Woodhead Publishing Series in Food Science, Technology and Nutrition

Advances in Cattle Welfare

Edited by Cassandra B. Tucker

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A volume in the Advances in Farm AnimalWelfare series

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Preface

Joy Mench

Animal welfare began to emerge as a scientific discipline in the 1960s, and there is now a large body of published research addressing a range of fundamental and applied topics. However, the field is currently in a stage of transition, with an increasing emphasis on translating the knowledge that has been gained into “real world” improvements. This is necessitating new and ever more sophisticated research approaches, including the collection of more complex data with an increasing focus on solutions, the development and use of new research methodologies and technologies, and integration of information across different disciplines. It also requires enhancing communication and collaboration among diverse stakeholders, as well as developing science-based approaches for setting “best practice” standards and on-site welfare assessments to help ensure public confidence.

The five books in this series provide overviews of key scientific approaches to assessing and improving the welfare of farm animals and address how that science can be translated into practice. The books are not meant to provide a comprehensive overview, but instead focus on selected “hot topics” and emerging issues for cattle, pigs, poultry, and sheep (as well as the overarching issue of linking animal welfare science and practice). Advances and challenges in these areas are presented in each book in the form of an integrated collection of focused review chapters written by top experts in the field. The emphasis is not just on discussing problems, but on identifying methods for mitigating those problems and the knowledge gaps that remain to be filled.

Although the topic reviewed in the cattle, pig, poultry, and sheep books are tailored to those most important for the particular species, all of the books include an overview of production systems and discussion of the most pressing animal welfare challenges and important advances associated with those systems from the perspectives of normal and abnormal behavior, animal health, and pain management. Emphasis is placed on both management and genetic approaches to improving welfare, as well as on emerging scientific tools for investigating questions about the welfare of that species. As relevant, the books also include reviews on human–animal interactions and transport and/or slaughter. Finally, practical tools for in situ (on the farm, during transport, or at the slaughter facility) assessment of welfare are presented. The reviews in the overview volume focus on animal welfare in the context of agricultural sustainability, and also address how science can be translated into practice taking into account ethical views, social developments, and the emergence of global standards.

The topics covered by these books are highly relevant to stakeholders interested in the current and future developments of farm animal welfare policies, including farmers, food industry, retailers, and policy makers, as well as researchers and veterinary practitioners. The editors hope that they serve not only to help improve farm animal welfare but also to encourage discussion about future directions and priorities in the field.

Series Editor

Introduction

Cassandra B. Tucker

The vision

This book has been a deeply personal endeavor, one that captures an overarching theme in my career: to be a constructive voice in our societal conversation about food. Constructive voices take many forms, depending on the person and their talents. As a scientist, I believe that research can inform our discussions about animal welfare. In its most applied form, research in this field generates and evaluates practical means to improve the day-to-day lives of cattle used for milk and meat. This knowledge requires advocates to take it into the world. Regardless of their training or expertise, my experience has been that the people who are most effective at this are able to respond to openings, to new possibilities in the dialog. They are able to perceive when a given group, for example, a producer, a veterinarian, a retailer, a non-profit organization, a legislator, a processor, etc., is ready to hear new information and use their influence to improve animal welfare.

This book represents the range of openings and possibilities I have seen emerge in the last few years. The inspiration for the topics has come from conversations with producers, academics, veterinarians, purchasers, and consumers of dairy and beef products, as well as time spent directly with the animals. The chapters address areas where I believe knowledge will provide insight and deepen the discussion. Each chapter is a review of academic literature that I felt was missing from our journals, but where command of this information is keenly needed in our conversations about cattle welfare.

The contents

The authors of each chapter took my invitation and inspiration for their topic and refined it. It was an honor to work with them. In the back-and-forth of the editing process, I came to see each chapter as a window into the author's insight and the depth of their care. Invariably, their reviews lead to new questions and, in this way, also inform future research.

The book begins with an overview of cattle production, portrayed with words and pictures by Marcia Endres and Karen Schwartzkopf-Genswein. Often, the starting point for conversations about cattle welfare is to understand what is involved in the process. This overview is useful for someone who might have had little experience with agriculture as well as those who are intimately involved in one sector, dairy for example, but perhaps have little contact with beef. They also highlight where the welfare concerns exist. This is useful, given that animal welfare inherently reflects our ethical priorities, and sometimes one person's concern is another's assumption about business as usual.

The next two chapters are about assessing cattle welfare on farms. In the first, Nigel Cook reviews common animal-based measures that are being widely used to evaluate dairy cattle welfare. He covers the basics of how these assessments are done and how they can be improved. He also discusses the extensive variability among farms and the concurrent opportunities for improvement. In the second chapter on this topic, Christoph Winckler examines what we do with information about animal welfare once it has been collected. His focus is on challenges and opportunities for both intervention and change on farms.

Cattle welfare assessment focuses predominately on health-related parameters, but I see growing interest in understanding more about the behavioral needs of the animals and potentially incorporating this into how farms are audited. The next chapters provide an update about three aspects of this dimension: human–animal interactions, cattle choices about feed, movement, and social contact. Lily Edwards-Callaway's chapter on human–animal interactions offers a fresh perspective on how humans treat cattle in their care, emphasizing that using feedback can make this a dynamic and rewarding relationship. The effects of cattle production are then reviewed in two chapters about physical, nutritional, and social restriction. Karin Schütz, Caroline Lee, and Trevor DeVries discuss what is known about the importance of pasture and roughage in cattle diets. They also review the physical implications of tie stalls and individually housing dairy calves. Margit Bak Jensen provides an overview of the social life of cattle. She covers the various forms and importance of interacting with others as well as contexts where cattle avoid social contact. Both chapters raise important questions about our current approaches to housing and feeding cattle.

The final section of the book focuses on disease and injury. The chapters emphasize that, despite our focus on health in cattle welfare, many questions remain unanswered, particularly in terms of how the affective states of the animals are influenced by disease and management practices. In the first chapter, Sarah Adcock and I focus on painful procedures commonly used in cattle and highlight that the majority of our current knowledge is about the immediate response to removal of horns and testicles. Our review covers the importance of understanding the longer-term effects of painful procedures, issues around pain being undertreated, and factors influencing measurement of pain. Rachel Toaff-Rosenstein's chapter reviews the top five diseases in cattle and highlights the importance of timely detection of illness and compassionate care in treatment, including euthanasia. Finally, the level of cattle performance, namely rapid growth and high levels of milk production, is reviewed by John Gaughan in the context of metabolic challenge. His chapter addresses how genetic potential, nutrition, climate, and exogenous production promotants affect and, under specific circumstances, may compromise cattle welfare.

My sincere hope is that this book contributes to your effectiveness as a constructive voice in our conversation about food. I hope that it provokes ideas, challenges assumptions, and provides inspiration about the best way to care for cattle.

August 2018

1

Overview of cattle production systems

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Abstract

This chapter provides a general, brief description of the production systems for dairy and beef cattle at various ages, from calf to adult. In addition, the chapter introduces key welfare issues related to cattle production systems.

Keywords

Dairy cattle; beef cattle; housing; management

1.1 Introduction

This chapter provides a general, brief description of the production systems for dairy and beef cattle at various ages, from calf to adult. In addition, the chapter introduces key welfare issues related to cattle production systems (Table 1.1).

Table 1.1

Key animal welfare concerns and whether they apply to dairy and/or beef cattle

Animal welfare concern	Dairy	Beef
Painful procedures (e.g., castration, dehorning, branding)	x	x
Transition health disorders (late gestation to early lactation)	x	
Transition health disorders (backgrounding to feedlot)		x
Other health issues (i.e. lameness, respiratory disease, mastitis, dystocia)	x	x
Dry-off practices	x	

Exposure to weather	x	x
Animal handling, human–animal interactions	x	x
Improper euthanasia, including method and timeliness	x	x
Nonambulatory animal handling	x	x
Transportation and slaughter	x	x
Extreme confinement, such as tie stall or small crates	x	
Inability to graze	x	x
Social isolation	x	
Weaning or separation from the dam	x	x
Injury	x	
Concerns about the quality and quantity of water or feed	x	x

1.2 Dairy cattle production systems

Dairy cattle are raised in confinement, semi-confinement, pasture-intensive or extensive housing conditions. Most dairy cattle in North America and Europe are in confinement freestall, tie-stall, dry lot or bedded pack systems with a smaller percentage on pasture. In other areas of the world such as South America, New Zealand, Australia and India for example, extensive, pasture-intensive or semi-confinement systems are more common than confinement systems. The size of these operations varies widely among geographic regions and housing type. Some farms may only have a few individual cows, while others will have thousands.

