrete than small (52.3%; 95% CI = 47.2 to 57.3) and large herds (63.7%; 95% CI = 60.2

to 67.1); and more large herds (27.3%; 95% = 24.4 to 30.4) used dirt than small (6.4%; 95% CI = 4.4 to 9.3) and medium herds (4.2%; 95% CI = 2.6 to 6.6).

The percentage of dairy operations that installed rubber belting or matting over concrete, to provide cows an alternative to walk on, differed by herd size (Table 2.4; $P < 0.001$). Similarly, cooling methods used for lactating dairy cows differed according to herd size (Table 2.4; $P < 0.05$), with more large dairies using sprinklers or misters than small and medium dairies, fewer small dairies using fans than medium or large dairies, and more small dairies using tunnel ventilation than medium or large dairies.

Table 2.4. Distribution of management practices used on US dairy operations for lactating cows during 2013, compared across herd size

	Herd size[1]							
	Small		Medium		Large		All operations	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Rubber belting								
Adjacent to feed bunk	3.6[a]	2.1, 6.0	6.1[a]	4.1, 9.1	25.8[b]	22.3, 29.7	6.8	5.5, 8.3
Freestall alleyways	5.2[a]	3.3, 8.0	3.4[a]	2.0, 5.8	22.7[b]	19.2, 26.6	6.6	5.2, 8.3
Walkway to parlor	2.6[a]	1.4, 4.8	8.0[a]	5.5, 11.4	32.3[b]	28.3, 36.6	7.5	6.2, 9.0
Holding pen	3.4[a]	2.0, 5.9	8.0[a]	5.6, 11.4	24.3[b]	20.7, 28.3	7.1	5.8, 8.7
Heat abatement								
Covered structure	80.6	76.3, 84.3	85.9	81.8, 89.1	84.5	81.2, 87.3	82.6	79.8, 85.1
Shade[2]	46.4[a]	41.4, 51.5	33.5[b]	28.5, 38.9	41.2[ab]	37.5, 44.9	42.0	38.7, 45.5
Sprinklers/misters	11.4[a]	8.6, 15.0	34.4[b]	29.5, 39.5	74.9[c]	70.5, 78.8	25.2	22.8, 27.8
Fans	70.8[a]	66.1, 75.1	82.2[b]	78.1, 85.7	84.8[b]	81.4, 87.6	75.7	72.6, 78.5
Tunnel ventilation	23.6[a]	19.5, 28.2	14.1[b]	10.6, 18.5	14.7[b]	11.8, 18.2	19.8	17.1, 22.8

[1]Small (30-99 cows), medium (100-499 cows), and large (≥ 500 cows)
[2]Shade represents a cooling method other than a covered structure/building, and can include trees
[a-c]Different superscripts in each row indicate differences among herd size ($P < 0.05$)

Data regarding nonambulatory cow prevalence and management is presented in Table 2.5. The majority of dairies had at least one nonambulatory cow during 2013, which increased with herd size ($P < 0.001$). In contrast, when comparing the farm-level prevalence of nonambulatory cows during 2013 on operations that had any nonambulatory cows, the prevalence was lower for large herds than small and medium herds ($P < 0.05$). Few dairy operations had guidelines or procedures in place for handling nonambulatory cows, which varied among herd size (*P* < 0.001).

Table 2.5. Distribution of the occurrence, prevalence, and outcome of nonambulatory cows, as well as management practices in place to manage nonambulatory cows, on US dairy operations during 2013, compared across herd size

	Herd size[1]									
	Very small[2]		Small		Medium		Large		All Operations	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Operations with at least 1 nonambulatory cow	38.8[a]	27.3, 51.7	76.4[b]	71.9, 80.5	90.1[c]	85.9, 93.2	98.4[d]	97.0, 99.2	76.5	73.1, 79.5
Prevalence of nonambulatory cows	4.5[a]	1.8, 7.3	3.9[ab]	3.5, 4.3	3.3[ab]	3.0, 3.7	2.4[ac]	2.2, 2.6	3.7	3.3, 4.2
SOPs in place for handling nonambulatory cows	-	-	15.5[a]	12.2, 19.6	24.1[b]	19.8, 29.1	57.1[c]	52.5, 61.6	22.6	20.1, 25.4
Assistance given to nonambulatory cows to rise	87.6[a]	66.8, 96.1	70.6[ab]	64.9, 75.7	81.8[ac]	77.1, 85.8	89.6[ad]	86.1, 92.4	77.5	74.1, 80.6
Outcome										
Recovered	-	-	25.2[a]	20.4, 30.0	28.4[ab]	24.7, 32.2	32.8[b]	27.4, 38.2	30.0	26.8, 33.3
Euthanized	-	-	46.7	41.3, 52.1	49.1	44.3, 53.9	51.1	46.2, 56.1	49.7	46.6, 52.7
Died	-	-	23.6[a]	19.2, 28.0	18.6[ab]	15.2, 21.9	14.8[b]	12.5, 17.2	17.7	15.9, 19.5

[1]Very small (< 30 cows), small (30-99 cows), medium (100-499 cows), and large (≥ 500 cows)
[2]Very small operations were only asked questions that were likely to be applicable to that operation size
[a-d]Different superscripts in each row indicate differences among herd size (*P* < 0.05)

When asked how soon after being recognized as nonambulatory cows were offered food, water, and shelter, the majority of operations offered these within 1 hour; 60.6% (95% CI = 57.0 to 64.1) of offered food, 62.6% (95% CI = 58.9 to 66.1) offered water, and 65.5% (95% CI = 61.8 to 69.0) offered shelter within 1 hour. A number of dairies did not offer these until at least 12 h after cows had become nonambulatory, with 5.0% (95% CI = 3.7 to 6.8) of operations waiting at least 12 h before offering food, 4.9% (95% CI = 3.6 to 6.7) before offering water, and 6.0% (95% CI = 4.4 to 8.0) before offering shelter. A total of 3.4% (95% CI = 2.3 to 5.1) of operations never offered nonambulatory cattle food, 2.6% (95% CI = 1.6 to 4.2) never offered water, and 9.1% (95% CI = 7.2 to 11.6) never offered shelter. Most dairy operations provided assistance to nonambulatory cows to help them rise, with the percentage increasing with herd size (*P* < 0.001). Of nonambulatory cows that were euthanized, 26.3% (95% CI = 22.8 to 30.1) were euthanized within 1 hour of being recognized as nonambulatory, 32.8% (95% CI = 28.9 to 36.9) between 1 and 2 hours, 34.6% (95% CI = 30.7 to 38.7) were euthanized between 2 and 6 hours, and 6.4% (95% CI = 4.6 to 8.9) were nonambulatory for 6 or more hours before being euthanized.

The percentage of cows that were permanently removed (culled) was 28.4% (95% CI = 27.4 to 29.4), and the annual death rate for all operations was 4.8% (95% CI = 4.6 to 5.0), with no differences among herd size. The percentage of operations that performed on-farm euthanasia was 60.6% (95% CI = 57.2 to 64.0), which increased with increasing herd size ($P < 0.001$); 20.7% (95% CI = 12.6 to 32.1) of very small, 56.4% (95% CI = 51.4 to 61.4) of small, 78.9% (95% CI = 73.7 to 83.2) of medium, and 96.8% (95% CI = 95.1 to 97.9) of large operations performed on-farm euthanasia. On operations that performed on-farm euthanasia, few (17.2%; 95% CI = 14.7 to 20.0) had written guidelines or procedures for euthanizing cattle. A greater percentage of large dairy operations (48.5%; 95% = 43.6 to 53.5) had written guidelines when compared to small (8.4%; 95% CI = 5.2 to 13.3) and medium operations (15.8%; 95% = 12.0 to 20.5; $P < 0.001$). No difference was found among herd size for the primary method of euthanasia, with the majority of operations (91.7%; 95% CI = 89.3 to 93.6) using gunshot, 5.9% (95% CI = 4.3 to 8.1) using lethal injection, and 1.4% (95% CI = 0.9 to 2.4) using captive bolt.

Survey results: phase 2

Of the 1,191 eligible operations, a total of 265 completed the survey for the second phase. Tail docking was performed on 31.7% (95% CI = 25.4 to 38.8) of operations, with the majority (97.0; 95% CI = 91.7 to 99.0) using a band to do so. No difference was found in the percentage of operations that docked tails and the method used, among herd size. Tail docking was done when animals were less than 2 mo of age on 31.4% (95% CI = 21.8 to 42.9) of operations, between 2 and 6 mo on 8.2% (95% CI = 4.4 to 14.7) of operations, between 6 mo and 2 yr on

14.5% (95% CI = 8.1 to 24.7) of operations, and when animals were 2 or more yr old on 45.9% (95% CI = 34.3 to 58.1) of operations. Fewer large operations (19.7%; 95% CI = 8.0 to 40.9) docked tails when animals were 2 years or older than small operations (64.7%; 95% CI = 41.6 to 82.4; $P < 0.05$), with no other differences in age found among the other herd sizes. Overall, very few operations used anesthesia and/or analgesia when docking tails (1.1%; 95% CI = 0.4 to 3.2); large operations were the only size group that used anesthesia and/or analgesia, with 4.9% (95% CI = 1.6 to 13.8) doing so.

The average number of full-time employees per operation was 5.1 (95% CI = 4.4 to 5.8), with larger operations having more full-time employees than smaller operations ($P < 0.001$). Small operations had an average of 1.8 (95% CI = 1.6 to 2.0) full-time employees, medium had 3.6 (95% CI = 3.1 to 4.1), and large had 17.3 (95% CI = 14.5 to 20.2). Table 2.6 illustrates the procedures that dairy personnel received training in during 2013, with differences identified among herd sizes in what trainings were offered ($P < 0.05$). Fewer training opportunities were offered on small and medium operations when compared to large operations.

Table 2.6. Distribution of procedures that dairy personnel received training in on US dairy operations during 2013, compared across herd size

	Herd size[1]							
	Small		Medium		Large		All Operations	
Training type	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Milking procedures	46.1[a]	34.0, 58.6	63.7[a]	50.5, 75.2	93.7[b]	85.5, 97.4	59.8	51.7, 67.3
Animal handling	44.1[a]	32.4, 56.5	61.8[ab]	48.9, 73.2	82.0[b]	69.9, 89.9	56.0	48.2, 63.6
Euthanasia practices	8.7[a]	3.7, 18.9	24.6[ab]	14.1, 39.3	41.0[b]	29.3, 53.9	20.0	14.5, 26.9
Handling of nonambulatory cows	19.7[a]	11.8, 31.1	30.6[a]	20.8, 42.6	79.0[b]	70.0, 85.9	33.4	27.1, 40.3
Surgical procedures	24.8[a]	15.1, 37.9	24.0[a]	15.0, 36.2	58.1[b]	44.9, 70.3	29.8	23.0, 37.6
Calving procedures	30.5[a]	20.2, 43.1	45.9[a]	34.3, 58.0	81.2[b]	71.5, 88.2	44.0	36.7, 51.6
Personnel safety	43.9[a]	32.0, 56.6	43.0[a]	32.0, 54.8	80.4[b]	69.0, 88.4	50.1	42.4, 57.8
Calf raising/feeding	55.8[a]	42.7, 68.1	56.5[a]	44.2, 68.1	83.0[b]	70.1, 91.0	60.2	52.0, 67.9
Feeding cows	50.3[a]	37.9, 62.7	51.6[a]	39.6, 63.4	73.7[b]	63.4, 81.9	54.8	46.9, 62.4

[1]Small (30-99 cows), medium (100-499 cows), and large (≥ 500 cows)
[ab]Different superscripts in each row indicate differences among herd size ($P < 0.05$)

DISCUSSION

Freestall and tie-stall barns were the predominant housing system used on the majority of US dairy operations. The use of freestalls, open/dry lots, and multiple animal inside (e.g. bedded pack) barns as the primary housing method have all increased from the 2007 NAHMS Dairy study (USDA, 2007), with freestall use increasing from 32.6% (95% CI = 30.4 to 34.6) to 39.8% (95% CI = 36.8 to 42.8), open/dry lots increasing from 4.6% (95% CI = 3.6 to 5.6) to 7.3% (95% CI = 5.9 to 9.1), and bedded pack barns increasing from 3.4% (95% CI = 2.2 to 4.6) to 6.4% (95% CI = 4.8 to 8.5). In contrast, the use of tie-stalls for housing lactating dairy cows has decreased from 49.2% (95% CI = 46.6 to 51.8) in 2007 to 39.0% (95% CI = 35.8 to 42.3) in 2014. A possible explanation for this change could be that the number of large dairy operations is increasing, while the number of small operations is decreasing (USDA, 2010). Results from the current study illustrate that very small and small operations tend to use tie-stalls for housing their dairy cows, while medium and large operations use more freestall barns, and large operations also use more open/dry lots. It makes sense then that as a result of dairy operations increasing in size, more freestall barns and open/dry lots are being used in the US. Another explanation for the shift towards freestall barns could be a result of dairy producers trying to decrease labor, and increase cow comfort and efficiency (Bewley et al., 2001). This assumption makes sense as freestall barns can house hundreds of cows, which have the freedom to move about the stall, and they can be cleaned using equipment rather than manpower. However, freestall barns have also been associated with an increase in lameness (Cook et al., 2004; Haskell et al., 2006; Cramer et al., 2009), and hock lesions (Haskell et al., 2006; Lobeck et al., 2011) when compared to other housing systems, suggesting that switching to freestall barns may not actually improve cow comfort, especially since lameness is one of the leading welfare concerns in the dairy industry (von Keyserlingk et al., 2012). Additional housing characteristics, such as bedding material and flooring type, have the potential to impact cow comfort and should be considered when determining the effects of a housing system on dairy cow welfare.

Not all bedding materials are equally suited for all housing systems, which was evident in the current study. The majority of free-stall barns used sand, while operations housing cows in tie-stalls, open lots, or on pasture used straw or hay, and bedded pack barns used sawdust or wood shavings. When compared to the NAHMS Dairy 2007 study (USDA, 2007), the percentage of operations using composted or dried manure has increased from 3.8% (95% CI = 2.8 to 4.8) in 2007 to 5.9% (95% CI = 5.2 to 6.8) in 2014; the percentage using rubber mats increased from 1.7% (95% CI = 0.3 to 3.1) to 6.2% (95% CI = 4.6 to 8.2); and straw and/or hay decreased from 37.3% (95% CI 31.5 to 43.1) to 29.7% (26.6 to 33.1), although this difference was not statistically significant. An 8% decrease is worth noting even if it is not significant, as it suggests that there is a downward trend in the percentage of operations using straw and/or hay for bedding lactating dairy cows. The bedding material used can depend on many different variables, including location, housing, and availability (Tucker et al., 2009). Increased costs and reduced availability of straw and/or hay may explain the decreased use of these materials for bedding (Husfeldt et al., 2012), and may also explain the increase in operations that used rubber mats and dried or composted manure. Sand bedding has shown to benefit cow comfort through reduced hock lesions and lameness (Weary and Taszkun, 2000; Cook et al., 2004; Norring et al., 2008), as well as being associated with lower bacterial counts when compared to organic bedding materials such as straw and sawdust (Hogan et al., 1989). While sand is commonly used in freestall barns, not all housing systems are ideally suited for sand bedding, such as bedded pack barns (e.g. compost barns) where the bedding material used is usually wood shavings or sawdust (Barberg et al., 2007). And while sand can be used in tie stall barns, many operations would have to undergo renovations to the stall base and manure handling systems to make this possible, potentially explaining why so many tie-stall operations still use straw or hay for bedding dairy cows. While sand bedding has proven benefits for udder health (Hogan et al., 1989), it is possible to achieve cow comfort with other bedding materials when managed properly. Deeply bedded stalls, whether it is with sawdust, compost, or sand, (Tucker and Weary, 2004; Drissler et al., 2005) improves the cushion and compressibility of the lying surface, and reduces the prevalence of hock lesions (van Gastelen et al., 2011).

Concrete was the predominant flooring for operations that housed cows in freestall and bedded pack barns, while rubber mats over concrete was the primary flooring type for tie-stall operations. Additionally, more small herds had rubber mats over concrete, more medium herds had concrete, and more large herds had dirt for the predominant flooring type for lactating dairy cows. These results are a little contradictory, as the primary housing type for large operations is freestall barns, yet the primary flooring type is dirt. More large dairy operations used open/dry lots than other sized operations, and about a third of large operations that used freestall barns allowed their cows access to an open/dry lot, which may explain this discrepancy. No differences were identified in flooring type between the 2007 and 2014 NAHMS Dairy studies (USDA, 2007). While concrete may be easier to clean than other flooring materials, it has been associated with an increased prevalence of lameness (Somers et al., 2003; Vanegas et al., 2006; Cook and Nordlund, 2007), highlighting an area of concern for the US dairy industry as far as lameness and dairy cow welfare are concerned. Concrete is an unforgiving and abrasive surface (Cook et al., 2004; Vokey et al., 2001), which may result in an increased prevalence of lameness due to claw horn lesions (Greenough and Vermunt, 1991; Cook et al., 2004; and Haskell et al., 2006), and white line disease (Cook et al., 2004). Additionally, the unyielding nature of concrete may exacerbate lameness and contribute to an imbalance in claw growth between the medial and lateral claws (Vokey et al., 2001). Rubber belting or matting over concrete has been associated with a decrease in dairy cow lameness (Vanegas et al., 2006; Chapinal et al., 2012), as it provides better traction, more secure footing, and increased compressibility compared to concrete (Rushen and de Passillé, 2006; Flower et al., 2007). Additionally, results from cow preference tests suggest that cows find rubber flooring more comfortable to stand on than concrete (Fergonesi et al., 2004; Telezhenko et al., 2007). A greater percentage of large operations used rubber belting to give cows a break from standing on concrete than medium and small operations, which agrees with Chapinal et al. (2012) who suggested that large herds are more likely to adopt practices that are associated with reduced lameness. While this may be true, more large dairies house cows in freestall barns which exposes them to concrete, increasing the need for management practices, such as rubber belting, to help mitigate the negative effects of concrete on dairy cow lameness and welfare. Either way, installing rubber over concrete provides cows with a break from standing on concrete, and can improve dairy cow welfare through decreasing lameness prevalence and improving cow comfort.