Cows are usually bred at 12–16 months of age, calve at about 24 months of age, milk for an average 305-day lactation until we dry them off (for a period of 50–60 days). Then the cycle is repeated. Lifespan varies with housing systems, and usually cows in confinement are replaced with younger cows (first lactation heifers) on average after approximately two lactations.

In all dairy systems, there are several health issues that are relatively common such as mastitis, lameness, dystocia and metabolic disorders such as ketosis or hypocalcemia. In addition, common injuries in adult cattle are on the legs: hock injuries on the hind legs and swollen knees. The most critical time for the dairy cow is when she transitions from gestation to early lactation, or the ‘transition period’. There is greater mortality and morbidity during the transition period than later in lactation and many cows may be culled from the herd at this time. Common causes for mortality and culling in dairy herds include injury, toxic mastitis, severe lameness, reproductive failure and metabolic disorders.

1.2.1 Confinement housing for adult dairy animals

Cows in confinement systems in general produce more milk than cows on pasture because they are fed a mixed ration balanced for more production per cow. The amount of milk produced per cow varies widely, but averages 7000–14,000 kg of milk per cow per lactation (305 days). They are usually milked two to three times per day and the method of milking depends on the housing type.

Tie-stall systems (Fig. 1.1) are still used in many countries to house lactating cows. In this system, cows are tethered to an individual stall and fed and usually milked in place; cows often have no or limited outdoor access during at least part of the year. Water is offered to each cow most commonly in individual water bowls placed in front of each stall. On some farms, a cow trainer, or an electrified rail above the cows, is used to make cows step back when they arch their back to urinate or defecate, such that the waste lands in the alleyway. Cows may be fed a mixed ration that includes forages and concentrates, or component feeding can be used where cows are fed forages (such as hay and silage) and concentrates separately. In that case, the producer usually delivers some forage in front of the cows first and then later top-dresses with concentrates. Concentrates include grains, protein, vitamins and minerals. Popescu (2013) summarized that 75% of Swedish, 88% of Norwegian, and one-third of German cows were housed in tie-stall systems, often without access to pasture. In the USA, 39% of dairy operations had tie-stalls or stanchions as primary housing type for lactating cows (USDA, 2016). Tie-stall housing limits animal social interaction and movement, including walking, grooming, and grazing. Some farms provide an exercise area where cows can spend portions of a day untethered and socializing.

FIGURE 1.1 An example of a tie-stall housing system where cows are tethered to a stall. *Source*: Photo courtesy of Marcia Endres, University of Minnesota, USA.

Freestall systems (Fig. 1.2) allow cows more freedom of movement within the pen compared to tie stalls. As the name implies, cows can move from stall to stall at will and are not tethered. They are taken to a milking parlor two or three times a day.

FIGURE 1.2 Cows housed in head-to-head freestalls with deep-bedded sand. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Milking parlors can be of various types such as low-cost step-up (Fig. 1.3), herringbone, parallel (Fig. 1.4) or rotary (Fig. 1.5). In front of the milking parlor there is a holding area where cows wait until they can enter the parlor. All cows within each pen or group are usually brought to the parlor together, therefore holding areas are designed to tightly fit the number of cows in the group. How cows are handled during this process of movement from the home pen to the milking parlor is an important consideration for animal welfare. Many farms include a crowd gate (Fig. 1.6) in the holding area to help move cows forward towards the milking parlor. The goal is to slowly reduce the size of the holding area and not use this gate inappropriately to push cows into the parlor, potentially causing cows to slip and fall or injure themselves. Cows can also be milked voluntarily in a robotic milking system (Fig. 1.7).

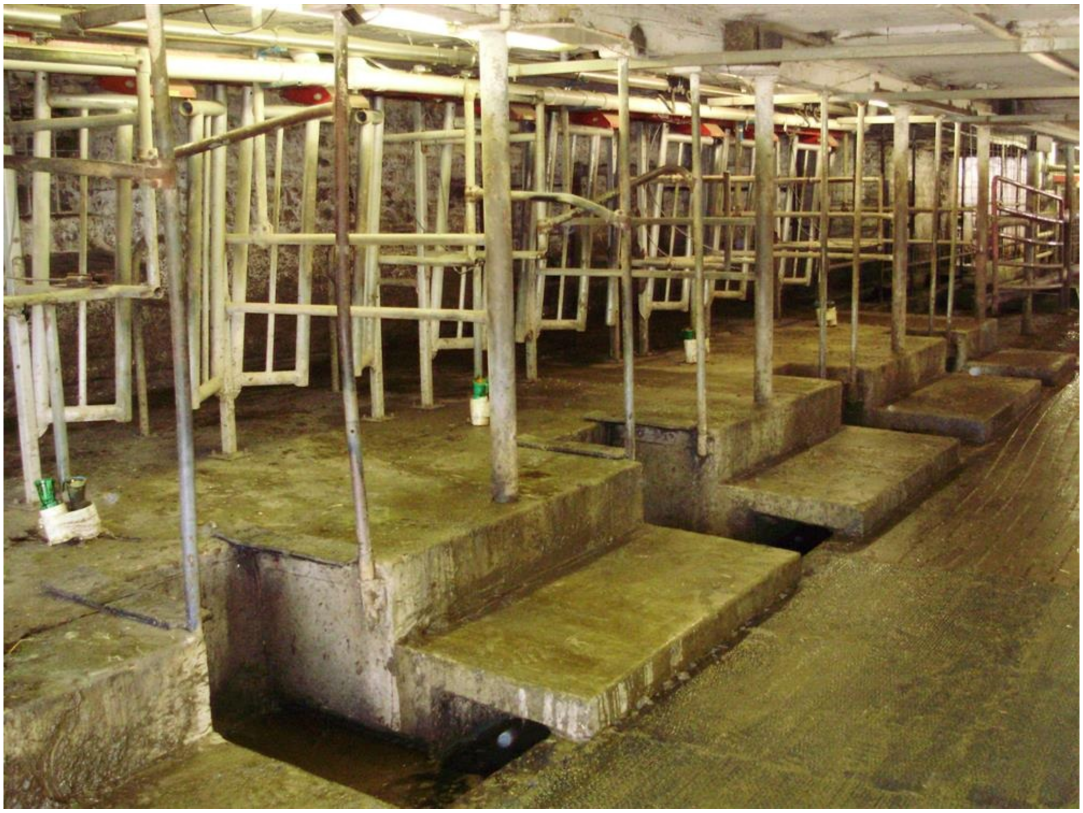

FIGURE 1.3 Example of double-8 step-up low-cost parlor. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.


FIGURE 1.4 Double-12 parallel parlor. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.5 Rotary parlor in a 2000-cow dairy farm. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.6 Crowd gate in holding area used to help move cows into the parlor. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.7 Cow being milked voluntarily in a robotic milking system box.
Source: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Freestall barns are built with two or three rows of stalls or defined lying areas per pen, with multiples of two pens being most common for naturally ventilated barns (Fig. 1.8A, B) resulting in four- or six-row barns. In cross-ventilated freestall barns (Figs 1.9, 1.10) as many as 20 rows of stalls can be included, with eight to 12 rows being more common (Lobeck et al., 2012). Stall surfaces can be concrete, rubber, mattress, waterbeds, or deep beds most commonly with sand, sawdust, straw or recycled, dried manure solids. The type of stall surface can influence the prevalence of lameness, hock and knee lesions on dairy farms, with deep beds being the preferred surface for good welfare.

FIGURE 1.8 View of a naturally ventilated freestall barn. (A) Outside view; (B) inside view. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.9 Inside view of a cross-ventilated freestall barn. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.10 Outside view of cross-ventilated freestall barn. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Cows are fed a totally mixed ration that includes forages and concentrates inside the freestall barn using a feed bunk (Fig. 1.9). Access to the feed bunk or lane can be through a post and rail system, which is more open, or through headlocks (as shown in Fig. 1.9) where cows can be locked for management procedures such as breeding and health checks for a short period of time (e.g. less than 1 h a day). Clean water should also be available at all times using water troughs with a minimum two troughs per pen (Fig. 1.11). Poor water quality (e.g. dirty troughs) or limited access (e.g. broken troughs) is a welfare concern across systems.

FIGURE 1.11 Example of a water trough in a freestall pen. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Bedded pack systems are composed of a large resting area bedded with straw or corn stalks (conventional bedded pack) or with small particle materials such as sawdust and stirred twice a day (compost bedded pack) and a feed alley usually with concrete flooring (Figs. 1.12–1.14). A conventional pack system is used frequently for housing dry cows in certain areas of the world especially during the winter time. The compost bedded pack system is used for lactating and dry cows (Endres and Janni, 2008). Bedded pack systems offer freedom of movement to the cows as there are no hindrances to positions assumed while lying down and the surface is soft. If well managed, bedded packs can result in excellent cow comfort and udder health. However, if the bedding gets too wet, it can result in greater mastitis incidence. In these systems, cows are also milked in a parlor and fed in a feed bunk (Fig. 1.14) as described previously.

FIGURE 1.12 Inside of a compost bedded pack barn. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.13 Stirring the compost bedded pack. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

FIGURE 1.14 Compost bedded pack barn feed bunk, with a post-and-rail barrier. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Dry lot systems used in the Western USA (Fig. 1.15) or other countries with arid climates also offer freedom of movement as cows are housed on large resting areas of dirt, and come to a feed bunk to eat, which might or might not be covered. There can also be shaded areas within the dirt lot and these can include cooling systems, such as fans. Heat stress can be a problem if appropriate heat abatement practices are not implemented. Muddy conditions can also cause stress during certain times of the year. Cows come to a parlor to be milked as described above.

FIGURE 1.15 Covered feed alley in a dry lot system. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

1.2.2 Pasture systems for adult dairy animals

Pasture-based systems for dairy come in several forms. In some, grass is closely managed and cows are offered a new paddock every 12 or 24 h. In other pasture systems, grass is less intensively managed and used more continuously without rotation among paddocks. Offering a new paddock every 12 or 24 h can result in greater milk production per cow and per acre than low-management pasture systems. In a semi-confinement system, cows are on pasture for part of the day but are also supplemented with forage and grain at a feed bunk, usually a covered area with concrete flooring or sometimes in some type of barn.

Cows on intensively managed pasture systems produce 3000–7000 kg of milk per lactation (305 days), depending on level of concentrate supplementation. Some farms choose to seasonally calve and not produce milk during the winter months when pasture availability is limited. Pasture systems provide animals with freedom of movement, the opportunity to graze, social interaction with herd mates and a soft surface to walk on which are all often perceived as positive in terms of animal welfare, but offer some challenges related to environmental stress such as lack of shade or muddy conditions and the potential for foot injury from rocky or uneven walking surfaces to and from the parlor. In addition, poor nutrition can be a problem at certain times of the year or if the pastures are not well managed. Finally, in all systems, including pasture-based dairies, the way lactation is ended (also called "dry off") is a welfare concern. Cows may be given less feed, lower quality feed, milking frequency may be reduced or abruptly stopped and hunger and discomfort may result.

1.2.3 Housing for young dairy animals

Preweaned dairy calves are usually separated from their mother soon after birth to prevent disease transmission. Dystocia, or difficulty calving, can adversely affect both the cow and the calf, and at least some intervention into the birth process is relatively common in many dairy systems. Once separated from the cow, calves are fed milk or milk replacer and these preweaned calves can be housed individually or in groups. In the USA, for example, 69.7% of dairy operations housed preweaned calves individually (USDA, 2016). Individual housing systems include hutches and individual pens within barns. Social isolation is an animal welfare concern for individually housed calves. Hutches may be constructed of wood, plastic or fiberglass with calves restrained by fencing or chain and collar (Fig. 1.16). Individual pens are constructed of similar materials and located in natural or mechanically ventilated buildings (Fig. 1.17). Feeding systems for individual housing include manual feeding with bottles or buckets although there is an automated milk-delivery system to calves in individual pens available on the market. Calves are highly motivated to suck, so systems that do not incorporate this behavior into milk feeding (e.g., buckets), limit the opportunity to engage in this behavior. Calves are usually fed milk (or milk replacer) twice a day until they are 8 or 9 weeks of age. For example, in the USA the majority of preweaned heifers (88.9%) were fed twice daily, while 6.8% were fed three times daily (USDA, 2016). Very commonly the amount offered (4–5 L) is half or less of what would be consumed if calves had ad libitum access to milk, and this is an animal welfare concern. In addition, the weaning practices employed (e.g., abrupt removal of milk compared to a gradual process) can also be a concern.

FIGURE 1.16 Example of an individual calf hutch system. This farm uses bottles to feed milk to their calves. Buckets are also used on dairy farms.
Source: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

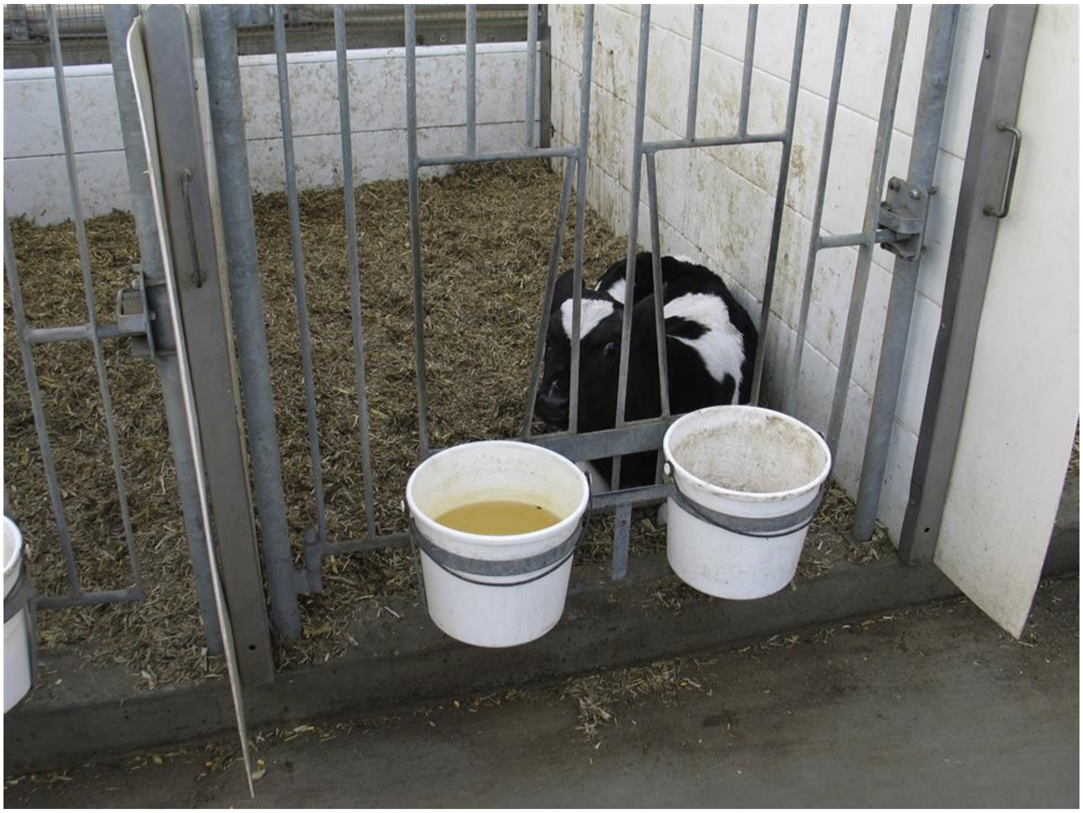

FIGURE 1.17 Example of indoor individual calf pen with two buckets; one bucket is used for calf starter grain mix and the other one for milk and water. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Preweaned calves can also be housed in groups (Fig. 1.18). Two main factors seem to have caused dairy producers to consider the practice of housing calves in groups: to improve labor efficiency and working conditions and to allow for easier feeding of higher amounts of milk per calf. Group housing also provides the benefit of social contact for the calves. Challenges in group housing include greater exposure to pathogens which could lead to greater disease incidence or mortality in these systems.