The majority of dairy operations provided shelter or shade for cows during the summer of 2013, although more large dairy operations provided additional cooling through sprinklers and misters than small and medium operations, and more medium and large operations used fans than small operations. Lactating dairy cows produce a large amount of metabolic heat and are particularly sensitive to heat stress (West, 2003; Rushen et al., 2008). The thermonuetral zone for lactating dairy cows is between 5 and 25°C (Kadzere et al., 2002), with temperatures above 25°C causing cows to experience heat stress. Increases in the core body temperature of dairy cows can have negative physiological effects on dairy cows, including reduced fertility, growth, and milk production (McDowell et al., 1976; Kadzere et al., 2002). Heat stress in dairy cattle has been associated with decreased dry matter intake (DMI) and decreased milk yield (West, 2003). Additionally, heat stress has been linked with decreased fertility during the summer months (De Rensis and Scaramuzzi, 2003). Providing supplementary cooling methods, through the use of fans and/or sprinklers and misters, can help to mitigate some of the negative effects of high temperatures on the welfare and productivity of dairy cows.

The finding that the percentage of dairy operations with at least one nonambulatory cow during 2013 increased with herd size was to be expected, because as the number of animals increases on an operation, so does the probability of at least one of those animals becoming nonambulatory. In contrast, when comparing the farm-level prevalence of nonambulatory cows during 2013 on operations that had any nonambulatory cows, the prevalence was actually lower for large herds than small and medium herds. Even with a lower prevalence, large dairy operations contribute substantially to the number of nonambulatory cows in the US, as a prevalence of 2.4% on a 2,000 cow dairy operation means that 48 cows were nonambulatory over the course of the year. The definition of nonambulatory used in the current study only included cows that had been recumbent for 24 h or more, which is longer than the definition used in previous studies (Fenwick et al., 1986; Smith et al., 1997; Green et al., 2008). The reason for using 24 h or more as the cut off was to be able to identify what management practices were in place for handling cows during prolonged recumbency, as well as to determine the recovery rate for these animals. Few dairy operations in the current study had guidelines or procedures in place for handling nonambulatory cows, with the percentage of operations with written guidelines increasing with herd size. Even though a greater percentage of large dairy operations had written guidelines for handling nonambulatory cows than small and medium sized operations, this only represented roughly half of the large operations, highlighting an area that the dairy industry can improve upon. A quarter of small dairy operations did not report any nonambulatory cows during 2013, suggesting that the occurrence of nonambulatory cows on small operations is not as common of an occurrence when compared to larger operations. This may explain why so few small operations have written guidelines in how to handle nonambulatory cows, although one could argue this is the exact reason as to why they should. Dairy personnel on small operations may not remember what the procedures are for dealing with nonambulatory cows as the occurrence is so low, illustrating the benefits of having written guidelines for them to follow. Another explanation for the lack of written guidelines may be that some small operations do not have any employees other than the owner, therefore making written guidelines for employees unnecessary. Dairy operations that have employees and provide written guidelines for them to follow help to ensure that nonambulatory cows are managed consistently, regardless of who is in charge of their care, which can be beneficial regardless of the size of the operation.

The majority of dairy operations offered cows food, water, and shelter within 1 h of being recognized as nonambulatory; however, a concerning number of dairies did not offer these until at least 12 h after cows had become nonambulatory, with some dairies never offering nonambulatory food, water or shelter. As with any sick animal, having adequate food and water is important for a successful recovery. Not bringing food and water to nonambulatory cows is quite concerning, as these animals are unable to get to the feed bunk and water on their own. Additionally, depriving nonambulatory cows of food, water and/or shelter is likely to greatly reduce the chances of recovery. Educational efforts from herd veterinarians and extension personnel focusing on the importance of providing adequate food, water, and shelter for nonambulatory cows, as well as highlighting the welfare concerns associated with not providing these things, is necessary to improve in this area.

As the time that a dairy cow is nonambulatory increases, her chances of recovery usually decrease. It is recommended to reposition nonambulatory cows, and to provide them with assistance in standing to prevent further injury and hasten recovery (Burton and Ollivett, 2009). Most dairy operations in the current study provided assistance to nonambulatory cows (such as through a hoist or flotation tank) to help them rise, with a greater percentage of large dairy operations providing assistance than small and medium. As small operations may go long periods of time before having a nonambulatory cow, it is possible that they are not aware of the benefits of providing assistance since they do not experience them as often as larger operations. Of nonambulatory cows that were euthanized, the majority were euthanized within 6 h after being identified as nonambulatory. In contrast, 17.7% of nonambulatory cows on dairy operations died without assistance, highlighting an area of concern for dairy cow welfare. Humane euthanasia is the best option for many nonambulatory cows, such as those that are no longer alert or able to eat and drink. Animals such as these should be humanely euthanized to prevent unnecessary suffering. Additionally, the time a cow is down should be considered when considering a treatment plan, as prolonged recumbency reduces the chances of recovery. Green et al. (2008) found that dairy cows that were nonambulatory for less than 24 h had greater odds of recovering than those that were nonambulatory for greater than 24 h. Emphasis needs to be placed on the timely identification and proper management of downer cows, including humane euthanasia, to prevent dairy cows with a poor prognosis from prolonged suffering.

The percentage of cows that were culled has increased from 23.6% (95% CI = 22.8 to 24.4) during the 2007 NAHMS dairy study, to 28.4% (95% CI = 27.4 to 29.4) in the current study (USDA, 2007). The culling rate found in the current study is similar to that found by Lobeck et al. (2011) involving dairy operations in the upper Midwest, with a cull rate of 24.6 to 30.1%. The annual death rate in the current study for all operations was 4.8% (95% CI 4.6 to 5.0), which is a decrease from the 5.7% (95% CI = 5.5 to 5.9) that was reported during the NAHMS dairy 2007 study. The death rate in the current study is slightly lower than that reported by Lobeck et al. (2011), who reported a death rate on dairy operations in the upper Midwest between 5 and 5.8%. This is the first time since NAHMS started conducting national studies that the death rate has decreased, as it had been on an increasing pattern from 3.8% in 1996, to 4.8% in 2002, reaching its peak at 5.7% in 2007 (USDA, 2008). This finding is encouraging and suggests that US dairy producers are implementing management practices on their operations to decrease dairy cow mortality, either through more timely culling or improved health management.

The percentage of operations that performed on-farm euthanasia increased with herd size, with the majority of large operations performing euthanasia during 2013, while a small percentage of very small operations euthanized cows. These results agree with those reported by Hoe and Ruegg (2006), who found that small operations were less likely to report performing euthanasia of sick animals compared to large farms. Again, the probability of a cow needing to be euthanized increases when a herd has more animals, so it makes sense that more large operations performed on-farm euthanasia than smaller operations. Of the operations that euthanized any heifers or cows during 2013, only 17.2% had written guidelines or protocols for euthanizing cattle. While a much greater percentage of large operations had written guidelines for euthanasia than small and medium operations, more than 50% of large dairy operations did not have written guidelines, highlighting an area of concern. The purpose of euthanasia is to provide a humane death, and having written guidelines for personnel to follow can help them to identify which animals should be euthanized, and prevent sick and injured animals from prolonged suffering (Thomsen et al., 2004). Additionally, the majority of operations in the current study stated gunshot was their primary method of euthanasia, which should be carried out by competent individuals who have protocols to follow in order to ensure quick death and human safety (AABP, 2013). Improperly administering euthanasia and not ensuring death can result in unnecessary suffering, which can be prevented through proper training and strict adherence to protocols.

Less than a third of the operations in the current study docked tails during 2013. Tail docking is a procedure that was introduced as a way to reduce the risk of mastitis on dairy farms, with the hypothesis being that the udder of a cow with a docked tail would be cleaner than that of one with a tail (Stull et al., 2002). Multiple studies have been conducted investigating the efficacy of tail docking, with the majority concluding that there is no difference in udder cleanliness and milk quality between cows with docked tails and those with tails (Tucker et al., 2001; Schreiner and Ruegg, 2002). A study involving 297 dairy operations in the US found that cows on operations that performed tail docking were actually dirtier than those on operations that did not dock tails (Lombard et al., 2010). Results such as these have caused many to question the efficacy of tail docking, stating that there is little merit in tail docking as a way to improve cleanliness and udder health (Tucker et al., 2001). With greater than 30% of the operations in the current study docking tails, it is clear that an opportunity exists for producer education, including alternatives to tail docking as a method of improving cow cleanliness and udder health. While the procedure itself appears to cause little acute pain, there are many behavioral and long term effects, such as the removal of the cow's natural fly-swatter, that have the potential to impact dairy cow welfare (Rushen et al., 2008).

As hired employees manage many of the day-to-day tasks on larger dairy operations, the need for competent personnel is critical to the success of the operation as well as the welfare of the cows. Training opportunities were provided for employees on fewer small and medium operations than large operations, indicating a need for improvement when it comes to providing training to dairy employees. It is possible that owners of small and medium operations don't feel the need to provide training when they have only a few full-time employees, however even a dairy with one employee would benefit from training. In fact, the impact on the health and welfare of cows on a dairy with few employees could be significant as each employee may be responsible for a larger percentage of the herd. Dairy personnel are the first line of defense when it comes to the health and welfare of the animals on a dairy farm, and adequate training not only ensures that dairy personnel have the knowledge necessary to handle dairy cows appropriately, but also that personnel have the ability to adequately identify cows that are sick or lame, both of which greatly impact dairy cow welfare. A study investigating the efficacy of a training program aimed at improving dairy worker attitudes towards working with dairy cattle concluded that the training program was successful in improving the interactions between dairy personnel and dairy cows (Hemsworth et al., 2002), with those that received training using fewer negative interactions when handling dairy cows than those that did not receive training. Other training programs have proven successful in educating dairy producers and employees on various components of the dairy operation, such as milking practices and calving management (Dalton and Jensen, 2006; Garry et al., 2007). Encouraging dairy producers to invest in on-farm training programs would not only increase the welfare of cows within the dairy industry, but would likely improve productivity of the farm as well through improved adherence to farm-wide management and treatment protocols.

CONCLUSIONS

The results from this survey highlight different aspects of dairy management that can be modified to improve dairy cow welfare. Expanding educational efforts, aimed at both dairy owners and personnel, can help to ensure that information presented in scientific literature reaches dairy producers, where it can be applied on the farm. Stressing the benefits of certain management practices on dairy cow welfare, such as installing rubber matting over concrete or having standard operating procedures in place for handling nonambulatory cows, can help to ensure that dairy producers have the knowledge and tools necessary to provide their cows with the best possible care.

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CHAPTER III: ASSOCIATIONS BETWEEN HOUSING AND MANAGEMENT PRACTICES ON THE PREVALENCE OF LAMENESS, HOCK LESIONS, AND THIN COWS ON US DAIRY OPERATIONS

INTRODUCTION

Lameness is a leading welfare concern in the dairy industry, with the average prevalence on dairies in the US reported to range from 20 to 55% (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012). Dairy characteristics, such as housing type, bedding material, and flooring design, have been shown to impact dairy cow lameness. Compost barns have been shown to have a reduced prevalence of lameness over freestall barns (Lobeck et al., 2011). Similarly, cows that were housed in freestall barns and had access to pasture had a lower prevalence of lameness compared to those housed in freestall barns with no access to pasture (17 versus 39%; Haskell et al., 2006). Deep sand bedding has been shown to reduce lameness on dairy operations, with herds using deep sand bedding having a lower prevalence of lameness than herds using mattress bedded stalls (Cook, 2013) or those using sawdust bedded stalls (Chapinal et al., 2013). Housing cows on concrete has also been associated with dairy cow lameness, with a study by Vanegas et al. (2006) finding that cows housed on concrete were 5 times as likely to be diagnosed as lame as those housed on rubber mats over concrete.

In addition, dairy characteristics can impact the occurrence of injuries to dairy cows, specifically hock lesions. Cows that have access to pasture have been reported to have fewer hock lesions compared to cows with no pasture access, with dairy cows on farms in New York, Oregon, and Wisconsin that had pasture access having a lower prevalence of hock lesions than cows on operations with no pasture access (Bergman et al., 2014). Multiple studies have illustrated the benefits of deep sand bedding on reducing the prevalence of dairy cows with hock lesions. In a survey of 297 freestall operations in the US, operations that housed cows on rubber mats or mattresses had a higher percentage of cows with severe hock lesions than operations that used sand bedding (Lombard et al., 2010). Similar results have been found in other studies, with rubber mats or mattresses resulting in an increase in hock lesions when compared to sand bedded stalls (Weary and Taszkun, 2000; Fulwider et al., 2007; Lobeck et al., 2011).

There are multiple herd level and cow level factors that have the ability to impact the body condition of dairy cows, such as various aspects of feeding management and overall production level. Cows on operations where they are required to consume 30% of their DMI through grazing have been shown to have lower BCS during the spring than operations that were fed a TMR at all times (Sato et al., 2005). The level of milk production for a given cow has been shown to influence BCS. As dairy cows are not able to consume enough feed to meet their energy requirements during early lactation, the BCS profiles of cows post calving have been illustrated to be a mirror image of the milk production curve, with BCS declining as milk production increases (Roche et al., 2007).

There is a wide range of housing and management systems that can be used on dairy operations, many of which have been shown to have the ability to impact dairy cow welfare, specifically lameness, the occurrence of hock lesions, and BCS. The National Animal Health Monitoring System (NAHMS) conducts national surveys to collect information on the health and management of domestic livestock species (USDA, 2014), and in 2014 a study was conducted to collect information about the US dairy industry. The information reported here is a component of the NAHMS 2014 dairy study. The objective of this study was to determine the association among different housing and management practices on the prevalence of lameness, hock lesions, and thin cows on US dairy operations.

MATERIALS AND METHODS

Study Design

The National Agricultural Statistical Service (USDA, 2013) "Cattle Report" was used to determine states for inclusion in the NAHMS Dairy 2014 study, with the goal of including states that accounted for at least 70% of the dairy operations and dairy cattle in the United States. Seventeen states were chosen for inclusion in the study representing 81.3% of dairy operations and 81.2% of dairy cows in the United States. The states included in the study were: California, Colorado, Idaho, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Texas, Vermont, Virginia, Washington, and Wisconsin. NASS used a sampling frame and selected a stratified random sample of dairy operations within each state to participate in the study. Operation-level weights were provided by NASS and accounted for the selection criteria and study nonresponse. These weights were used to generate national estimates of the US dairy industry. Dairy size was categorized as very small (1 to 29 cows), small (30 to 99 cows), medium (100 to 499 cows), and large (500 or more cows).

NASS enumerators visited dairy operations to complete the survey with dairy producers in January 2014 (Phase I). During the same time period, operations with fewer than 30 cows were mailed a shortened version of the initial questionnaire, which consisted of a subset of questions that were applicable to very small operations. In order to be eligible for the second phase, dairy operations had to have 30 or more adult cows and have completed the initial questionnaire. USDA:VS and state animal health staff visited dairy operations between March and July 2014 and completed the survey for the second phase of the study.

The survey for the first phase included 171 questions for small, medium, and large operations, with 68 questions included in the mail-in version for very small operations. The survey collected information regarding dairy cow and heifer inventory, dairy type (e.g., organic, grazing, conventional), productivity, housing, preventive practices, management of nonambulatory cattle, and euthanasia practices. The survey for the second phase included 144 questions and collected information regarding milking procedures, employee training, morbidity estimates, lameness prevention and management, culling, and mortality. Both questionnaires are available on the NAHMS website (USDA, 2014). Questionnaires were designed to take no more than 2 hours to complete, and were pretested in multiple states to evaluate the validity and clarity of questions. Problematic questions were rewritten to improve validity and the ease of survey administration. NASS and USDA staff received training prior to administering the questionnaires, and manuals were constructed that could be referenced while administering the surveys, providing clarification for the terms and procedures referenced in the questionnaires. Prior to each visit, dairy owners were provided with a list of information that would be asked in the questionnaire, in order for them to gather the information prior to the visit, and to expedite the interview process.

Cow Evaluations

All data were recorded on a specifically developed evaluation form. Evaluators were asked to score all cows on dairy operations with 100 cows or fewer, and to select 1 or 2 pens to score on operations with more than 100 cows. Evaluators recorded the number of cows scored on each operation, the group of cows scored (e.g. entire herd, high production pen etc.), the surface that cows were scored on (e.g. concrete or dirt), and the condition of the scoring surface (e.g. wet, icy etc.). Dairy cows were evaluated for locomotion, hock, and body condition scores by the veterinary medical officers or animal health technicians. Each evaluator was trained by coordinators within each state, with trainings consisting of a video along with reference sheets to use for locomotion, hock, and body condition scoring. A 3-point locomotion scoring (LS) system was developed specifically for use in this study, through collaboration with researchers in the area of dairy cow lameness in the US and Canada (USDA, 2014): 1 = sound, 2 = mild or moderately lame, and 3 = severely lame. Hock scoring (HS) was conducted using a 3-point system developed by Cornell University (2009), with 1 = no lesion, 2 = mild lesion, and 3 = severe lesion. To make the process easier, evaluators were asked only to record the number of cows that received a score of 2 or 3 for both locomotion and hock scoring, and then subtract that from the total number of cows scored (either on the farm or in the pen) to determine the number of score 1 cows. Body condition scoring was conducted using a 5-point system developed by Elanco (Elanco Animal Health ©, Greenfield, IN), which was adapted from the scoring systems developed by Wildman et al (1982) and Ferguson et al (1994), which ranges from 1 = emaciated to 5 = obese. Evaluators were asked to record the number of cows with a BCS of 2.25 or less, representing a thin cow, and then subtract that from the total number of cows scored to determine the number of cows with adequate BCS. As time constraints were likely to limit the amount of information that could be collected while cows passed the evaluators, they were instructed to score cows for LS and BCS as they returned from the milking parlor to their home pens, and follow the cows back to the pen to assess hock lesions. A total of 76 different evaluators assessed cows on the 192 operations.