FIGURE 1.18 Preweaned calves housed in groups. This example includes an automated calf feeder in the top left corner of the pen (*red panel*) that feeds one calf at a time. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

There are three major types of feeding systems that can be used in group housing: mob feeders, ad libitum acidified milk feeders and automated calf feeders. The use of automated calf feeders to feed calves in groups is more common in Europe than other areas of the world, but their use is increasing in North America. Mob feeding of calves is more common in grazing dairies practicing seasonal calving where large numbers of cows calve during a short period of time. This system involves placing containers with multiple nipples in a calf pen until all the liquid is consumed, which is generally less than 10 min. Systems using acidified milk or milk replacer enable feeding of calves in groups on an ad libitum basis. The liquid is acidified with the addition of organic acids, such as formic and citric, to reduce pH of the liquid to 4–4.5. The simplest system is a barrel with nipples connected to plastic or vinyl lines. Finally, all calves of all ages should have access to water, but this is not always provided.

Dehorning (or when done early, disbudding) is often done preweaning most commonly using a thermal dehorner or on some farms, caustic paste. Surgical removal of extra teat(s) is also done at an early age. These painful procedures are, for the most part, still performed on many dairy farms without the use of local anesthetic or analgesics and this is an animal welfare concern. In addition to painful procedures, health is also a concern. Diseases such as diarrhea and pneumonia are relatively common prior to or soon after weaning.

Weaned heifers are housed in groups on pasture or barns with bedded packs or freestalls. Buildings tend to be simpler or less expensively built than facilities for lactating animals (Fig. 1.19). Sometimes inadequate nutrition, overstocking, lack of protection from sun in summer or muddy conditions in winter can be of concern.

FIGURE 1.19 Example of a barn for weaned dairy heifers. *Source*: Photo courtesy of Dr Marcia Endres, University of Minnesota, USA.

Male young animals are most commonly raised for beef in feedlots or pasture settings (these systems are described in the beef cattle section of this chapter), raised for veal or culled. Veal facilities can sometimes have inadequate space limiting calf movement, but there has been some growth in group housing or larger stalls for veal calves in recent years.

Most dairy farms use artificial insemination for breeding their animals, but some farms keep their males as intact bulls for breeding, largely used more for clean-up, i.e. in case cows do not become pregnant with artificial insemination. Bulls can be a human safety issue due to their aggressive nature.

1.3 Beef cattle production systems

In general, beef production in North and South America, Australia, New Zealand, and Europe is divided into three sectors; the cow/calf (suckler calf), stocker and the feedlot sectors. Housing, feeding, health and management of cattle within these sectors can vary greatly by geographic region and climate as do the welfare issues associated with them.

1.3.1 Cow/calf production system

The cow/calf sector represents an extensive production system that focuses on breeding cows and bulls with the ultimate goal of producing an annual calf crop. Calves are maintained on pasture until they are either weaned or sold to a feedlot as "receiving" calves at approximately 6 months of age in North America and Europe and 7–9 months of age in South America. Calves can also be sold as stockers (weaned calves up to 1 year of age) or yearlings where they would enter the feedlot at approximately 12–14 months of age. The marketing of calves and yearlings occurs either direct to a feedlot that has purchased them or through a sale barn (auction market) where calves from different ranches may be mixed and sold as a single multi-ranch group to a feedlot.

The period of transition from the ranch to the feedlot is one of the most challenging times in a beef animal's life from a welfare perspective. This is related to the multiple stressors that newly received calves and yearlings are exposed to prior to coming to the feedlot such as weaning (separation), castration and dehorning (common in North America and Australia), branding, vaccination, handling, transport, potential mixing at an auction market, exposure to a new diet and a novel environment including pens, waterers, and feed bunks (Tucker et al., 2015). These stressors are believed to be the major contributing factor to bovine respiratory disease (BRD) that is the leading cause of morbidity in the beef industry accounting for approximately 29% of all calf death losses in the United States (NAHMS, 2009). A practice known as preconditioning was designed to reduce the economic losses associated with these stressors when calves are transitioned from the cow herd to the feedlot. Preconditioning programs include the use of low-stress weaning techniques conducted 45 days prior to selling and transporting calves, castrating and dehorning as early as possible (preferably within the first month of age), vaccinating calves with the appropriate vaccines 2–3 weeks prior to weaning, treating calves for internal and external parasites, and starting calves on feed 2–3 weeks prior to weaning from a feed bunk (Duff and Galyean, 2007).

The cow/calf production system can be defined as an extensive, grazing-dependent system in which cows, calves, and bulls are housed on native grass or planted pastures that contain natural (rivers, springs, lakes) or manmade (dugouts, trough or automated) watering sites (Fig. 1.20). Geographic and topographic features of cattle grazing pastures can vary greatly within and between countries. Typically pastures occur on large tracts of flat or mountainous land that are not optimal for growing cash crops (i.e. Australia and Brazil).

FIGURE 1.20 Cows and calves grazing on short grass prairie pasture with a dugout for a water source. *Source*: Photo courtesy of Amanda Genswein.

This production system has relatively low economic inputs (compared to the feedlot sector) only requiring that pastures be enclosed by a fence or some other natural barriers (river, mountain ranges, gulleys, etc.) for ease of gathering, and that they have access to shelter (natural or manmade) during inclement (too hot or cold) weather. Barns are usually more common and sophisticated in temperate climates where calving cows and newborn calves can succumb to conditions such as extreme cold or wet weather and winter storms. The calving barn provides shelter and safety for the newborn calf preventing the possibility of frozen ears or tails and separates the cow/calf pair facilitating bonding and successful suckling of the calf. Holding pens within the barn are well bedded with dry straw or wood chips.

These barns are well lit (may or may not be heated) and have specialized handling equipment/facilities needed to assist and facilitate easy and safe handling of a cow in case she is having calving difficulty (dystocia). This includes a calving chute in which the sides can open fully to gain access to the cow or allow the cow to lie down and maternity pens to monitor cows that are close to calving or recently calved cows (Fig. 1.21A, B). High-quality forage, mineral supplements and clean water are also available within the calving pens as pasture quality and quantity are low during the final few months prior to calving. Loading (unloading) chutes (Fig. 1.22) are also necessary so that when cattle need to be transported within or off the ranch by vehicle they can be handled safely. Inadequate or poor handling practices can be a welfare issue when handling heavily pregnant or recently calved cows that can be highly protective of their calves.

FIGURE 1.21 (A) Calving barn with calving chute that can open up to ensure the safety of the cow and the calf if the cow goes down in the chute. (B) Outdoor maternity pens. *Source*: (A) Photo courtesy of Dr Joyce van Donkergoed. (B) Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

FIGURE 1.22 (A) An example of a (un)loading chute (B) with treads.
Source: Photos courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

With the exception of calving, cows and calves are housed on pasture year-round. Bulls are housed separately in paddocks away from cows (with the exception of a 2-month breeding period) to eliminate breeding outside of the breeding season (Fig. 1.23).

FIGURE 1.23 Bulls on pasture. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

Some welfare issues associated with this production system include exposure to extreme weather conditions, insects, parasites, and predators, as well as limited medical treatments or interventions (i.e. calving assistance or disease) due to reduced ability for stock personnel to track and handle cattle under extensive conditions. In both temperate and tropical climates, malnutrition and adequate water availability may be an issue related to extended periods of drought while in temperate climates deep and or crusted snow can severely restrict access to adequate amounts of good-quality forage as well as water if the available source is frozen.

1.3.2 Stocker production system

The stocker sector represents another extensive production phase where weaned steer and heifer calves or yearlings are grazed on native grass or other roughage. These cattle are maintained over the winter months on low-quality feed until new grass can support their nutritional requirements (Fig. 1.24). The calves/yearlings can be supplemented with other forage and small amounts of grain depending on the targeted weight at the time of marketing as well as cost of gain. Stocker cattle are usually sold (at approximately 400 kg) and transported to feedlots at the end of the grazing season when nutritional quality of the forage begins to decline again. In Brazil, the stocker sector constitutes the greatest part of the production cycle (Millen et al., 2014) and is one reason why the average age of finishing is between 30 and 36 months as opposed to 18–22 months for North American cattle. Handling of the calves/yearlings (using similar facilities as described for the cow/calf sector) during this period of time is minimal with the exception of administration of booster vaccinations and growth promotants (in North America only). The welfare issues associated with the stocker sector are the same as those identified for the cow/calf sector indicated earlier.

FIGURE 1.24 Stocker calves grazing on rangeland on low-quality forage.
Source: Photo courtesy of Amanda Genswein.

1.3.3 Feedlot production system

The feedlot sector represents an intensive production system with the goal of growing and or fattening cattle until they reach slaughter weight. The feedlot sector can be further divided into growing (backgrounding) and finishing (fattening) phases. In North America the backgrounding phase (typically the first 90 days after arrival for feedlot calves) focuses on feeding high-forage/low-grain rations with the goal of maximizing growth and minimizing fat deposition. Welfare issues in the backgrounding phase can include injuries during handling associated with revaccination and implant protocols, as well as increased morbidity due to the stressors related to transition from the ranch to the feedlot indicated earlier. The finishing phase (typically the last 100 days after backgrounding) focuses on feeding high-grain/low-forage rations to backgrounded calves or yearlings until they reach a prescribed finish (fat cover) before marketing for slaughter. Welfare issues in the fattening phase are predominantly related to the feeding and include free gas bloat, acidosis, liver abscesses, and laminitis, all of which are associated with high concentrate feeding typical in North America and Europe. Some feedlots focus solely on either backgrounding or finishing, however, it is not uncommon to have one feedlot feed calves from growth to finish. Some ranches have their own feedlot facilities where cattle are bred and finished for slaughter by the same producer, but this is less common. Although pasture finishing is the most predominant system in Brazil, a growing percentage of cattle are being finished in feedlots (approximately the last 70 days before slaughter) where they are fed a diet with higher forage content than North American cattle (Millen et al., 2009).

Both the background and finishing (fattening) phases of the feedlot sector use the same housing and facilities. The phases are defined more by the type of cattle and how they are fed rather than the way they are housed. Consequently, the following description will cover the environmental/housing conditions of both and will be referred to as ‘feedlot production’ in this section.

Feedlot production represents an intensive confinement system that has high input costs (compared with suckler calf and stocker production) associated with extensive infrastructure, feeding, medical, and labor costs. There are two types of feedlots, outdoor and indoor. The outdoor feedlot is suited for drier climates (Fig. 1.25). In addition to animal comfort, indoor facilities also function to keep feed and bedding dry. It is for these reasons that in wetter climates cattle are housed indoors or in partially enclosed shelters or barns. The main difference between indoor and outdoor lots is that indoor feedlots are much smaller and hold fewer cattle per pen but at higher stocking density. They usually have slatted floors so the manure can to fall through to a holding pit (Fig. 1.26A). The indoor facility, as is implied, has a roof and side walls (solid or curtains) that can be opened when weather is moderate (Fig. 1.26B). With the exception of these features, indoor and outdoor facilities are very similar.

FIGURE 1.25 Outdoor feedlot facility. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

FIGURE 1.26 (A) Fully enclosed (indoor) feedlot facility with slatted floors and (B) semi open feedlot facility. *Source*: (A) Photo courtesy of Dr Derek Haley. (B) Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

In temperate climates both indoor and outdoor feedlots typically have barns for handling and processing cattle (known as processing barns). The barns contain pens and handling equipment such as holding pens (Fig. 1.27), a crowd tub and curved or straight chute (Fig. 1.28) that leads to a squeeze chute (Fig. 1.29) where the cattle can be restrained to receive vaccinations or other medical treatments. The barn can be completely or partially closed which is more for the comfort of the feedlot staff than the animals. In tropical climates, barns are not as common and usually only consist of the handling components of the facility such as the crowd pen, chutes, and squeeze chutes. European feedlots have minimal handling equipment or infrastructure such as central handling alleys which makes handling a welfare issue for both the cattle and the stock attendants.

FIGURE 1.27 Example of a central handling alley with holding pens.
Source: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

FIGURE 1.28 An example of a crowd tub and curved chute within a processing barn. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

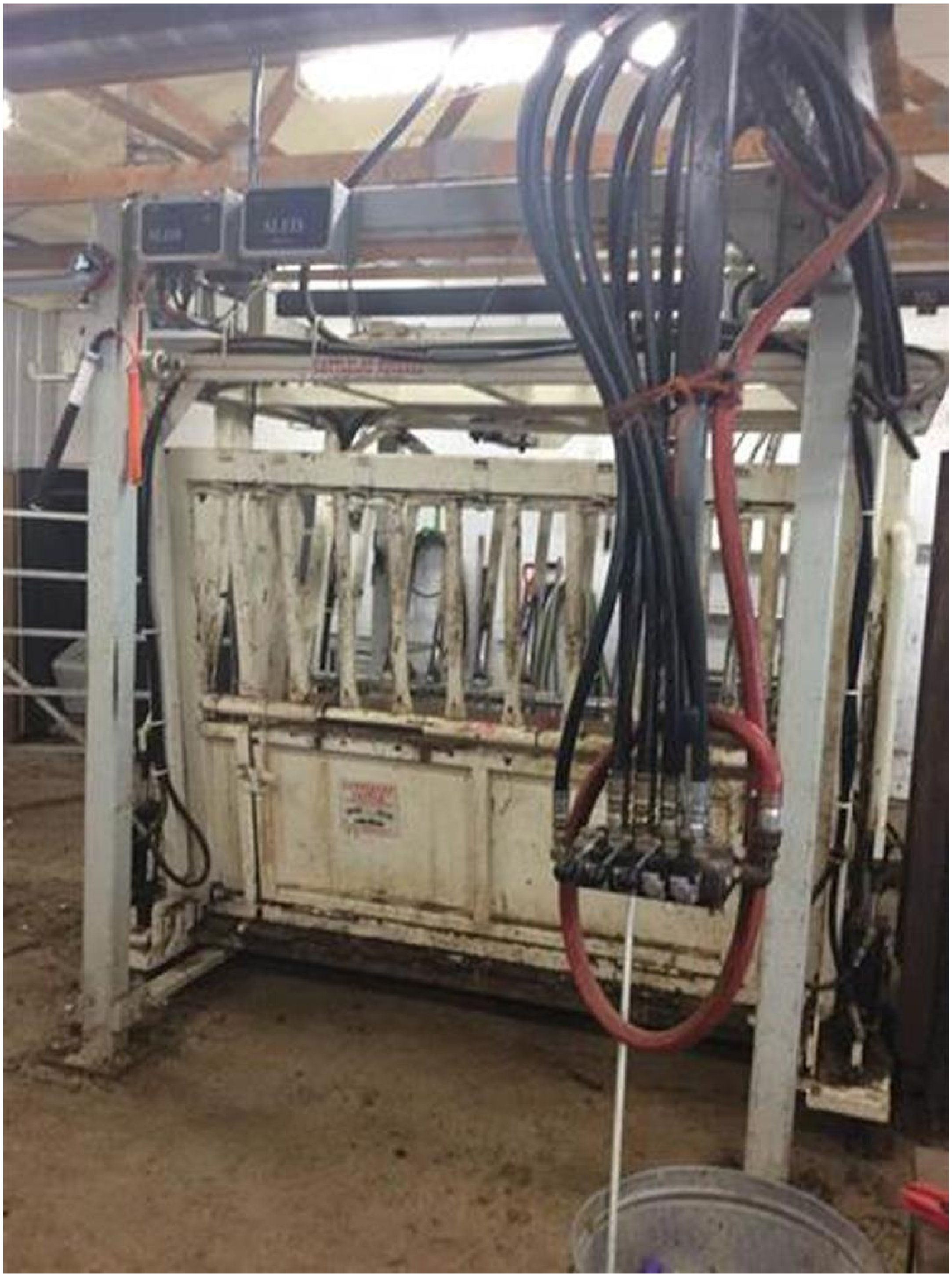

FIGURE 1.29 A squeeze chute used to restrain cattle for the delivery of vaccinations or medical treatments. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