Statistical Analysis

Data from the first survey were entered and validated by NASS staff using SAS (version 9.4; SAS Institute Inc., Cary, NC). Once all of the data had been compiled from all 17 states, the entire data set was validated again by NAHMS staff. Descriptive data were analyzed using the statistical program SUDAAN within SAS, with the CROSSTAB and DESCRIPT procedures being utilized for categorical and continuous data, respectively. Additionally, PROC RATIO was used to determine what proportion of cows in each herd fit certain criteria (e.g. percent of cows that were lame).

Models were constructed to evaluate the outcomes of lame (LS ≥ 2), severely lame (LS = 3), hock lesion (HS ≥ 2), severe hock lesion (HS = 3), and thin (BCS ≤ 2.25). Several steps were used to determine which explanatory variables would be included in the final models. Variables that were considered for inclusion in the analysis had plausible biological links with the outcome variables, as well as variables that had proven to be significantly linked with the outcome variables in previously reported research studies. All potential predictor variables were screened for significance for inclusion in the univariate model using PROC LOGLINK using the SAS-callable SUDAAN program. The pen scored (high, mid, low-production), scoring surface (concrete, dirt, and other), and the surface condition (dry, wet, snow/ice, other) were noted, and considered as covariates in the analysis when significant. Variables with a $P < 0.20$ were considered for inclusion in the multivariate model. Stepwise backwards elimination procedures were used in PROC LOGLINK to construct the final models, with $P < 0.05$ indicating significance and inclusion in the model.

RESULTS

The distribution of scores for the outcome variables is presented in Table 3.1. Few cows were scored as lame or severely lame, with 9.8% (95% CI = 8.4 to 11.2) cows were determined to be lame (LS ≥ 2) and 2.8% (95% CI = 2.1 to 3.5) were severely lame. A larger percentage of cows were found to have hock lesions (HS ≥ 2), with 12.9% (95% CI = 10.0 to 15.8) having any lesion and 2.6% (95% CI = 1.9 to 3.4) having severe lesions. A small percentage of cows (4.1%; 95% CI = 2.7 to 5.6) were determined to be thin (BCS ≤ 2.25).

Table 3.1. Distribution of scores for the outcome variables lame, severely lame, hock lesion, severe hock lesion, and thin on US dairy operations

Outcome variable	Operations (n)	Minimum (%)	10th percentile (%)	Mean (%)	90th percentile (%)	Maximum (%)
Locomotion score (LS)	185					
Sound cows (LS = 1)		52.1	79.1	90.3	98.7	100.0
Mild/moderately lame cows (LS = 2)		0.0	0.7	6.9	16.9	25.5
Severely lame cows (LS = 3)		0.0	0.0	2.8	7.1	25.0
Hock score (HS)	192					
Cows with no lesions (HS = 1)		8.9	61.6	87.3	100.0	100.0
Cows with mild lesions (HS = 2)		0.0	0.0	10.1	31.0	66.1
Cows with sever lesions (HS = 3)		0.0	0.0	2.6	9.8	35.6
Body condition score	191					
Thin cows (BCS ≤ 2.25)		0.0	0.0	4.2	11.5	62.9

The explanatory variables that were included in the univariate models for lameness and hock lesions are presented in Table 3.2.

Table 3.2. Categorical variables used in the univariate analysis of variables associated with lameness, severe lameness, hock lesions, and severe hock lesions on US dairy operations

			P-value			
Categorical variable	Level	Farms (%)	Lame[1]	Severely lame[1]	Any hock lesions[2]	Severe hock lesions[2]
Region	West	20.4	0.475	0.036	0.086	<0.001
	East	79.6				
Size	Small	26.2	0.148	0.069	<0.001	<0.001
	Medium	30.4				
	Large	43.5				
Operation type	Conventional (C)	78.7	0.335	0.147	<0.001	0.001
	Grazing (G)	3.2				
	Combination C-G	11.7				
	Organic	6.4				
Housing type	Tie-stall/stanchion	16.4	0.151	0.044	<0.001	<0.001
	Pasture	5.3				
	Freestall	68.3				
	Open lot	10.1				
Bedding material	Straw/hay/corn stalks	20.4	0.003	0.244	<0.001	<0.001
	Sand	33.5				
	Sawdust/wood products	17.8				
	Dried or composted manure	14.7				
	Rubber mats/mattresses	8.4				
	Other	5.2				
Flooring type	Concrete	74.1	0.397	0.038	<0.001	<0.001
	Rubber mats on concrete	11.1				
	Pasture	4.2				

	Dirt	10.6				
Rubber mats in freestall alleyway	Yes	8.9	0.933	0.049	NA[3]	NA[3]
	No	91.1				
Rubber mats in walkway to parlor	Yes	15.3	0.208	0.051	NA[3]	NA[3]
	No	84.7				
Sprinklers/misters for cooling	Yes	46.0	0.215	0.080	0.006	<0.001
	No	54.0				
Fans for cooling	Yes	82.1	0.020	0.083	0.211	0.130
	No	17.9				
When lame cows receive treatment	Within a few hours	9.0	0.049	0.161	NA[3]	NA[3]
	Within a day	38.6				
	Within a week	43.4				
	Within a month	9.0				
Yearly visits by a hoof trimmer	None	22.0	0.618	<0.001	NA[3]	NA[3]
	Every other month	30.4				
	Monthly	13.1				
	Twice per month	7.9				
	Weekly	14.7				
	More often	12.0				
Frequency of hoof trims	Twice per lactation/year	34.6	0.124	0.282	NA[3]	NA[3]
	Once per lactation/year	35.1				
	Only when visibly lame	20.4				
	Other	2.6				
	Never	7.3				
Hoof trimming personnel	Professional hoof trimmer	82.5	0.015	0.125	NA[3]	NA[3]
	Veterinarian	2.8				
	Dairy personnel	14.7				
Outside area for the winter – lactating cows	Pasture	5.3	0.020	0.066	0.026	0.005
	Concrete	14.7				
	Open/dry lot	30.5				
	None	49.5				
Outside area for the summer – dry cows	Pasture	36.3	0.332	0.032	0.315	0.474
	Concrete	10.0				
	Open/dry lot	27.9				
	None	25.8				
Outside area for the winter – dry cows	Pasture	10.1	0.013	0.345	<0.001	<0.001
	Concrete	11.1				
	Open/dry lot	42.9				
	None	36.0				
Surface moisture – summer	Dry	47.9	0.116	0.046	NA[3]	NA[3]
	Wet half the time	23.7				
	Almost always wet	28.4				
	Standing water/slurry	0.0				
Surface moisture – winter	Dry	31.1	0.546	0.137	NA[3]	NA[3]
	Wet half the time	33.2				
	Almost always wet	35.8				
	Standing water/slurry	0.0				

[1]Lame indicates a LS ≥ 2 and severely lame indicates a LS = 3 on a 3-point scale (USDA, 2014)
[2]Any lesion indicates a HS ≥ 2 and severe lesion indicates HS = 3 on a 3-point scale (Cornell University, 2009)
[3]NA = variable not included in univariate analysis

Of the 10 variables that were considered for inclusion in the multivariate model, 7 met the criteria for inclusion in the final model as being associated with lameness (Table 3.3), after controlling for the condition of the surface that cows were evaluated on. Additional variables that were considered for inclusion but did not meet the criteria included: footbath use, outside area for lactating cows during the summer, whether or not personnel received training in dairy cow handling, and rubber mats in the holding pen or in front of the feedbunk.

Table 3.3. Explanatory factors included in the multivariate analysis for association with dairy cows being lame on US dairy operations (n = 163)

Variable	Level	Predicted marginal	Incidence density ratio	Beta coefficient	SE	*P*-value
Size	Small	0.10	1.37	0.31	0.28	0.272
	Medium	0.11	1.51	0.42	0.16	0.008
	Large	0.07	Ref			
Housing type	Tie-stall/stanchion	0.08	2.38	0.87	0.44	0.052
	Open/dry lot	0.07	1.89	0.63	0.38	0.101
	Freestall	0.11	3.16	1.15	0.30	<0.001
	Pasture	0.04	Ref			
Bedding material	Straw/hay/corn stalks	0.11	2.07	0.73	0.34	0.032
	Sand	0.06	1.26	0.23	0.36	0.523
	Sawdust/wood products	0.12	2.26	0.82	0.35	0.021
	Dry or composted manure	0.11	2.17	0.77	0.35	0.028
	Other	0.17	3.24	1.17	0.36	0.001
	Rubber mats/mattresses	0.05	Ref			
When lame cows receive treatment	Within a few hours	0.15	1.06	0.06	0.29	0.835
	Within a day	0.09	0.62	-0.50	0.20	0.014
	Within a week	0.09	0.61	-0.48	0.19	0.012
	Within a month	0.14	Ref			
Hoof trimming personnel	Professional hoof trimmer	0.09	1.29	0.25	0.22	0.243
	Dairy personnel	0.13	1.84	0.61	0.25	0.015
	Veterinarian	0.07	Ref			
Fans for cooling	Yes	0.10	1.62	0.48	0.15	0.002
	No	0.06	Ref			
Surface moisture – summer	Dry	0.12	1.72	0.54	0.20	0.006
	Almost always wet	0.10	1.45	0.37	0.21	0.077
	Wet half the time	0.07	Ref			

The size of the operation was associated with dairy cow lameness, with medium dairies having more lame cows than large operations (P = 0.008). When considering housing type, operations housing cows in freestalls had more lameness than those with cows housed on pasture (P = 0.024), and those housing cows in tie-stall/stanchion barns had a strong tendency to have more lameness than those on pasture (P = 0.052). Lameness was associated with bedding material, with operations using rubber mats/mattresses having a lower prevalence of lameness than those using straw/hay/corn stalks (P = 0.032), sawdust/wood products (P = 0.021), and dried or composted manure (P = 0.028), with no difference found between sand and rubber mats/mattresses. The amount of time prior to cows receiving treatment after being identified as lame was associated with lameness, with the prevalence of lameness on operations where dairy cows received treatment within a day (*P* = 0.035) or week (*P* 0.034) being lower than on operations where the average lame cow received treatment within a few hours. An association was identified between the person responsible for trimming hooves and lameness, with operations on which dairy personnel trimmed hooves illustrating an increase in lameness compared to those on which the herd veterinarian did it. Dairy operations that used fans to provide cooling for cows actually had an increased prevalence of lameness when compared with operations that did not use fans (*P* = 0.002). The moisture of the standing area that dairy cows had access to during the summer was shown to have an effect, with operations where the surface was wet half of the time having fewer lame cows than those where the surface was dry (*P* = 0.006).

Of the 16 variables considered for predictors of severe lameness, 5 were found to be associated with severe lameness (Table 3.4), after controlling for the condition of the surface that cows were scored on. Additional variables that were considered for inclusion but did not meet the criteria included: footbath use, outside area for lactating cows during the summer, whether or not personnel received training in dairy cow handling, and rubber mats in the holding pen or in front of the feedbunk.

Table 3.4. Explanatory factors included in the multivariate analysis for association with dairy cows being severely lame on US dairy operations (n = 176)

Variable	Level	Predicted marginal	Incidence density ratio	Beta coefficient	SE	*P*-value
Housing type	Tie-stall/stanchion	0.01	3.90	1.36	1.00	0.176
	Freestall	0.04	14.71	2.69	0.99	0.007
	Open lot	0.03	10.77	2.38	0.93	0.012
	Pasture	0.00	Ref			
Yearly visits by a hoof trimmer	Every other month	0.02	0.60	-0.52	0.28	0.062
	Monthly	0.02	0.69	-0.37	0.37	0.321
	Twice per month	0.03	0.80	-0.22	0.39	0.570
	Weekly	0.02	0.68	-0.38	0.32	0.241
	More often	0.01	0.25	-1.39	0.35	<0.001
	None	0.04	Ref			

Outside area for the winter – lactating cows	Pasture	0.02	0.40	-0.93	1.01	0.360
	Open/dry lot	0.02	0.40	-0.92	0.25	<0.001
	None	0.02	0.28	-1.27	0.29	<0.001
	Concrete	0.06	Ref			
Outside area for the summer – dry cows	Pasture	0.03	3.05	1.11	0.37	0.003
	Open/dry lot	0.01	1.23	0.20	0.44	0.645
	None	0.04	3.48	1.25	0.44	0.006
	Concrete	0.01	Ref			
Surface moisture – summer	Dry	0.03	2.76	1.01	0.32	0.002
	Almost always wet	0.03	2.55	0.94	0.28	0.001
	Wet half the time	0.01	Ref			

Housing type was shown to have an effect on the percentage of cows that were severely lame, with operations that housed cows on pasture having a lower prevalence of severely lame cows than those that housed them in open/dry lots ($P = 0.012$) or freestall barns ($P = 0.007$). The number of visits by a hoof trimmer each year was shown to influence severe lameness, with operations that did not have any visits from a hoof trimmer during 2013 having an increased prevalence of severely lame cows when compared to those that had a hoof trimmer come more often than weekly ($P < 0.001$). Operations that did not allow lactating cows access to the outside during the winter, or allowed them access to an open/dry lot, had a lower prevalence of severely lame cows than those on which lactating cows were on concrete when they were outside during the winter ($P < 0.001$). The outside area that dry cows had access to during the winter was associated with severe lameness, with those housing cows on concrete actually having a lower prevalence of severely lame cows than those housing cows on pasture ($P = 0.003$) and those on which dry cows did not have any outside access ($P = 0.006$). Finally, the surface moisture of the ground that lactating cows stood on had an effect on severe lameness, with operations where the surface moisture was wet half of the time having a lower prevalence of severely lame cows than those where it was either dry ($P = 0.002$) or almost always wet ($P = 0.001$).

Nine variables were included in the univariate analysis for the prevalence of hock lesions, with 4 being included in the final multivariate model (Table 3.5) after controlling for scoring group. The outside area that lactating cows had access to during the summer was also considered for inclusion in the multivariate model, but did it not meet the criteria.

Table 3.5. Explanatory factors included in the multivariate analysis for association with dairy cows having hock lesions on US dairy operations (n = 185)

Variable	Level	Predicted marginal	Incidence density ratio	Beta coefficient	SE	*P*-value
Housing type	Tie-stall/stanchion	0.21	5.14	1.64	0.36	<0.001
	Pasture	0.45	11.06	2.40	0.37	<0.001
	Freestall	0.14	3.35	1.21	0.31	<0.001
	Open lot	0.04	Ref			
Operation type	Conventional (C)	0.23	11.19	2.42	0.52	<0.001
	Combination C-G	0.13	6.20	1.82	0.55	0.001
	Organic	0.07	3.49	1.25	0.55	0.024
	Grazing (G)	0.02	Ref			
Bedding material	Straw/hay/corn stalks	0.31	9.14	2.21	0.43	<0.001
	Sawdust/wood products	0.16	4.81	1.57	0.44	<0.001
	Dry or composted manure	0.12	3.66	1.30	0.39	0.001
	Rubber mats/mattresses	0.15	4.41	1.48	0.46	0.001
	Other	0.03	0.76	-0.27	0.41	0.514
	Sand	0.03	Ref			
Outside area for the winter – dry cows	Concrete	0.20	2.66	0.98	0.52	0.062
	Open/dry lot	0.14	3.46	1.24	0.34	<0.001
	None	0.18	3.81	1.34	0.35	<0.001
	Pasture	0.05	Ref			

Housing type was associated with the occurrence of hock lesions ($P < 0.001$), with cows housed in an open/dry lot having fewer lesions than those housed in freestalls, tie-stall/stanchions, or on pasture. The type of operation had an effect on hock lesions, with operations that allowed cows to graze being associated with a lower prevalence of hock lesions than the other operation types. A relationship was found between hock lesions and bedding material, with sand bedding being associated with fewer hock lesions than straw/hay/corn stalks ($P < 0.001$), sawdust/wood products ($P < 0.001$), dry/composted manure ($P = 0.001$), and rubber mats/mattresses ($P = 0.001$). Finally, the outside area that dry cows had access to during the winter had an effect, with operations housing dry cows on pasture having a lower prevalence of hock lesions than those housing them in open/dry lots ($P < 0.001$) or that did not provide dry cows with outside access ($P < 0.001$).

After controlling for scoring group, 6 of the 10 variables considered were found to be predictors in the multivariate model for severe hock lesions (Table 3.6). The outside area that lactating cows had access to during the summer was also considered for inclusion in the multivariate model, but did it not meet the criteria.

Table 3.6. Explanatory factors included in the multivariate analysis for association with dairy cows having severe hock lesions on US dairy operations (n = 183)

Variable	Level	Predicted marginal	Incidence density ratio	Beta coefficient	SE	*P*-value
Operation type	Conventional (C)	0.05	6.90	1.93	0.44	<0.001
	Combination C-G	0.03	4.01	1.39	0.53	0.009
	Organic	0.01	1.43	0.36	0.89	0.665
	Grazing (G)	0.01	Ref			
Flooring type	Concrete	0.02	3.62	1.29	0.64	0.045
	Rubber mats on concrete	0.06	10.62	2.36	0.67	<0.001
	Pasture	0.06	10.37	2.34	0.62	<0.001
	Dirt	0.01	Ref			
Bedding material	Straw/hay/corn stalks	0.06	5.99	1.79	0.46	<0.001
	Sawdust/wood products	0.04	4.19	1.43	0.47	0.003
	Dry or composted manure	0.01	0.99	-0.01	0.54	0.980
	Rubber mats/mattresses	0.02	1.82	0.60	0.50	0.234
	Other	0.00	0.44	-0.81	0.75	0.278
	Sand	0.01	Ref			
Sprinklers/misters for cooling	Yes	0.02	0.48	-0.74	0.32	0.024
	No	0.04	Ref			
Outside area for the winter – lactating cows	Pasture	2.30	106.60	4.67	0.83	<0.001
	Open/dry lot	0.03	1.26	0.23	0.32	0.472
	None	0.05	2.10	0.74	0.32	0.021
	Concrete	0.02	Ref			
Outside area for the winter – dry cows	Pasture	0.00	0.00	-5.59	0.54	<0.001
	Open/dry lot	0.14	0.95	-0.05	0.36	0.881
	None	0.09	0.60	-0.52	0.39	0.185
	Concrete	0.14	Ref			

Operation type was related to the prevalence of severe hock lesions, with conventional dairy operations having a higher percentage of cows with severe hock lesions than organic operations ($P = 0.053$). Cows that were housed on dirt had a lower prevalence of severe hock lesions than those with other flooring types. Bedding material had an effect, with operations using sand bedding having a lower prevalence of severe hock lesions than those using straw/hay/corn stalks ($P < 0.001$) or sawdust/wood products ($P = 0.003$). The use of sprinklers or misters for cooling dairy cows was associated with fewer severe hock lesions when compared with operations that did not use sprinklers or misters ($P = 0.024$). The outside area that both dry and lactating cows had access to during the winter had an effect on the prevalence of severe hock lesions. Lactating cows that had access to concrete during the winter had a lower prevalence of severe hock lesions than those that had access to pasture (P < 0.001) or that did not have outside access (P = 0.021); in contrast, dry cows that had access to concrete during the winter had an increased prevalence of severe hock lesions when compared to those that were allowed on pasture during the winter (P < 0.001).

Nine variables were included in the univariate model for the occurrence of thin cows (Table 3.7), of which 2 were included in the final multivariate model (Table 3.8) after controlling for scoring group.

Table 3.7. Categorical variables used in the univariate analysis of variables associated with the prevalence of thin[1] cows on US dairy operations

Categorical variable	Level	Farms (%)	*P*-value Thin cows
Size	Small	26.2	0.016
	Medium	30.4	
	Large	43.4	
Operation type	Conventional (C)	78.7	0.058
	Grazing (G)	3.2	
	Combination C-G	11.7	
	Organic	6.4	
Feed-line type	Head locks/fence line	48.2	<0.001
	Tie stall	14.1	
	Stanchion	3.7	
	Post and rail	23.0	
	Elevated feed bunk in pen	10.0	
	Other	1.0	
Sprinklers/misters for cooling	Yes	45.8	0.006
	No	54.2	
Person who balances rations	Nutritionist	79.1	<0.001
	Dairy owner	16.7	
	Other	4.2	
Forage tests used when balancing rations	Yes	93.2	0.027
	No	6.8	
Total Mixed Ration fed	Yes	82.7	0.045
	No	17.3	
RHA	< 22,000	36.1	0.067
	≥ 22,000	63.9	
BST	Yes	18.0	0.213
	No	82.0	

[1]Thin indicates a cow with BCS ≤ 2.25 on a 5-point scale (REF)

Additional variables that were considered for inclusion but did not meet the criteria included: region, housing type, how lactating cows were fed (e.g. based on production level), milk urea nitrogen testing, and whether or not dairy personnel received training in how to feed dairy cows.

Table 3.8. Explanatory factors included in the multivariate analysis for association with thin dairy cows on US dairy operations (n = 189)

Variable	Level	Predicted marginal	Incidence density ratio	Beta coefficient	SE	*P*-value
Feed-line type	Tie stall	0.04	1.19	0.17	0.46	0.703
	Stanchion	0.14	4.22	1.44	0.46	0.002
	Post and rail	0.04	1.04	0.04	0.45	0.937
	Elevated feed bunk in pen	0.06	1.87	0.63	0.53	0.241
	Other	0.01	0.22	-1.51	1.15	0.191
	Head locks/fence line	0.03	Ref			
Person who balances rations	Dairy owner	0.09	2.74	1.01	0.33	0.003
	Other	0.14	4.16	1.43	0.42	<0.001
	Nutritionist	0.03	Ref			

The feed-line that dairy cows had access to was shown to be associated with cows being thin, with operations using a stanchion feed-line having an increase in the percentage of thin cows when compared to those that used head locks or fence lines ($P = 0.002$). Additionally, the person who was in charge of balancing the ration fed to lactating cows had an effect on the prevalence of thin cows, with operations using a nutritionist to balance rations having fewer thin cows than those where the owner ($P = 0.003$) or other personnel ($P < 0.001$) balanced the ration.

DISCUSSION

The prevalence of lame and severely lame cows in the current study was lower than prevalence levels previously reported. The mean prevalence of lameness in Wisconsin dairy herds during the summer was found to be 21.1% (Cook, 2003), which is almost double the 10.8% that was found in the current study. Espejo et al (2006) found the mean prevalence of lameness to be 24.6% for high producing dairy cows in Minnesota, which was again much greater than what was found in the current study. A study investigating lameness in dairy herds in California, British Columbia (BC) in Canada, and New England reported a mean lameness prevalence of 30% in CA and BC, and 55% in NE (von Keyserlingk et al., 2012). This same study reported fewer cases of severe lameness, with a mean prevalence of 4% in CA and 8% in BC and NE. All of these rates were substantially higher than what was reported in the current study. When just considering the top 25th percentile of herds in Wisconsin, similar rates of lameness were found in comparison to the current study, with a mean prevalence of lameness of 11.2% (Cook, 2003). Similarly, the top 10th percentile of herds in Minnesota had a mean prevalence of 5.4% for lameness and 1.5% for severe lameness (Espejo et al., 2006), which are closer to the estimates reported in this study.

Lameness is considered one of the leading dairy cow welfare problems facing the US dairy industry (O'Callaghan et al., 2003; Rushen et al., 2007), with different dairy characteristics contributing to the prevalence of lameness. Operation size was included in the models for predicting the prevalence of lame cows. Large dairy operations had a lower percentage of lame cows than those on small and medium operations. The findings in the current study agree, with those of Chapinal et al (2013), who found that herd size was negatively associated with lameness on dairy operations in NE. The authors credited this association with the ability of large dairy operations to have greater availability of dairy personnel to manage dairy cow lameness and hoof health. Housing type was associated with the prevalence of lame and severely lame cows on US dairy operations. Housing cows on pasture was protective against lameness in the current study, with the prevalence being higher on operations that housed cows in freestall or tie-stall barns compared with housing cows on pasture. Additionally, there was an increase in the prevalence of severely lame cows on operations that housed cows in freestall barns or in open lots when compared to pasture, suggesting there are benefits to hoof health in pasture based systems that are not realized in other housing types. These findings have been illustrated in other studies as well, with the prevalence of lameness being lower on freestall operations that allowed cows access to pasture than on operations where cows were kept in freestalls year round (Haskell et al., 2006). Bedding material was associated with the prevalence of lameness on dairy operations, with operations using organic materials such as straw, hay, sawdust, or dried/composted manure having an increase in lameness when compared to operations that used rubber mats/mattresses for bedding. Similar results were found in dairy herds in NE, with sawdust bedding being associated with an increase in dairy cow lameness (Chapinal et al., 2013). Surprisingly, no difference was found between the prevalence of lameness between dairy operations using sand and those using rubber mats/mattresses, which contradicts previous findings. In a study investigating dairy cow lameness on farms in Wisconsin, the prevalence of lameness was significantly lower for herds with sand bedding when compared with herds using mattress stalls (Cook, 2013). The different results between the two studies may be due to the Wisconsin study primarily involving freestall operations, while the current study included a wider range of housing types.

Prompt identification and treatment of lameness is suggested to limit the duration and prevalence of lame cows, by catching lameness before it progresses and shortening the healing process. Dairy operations that treated lame cows within a day or week of identifying them as lame had a lower prevalence of lameness than operations that waited as long as a month to treat cows. These results support previous findings, where the prevalence and duration of lameness was lower on dairy operations with increased awareness and early identification of lame cows (Clarkson et al., 1996; Gundelach et al., 2013). An interesting finding from the current study was that treatment of cows within a few hours of being identified as lame was actually associated with an increase in lameness prevalence, which is contrary to what would be expected. A possible explanation for this may be that operations with a higher prevalence of lameness may implement prompt treatment of lame cows to address an existing lameness problem.

Routine hoof trimming has been shown to benefit dairy cow hoof health (Blowey, 2005; Mülling et al., 2006), with routine hoof trimmings being a benefit to dairy cow lameness by promoting the early identification and treatment of hoof problems (Manske, 2002). This was evident in the current study by dairy operations that did not have a hoof trimmer come during 2013 having an increased prevalence of severely lame cows than operations that had a hoof trimmer on-farm more often than once a week. Additionally, while it is important for cows to receive routine trimming, the protective effects may be compromised if the hoof trimming personnel is not competent (Bell et al., 2009; Mülling et al., 2006). In the current study, dairy operations that had their veterinarian trim hooves had a lower prevalence of lameness than those on which dairy personnel were responsible for trimming hooves, which was not to be expected as one would expect that having dairy personnel manage lameness would result in prompt treatment and a reduction in the prevalence of lame cows. This finding suggests that not all dairy personnel are competent in hoof trimming and would likely benefit from training to ensure that cows are not becoming lame as a result of routine hoof care.

The occurrence of hock lesions was lower than previously reported by Weary and Taszkun (2000), where 72.6% of cows of farms in BC had some sort of hock lesion, compared to an average of 12.9% for the current study. A study including dairy operations in Wisconsin, Minnesota, New York, Iowa, and Indiana found similar prevalences of hock lesions (Fulwider et al., 2007), with the percentage of cows with no hock lesions ranging from 28.4 to 100.0%, depending on the type of bedding material used.

Hock lesions can be a result of the quality and type of lying surfaces that dairy cows have access to. Housing type was found to be associated with an increased occurrence of hock lesions, with cows housed on open/dry lots having a fewer hock lesions than those housed on pasture, or in tie-stall or freestall barns. Housing cows in open/dry lots was found to be protective against hock lesions, while housing cows on pasture, in tie-stall/stanchions, and in freestall barns resulted in an increased prevalence of hock lesions. This finding disagrees with previous studies, where cows on pasture were actually found to have fewer hock lesions (Bergman et al., 2014). This discrepancy may be a result of evaluations being conducted during late spring/early summer, shortly after cows would have been reintroduced to pasture from winter housing. The increased prevalence of hock lesions may be a result of the winter housing rather than being housed on pasture, although this was not investigated in the current study. The association of hock lesions and tie-stalls agrees with previous work, with cows housed in tie-stalls having an increased prevalence of hock lesions and swollen knees (Rushen et al., 2008). The type of operation was related to the occurrence of hock lesions, with grazing operations having a lower prevalence of mild hock lesions when compared to other operation types, and fewer severe hock lesions than conventional and combination of conventional/grazing operations. The type of flooring used for lactating dairy cows was associated with the occurrence of severe hock lesions, with those housed on dirt having fewer lesions than those housed on concrete, rubber mats over concrete, or pasture. Bedding material for lactating cows can impact the occurrence of hock lesions. Sand bedding was found to be beneficial, with cows housed on sand bedded stalls having a lower prevalence of hock lesions, both mild and severe, when compared to the other bedding material types. Multiple studies have highlighted the benefits of using sand bedding, with operations housing cows on sand bedded stalls having a lower prevalence of hock lesions than those housed on rubber mats or mattresses (Weary and Taszkun, 2000; Lobeck et al., 2011). A study investigating associations between hock injuries and stall design found that farms that used sand had the lowest percentage of severe hock lesions when compared to those using manure solids, straw, and sawdust bedding (Lombard et al., 2010).

The finding of few dairy cows with a BCS ≤ 2.25 suggests that the majority of dairy cows are being maintained at a BCS around the optimal level for lactating cows (Bowell et al., 2003). When examining farm and cow level factors thought to influence the body condition of lactating dairy cows, only the type of feed-line and the person responsible for balancing rations were associated with the prevalence of thin cows. Operations that used a stanchion style feed-line had a higher percentage of thin cows than operations that used head locks or fence lines. Also, dairy operations that used a nutritionist to balance rations for lactating cows had a lower percentage of thin cows than those where the dairy owner or other personnel balanced rations. As dairy nutritionists understand the energy demands of dairy cows during different stages of lactation, it is understandable that they would be beneficial for balancing rations and minimizing the number of thin cows on a dairy operation.

There are limitations to the methodology of this study, with cow evaluations being collected in a single visit rather than over time. As this study is national in scope and relied on multiple evaluators, it was not possible to conduct multiple evaluations for every dairy. Additionally, with a subsample of dairy operations participating in the cow evaluation portion of the study, it’s possible that the results are biased due to nonresponse. Despite the methodological limitations of the study, the findings presented provide valuable information regarding national estimates for the prevalence of lameness, hock lesions, and body condition scores on US dairy operations. This study highlights housing and management practices that are associated with dairy cow lameness, hock lesions, and body condition, allowing the industry to determine which practices are beneficial, and which practices should be improved upon.

CONCLUSIONS

Despite the relatively low prevalence estimates reported in the current study, many associations were identified between dairy operation characteristics and the risk of lameness, hock lesions, and thin cows on US dairy operations. Large dairy operations had fewer lame and severely lame cows than smaller operations. Operations that housed cows on pasture had fewer lame and severely lame cows than operations that housed cows in freestall barns, while operations that housed cows in open/dry lots were shown to have fewer hock lesions. Using sand as a bedding material for lactating dairy cows was protective against both lameness and hock lesions, with the prevalence being lower than on operations that used other bedding materials. Additionally, dairy operations that used a nutritionist to balance rations for lactating dairy cows had a fewer thin cows than those where the dairy owner or other personnel balanced rations. Results from this study highlight different management practices on dairy operations that can be implemented to impact the prevalence of lameness, hock lesions, and thin cows on dairy operations in the US.

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CHAPTER IV: LOCOMOTION SCORING DAIRY COWS: A COMPARISON AMONG THREE DIFFERENT LOCOMOTION SCORING SYSTEMS ON INTRA- AND INTERRATER RELIABILITY AND AGREEMENT

INTRODUCTION

Lameness is a leading welfare concern in the dairy industry, mainly due to the fact that lame animals are in pain (O'Callaghan et al., 2003; Rushen et al., 2007). Lameness in dairy cattle is usually identified by assessing the locomotion of dairy cows and assigning a score to the cow based on different characteristics of the animal's gait. There are multiple scoring systems that are used to score dairy cow locomotion, which differ by the number of categories in each system and the classification of each category. Three common systems include 3, 4 and 5 categories, with multiple systems available to choose from within each category range. The National Dairy FARM program (NDPF, 2013) uses a simple 3-point scoring system in its welfare monitoring program, where a score of 1 is representative of a sound cow, 2 is moderately lame where the affected limb is identifiable, and 3is severely lame where the affected limb is obvious both when the cow is walking and standing. A similar system was developed for use in the most recent National Animal Health Monitoring System (NAHMS) Dairy survey. USDA collaborated with industry experts to develop a 3-point system, with the goal being ease of use and repeatability, as multiple people would be responsible for scoring cows for the NAHMS Dairy 2014 study (USDA, 2014). In this system a score 1 represents a sound cow with no gait abnormality, score 2 is a mildly/moderately lame cow with an abnormal gait but the affected limb was not obvious, and score 3 represents a severely lame cow that was hesitant to bear weight on one or more limbs. The biggest difference when compared to the FARM program's 3-point system is that in the USDA system a cow that is obviously favoring a limb is considered severely lame, while cows that have a gait abnormality (e.g. uneven gait or head bob) but the affected limb is not obvious would be scored a 2.

Four point systems are more common in other parts of the world, although there are a couple that are in use in the US. A system in New Zealand uses six indicators of lameness: walking speed, walking rhythm, stride length and foot placement, weight bearing, back alignment, and head position (Dairy NZ, 2014). The definitions of the different categories are as follows: a cow with a lameness score of 0 is considered normal; a lameness score 1 represents a cows that is showing the early signs of lameness including shorter steps and uneven stride lengths; a cow with a lameness score of 2 is moderately lame with a shortened stride length and uneven weight bearing on a limb that is easily identifiable; a lameness score 3 represents a severely lame cow that favors one or more limbs with shortened strides, an obvious head bob, and potentially arched back that cannot keep up with the rest of the herd. Vokey et al. (2001) used a 4-point scoring system to gauge the effect of freestall surfaces on dairy cow lameness. The scoring system categorized score 1 cows as those with a normal gait; score 2 cows as those with some gait asymmetry, compromised walking speed, slight abduction/adduction, with no obvious head bob; score 3 cows as those with an asymmetric gait, shortened stride length, some reluctance to move, and limping with an obvious head bob; and score 4 cows as those with severe gait asymmetry with very deliberate steps, extreme reluctance or inability to bear weight on one or more limbs, reduced walking speed, and obvious back arch. Other 4-point scoring systems have been developed by Cook (2003), Stokes et al. (2008), and DairyCo in the United Kingdom (AHDB, 2015).