A typical outdoor feedlot has perimeter as well as internal fencing. In temperate climates, porosity fencing is constructed to reduce the effects of wind chill (Fig. 1.30). Heat stress can be more severe in feedlot environments where cattle may have little access to shade, are in close proximity to other cattle and have high heat loads associated with rumen fermentation. It is for these reasons that heat stress abatement strategies are used in hotter regions and include sprinklers or shade structures within the pens. For example, every year hundreds of cattle die during heat waves in the USA where daily and evening temperatures are similar and cattle have no way of dissipating their heat load.

FIGURE 1.30 Outdoor feedlot with perimeter and porosity fencing. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

All feedlots have feed troughs/bunks lined along one side of the pen where feed can be delivered usually by trucks or tractors (Fig. 1.31). Bunks keep feed from being scattered and minimize contamination from manure and mud. Feed bunks can be made of wood, metal or concrete and often have a concrete apron in front of them so that cattle can stand on a level surface while feeding (Fig. 1.31). Each pen contains a water trough that is usually automatic and a raised dirt mound or sloped area where straw or wood chip bedding can be spread. The mound or sloped area supplies an area where cattle can lie down particularly when the pens get excessively muddy during rainy or snow thaw periods (Fig. 1.32). Depending on the size of the pen, cattle are housed in groups ranging in size from 50 to 350 head. Pens are graded to a slope that allows drainage. In both indoor and outdoor systems welfare may be compromised as a result of muddy pen conditions. In comparison to pasture conditions there is an increased incidence of lameness and injury because mud creates slippery conditions and facilitates spread of infectious claw-related disease such as foot rot or digital dermatitis (Stokka et al., 2001). There is limited research on beef cattle lameness in feedlots with concrete or slatted floors. However, claw health appears better for beef cattle kept in straw yards or deep litter rather than on slatted floors (Tessitore et al., 2009). Mud also makes locomotion more difficult and results in greater energy expenditure and can also affect heat loss. There is also evidence that cattle lying behavior may be affected by mud. Overall movement may be more limited within a feedlot pen versus on pasture as a result of higher stocking density and available space per animal as well as the effects of excessive mud which is known to limit ambulation within the pen.

FIGURE 1.31 Feed bunks with concrete apron in an outdoor feedlot.
Source: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

FIGURE 1.32 Dirt mounds or slopped areas are used to provide drier areas in outdoor feedlots. *Source*: Photo courtesy of Dr Karen Schwartzkopf-Genswein, Lethbridge, Alberta, Canada.

1.4 Cattle handling

Regardless of production system, animal handling is necessary and inevitable. In general, low stress methods are advocated as they are more humane and improve welfare, reduce handling time and frustration, potentially improve production performance and ultimately reduce bruising and enhance carcass quality. Low-stress handling requires that the handler move slowly and calmly without shouting or running and understand cattle behavior so that proximity and orientation to the animal results in efficient movement. It also requires that an electric prod is not used or any other aggressive form of handling such as hitting, dragging, etc. At this time relatively little is known about the effects of good handling on improved welfare and performance in beef cattle whereas more information is available on the effects of handling on milk production. Many factors can affect stress levels during handling including animal breed, temperament, previous handling experience, age, fitness, and quality of the handling facility. These factors need to be taken into consideration when training personnel and improving handling skills.

1.5 Euthanasia

Euthanasia literally means “good death” and thus is an appropriate term for the timely ending of life for animals that are suffering or that are not likely to recover from severe health issues or injury. Improper or failed euthanasia are major welfare concerns. Common reasons for euthanasia include but are not limited to conditions like broken legs, severe cancer eye, lameness, unresponsiveness to medical treatments, etc. Culling and euthanasia are not synonymous as culling is the removal of animals from the herd or group but not necessarily to euthanize them.

There are many good references describing the optimal technique (position of fire arm relative to the skull, type of ammunition, size of the firm arm) for rendering an animal insensible before a final killing step such as bleeding out or pithing is conducted (Grandin, 1994; Woods et al., 2010). The testing for a corneal reflex is a common method of ensuring an animal is dead and can easily be done in an on-farm situation.

Regardless of the production system, euthanasia is required to minimize animal suffering and the greatest welfare issues exist when it is not done soon enough. The timeliness of this procedure is often debated amongst veterinarians and herd owners, however, there is no clear cut-off for all scenarios. Most producers do not like putting an animal down and describe it as an unpleasant experience which unintentionally may prolong animal suffering.

The handling/care of nonambulatory animals is another major animal welfare concern in the cattle industry. Salvage value is the main reason producers will transport unfit cattle to slaughter even though it is inhumane and in some cases illegal. Many countries have government regulations or industry guidelines as to what constitutes fitness for transport. Some examples of these would include when calving is imminent, broken leg, severe cancer eye, severe lameness and being newborn.

1.6 Transportation issues

Managing and marketing cattle ultimately means that they must be transported. Cattle may be transported many times in their life including movement within and between farms, to sales barns and to slaughter. Transport can occur by truck, ship, train or air; the latter two being less common. Several factors (alone or in combination) determine welfare outcomes during transport and include loading density, transport duration, trailer design and ventilation, driving and handling quality, road and environmental conditions and fitness of the animals (Schwartzkopf-Genswein et al., 2012; Tucker et al., 2015). The transport of unfit animals is a major welfare transport issue.

1.7 Conclusions

Taken together, there are key animal welfare concerns that are shared across production systems and sectors, such as health concerns, animal handling, euthanasia, exposure to weather, and water access and quality. Other issues are specific to particular aspects of these production systems, for example ability to engage in some natural behaviors (e.g., social contact, maternal behavior, grazing) is a concern only in some aspects of cattle production. Overall, a key take-home of this chapter is that within each aspect of cattle production, there is considerable variation in housing and management. This variation has implications for the welfare of cattle in all systems, and this theme will be explored in many of the chapters that follow.

References

1. Duff GC, Galyean ML. Recent advances in management of highly stressed, newly received feedlot cattle. *J Anim Sci*. 2007;85:823–840.
2. Endres, M.I., Janni, K., 2008. Compost bedded pack barns for dairy cows. <http://articles.extension.org/pages/9471/compost-bedded-pack-barns-for-dairy-cows>.
3. Grandin T. Euthanasia and slaughter of livestock. *J Am Med Assoc*. 1994;204:1354–1360.
4. Lobeck KM, Endres MI, Janni KA, Godden SM, Fetrow J. Environmental characteristics and bacterial counts in bedding and milk bulk tank of low profile cross-ventilated, naturally ventilated, and compost bedded pack dairy barns. *Appl Eng Agric*. 2012;28:117–128.
5. Millen DD, Pacheco RDL, Arrigoni MDB, Galyean ML, Vasconcelos JT. A snapshot of management practices and nutritional recommendations used by feedlot nutritionists in Brazil. *J Anim Sci*.

2009;87:3427–3439.
6. Millen DD, Pacheco RDL, Meyer PM, Mazza Rodrigues PH, De Beni Arrigoni M. Current outlook and future perspectives of beef production in Brazil. *Anim Front.* 2014;1:46–52.
7. Popescu S, Borda C, Diugan EA, Spinu M, Groza IS, Sandru CD. Dairy cows welfare quality in tie-stall housing system with or without access to exercise. *Acta Vet Scand.* 2013;55:43–54.
8. Schwartzkopf-Genswein KS, Faucitano L, Dadgar S, Shand P, González LA, Crowe TG. Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: a review. *Meat Sci.* 2012;92:227–243.
9. Stokka GL, Lechtenberg K, Edwards T, et al. Lameness in feedlot cattle. *Vet Clin North Am Food Anim Pract*. 2001;17:189–207.
10. USDA. 2009. NAHMS Beef 2007–08, Part II: Reference of beef cow-calf management practices in the United States, 2007–08USDA:APHIS:VS, CEAH. Fort Collins, CO#N512.0209.
11. USDA. 2016. NAHMS Dairy 2014, Dairy cattle management practices in the United States. USDA-APHIS-VS-CEAH-NAHMS. Fort Collins, CO. Accessed July 1 2016. <https://www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dai
12. Tessitore E, Boukha A, Guzzo L, Cozzi G. Effects of pen floor on clinical and behavioural parameters of newly received beef cattle fattened under intensive rearing systems. *Ital J Anim Sci.* 2009;8:190–192.
13. Tucker CB, Coetzee JF, Stookey J, Thomson DU, Grandin T, Schwartzkopf-Genswein KS. Beef cattle welfare in the USA: Identification of priorities for future research. *Anim Health Res Rev* 2015; http://dx.doi.org/10.1017/S1466252315000171.
14. Woods J, Shearer JK, Hill J. Recommended on-farm euthanasia practices. In: Grandin T, ed. *Improving Animal Welfare: A Practical Approach*. Wallingford Oxfordshire, UK: CABI Publishing; 2010;186–213.

2

Assessment of cattle welfare

Common animal-based measures

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Abstract

Animal welfare audits have been used in the beef and dairy industry to assure consumers that the meat and milk is safe, and that the animals are well cared for. Increasingly, audits have moved away from process control toward measurements of welfare. For cattle, assessment of locomotion, hygiene, injury and body condition have become commonplace. This chapter discusses the reasoning for the inclusion of these metrics in an assessment of cattle welfare, describes the efforts made to make assessment of these parameters reliable, summarizes the available benchmarks for each outcome and investigates the pros and cons of the different sampling strategies being used. Ultimately, audits should strive for continuous improvement and the achievement of excellence, rather than settling for the propagation of mediocrity.

Keywords

Cattle welfare outcomes; lameness; injury; hygiene; body condition scores

2.1 Introduction

Many factors have driven an increase in consumer concern for the welfare of dairy cattle, not least the increasing awareness of the intensification of the dairy industry, with a move from pasture-based systems of management, to the confinement housing of larger herds of cattle without free access to the outdoors (von Keyserlingk et al., 2013; Cardoso et al., 2016).

Either side of the Atlantic Ocean, different pressures have driven an interest in farm assurance and animal welfare audits. In Europe, the bovine spongiform encephalopathy (BSE) outbreak generated significant consumer concern for the safety of meat and milk and more interest in the care of the animals on farms. In order to combat the significant loss in consumer confidence, farm-assurance programs were born to promote food safety, and ensure that the animals were well cared for. These programs, such as the Milk Marque Code of Practice (1996), the Unigate Superior Stockmanship Standards (1997), and subsequently the RSPCA Freedom Food welfare standards for dairy cattle (2008) were based upon use of the "Five Freedoms", developed by the Farm Animal Welfare Council in the UK in the late 1970s. They were focused more on process control and less on outcome measurement, and while these programs were relatively successful as a vehicle to promote food safety, their impact on welfare was far from clear (e.g., Main et al., 2003).

The US has been largely spared the dramatic impact of BSE or other food-borne disease outbreaks, but in contrast to Europe, well-funded animal activist groups have driven the discussion of management practices and identified significant welfare issues in the beef and dairy industries. In response, national organizations sought to create similar farm audit and assessment tools, to assure consumers and the marketplace that the animals were well cared for on farms. The US beef industry has come together around one central effort, Beef Quality Assurance (http://www.bqa.org/), while there have been multiple efforts on the dairy industry side which have culminated in the National Milk Producers Federation DairyFARM (Farmers Assuring Responsible Management) program (http://www.nationaldairyfarm.com/), and several other state and US supply-chain audits (e.g., New York State Cattle Health Assurance Program https://ahdc.vet.cornell.edu/programs/NYSCHAP/ and Certified Humane (http://certifiedhumane.org/wp-content/uploads/2014/02/Std14.DairyCattle.1J.pdf).

Increasingly, assurance and audit programs have moved from process-oriented approaches, to rely more on outcome assessments, to evaluate the welfare of beef and dairy cattle.

While it is very challenging in the field to assess the affective state of the individual animal, there are a number of obvious physical changes that can be identified that indicate potential problems with physical welfare, and with the trend toward confinement housing of dairy cattle globally, these measures have become more critical to assess. Indeed, because of the significant impact housing practices have on these measurable outcomes in dairy cattle, this chapter will focus on their assessment largely in dairy herds, given that beef cattle are typically more extensively managed. Lameness/mobility, hygiene/cleanliness, hock, knee (carpus) and injuries to the neck, back, tail and other regions of the body, and body condition score may visually be assessed on all cows or a proportion of the herd and have been used as outcome measures in many of the more recent dairy audit systems around the world (e.g., Dairy FARM in the US, Welfare Quality in the EU (http://www.welfarequalitynetwork.net/network/45848/7/0/40) and Red Tractor Assurance in the UK (http://assurance.redtractor.org.uk/contentfiles/Farmers-5614.pdf). These programs, either on a voluntary basis through self assessment (e.g., Red Tractor), or through second- or third-party assessment (e.g., DairyFARM, Welfare Quality) utilize these outcomes to evaluate the welfare of the cattle in the herd.

In this chapter, I will try to summarize the use of outcome assessments of lameness, hygiene, injury, and body condition used in welfare audits, using dairy cattle as an example. Specifically, I will try to answer four questions:

1. Does the measurable outcome reflect the welfare status of the animal?
2. What scoring systems are being used, and how repeatable are they within and between observers?
3. How do we set an outcome goal or benchmark the population?
4. What is the correct sample size and how do we sample for the outcome to be measured?

2.2 Does the measurable outcome reflect the welfare status of the animal?

The welfare measures most commonly included in dairy cattle audits for outcome assessment are lameness/mobility, hygiene/cleanliness, injury, and body condition score. Injuries include alterations to the hock, knee (carpus) and other body regions – such as the neck, back, tail, and wounds over the hook bones (tuber coxae).

2.2.1 Lameness

There is general agreement that lameness significantly impacts the welfare of any animal justifying its inclusion in welfare audits, especially in dairy cattle where it remains a significant problem. An abnormal gait impacts lying behavior, eating time, activity, it adversely affects milk production, the ability for the cow to reproduce and ultimately remain in the herd (Cook and Nordlund, 2009; Bicalho and Oikonomou, 2013). Locomotion or mobility scoring has been widely used to perform a prevalence assessment of the degree of lameness on the farm and Table 2.1 summarizes 23 peer reviewed studies since 2003. More than half of these studies were performed in North America, mostly in freestall herds, averaging 371 cows in size and the average lameness prevalence across all studies was 23%.