Five point systems are commonly used in studies investigating dairy cow lameness, with many studies using either the system developed by Sprecher et al. (1997) or the one developed by Flower and Weary (2006). The system by Sprecher et al. (1997) focuses on the arch of the cows back to categorize lameness. According to this system a lameness score 1 is a normal cow that stands and walks with a level back; a score 2 cow is mildly lame and stands with a flat back, but arches her back when walking; a score 3 represents a moderately lame cow that stands and walks with an arched back, with shortened stride lengths; score 4 cows are considered lame with an obvious arch in the back at all times and the favoring of one or more limbs; a score 5 cow is considered severely lame and in addition to the characteristics of a score 4 cow, is extremely reluctant to bear weight on one or more limbs. The system developed by Flower and Weary (2006) uses a numerical rating system (NRS) and ranges from sound to severely lame. The key components of the system include: NRS 1 is a cow that walks with smooth and fluid movements, with a flat back, symmetrical gait, and equal weight bearing on all limbs; a NRS 2 cow has imperfect locomotion but her ability to move freely is not diminished, with a mildly arched back, slightly asymmetric gait, with all legs equally bearing weight; a NRS 3 represents a cow with a diminished ability to move freely, with an arched back, asymmetrical gait, signs of joint stiffness, and a slight limp; a cow with a NRS of 4 is not able to move freely, with an obvious back arch, asymmetric gait, slight head bob, stiff joints and hesitant strides, and reluctant (but able) to bear weight on one or more limbs; the movement of a cow with NRS 5 is severely restricted, and is characterized by an extremely arched back, obvious head bob, asymmetric gait, obvious joint stiffness with very hesitant strides, and the inability to bear weight on one or more limbs.

Multiple studies have reported intra- and interrater reliability and agreement for various 5-point scoring systems (O'Callaghan et al., 2003; Thomsen et al., 2008; Schlageter-Tello et al. 2014), although evidence of intra- and interrater reliability and agreement are lacking for the 3-

and 4- point systems. With a variety of locomotion scoring systems available, it is difficult to decide which one is the best one to use. The best system may depend on the objective of the individual, with farm personnel potentially using a simpler system to identify cows that require treatment, while researchers may prefer a more detailed system to define different characteristics of dairy cow lameness. The objectives of this study were to: 1) determine differences in intra- and interrater reliability among three different locomotion scoring systems for dairy cows; and 2) gather information pertaining to user experience and preference among the three locomotion scoring systems.

MATERIALS AND METHODS

Three different locomotion scoring systems were used in this study: 3-, 4-, and 5-point. As there were many scoring systems to choose from, to be eligible for use in this study the scoring systems had to have training material, specifically a video, available for participants. The 3-point scoring system used was the one designed by USDA for the NAHMS Dairy 2014 study (USDA, 2014), the 4-point system used was the one designed by DairyNZ (2014), and the 5-point system used was the one developed by Sprecher et al, (1997).

University personnel throughout the US with a research interest in dairy cow lameness were recruited via e-mail to participate in this study, with dairy personnel being recruited in person on dairy farms in Colorado. The goal was to achieve adequate participation from both university and dairy personnel in order to represent those involved in research and those working on farm. Video footage of dairy cows returning from the milking parlor was recorded, and a total of 45 video clips were created. The selected 3-, 4-, and 5-point locomotion scoring systems were used by participants to score the gait of cows in each of the video clips. Participants were provided with training material consisting of a training video and written descriptions of each of the scoring systems and instructed to watch the training videos prior to completing the study. Every participant scored the set of video clips four times, once using each of the three scoring systems, then again repeating one of the three systems. The order of presentation of the video clips was randomized between each viewing, and participants were randomly assigned to repeat one of the three scoring systems. Dairy personnel recorded locomotion scores on paper which was then entered into an excel spreadsheet, while university personnel recorded locomotion scores directly into the excel spreadsheet. In addition to scoring the video clips, participants were asked to complete a brief survey detailing their experience in the dairy industry, previous training and experience with different locomotion scoring systems, and their preference for a locomotion scoring system.

Descriptive statistics for the percentage of cows in each category per scoring system were calculated using PROC FREQ in SAS (version 9.4, SAS Institute Inc., Cary, N.C.). Intra- and interrater reliability were calculated as the weighted kappa coefficient (**κw**; Cohen, 1968) using the "agree" statement in PROC FREQ. Intra- and interrater agreement were calculated as exact percentage of agreement (**PA**) for each of the three systems. The overall mean and 95% confidence intervals for κw and PA were calculated using PROC MEANS. The scoring systems were further broken down into lame (yes/no) and severely lame (yes/no) and then compared using the "oddsratio" option in the LSMEANS statement of PROC GENMOD to determine if there were differences among the three systems in individual cows being categorized as lame or severely lame. For the 3-point system, lame represented cows that were scored with a 2 or a 3, and severely lame represented cows that were scored with a 3. Lame cows were those with a score 2 or 3 when using the 4-point system (recall the 4-point system ranges from 0 to 3), and severely lame cows were those with a score 3. For the 5-point system, lame represented cows that received a score 3 or greater, and severely lame represented cows that received a score 4 or greater.

RESULTS AND DISCUSSION

Forty-two people agreed to participate, of which 27 were university personnel and 15 were dairy personnel completing the study. Forty-five cows were scored with each system, and the distribution of scores for each cow broken down by locomotion scoring system is given in Table 3.9.

Table 3.9. Distribution of lameness scores given by 42 participants for each video clip of lactating dairy cows using three different locomotion scoring systems, broken down by cow and scoring system[1]

	3-point system			4-point system				5-point system				
Cow	LS1 %	LS2 %	LS3 %	LS0 %	LS1 %	LS2 %	LS3 %	LS1 %	LS2 %	LS3 %	LS4 %	LS5 %
1	31.7	65.9	2.4	9.8	56.1	34.2	0.0	10.3	53.9	33.3	2.6	0.0
2	73.2	26.8	0.0	43.9	46.3	7.3	2.4	17.1	56.1	24.4	2.4	0.0
3	85.4	14.6	0.0	63.4	31.7	2.4	2.4	73.2	17.1	9.8	0.0	0.0
4	65.9	31.7	2.4	41.5	43.9	14.6	0.0	58.5	31.7	9.8	0.0	0.0
5	7.3	73.2	19.5	0.0	26.8	58.5	14.6	0.0	12.2	58.5	24.4	4.9
6	26.8	61.0	12.2	12.2	41.5	36.6	9.8	0.0	24.4	46.3	26.8	2.4
7	2.4	48.8	48.8	2.4	2.4	63.4	31.7	2.4	2.4	41.5	48.8	4.9
8	2.4	24.4	73.2	0.0	2.4	4.9	92.7	0.0	0.0	9.8	46.3	43.9
9	58.5	41.5	0.0	29.3	61.0	9.8	0.0	34.2	43.9	22.0	0.0	0.0
10	85.4	14.6	0.0	78.1	19.5	2.4	0.0	82.9	12.2	4.9	0.0	0.0
11	73.2	24.4	2.4	48.8	41.5	9.8	0.0	36.6	43.9	14.6	2.4	2.4
12	58.5	39.0	2.4	34.2	43.9	22.0	0.0	14.6	56.1	26.8	2.4	0.0
13	0.0	34.2	65.9	0.0	4.9	26.8	68.3	2.4	22.0	61.0	14.6	0.0
14	2.4	65.9	31.8	2.4	9.8	56.1	31.7	2.4	9.8	61.0	19.5	7.3
15	46.3	51.2	2.4	17.1	56.1	24.4	2.4	22.0	51.2	24.4	2.4	0.0
16	0.0	65.9	34.2	0.0	17.1	61.0	22.0	0.0	7.3	31.7	61.0	0.0
17	5.0	45.0	50.0	0.0	4.9	46.3	48.8	0.0	4.9	26.8	56.1	12.2
18	39.0	56.1	4.9	12.2	58.5	29.3	0.0	31.7	43.9	24.4	0.0	0.0
19	70.7	29.3	0.0	51.2	36.6	12.2	0.0	17.1	56.1	24.4	2.4	0.0
20	30.0	67.5	2.5	7.3	68.3	19.5	4.9	7.3	34.2	51.2	7.3	0.0
21	56.1	41.5	2.4	26.8	46.3	24.4	2.4	19.5	46.3	34.2	0.0	0.0
22	53.7	43.9	2.4	26.8	63.4	9.8	0.0	36.6	46.3	14.6	2.4	0.0
23	26.8	58.5	14.6	4.9	53.7	36.6	4.9	7.3	41.5	51.2	0.0	0.0
24	63.4	34.2	2.4	26.8	53.7	19.5	0.0	19.5	48.8	31.7	0.0	0.0
25	47.5	50.0	2.5	22.0	48.8	26.8	2.4	22.0	56.1	22.0	0.0	0.0
26	9.8	73.2	17.1	2.4	39.0	46.3	12.2	4.9	24.4	51.2	19.5	0.0
27	92.7	7.3	0.0	61.0	34.2	4.9	0.0	87.8	12.2	0.0	0.0	0.0
28	65.9	31.7	2.4	53.7	39.0	7.3	0.0	36.6	43.9	17.1	2.4	0.0
29	17.1	78.1	4.9	4.9	41.5	51.2	2.4	24.4	46.3	14.6	14.6	0.0

30	2.4	58.5	39.0	4.9	14.6	68.3	12.2	0.0	19.5	43.9	34.2	2.4
31	39.0	53.7	7.3	17.1	51.2	26.8	4.9	29.3	43.9	17.1	7.3	2.4
32	51.2	43.9	4.9	39.0	43.9	14.6	2.4	31.7	36.6	26.8	4.9	0.0
33	4.9	70.7	24.4	0.0	22.0	65.9	12.2	2.4	14.6	56.1	26.8	0.0
34	4.9	51.2	43.9	0.0	14.6	70.7	14.6	2.4	7.3	31.7	56.1	2.4
35	7.3	87.8	4.9	7.3	31.7	58.5	2.4	4.9	24.4	68.3	0.0	2.4
36	2.4	7.3	90.2	0.0	0.0	2.4	97.6	0.0	0.0	0.0	26.8	73.2
37	2.4	68.3	29.3	2.4	14.6	68.3	14.6	0.0	12.2	70.7	17.1	0.0
38	2.4	0.0	97.6	2.4	2.4	95.1	0.0	0.0	2.4	0.0	12.2	85.4
39	2.4	61.0	36.6	2.4	4.9	53.7	39.0	0.0	4.9	31.7	51.2	12.2
40	0.0	12.2	87.8	2.4	2.4	7.3	87.8	0.0	2.4	0.0	63.4	34.2
41	39.0	58.5	2.4	14.6	46.3	39.0	0.0	14.6	34.2	43.9	7.3	0.0
42	85.4	14.6	0.0	46.3	51.2	0.0	2.4	73.2	22.0	2.4	2.4	0.0
43	73.2	26.8	0.0	61.0	26.8	9.8	2.4	65.9	31.7	2.4	0.0	0.0
44	2.4	85.4	12.2	4.9	31.7	48.8	14.6	2.4	29.3	46.3	22.0	0.0
45	2.4	34.2	63.4	4.9	4.9	41.5	48.8	0.0	2.4	14.6	73.2	9.8

[1]Totals for each scoring system may not sum up to 100% due to rounding

While the general spread of responses appeared similar among the three systems, a shift away from the extremes was evident as the number of categories increased. The distribution suggests that participants are less willing to assign a cow a sound or severely lame score when they have more options to choose from, as evidenced by the decreasing number of cows scored in these categories as the scoring system progresses from the 3- to the 5-point system. This is not surprising when comparing the 3- and the 5-point systems, since the only category to choose when using the 3-point system for a cow with an obvious limp for one or more limbs is a 3, while a cow with a limp can be scored a 4 or a 5 using the 5-point system depending on the severity of the limp. The 4-point system emphasizes that a severely lame cow (with a score of 3) favors one or more limbs and cannot keep up with the herd (AHDB, 2015), while the 5-point system states that a severely lame cow (with a score of 5) is extremely reluctant to bear weight on the affected limb (Sprecher et al., 1997). Although there were quite a few cows that were obviously favoring one or more limbs in the set of video clips used in this study, very few were extremely reluctant to bear weight on the affected limb, explaining the limited number of severely lame scores given using the 5-point system in the current study compared to the greater number of severely lame scores given using the 3- and 4-point systems.

Intra- and interrater reliability and agreement are presented in Table 3.10. For both intra- and interrater comparisons, the overall PA decreased as the number of categories increased, while the κw increased. It is expected that PA would be higher with fewer categories as there are fewer opportunities to disagree. In contrast, it is a little surprising that both intra- and interrater reliability (κw) increased with increasing categories.

Table 3.10. Intra- and interrater reliability (κw) and agreement (PA) for scores given by 42 participants when using three different locomotion scoring systems[1]

	Interrater				Intrarater			
	Reliability (κw)		Agreement (PA)		Reliability (κw)		Agreement (PA)	
System	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
3-point	0.42	(0.41, 0.43)	56.6%	(55.7, 57.5)	0.57	(0.43, 0.71)	69.0%	(59.3, 78.8)
4-point	0.43	(0.42, 0.44)	47.0%	(46.1, 47.9)	0.60	(0.53, 0.68)	61.9%	(54.8, 69.0)
5-point	0.47	(0.46, 0.48)	42.8%	(42.0, 43.6)	0.64	(0.55, 0.72)	56.6%	(49.4, 63.7)

[1]3-point (USDA, 2014), 4-point (AHDB, 2015), 5-point (Sprecher et al., 1997)

Intra- and interrater reliability for the 5-point system in the current study (κw = 0.64 and 0.47, respectively) was lower than those previously reported by Schlageter-Tello et al. (2014) who reported an intrarater κw of 0.77 interrater κw of 0.65 for the 5-point system by Flower and Weary (2006). Participants in that study mainly consisted of researchers and veterinarians who had previous experience with locomotion scoring dairy cows, which may explain why the intra- and interrater reliability were better than in the current study as just over a quarter (26%) of those participating in the current study had no previous experience locomotion scoring dairy cows. Results in the current study were similar to those in a study evaluating the 5-point locomotion scoring system, which found a mean intrarater κw of 0.60 and a interrater κw of 0.48 for participants prior to receiving training in the scoring system (Thomsen et al., 2008). After training intrarater reliability actually decreased (κw = 0.53) while interrater reliability increased (κw = 0.52). While participants in the current study were encouraged to watch the provided training videos for each of the three systems, no additional training was provided; it is therefore understandable that the results would fall in between those reported by Thomsen et al. (2008)

prior to and after training. The video provided more training than what those participating in the study by Thomsen et al. (2008) received initially, but was less than what they received over time.

Interrater reliability and agreement were lower in the current study, and in previous studies (O'Callaghan et al., 2003; Thomsen et al., 2008; Schlageter-Tello et al., 2014), than intrarater reliability and agreement. This is understandable as it would be expected that there would be greater variation between observers' scores rather than within observer's scores. Interrater reliability in the current study was κw = 0.42, 0.43, and 0.47 for the 3-, 4-, and 5-point systems respectively, none of which achieved the threshold κw ≥ 0.60 indicating good reliability (Gibbons et al., 2012). Using the classification system suggested by Landis and Koch (1977), interrater reliability achieved moderate agreement (κw = 0.4 to 0.59). In contrast, intrarater reliability in the current study was κw = 0.57, 0.60, and 0.64 for the 3-, 4-, and 5-point locomotion scoring systems, respectively. Both the 4- and the 5-point scoring systems achieved good reliability according to Gibbons et al. (2012), and the 3-point system achieved moderate reliability (Landis and Koch, 1977).

Of the 42 people who participated in the study, 27 (64%) were university personnel and 15 (36%) were dairy personnel. Table 3.11 provides a breakdown of intrarater reliability and agreement for university and dairy personnel. The mean κw was higher for university personnel than dairy personnel, although these differences were not significant.

Table 3.11. Intrarater reliability (κw) and agreement (PA) for scores given by participants when using three different locomotion scoring systems,[1] presented for university (n = 27) and dairy personnel (n = 15)

	University personnel				Dairy personnel			
	Reliability (κw)		Agreement (PA)		Reliability (κw)		Agreement (PA)	
System	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
3-point	0.66	(0.52, 0.79)	74.7%	(65.1, 84.3)	0.36	(-0.09, 0.81)	55.0%	(25.8, 84.2)
4-point	0.63	(0.54, 0.71)	64.0%	(57.2, 70.7)	0.57	(0.33, 0.80)	58.2%	(36.2, 80.2)
5-point	0.68	(0.54, 0.81)	60.6%	(51.2, 70.0)	0.58	(0.44, 0.72)	51.1%	(37.8, 65.5)

[1]3-point (USDA, 2014), 4-point (AHDB, 2015), 5-point (Sprecher et al., 1997)

The majority of university personnel (65%) in this study have been involved in the dairy industry for 10 years or more, compared to 53% of dairy personnel who have been involved in the industry for 5 years or less, of which 33% have been involved for less than 1 year. This difference in experience may explain why university personnel tended to be more consistent when scoring dairy cows. Probably more importantly, the majority of university personnel had previous experience scoring locomotion in dairy cows (92%), compared to 47% of dairy personnel with experience. Of those with experience (n = 31; 74%), most (55%) had experience with the 5-point system, 24% had experience with the 3-point system, and 21% had experience with the 4-point system. The mean intrarater κw for those that had experience with locomotion scoring, regardless of which system they had experience in, was 0.68 (95% CI = 0.57 to 0.79) for the 3-point system (n = 10), 0.64 (95% CI = 0.57 to 0.71) for the 4-point system (n = 11), and 0.65 (95% CI = 0.54 to 0.76)) for the 5-point system (Table 3.12). For those that did not have experience, the mean intrarater κw was 0.31 (95% CI = -0.11 to 0.72) for the 3-point system (n = 4), 0.48 (95% CI = 0.05 to 0.91) for the 4-point system (n = 3), and 0.60 (95% CI = 0.35 to 0.86) for the 5-point system (n = 4).

Table 3.12. Intrarater reliability (κw) and agreement (PA) for scores given by participants when using three different locomotion scoring systems,[1] presented for those with previous experience in locomotion scoring (n = 31) and those with no previous experience (n = 11)

	Experience				No experience			
	Reliability (κw)		Agreement (PA)		Reliability (κw)		Agreement (PA)	
System	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
3-point	0.68	(0.57, 0.79)	76.0%	(65.1, 84.3)	0.31	(-0.11, 0.72)	51.7%	(25.6, 77.7)
4-point	0.64	(0.57, 0.71)	65.1%	(57.2, 70.7)	0.48	(0.05, 0.91)	50.4%	(11.2, 89.5)
5-point	0.65	(0.54, 0.76)	56.5%	(51.2, 70.0)	0.60	(0.35, 0.86)	56.7%	(38.3, 75.0)

[1]3-point (USDA, 2014), 4-point (AHDB, 2015), 5-point (Sprecher et al., 1997)

These findings agree with those of March et al. (2007) who reported that κw increased with increased experience with gait scoring, from κw 0.41 for those with no experience to κw = 0.75 after scoring 1,859 cows. Using the classification of good reliability by Gibbons et al. (2012), all of those with previous experience with locomotion scoring dairy cows achieved this threshold ($\kappa w \geq 0.60$), while this threshold was only reached for those using the 5-point system among participants with no previous experience. Even though the κw was numerically different between those who had experience with locomotion scoring and those who did not, this difference was not significant.

As the ultimate goal of locomotion scoring dairy cows is to identify lame cows, we compared three scoring systems on the odds of a cow being diagnosed as lame or severely lame. Cows had higher odds of being classified as lame when using the 3-point system than when using the 4-point system (OR = 2.1; 95% CI = 1.9 to 2.3; $P < 0.0001$), and when using the 3-point system compared to the 5-point system (OR = 1.7; 95% CI = 1.6 to 1.9; $P < 0.0001$). When comparing the 4- and 5-point systems, cows had lower odds of being classified as lame than if they were scored with the 5-point system (OR = 0.8; 95% CI = 0.8 to 0.9; $P < 0.0001$) than with the 4-point system. Cows were at an increased odds of being scored severely lame when comparing the 3-point system to the 4-point system (OR = 1.2; 95% CI: 1.1. to 1.3; $P = 0.0007$). In contrast, cows had reduced odds of being classified as severely lame when using the 3-point system (OR = 0.8; 95% CI = 0.7 to 0.9; $P < 0.0001$) or the 4-point system (OR = 0.7; 95% CI = 0.6 to 0.7; $P < 0.0001$) when compared to the 5-point system. While all of the systems differ significantly in their likelihood of classifying cows as lame or severely lame, the differences are relatively small. These results do suggest, however, that the 3-point system may be more conservative and promote the early identification of lame cows, while the 5-point system highlights the classification of severely lame cows.

When asked which of the three scoring systems participants preferred, 64% indicated they preferred the 3-point system, 23% preferred the 4-point system, and 13% preferred the 5-

point system. The main reasons given for choosing the 3-point system were that it was easy to use and teach, it was the most practical system for on-farm application, and it classified cows according to those that needed treatment soon and those that needed attention immediately. For those who preferred the 4-point system, reasons given included that the system focused on the rhythm of the cow walking rather than back arch, which allows for the identification of cows with multiple affected limbs which might prevent the easy identification of one affected limb that is key in the other scoring systems; additionally, participants stated that the 4-point system allowed for classification of cows into mildly and moderately lame, which the 3-point did not, but it did not go into as much detail as the 5-point did which participants didn't feel was necessary. The reasons given for preferring the 5-point system were that they had previous experience with this system so preferred to continue using it, and others preferred it because of the amount of detail it provided for different stages of lameness. Two participants refrained from choosing a system stating that they didn't have a preference. One of these participants stated that the 3-point system would be best for on-farm use for the quick identification of lame cows, while the 5-point system is more technical and accurate and probably best for research. The other participant actually did not like any of the scoring systems, stating that too much emphasis was placed on identifying the affected limb, and additionally, too much emphasis was placed on the back arch in the 5-point system. Other participants questioned the practicality of using the back arch as main criterion for the 5-point system, because in order to follow the system observers would need to see cows both standing and walking. It was not always possible to observe cows when they were standing in the video clips, which is similar to what can be expected when cows are returning to their home pen from the milking parlor. This highlights the blurred lines between the intermediate scores in the 5-point system.

Regardless of this concern, the 5-point system scored higher than the other two systems in intra- and interrater reliability and agreement, suggesting that the amount of resources invested by companies promoting the 5-point system in the dairy industry has been a success. With the majority of participants preferring the 3-point system over the other systems, it would be beneficial for improved access to educational materials promoting the 3-point system within the dairy industry, similar to those of the 5-point system, to improve intra- and interrater reliability and agreement for the system.

CONCLUSIONS

Intra- and interrater reliability and agreement vary among the 3-, 4-, and 5-point locomotion scoring systems, with agreement decreasing and reliability increasing as the number of categories increase. Intra- and interrater reliability and agreement were improved for those who had previous experience with locomotion scoring dairy cows, compared to those that had no experience, highlighting the importance of increased exposure for improving reliability and agreement among the three systems. Participants overwhelmingly preferred the 3-point locomotion scoring system over the other two, although intra- and interrater performance was lower for this system than the other two. Future work, increasing the exposure of those in the dairy industry to the 3-point system should allow this system to be utilized in the industry with improved success.

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CHAPTER V: EFFECT OF ON-FARM DAIRY BEEF QUALITY ASSURANCE TRAINING ON SELECTED WELFARE AND BEEF QUALITY ASSURANCE RELATED TRAITS IN LACTATING DAIRY COWS

INTRODUCTION

While dairy cows are bred and raised for milk production, the majority end up as cull animals and enter the beef supply. Dairy cows are a substantial contributor to the US beef supply, with 3,125,000 harvested in 2013, accounting for 9.8% of all of the animals harvested for beef in the US (USDA, 2014). With the average herd culling approximately one-third of their cows annually (Smith et al., 2000; Hadley et al., 2006), a sizable proportion of cows on each dairy operation will become beef each year. The US National Beef Quality Assurance (BQA) program details how practices should be carried out on an operation to ensure that beef products are high quality and safe for consumers (BQA, 2012). While this program has proven successful for the beef cattle industry, it is currently underutilized in the dairy cattle industry.

Many practices that promote BQA also promote dairy cow welfare. Lameness is one of the leading welfare concerns in the dairy industry, with the average prevalence of lameness on dairies ranging from 20 to 55% (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012). Additionally, lameness is a BQA issue, with dairy cows accounting for the majority of lame cattle that are marketed each year (Ahola et al., 2011a). Early identification of lame cows helps to ensure prompt treatment, increasing the chances of recovery and reducing the risk of sending severely lame animals to harvest (Whay, 2002; Nordlund et al., 2004).

Since its inception, the BQA program has led to substantial improvements in end-product quality and the value of carcasses from fed steers and heifers (NCBA, 2007). Widespread implementation of a dairy BQA program has the potential to markedly improve the welfare of dairy cows and quality of carcasses from market cows. The objectives of this study were to: 1) evaluate the effect of on-farm BQA training on welfare- and BQA-related traits in dairy cows, including locomotion score (LS) and BCS, and 2) determine practices were in place on dairy farms than impact dairy cow welfare and BQA.

MATERIALS AND METHODS

An employee-focused training program was developed to teach core components of the dairy BQA program (NDHIA, 2009), which was facilitated using Spanish-language materials. Topics covered included injection techniques, humane handling, residue prevention, lame cow identification, body condition and locomotion scoring, and management of non-ambulatory cows. The training program included a PowerPoint presentation (Microsoft©, Redmond, WA), printed information, and a video. The presentation covered how to: identify lame cows using a 5-point locomotion scoring system (Sprecher et al., 1997); score the body condition of dairy cows (Wildman et al., 1982; Ferguson et al., 1994); properly handle dairy cows; and properly administer injections. Printed material included the Spanish version of the Idaho dairy BQA manual (Idaho BQA, 2008), the Guidelines for Responsible Antibiotic Use poster in Spanish (MBC, 2013), and the Beef Quality Assurance for Dairy and Beef Farmers poster in Spanish (MBC, 2013). The video that participants watched was the Spanish version of "Prevention and Management of Non-ambulatory Dairy Cows" (WDA, 2010). In order to determine if on-farm dairy BQA training had an effect on dairy worker knowledge of BQA and welfare-related practices, pre- and post-training exam scores were compared for dairy personnel who participated in the training; results of which have been reported (Adams et al., 2015).

A survey was designed to collect information regarding management and housing practices on each dairy that could have an impact on dairy cow welfare and BQA. Questions included lame cow management, euthanasia practices, injection techniques, employee training, sick cow management, and culling practices. Additional questions were included to obtain basic dairy information, including: herd size, housing type, and general management practices.

Dairy farms in Colorado and Idaho with a history of collaborating with Colorado State University and the University of Idaho were contacted by extension personnel to participate in this pilot project, with all of those contacted agreeing to participate. Six conventional dairies in each state (n = 12), chosen based on size, agreed to participate. Of the 6 dairies in each state, 2 dairies were chosen to represent each of the following size categories: small (1 to 199 cows); medium (200 to 1,499 cows); and large (1,500 cows or more). In each state, 1 dairy from each size category was randomly chosen to receive BQA training (n = 6), while the remaining 6 dairies did not receive training. All dairies were visited twice during the study; the pre-training visit occurring in June or July 2013, and the post-training visit occurring in September or October 2013. The survey was administered to participating dairy producers during both pre- and post-training visits, with the goal of determining the effect of training on various dairy management practices pertaining to dairy cow welfare and BQA. All lactating cows were observed for LS and BCS during both the pre- and post-training visits. Cows were scored for LS and BCS by an experienced scorer as they exited the milking parlor using the same systems taught during BQA training sessions. A 5-point LS system was used (Sprecher et al., 1997; 1 = sound, 5 = severely lame) and scores were noted to a whole number. Body condition was scored using a 5-point system (Wildman et al., 1982; Ferguson et al., 1994), where 1 = emaciated and 5 = obese, and scores were noted to the half score. Time constraints did not allow for all lactating cows to be observed on 2 of the dairies during the pre-training visit. For those 2 dairies, the same pens of cows that were observed during the pre-training visit were observed again during the post-training visit. On dairies that received training, training sessions were carried out with all dairy employees (including management) concurrent with the pre-training cow evaluation visit.

Data were analyzed using SAS (version 9.3; SAS Institute Inc., Cary, NC). Survey frequency and mean data were calculated using the SURVEYMEANS and SURVEYFREQ procedures. The Wilcoxon Signed Rank and Kruskal Wallis tests for nonparametric data were used to identify differences in participant responses by operation size and by training, as well as to determine the effect of training on LS and BCS, and the prevalence of lame (LS $\geq$ 3), severely lame (LS $\geq$ 4), over-conditioned (BCS $\geq$ 4), and under-conditioned (BCS $\leq$ 2) cows, with the EXACT option for small sample sizes being specified in the NPAR1WAY procedure. Descriptive statistics for cow evaluation data were obtained using PROC UNIVARIATE in SAS, and reported as estimate ± the standard error.

RESULTS AND DISCUSSION

Survey Results

Data are presented for both the pre- and post-BQA training visits when differences were noted; otherwise data are presented from the pre-training visit only. Mean lactating cow inventory per herd was 134 cows for small (range 102 to 182), 1,231 for medium (range 887 to 1,458), and 2,865 cows for large (range 2,229 to 3,300). The majority of dairies (n = 8) used a combination of free-stalls and dry lots for the primary housing type for their cows, and 4 used dry lots. All of the large and medium sized dairies reported milking their cows 3 times per day, while all of the small dairies milked their cows 2 times per day.

All of the dairies that participated in the study stated that they offered training to milkers in proper milking techniques. On 7 operations, management was responsible for providing training to milkers, while on the remaining 5 dairies training was provided by both management and extension/industry personnel (n = 2), co-workers in the parlor (n = 1), extension personnel (n = 1), and a combination of management, veterinarians, and extension personnel (n = 1). With the exception of 2 small dairies, all of the operations in the current study relied predominantly on Hispanic workers to carry out the day-to-day tasks on the farm, including milking. In order for a training program to be effective it needs to be presented in the native language of those attending (Dalton and Jensen, 2006). All 10 of the dairies that relied on Hispanic employees to milk their cows offered the training sessions in Spanish.

Overall, the average milk production was 34.9 ± 1.9 kg during the pre-training visit and 35.1 ± 1.6 kg during the post-training visit. The average milk production for small operations was 27.9 ± 4.0 and 29.6 kg ± 3.3 for the pre- and post-training visits, respectively; for medium sized operations the average milk production was 38.6 ± 0.8 kg during the pre- and 37.3 ± 0.6 kg during the post-training visit; and for large operations the average milk production for the pre- and post-training visits was 38.1 ± 0.7 kg and 38.4 ± 0.9 kg, respectively. While there was a numerical difference in the amount of milk produced among the different dairy sizes, it is possible that the limited sample size prevented this difference from being observed during both the pre-training visit ($P = 0.17$) and the post-training visits ($P = 0.16$). This pattern, of increased milk production with increased herd size, agrees with data reported in the NAHMS Dairy 2007 study (USDA, 2007).

The average annual cull rate, excluding deaths, was 31.2 ± 4.5% pre-training, and 35.4 ± 3.4% post-training, which was consistent with previous studies (Smith et al., 2000; Hadley et al., 2006). The average annual cull rate for small dairies was 14.0 ± 3.4% during the pre- and 23.3 ± 5.5% during the post-training visit; for medium dairies it was 39.8 ± 6.9% and 38.9 ± 3.4% for the pre- and post-training visits, respectively; and for large dairies the average annual cull rate was 39.8 ± 4.3% for the pre- and 44.1 ± 3.2% for the post-training visits. The average annual cull rate differed among dairy sizes for both the pre- ($P < 0.05$) and the post-training ($P < 0.05$) visits. Participants indicated that an overwhelming 79.8 ± 9.0% of cull cows were sent to market, auction, or a stockyard, while 18.0 ± 8.5% were sold directly to the packer or slaughter plant, and 1.8 ± 1.8% were sold to another dairy. These results are similar to those reported in previous studies looking at culling patterns on dairy operations (Rogers et al., 2004; Glaze and Chahine, 2009; Adams et al., 2014). The majority (74.3 ± 8.2%) of cows were culled late in lactation (> 200 DIM), with 12.5 ± 6.0% and 12.7 ± 3.6% being culled in early (< 50 DIM) and mid-lactation (50 to 200 DIM), respectively. The average annual mortality rate on participating dairies was 6.6 ± 1.7% and 8.0 ± 1.6% for the pre- and post-training visits, with no difference found among dairy sizes. Most death losses (54.1 ± 9.1%) occurred early in lactation, 26.7 ± 7.6% in mid-lactation, 15.1 ± 5.1% in late lactation, and 4.2 ± 2.1% in dry cows.

Dairy producers were asked if they had received any condemnations or discounts when marketing cull cows in the 3 mo leading up to the pre-training visit, and in the time between pre- and post-training visit. Four dairies reported having at least 1 cull cow carcass condemned during both the pre- and post-training visit. The reasons given for condemnations included cancer, pyometra, peritonitis, and sepsis. One respondent reported receiving at least 1 carcass discount during the pre-training visit, and 4 reported discounts at the post-training visit. As many participants sold their market cows through auction markets, it is possible that their cows received a lower price (another form of discount), but a specific defect was never reported to them and they were unaware of it. A study investigating the effect of specific BQA defects on selling price in auction markets in the Western US found that many BQA related characteristics had a negative effect on selling price (Ahola et al., 2011b). For instance, cows with a BCS of 2.5 received, on average, \$2.81/45.5 kg less than cows with a BCS of 3.0, and those with a BCS of 2.0 received \$5.82/45.5 kg less.

When asked about protective practices in place to prevent milk from cows with a drug residue from making it into the milk supply, small dairies had an average of 2 ± 0.4 practices in place, medium dairies used 3.5 ± 0.3 practices, and large dairies had 4.8 ± 0.5 practices in place. The number of measures in place to protect the milk supply from drug residues differed among operation size ($P < 0.01$). The most common practices were housing cows in a separate pen (n = 11), using written records (n = 10), and physically marking cows (n = 9). Additional methods included utilizing computer records (n = 6), dairy personnel "knowing" which cows had a milk residue (n = 4), and milking cows with a drug residue in a separate parlor (n = 3). When asked about protective practices in place to ensure that cows with a meat residue would not make it into the food supply, small dairies had only 1.0 ± 0.0 protective practice in place, medium dairies had 2.5 ± 0.3 practices in place, and large dairies had 2.3 ± 0.5 protective practices in place. Similar to protecting the milk supply, the number of measures in place to protect the meat supply from drug residues differed among operation size ($P < 0.05$). The most common methods used included the use of written records (n = 10) and computer records (n = 8). Additional methods used included housing cows in a separate pen (n = 3), physically marking the cows (n = 1), and dairy personnel "knowing" which cows had not met their meat withdrawal period (n = 1). It's possible that other methods were in place to protect the milk and meat supply, such as sampling and testing milk or urine from individual cows prior to marketing their milk or meat, but only the above options were included in the survey. Dairy producers in the current study had more residue prevention measures in place for milk leaving their operations than they had in place for cows that were being marketed for beef ($P < 0.01$). It is likely that producers are more concerned with ensuring that the milk they market is free of all residues since it is their main source of income. Even with fewer procedures in place to ensure that cows are not being marketed with drug residues, none of the dairies surveyed indicated that they had received a condemnation for residues in the past 6 mo, suggesting that they are doing an adequate job of ensuring that cows they sell are meeting this standard.

According to the Animal Medicinal Drug Use Clarification Act of 1994, extra-label use (ELDU) is legal for certain approved drugs by a veterinarian or under their direct order (FDA, 1994). The majority (n = 8) of producers in the study stated that extra-label medications were administered on their farms. When asked how withdrawal times were adjusted to account for ELDU, 6 of the 8 respondents indicated that they based their decision on their veterinarian's recommendations. However, of the 2 dairies that did not do this, 1 indicated that they adjusted the withdrawal time based on calculations found online (without providing a source), and the other dairy indicated that days were added to the label withdrawal time based on best estimates by dairy employees. Under the Animal Medicinal Drug Use Clarification Act of 1994, veterinarians are required to label all extra-label drugs with the adjusted withdrawal times for meat and milk from treated animals (FDA, 1994). As 2 of the dairies in the current study indicated that they determined adjusted withdrawal times for ELDU without their veterinarian's advice, it's apparent that a need exists for producer education on ELDU.

As a key component of the BQA program is to ensure that all injections are administered to preserve the quality and safety of meat (BQA, 2010), questions were included pertaining to injection practices. The average number of injections administered to an average, healthy cow each year was 16.4 ± 3.7 for participating dairy operations. On average per year, small dairies administered 5.5 ± 0.9 injections, medium gave 24.0 ± 7.9 injections, and large dairies reported 19.8 ± 5.1 injections. The average number of injections administered to each cow annually differed among dairy sizes ($P < 0.05$). This finding is not surprising, as 2 small operations reported only administering antibiotics and vaccines on their dairies, while all of the medium and large operations reported administering reproductive hormones, and 3 (2 medium and 1 large) operations reported administering the production hormone bovine somatotropin on their operation. Dairies that administered reproductive or production hormones would be expected to give more injections per year than those that do not, as an estrus synchronization program requires administering between 3 and 5 injections prior to insemination (Moreira et al., 2001), and bovine somatotropin is typically administered once every 14 d, beginning 57 to 70 DIM and continuing until just prior to dry-off (Posilac®, Elanco Animal Health, Greenfield, IN).

When asked where injections were given, participants reported that 63.9 ± 8.7% were administered in the neck, 17.3 ± 6.2% were given in the hind leg, 15.3 ± 8.5% were administered in the upper hip/rump, 3.1 ± 1.8% were given in the shoulder, and 0.4 ± 0.4% were given in the tailhead. With the neck being the only BQA approved location for administering injections i.m. and s.c. (BQA, 2010), it is apparent that educational efforts are needed to improve injection practices on dairy operations. During the pre-training visit, 56.3 ± 9.8% of injections were administered i.m., 38.4 ± 10.7% were given s.c., and 5.3 ± 2.0% were administered i.v. During the post-training visit 54.5 ± 10.6% of injections were given i.m., 36.9 ± 10.5% were administered s.c., and 8.6 ± 2.2% were given i.v. On operations that received BQA training, the percentage of injections administered i.m. decreased from 57.3 (± 13.6) to 54.2% (± 15.2), the percentage given s.c. increased from 37.3 (± 15.5) to 36.5% (± 15.0), and those given i.v. increased from 5.3 (± 3.3) to 9.3% (± 3.7). In contrast, on operations that did not receive training the percentage of injections administered i.m. increased slightly from 54.7 (± 16.1) to 55.0% (± 16.2), those given s.c. decreased from 40.0 (± 15.7) to 37.5% (± 16.4), and injections given i.v. increased from 5.3 (± 1.8) to 7.5% (± 1.4). While these differences were not significant, even a small improvement in the percentage of injections being given i.m. suggests that implementing a training program would help improve BQA practices on dairy operations. When administering injections, 2 dairies stated that needles were changed after every cow, 5 changed needles after 2 to 5 injections, 2 operations changed after 6 to 10 injections, 1 changed after 11 to 20 injections, and 2 dairies stated that the same needle was used on 20 or more cows before being changed. The BQA program recommends changing needles often (after a maximum of 10 cows) to prevent the needles from becoming dull and contaminated, both of which increase the chances of tissue damage and lesion formation (BQA, 2010). Educating producers on the importance of using clean needles will not only improve BQA on their farm, but will also reduce the chance of spreading disease, such as the bovine leukemia virus, within their herd.

During the pre-training visit, a professional hoof trimmer was responsible for trimming hooves on 7 of the participating dairies, and dairy personnel were responsible on the remaining 5 dairies. Between the pre- and post-training visit, 1 of the dairy producers who received BQA training decided to hire a full-time employee to provide hoof care on their farm rather than rely on a professional hoof trimmer, stating that the BQA training instilled the importance of early identification and management of lame cows. Hiring a fulltime employee can be considered a substantial management decision, indicating that a BQA training program has the potential to encourage significant changes in BQA- and welfare-related practices on dairy operations.

Overall, cows visited the hoof trimmer an average of twice per year or lactation on 5 dairies, once per year or lactation on 3 operations, and only when obviously lame or in visible need of trimming on 4 dairies. The average annual percentage of cows that were identified as lame by dairy personnel was 9.5 ± 3.6% during the pre- and 10.9 ± 4.1% for the post-training visit. The increase in the percentage of cows identified as lame was noticed on both dairies that received the BQA training, and those that did not. Since cows on all operations were evaluated during both the pre- and post-training visits, it is possible that just having an additional person on the farm evaluating cows for lameness made dairy personnel more aware of lame cows, regardless if they received training or not.

Cow Evaluation Results

A total of 28,687 cow observations were made over the course of this study; 14,320 during the pre-training visit and 14,367 during the post-training visit. The majority of cows were found to be sound or mildly lame, with a locomotion score of 1 or 2 being assigned to an average of 82.4 ± 2.8% of cows on all of the dairies during the pre-training visit, and 86.0 ± 1.5% during the post-training visit (Table 4.1). During the pre-training visit an average of 14.7 ± 2.8% of cows per farm were found to be lame, of which 3.9 ± 0.9% were classified as severely lame.

Table 4.1. Distribution of locomotion scores (LS) for cows on 12 dairy operations in Colorado and Idaho, 6 of which received training in beef quality assurance practices, during the pre- and post-training evaluations

	Pre-training			Post-training		
	Trained	Not trained	Overall	Trained	Not trained	Overall
LS[1]	Mean % (range)	Mean % (range)	Mean % (range)	Mean % (range)	Mean % (range)	Mean % (range)
1	60.5 (43.3-82.4)	50.0 (30.7-67.2)	55.3 (30.7-82.4)	63.0 (58.1-73.8)	59.2 (50.4-68.0)	61.1 (50.4-73.8)
2	25.1 (9.4-43.3)	35.0 (21.0-46.5)	30.1 (9.4-46.5)	23.6 (18.4-26.8)	26.2 (17.7-32.1)	24.9 (17.7-32.1)
3	9.5% (2.2-16.7)	12.2 (2.9-22.8)	10.8 (2.2-22.8)	9.0 (2.8-12.7)	10.7 (7.1-16.9)	9.8 (2.8-16.9)
4	4.0 (0.6-7.9)	2.4 (0.0-7.6)	3.2 (0.0-7.9)	3.9 (0.9-6.2)	3.0 (0.9-5.5)	3.5 (0.9-6.2)
5	0.9 (0.0-2.4)	0.4 (0.0-0.9)	0.6 (0.0-2.4)	0.5 (0.0-1.4)	0.9 (0.0-4.5)	0.7 (0.0-4.5)
≥ 3[2]	14.4% (4.5-24.9)	15.0% (2.9-31.3)	14.7% (2.9-31.3)	13.4% (7.8-18.6)	14.6% (8.3-23.6)	14.0% (7.8-23.6)
≥ 4[3]	4.9% (0.7-9.7)	2.8% (0.0-8.5)	3.9% (0.0-9.7)	4.4% (1.5-6.9)	3.9% (0.9-10.0)	4.2% (0.9-10.0)

[1] 1 = sound, 5 = severely lame (Sprecher et al., 1997).
[2]LS ≥ 3 was considered lame.
[3]LS ≥ 4 was considered severely lame.

Similar results were found during the post-training evaluation, with 14.0 ± 1.5% of cows being lame and 4.2 ± 0.8% being severely lame. The results in the current study are lower than those previously reported (Cook, 2003; Espejo et al., 2006; von Keyserlingk et al., 2012). Since the dairies that were chosen to participate in this project were done so because of their relationships with Colorado State University and the University of Idaho, it is possible that they represent dairies that are more proactive when it comes to cow comfort and hoof health. Both the dairies that received training in BQA practices and those that did not showed a decrease in the average percentage of lame cows per dairy (-1.0 and -0.4%, respectively), with no difference between the 2 groups ($P = 0.53$). The percentage of severely lame cows decreased numerically on dairies that received BQA training from the pre- to the post-training visits (-0.4%), while it increased numerically on dairies that did not receive the training (+1.1%). These differences, however, were not found to be significant ($P = 0.15$). As this pilot project only included 12 dairies, it is not surprising that differences were not found in the prevalence of lame and severely lame cows between dairies that received BQA training and those that did not. However, the numerical decrease in both lame and severely lame cows over the course of the study for dairies that received training does provide evidence of the potential impact of training programs, such as the BQA training provided in this study, on the prevalence of lame and severely lame cows on dairy operations. As lameness is one of the leading welfare concerns facing the dairy industry, a need exists for improvement in this area, and producer education and training programs are a sound starting point.

The majority of cows observed during the study were found to be in adequate condition (Table 4.2), with an average of 82.4% (± 2.2) and 78.3% (± 2.1) cows per farm having a BCS of 3.0 or 3.5 during the pre- and post-training visits, respectively.

Table 4.2. Distribution of BCS for cows on 12 dairy operations in Colorado and Idaho, 6 of which received training in beef quality assurance practices, during the pre- and post-training evaluations

	Pre-training			Post-training		
	Trained	Not trained	Overall	Trained	Not trained	Overall
BCS[1]	Mean % (Range)	Mean % (Range)	Mean % (Range)	Mean % (Range)	Mean % (Range)	Mean % (Range)
≤ 2.0[2]	0.1 (0.0-0.3)	0.6 (0.0-2.9)	0.3 (0.0-2.9)	0.6 (0.0-1.4)	1.1 (0.1-3.7)	0.9 (0.0-3.7)
2.5	17.4 (7.3-30.7)	16.6 (9.8-26.3)	17.0 (7.3-30.7)	19.7 (13.2-26.8)	21.5 (8.9-32.7)	20.6 (8.9-32.7)
3.0	61.6 (41.6-71.1)	63.2 (57.0-70.7)	62.4 (41.6-71.1)	65.6 (59.7-70.6)	65.5 (55.5-73.4)	65.5 (55.5-73.4)
3.5	20.8 (8.3-27.7)	19.1 (12.8-23.8)	20.0 (8.3-27.7)	13.9 (5.8-19.9)	11.7 (5.3-24.8)	12.8 (5.3-24.8)
≥ 4.0[3]	0.1 (0.0-0.3)	0.5 (0.0-2.0)	0.3 (0.0-2.0)	0.3 (0.0-0.7)	0.3 (0.0-0.9)	0.3 (0.0-0.9)

[1]1 = emaciated, 5 = obese (Wildman et al., 1982; Ferguson et al., 1994).
[2]BCS ≤ 2 was considered under-conditioned.
[3]BCS ≥ 4 was considered over-conditioned.

These results agree with those previously reported by Berry et al. (2007) but are higher than those reported by Loker et al. (2012), where the mean BCS of cows on Canadian farms was 2.68. The Canadian study only included BCS for first lactation heifers, which may explain the discrepancy. The average percentage of under-conditioned cows per farm went from 0.3% (±

0.2) pre-training to 0.9% (± 0.3) post-training, while the percentage of over-conditioned cows stayed consistent at 0.3% (± 0.2) during both visits. It is possible that there was a seasonal effect on BCS over the course of the study (Markusfeld et al., 1997), explaining the decrease in BCS from the summer to the fall. Even with the decrease in BCS over the course of the study, the majority of cows remained in the ideal body condition range, indicating that participating dairies are doing an excellent job at providing their cows with the energy requirements to maintain adequate BCS.

IMPLICATIONS

Results from this study indicate that implementation of an on-farm BQA training has the potential to result in significant changes in BQA- and welfare-related practices on dairy operations, as evidenced by one dairy hiring a full-time employee to manage lameness. Although not significant, a substantial numerical difference was found in the prevalence of lame and severely lame cows between dairies that received training in BQA practices and those that did not. Further investigation is recommended, with a larger sample size and a longer observational period, in order to determine whether or not differences observed in dairy cow lameness are due to seasonal effects or BQA training. Further investigation also has the potential to highlight additional BQA- and welfare-related practices that may benefit from on-farm training programs, such as the BQA program in the current study.

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CHAPTER VI: EFFECT OF ON-FARM DAIRY BEEF QUALITY ASSURANCE (BQA) TRAINING ON DAIRY WORKER KNOWLEDGE OF BQA AND WELFARE RELATED PRACTICES

INTRODUCTION

Unlike most sectors of animal agriculture, the dairy industry is responsible for providing two valuable food products: dairy and beef. While the primary purpose of a dairy cow is to produce milk, at the end of her productive life she will be culled from the herd and enter the beef supply. During 2013, over 3 million dairy cows were slaughtered in the US (USDA, 2014), illustrating the importance of this class of cattle on the beef supply. Despite this, Beef Quality Assurance (BQA) practices are lacking on many dairy operations. Market dairy cows have historically had more BQA defects than market beef cows, with more injection site lesions (Roeber et al., 2002), increased incidence of lameness (NMCBBQA, 2007), and more thin cows (Ahola et al., 2011).

The main goal of the dairy BQA program is to ensure that beef from dairy cows meets the quality and safety expectations of consumers (NDHIA, 2009). In addition, the dairy BQA program emphasizes proper handling and management, promoting dairy cow welfare. The early identification and marketing of cull cows maximizes profits for dairy producers while ensuring that dairy cattle are marketed in a timely manner, prior to compromising their welfare. Many other practices affect both dairy cow welfare and BQA. For example, administering all injections according to BQA guidelines not only preserves the quality of meat in hindquarters of an animal, it also results in injections being given in neck muscle, which has been found to heal faster than rump muscle (Li, Yin, Wang, and Miao, 2012).

Historically, on-farm training programs have been an excellent way of educating dairy producers and employees on various components of dairy operations, such as milking and calving management (Dalton and Jensen, 2006; Garry, Roman-Muniz, Lombard, and Van Metre, 2007). In order for training to be effective though, it's important that they are conducted in the native language of those attending, which for many dairy employees in the US is Spanish. A milker training program developed by the University of Idaho Extension team, which was conducted in Spanish, proved to be quite beneficial in improving worker knowledge of milking management (Dalton and Jensen, 2006). Similar training programs focusing on other aspects of dairy operations are likely to be met with success as well.

OBJECTIVE

The objective of the study was to determine if on-farm dairy BQA training has an effect on dairy worker knowledge of BQA and welfare-related practices.

METHODS

The study findings reported here are from a larger study investigating effects of on-farm BQA training on health and welfare of dairy cows (Adams, Ahola, Chahine, Ohlheiser, and Roman-Muniz, 2015). Through collaboration between Colorado State University and the University of Idaho, dairies in both states were included in this study. Six conventional dairies in each state (n = 12) chosen based on size agreed to participate. Of the 6 dairies in each state, 2 dairies were chosen to represent each of the following size categories: small (1 to 199 cows); medium (200 to 1,499 cows); and large (1,500 cows or more). In each state one dairy from each size category was chosen to receive BQA training (n = 6), while the remaining dairy did not receive training. Results presented here represent the 6 dairies that received the BQA training.

Training sessions were facilitated on each dairy by University extension personnel using Spanish-language materials, and included a PowerPoint presentation, video, and printed information. Training sessions lasted approximately 60 minutes and covered the following material:

- The Idaho dairy BQA manual, Spanish version (Idaho BQA, 2008)
- Prevention and management of non-ambulatory dairy cows [video], Spanish version (WDA, 2010)
- Guidelines for Responsible Antibiotic Use poster, Spanish version (MBC, 2013)
- Beef Quality Assurance for Dairy and Beef Farmers poster, Spanish version (MBC, 2013)
- A dairy BQA PowerPoint presentation in Spanish covering:
    - Identifying lame cows using the 5-point locomotion scoring system (Sprecher et al., 1997)
    - Scoring body condition of dairy cows (Ferguson et al., 1994)
    - Handling of dairy cows
    - Proper injection techniques

A total of 28 dairy personnel participated in the training sessions, and all were administered a pre- and post-exam in order to determine the amount of knowledge gained during the BQA training (Table 4.3).

Table 4.3. Exam Instrument for Dairy Personnel Who Received Training in Beef Quality Assurance (BQA), Administered Both Pre- and Post-Training in Order to Gauge the Amount of Knowledge Gained[1]

Question	**Possible Answers**

1. Which of the following can the dairy beef quality assurance (BQA) program affect?	a) animal health* b) dairy farm profitability* c) animal well-being* d) milk and beef quality*
2. According to BQA guidelines, where should intramuscular (IM) injections be given?	a) in the rump b) in the neck* c) in the back leg d) in the mammary vein
3. According to BQA guidelines, where should subcutaneous (SQ) injections be given?	a) in the rump b) in the neck* c) in the back leg d) in the jugular vein
4. According to BQA guidelines, where should intravenous (IV) injections be given?	a) in the rump b) in the jugular vein* c) in the back leg d) in the mammary vein
5. According to BQA guidelines, if you have the option of giving an injection subcutaneous (SQ) or intramuscular (IM), which is the preferred method to maximize beef quality?	a) subcutaneous (SQ)* b) intramuscular (IM
6. What is the milk or meat withdrawal period?	a) the time that should pass before you inject the cow again b) the time needed before the milk or meat is suitable for human consumption*

	c) the time needed for a drug to cure a disease d) a suggestion, not strictly enforced
7. Which of the following can affect beef quality and safety?	a) injection site damage* b) shipping to slaughter before completion of drug withdrawal period* c) systemic diseases* d) body condition score *
8. By itself, which of the following is an acceptable procedure to euthanize mature cows?	a) gunshot to the head* b) intravenous injection with disinfectant solution c) blunt trauma to the head with a hammer e) exsanguination (bleeding out) by cutting the jugular or mammary vein
9. Which of the following cows should be sent to slaughter?	a) a healthy cow that hasn't gotten pregnant in the last year* b) a cow recently diagnosed with cancer c) a cow with severe pneumonia and with a lameness score of 4 d) a very weak cow with body condition score of 1 e) a cow treated with penicillin and flunixin yesterday

10. What is the locomotion score of a cow that shows pronounced arching of her back and is reluctant to move, with almost no weight bearing on the affected leg?	a) 1 b) 2 c) 3 d) 4 e) 5*
11. Which of the following cows has a body condition score of 2?	
a)  *	b) 
Zinpro Performance Minerals®, Eden Prairie, MN	

*Indicates correct response
[1]Exams were administered in Spanish and translated to English for publication

Pre- and post-exam results were compared in SAS 9.3 (SAS Institute Inc., Cary, NC) using the Wilcoxon signed rank sum test in PROC UNIVARIATE for comparing individual questions, and the paired t-test procedure for comparing the difference in participants overall exam scores, with significance being set at $P \leq 0.05$.

RESULTS

Results comparing responses before and after training are included in Table 4.4. With the exception of the question regarding what a milk and meat withdrawal is, there was an increase in the percent of correct responses for all questions ($P < 0.0001$).

Table 4.4. Percent of Correct Responses for Dairy Personnel (n = 28) Who Received Training in Beef Quality Assurance (BQA) for the Pre- and Post-Training Exams

Question	% Correct Response, Pre-Exam	% Correct Response, Post-Exam	Difference (Post-Exam)-(Pre-Exam)
1. What BQA affects	34.8	36.6	+ 1.8
2. IM injections	64.3	96.4	+ 32.1[a]
3. SQ injections	83.9	96.4	+ 12.5
4. IV injections	75.0	100.0	+ 25.0[a]
5. IM vs. SQ injections	42.9	85.7	+ 42.8[a]
6. Milk & meat withdrawal	53.6	53.6	0.0
7. What affects BQA	33.0	33.9	+ 0.9
8. Euthanasia	83.9	100.0	+ 16.1[a]
9. Suitable for slaughter	64.3	94.6	+ 30.3[a]
10. Locomotion	16.1	57.1	+ 41.1[a]
11. Body condition	46.4	75.0	+ 28.6[a]

[a]Indicates that a difference ($P < 0.05$) was found between the pre- and post-exam scores

The overall exam scores increased 21.0 points after the training, from 54.4 for pre-exams to 75.4 for post-exams ($P < 0.0001$).

DISCUSSION

Results indicate that on-farm dairy BQA training had an effect on dairy worker knowledge of BQA and welfare-related practices, as indicated by the increase in overall score from pre- to post-training exams. Results presented here agree with those presented by Imler, Carr, Hersom, Johnson, and Thrift (2012), who reported that a Dairy BQA Extension Program was effective at teaching producers how to optimize cow welfare and meat quality and improve value of cull dairy cattle. While most of the questions in the current study illustrated a marked improvement, there were a few questions that either showed minimal improvement (Q1 and Q7), or did not improve at all (Q6). In order for both Q1 and Q7 to be considered correct, participants had to select all of the answers, which could have been confusing for some and may explain the lack of improvement after receiving training. It is possible that further instruction, ensuring that all participants understood that some questions required more than one answer, would have allowed a difference to be discernable between pre- and post-training exam scores for these questions. In order to avoid confusion, future studies should have an "all of the above" option for this type of question.

An area of concern from this study is the fact that Q6, which asked participants to select the definition of meat and milk withdrawal, showed no improvement. It is likely that the training material did not cover these topics thoroughly enough to improve knowledge of attendees with little or no previous experience with these terms. Future training programs should focus on covering these topics in more depth, stressing the importance of adhering to strict withdrawal times in order to protect the meat and milk supply from risk of drug residues. In addition, stressing the negative consequences of a meat or milk residue, on both the dairy industry and human health, may impress upon dairy workers the severity of the issue.

CONCLUSIONS AND IMPLICATIONS

Improvement in dairy worker knowledge suggests that BQA training programs have the potential to positively influence the dairy industry. Educating dairy owners and employees on proper BQA and welfare-related practices could potentially result in improved handling and management of dairy cows, as well as the quality of cull cows that are being sent to market. Further research, including a larger sample size and follow-up visits to gauge employee knowledge retention and changes in behavior, is needed to investigate the long-term effect of on-farm BQA training on dairy worker knowledge and management practices.

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APPENDIX I:

Survey Instrument for Locomotion Scoring System Study

Locomotion Scoring of Dairy Cattle: Brief Demographic Survey

1. Which of the following best describes your involvement in the dairy industry?
    a. Dairy producer/owner
    b. Dairy manager/herdsperson
    c. Dairy personnel (e.g., milker, breeder)
    d. University personnel (e.g., extension specialist, professor, researcher)
    e. Veterinarian
    f. Industry personnel (e.g., consultant)
    g. Other (specify: ____)

2. How long have you worked in the dairy industry?
    a. Less than 1 year
    b. 1 – 5 years
    c. More than 5, but less than 10 years
    d. 10 years or more

3. Do you have previous experience locomotion scoring dairy cows?
    a. Yes
    b. No (if no, skip to #5)

4. Which of the following three locomotion scoring systems do you have the most experience using?
    a. The 3-point system (sound, mildly lame, moderately/severely lame)
    b. The 4-point system (sound, mildly lame, moderately lame, severely lame)
    c. The 5-point system (sound, mildly lame, moderately lame, lame, severely lame)

5. Prior to this study, have you received training in how to locomotion score dairy cows?
    a. Yes
    b. No (if no, skip to #7)

6. Which of the following best describes your previous training?
    a. Classroom setting with an instructor (on- or off-farm)
    b. Video training
    c. On-the-job training
    d. Other (specify: ____)

7. Which scoring system do you prefer and why?

a. The 3-point system (sound, mildly lame, moderately/severely lame)
b. The 4-point system (sound, mildly lame, moderately lame, severely lame)
c. The 5-point system (sound, mildly lame, moderately lame, lame, severely lame)

Reason____
____
____

APPENDIX II:

Survey Instrument for Dairy Beef Quality Assurance Study

Dairy #: _______ Date: _______________

Management Characteristics

Section 1 – Dairy Dynamics

Choose one option unless otherwise indicated.

Location: _____________________________

Size:

Lactating ______ Dry ______ Heifers ______

1. Housing types:

□ Free-stall Barns □ Dry Lot □ Combination

2. Bedding types (check all that apply):

□ Straw/Hay □ Sand □ Compost □ Sawdust/Wood products □ Other

3. Pen stocking percentage (by available beds):

□ < 75% □ 75-100% □ 100-125% □ > 125%

4. How are the majority of pen movements determined?

□ Based on milk production (high, mid, low)
□ Based on body condition score
□ Based on parity (heifer pens, cow pens)
□ Based on pregnancy status
□ Other (specify): ____

5. How often are the majority of pen movements carried out?

□ Daily □ Once a week
□ Every other week □ Once a month
□ Other (specify): __________________

6. How often are cows milked each day?

□ 1X per day □ 2X per day □ 3X per day □ 4X per day

7. Do milkers receive training on proper milking techniques? □ Yes □ No

If answered "No" skip to question 10.

8. Who is responsible for training the milkers on proper milking techniques?

□ Management □ Extension personnel or other industry professional
□ Other milkers □ Other (specify) _______________________
□ Veterinarian

9. What language is the training offered in?

□ English □ Spanish □ English & Spanish □ Other (specify) ___________________

10. How are cows with milk withdrawal identified (check all that apply)?

□ Housed in a separate pen
□ Milked in a separate parlor
□ Written records
□ Computer records
□ Physically marked (e.g. leg band, chalk marking, etc.)
□ Dairy personnel "know" when a cow has met their withdrawal
□ Milk alarm
□ Other (specify): ____

11. How are cows with meat withdrawal identified (check all that apply)?

□ Computer records
□ Physically marked (e.g. leg band, chalk marking, etc.)
□ Written records
□ Computer records
□ Dairy personnel "know" when a cow has met their withdrawal
□ Housed in a separate pen
□ Other (specify): ____

12. If a drug is administered "off-label", are meat withdrawal times adjusted to account for this?

□ Yes □ No

If answered "No" skip to question 14.

13. How is the adjusted withdrawal time determined?

□ Veterinarian recommendations
□ Pharmaceutical company recommendations
□ Calculations found online
□ Additional days added based on best estimate by dairy personnel
□ Other (specify): ____

Section 2 – Euthanasia Practices

14. Is euthanasia practiced on this operation? □ Yes □ No

If answered "No" skip to question 20.

15. What is the primary method of euthanasia used?

□ Gunshot
□ Captive bolt (e.g. stunning)
□ Captive bolt with additional steps (e.g. bleed out) to ensure death
□ Barbiturates
□ Chlorhexidine
□ Rendering services

□ Other (specify): ____

16. Who is in charge of deciding when it is time to euthanize (check all that apply)?

□ Owner
□ Manager
□ Both owner and manager can decide
□ Employees
□ Other (specify): ____

17. Who is in charge of administering euthanasia (check all that apply)?

□ Owner
□ Manager
□ Both owner and manager
□ Employees
□ Other (specify): ____

18. Do managers/employees receive training in proper euthanasia techniques?

□ Yes □ No

If answered "No" skip to question 20.

19. Who is responsible for training employees in proper euthanasia techniques (check all that apply)?

□ Veterinarian
□ Owner
□ Manager
□ Extension personnel
□ Other (specify) ____

<u>Section 3 – Market Cow Practices</u>

20. Of those permanently removed, how many (% or #) went directly to:	%	#
a. Market, auction, or stockyard	______	______
b. Packer or slaughter plant	______	______
c. Another dairy	______	______
d. A feed yard to be fed prior to slaughter	______	______
e. Other (specify):	______	______

____

21. In the past 3 months, have you received any of the following when marketing cows?

a. Discounts □ Yes □ No

If yes, please explain: ____

If yes, what percent of cull cows marketed? ______%

b. Condemnations □ Yes □ No

If yes, please explain: ____

If yes, what percent of cull cows marketed? ______%

Section 4 – Injection Techniques

22. What types of injections are administered on this operation (check all that apply)?
    - □ Antibiotics
    - □ Reproductive hormones
    - □ Production hormones (e.g. rBST)
    - □ Vaccines
    - □ Other (specify): ____

23. How many injections did a typical cow receive in the past 12 months? _____________

24. What percentage of injections was given by the following? %
    - a. Farm personnel _______
    - b. Veterinarian _______
    - c. Other (specify) _____________________________ _______

25. Do employees receive training in proper injection techniques? □ Yes □ No

    If answered "No" skip to question 27.

26. Who is responsible for training employees on proper injection techniques (check all that apply)?
    - □ Management
    - □ Other employees
    - □ Veterinarian
    - □ Extension personnel or other industry professional
    - □ Other (specify) ____

27. When administering injections in the past 3 months, how often did farm personnel change needles?
    - □ After every cow
    - □ Between 2-5 injections
    - □ Between 5-10 injections
    - □ Between 10-20 injections
    - □ >20 injections per needle

28. What percentage of injections was administered in the following locations, by type?

	Antibiotic%	R. Hormone%	P. Hormone%	Vaccine%	Other%
Neck	_______	_______	_______	_______	_______
Shoulder	_______	_______	_______	_______	_______
Next to tailhead	_______	_______	_______	_______	_______
Upper hip	_______	_______	_______	_______	_______

Hind Leg ______ ______ ______ ______ ______

29. Of all injections administered in the past 3 months, what percentage was: %

a. Intramuscular (IM) ______

b. Subcutaneous (SQ) ______

c. Intravenous (IV) ______

Production Variables

Section 5 - Milk Production

30a. What is the average milk production (pounds per cow) for the past 3 months? ____________

30b. By month?

Month 1: ____________________ Production: ____________

Month 2: ____________________ Production: ____________

Month 3: ____________________ Production: ____________

31a. What is the average Days in Milk (DIM) for the past 3 months? ____________

31b. By month?

Month 1: ____________________ DIM: ____________

Month 2: ____________________ DIM: ____________

Month 3: ____________________ DIM: ____________

Section 6 – Health

32a. What is the overall morbidity, excluding lameness, for lactating cows over the past 3 months? (# diagnosed) ____________

32b. By month?

Month 1: ____________________ SCC: ____________

Month 2: ____________________ SCC: ____________

Month 3: ____________________ SCC: ____________

33. In the past 3 months, how many animals were recorded as being lame (gait abnormality)?

____

33b. By month?

Month 1: ____________________ # Treated: ____________

Month 2: ____________________ # Treated: ____________

Month 3: ____________________ # Treated: ____________

Section 7 – Market Cow Practices

34. Excluding death loss, how many cows were permanently removed in the past 3 months? _________

35. What was the death loss for the past 3 months? __________

36. Of those that died, how many (% or #) were:	%	#
a. < 50 DIM (early lactation)	______	______
b. 50 – 200 DIM (mid lactation)	______	______
c. 200 – Dry-off (late lactation)	______	______
d. Dry	______	______

37. Of those permanently removed, how many (% or #) were due to:	%	#
a. Low production	______	______
b. Mastitis	______	______
c. Reproduction	______	______
d. Lameness	______	______
e. Illness (pneumonia, etc.)	______	______
f. Injury	______	______
g. Other (specify): ________________________________	______	______

38. Of those permanently removed, how many (% or #) were:	%	#
a. < 50 DIM (early lactation)	______	______
b. 50 – 200 DIM (mid lactation)	______	______
c. 200 – Dry-off (late lactation)	______	______
d. Dry	______	______

Section 8 – Locomotion

39. In the past 3 months, what was the percentage of cows that had their hooves trimmed? ______

40. Who is responsible for the majority of trimming?
- □ Professional hoof trimmer
- □ Owner/dairy personnel
- □ Veterinarian
- □ Other (specify) ____

41. How often do cows visit the hoof trimmer?
- □ Two times per year/lactation
- □ Once a year/lactation
- □ Only when lame/visibly in need of a trim

Section 9 – Reproduction

42. What is the primary method of breeding cows?
- □ Natural service

□ AI to natural estrus (heat breeding)
□ AI to induced estrus (reproductive hormones)
□ Other (specify): ____

43. Who is responsible for the majority of AI practices?
□ Owner
□ Manager
□ General employee
□ Veterinarian
□ AI technician
□ Other (specify): ____

44a. What is the average Conception Rate (CR) for the past 3 months? ______
44b. By month?

Month 1: ____________________	CR: ____________
Month 2: ____________________	CR: ____________
Month 3: ____________________	CR: ____________

45a. What is the average AI Services per Conception (SPC) for the past 3 months? ______
45b. By month?

Month 1: ____________________	SPC: ____________
Month 2: ____________________	SPC: ____________
Month 3: ____________________	SPC: ____________

APPENDIX III:

Dairy Cow Evaluation Form for NAHMS Dairy 2014 Study

Dairy 2014
Cow Evaluation

Animal and Plant Health
Inspection Services

Veterinary Services

NAHMS ID: (6 digits)	# of people involved:	Primary collector name and phone:	Date: (mm/dd/yy)
	____ Fed VMO ____ Fed AHT ____ State VMO ___ State AHT ____ Producer ____ Others—specify:	______-_______-_______	

National Animal Health Monitoring System

2150 Centre Ave, Bldg B Fort Collins, CO 80526

Form Approved OMB Number 0579-0205 Approval expires: 09/30/2016

# of cows scored (or # in pen):	Cows scored:	Scoring surface:
C101	☐1 Whole herd scored ☐2 One pen scored: ☐1 High production (DIM: _____) ☐2 Medium production (DIM: _____) ☐3 Low production (DIM: _____) ☐4 Other (specify:)C103OTH C102/C103	C104 ☐1 Concrete ☐2 Dirt ☐3 Other (specify:) C104OTH **Surface:** C105 ☐1 Dry ☐2 Wet ☐3 Snow/ice ☐4 Other (specify:) C105OTH

SCORE	Locomotion score	Hock score
1	Do not need to score—calculate after scoring	Do not need to score—calculate after scoring
Total:		
2	C110	C112
Total:		
3	C111	C113
Total:		

SCORE	Body condition score <2.25
Yes	C114
Total:	
No	Do not need to score—calculate after scoring
Total:	

According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0579-0205. The time required to complete this information collection is estimated to average 0.75 hours per response, including the time to review instructions, search existing data resources, gather the data needed, and complete and review the information collected.	**NAHMS-312**