Table 2.1

Lameness prevalence reported in peer reviewed studies since 2003

First author	Date	Country	# herds	Production (kg per lactation)	Housing type	Mean herd size	Mean lameness %	Range lameness %	Mean severe lameness %	Range severe lameness %	Scoring system - points	Location of scoring	Cow population selected	# Observers	Observer reliability
Barberg	2007	USA (MN)	12	10,457	BP	73	7.8	0 to 22.4	NR	NR	5	Parlor exit	all cows	1	NR
Richert	2013	USA (NY, OR, WI)	282	NR	FS/TS/G	NR	8	0 to 54	NR	NR	5	In tiestall or at pasture	20% of cows (>50)	NR	NR
Fabian	2014	NZ	59	NR	G	421	8.3	1.2 to 36	1.8	0 to 20.2	4	Parlor exit	all cows	1	NR
Cook	2016	USA (WI)	66	14,400	FS	851	13.2	2.8 to 36.1	2.5	0 to 15.7	5	Parlor exit	high producing cows	1	NR
Westin	2016	Canada and US	36	9,346	FS/AMS	125	15	2.5 to 46	4	NR	5	In pen	sample 40 cows 10-120DIM	2	weighted kappa>0.6
Amory	2006	Netherlands	19	8,439	FS/G	76	16.5	3.8 to 30.8	NR	NR	3	NR	all cows	1	NR
Kielland	2009	Norway	232	7,052	FS/G	39	16.9	NR	4.7	NR	5	NR	10 cows per farm	5	none described
Husfeldt	2012	USA (MN)	34	10,659	FS	1299	17.1	NR	4.8	NR	5	Parlor exit	>50% of cows	1	NR
Rutherford	2009	UK	80	7,873	FS/BP/G	148	17.2	NR	NR	NR	4	Parlor exit	all cows	2	weighted kappa 0.69, PABAK 0.88
Popescu	2013	Romania	80	NR	TS	69	19	NR	NR	NR	3	NR	sample size	3	none described
Solano	2015	Canada	141	10,238	FS	124	20.8	0 to 69	NR	NR	5	Parlor exit	sample 40 cows 10-120DIM	6	82% agreement, 94% weighted kappa>0.8
Cook	2003	USA (WI)	30	10,481	FS/TS	121	22.5	7.3 to 51.9	3.1	0 to 16.7	4	Parlor exit	all cows	1	NR
Sarjokari	2013	Finland	87	8,984	FS/G	49	23	NR	6	NR	5	Parlor exit	all cows	3	none described
Nash	2016	Canada	100	9,570	TS	66	24	NR	NR	NR	2	In tiestall	sample 40 cows 10-120DIM	10	weighted kappa>0.6
Huxley	2004	UK	15	NR	FS/G		24.2	6.8 to 55.6	NR	NR	4	Parlor exit	all cows	1	NR
Espejo	2006	USA (MN)	50	11,468	FS	470	24.6	2 to 62	6.1	0 to 20.6	5	Parlor exit	high producing cows	2	kappa 0.77
King	2016	Canada	41	NR	FS/AMS	105	26.2	2.5 to 57.5	2.2	0 to 12.2	5	In pen	sample 40 cows 10-120DIM	1	NR
Popescu	2014	Italy	60	5,143	TS/BP	98	26.7	NR	NR	NR	3	In pen	sample size	2	80% agreement
von Keyserlingk	2012	Canada	42	11,734	FS	170	27.9	NR	7.1	NR	5	Parlor exit	high producing cows	2	PABAK 0.84
von Keyserlingk	2012	USA (CA)	39	12,029	FS	1796	30.8	NR	3.6	NR	5	Parlor exit	high producing cows	2	PABAK 0.85
Dippel	2009	Austria	30	8,210	FS/G	35	31	NR	12	NR	5	Parlor exit or pen	sample 22-37 cows	1	NR
Chapinal	2014	China	34	NR	FS	1380	31	7 to 51	10	0 to 27	5	Parlor exit	high producing cows	2	none described
Dippel	2009	Germany/Austria	103	8,015	FS/G	48	33	0 to 81	16	NR	5	In pen	sample 22-52 cows	1 or 2	PABAK 0.58-0.70
Barker	2010	UK	205	7,202	FS/BP/G	163	36.8	0 to 79	5.3	0 to 31.2	4	Parlor exit	all cows	4	0.67 to 0.93 between paired observers lame vs non-lame
von Keyserlingk	2012	USA (NY, PA)	40	12,238	FS	826	54.8	NR	8.2	NR	5	Parlor exit	high producing cows	2	PABAK 0.86

Key: Housing type reported as Bedded Pack (BP), Freestall/cubicle barn (FS), Tiestall (TS), Automated Milking System (AMS), Grazing (G). Not recorded (NR).

The majority of audits assess lameness at locomotion scores where a “noticeable weight transfer or a limp” can be detected, in the belief that this degree of lameness impacts cow welfare negatively. The identification of weight transfer implies the presence of a painful lesion in the affected foot and a shift in weight to the contralateral limb. Since the majority of lameness in dairy cattle relates to lesions of the foot rather than upper limb problems (Shearer and Van Amstel, 2013), the system is somewhat predictive. The likelihood of the presence of a painful lesion has been estimated with a sensitivity of 67% and specificity of 85% in one study when weight transfer is detectable (Bicalho et al., 2007), and since the behavioral modifications are likely as a result of pain (Cook and Nordlund, 2009), it seems reasonable to report lameness at this level.

However, we also know that producers are generally poor at recognizing lower degrees of lameness (e.g., Espejo et al., 2006; Fabian et al., 2014). Likely of greater concern to the general public is the obviously severely lame cow, barely able to bear weight on the affected limb – since consumers, like farmers, would be expected to be similarly challenged when it comes to identifying lameness at more subtle levels. These cows frequently represent a failure of the farm lameness detection and treatment system and create significant problems for the handling and eventual slaughter of the animal. Only two-thirds of the studies in Table 2.1 report severe lameness, but the average across those studies was 6%.

In my view, severe lameness deserves to be categorized and monitored separately. It can be argued that “lameness” is a measure of the success of the prevention program, while “severe lameness” represents a failure to identify and treat lame cows successfully. To that end, whatever scoring system is used, it should report nonlame cows, cows with weight transfer and a change in cadence of gait (mild to moderate), and cows who are almost unable to bear weight (severe), separately.

2.2.2 Hygiene and cleanliness

Welfare audits often report animal cleanliness. However, it is unclear whether or not this is because of a potential link between hygiene and poor welfare, or because clean cows are valued for predominantly marketing reasons. Indeed, the argument that poor hygiene is a welfare issue is complex. For example, a dairy cow may find a bed of warm wet manure, or a soaking pond very comfortable during a hot summer day; however, the cow will be unaware of the elevated risk of mastitis that she may endure as a result of her action. Conversely, there are times when a wet soft bed is avoided (Fregonesi et al., 2007), suggesting that cows have different preferences under different circumstances.

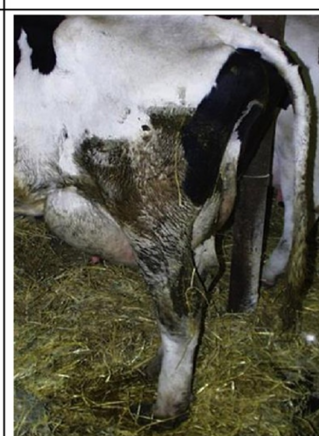
There are proven associations between udder hygiene and udder health (Schreiner and Ruegg, 2003; Reneau et al., 2005), and foot hygiene and foot health (Rodriguez-Lainz et al, 1999; Gomez et al., 2015), making assessment of hygiene a reasonable outcome to include in a welfare audit. However, there are several hygiene scoring systems in use which score different regions of the body on different scales, with poor agreement regarding what constitutes a cow that is "too dirty." Systems also vary in whether or not they report one overall hygiene score for the whole cow, or sub-scores for zones within each animal.

The system described by Reneau et al. (2005) considers hygiene in five regions (tailhead, upper rear leg, ventral abdomen, udder and lower rear leg) with a five-point scale. Users typically report a mean score for all regions combined using this system (Barberg et al., 2007; Husfeldt et al., 2012), but others have reported the proportion of cows at each score category (Fulwider et al., 2007). Schreiner and Ruegg (2003) used a four-point scale and scored only the udder and lower leg, while the system described by Cook and Reinemann (2007) used a similar approach, but also added the upper leg and flank region, with separate scores for each zone. This latter system has been adapted and used in welfare audits and surveys (e.g., Lombard et al., 2010; Cook et al., 2016). Zurbrigg et al. (2005b) also used a categorical system for udder and hind limb hygiene. With little data on repeatability of these systems, more work is required to simplify and refine a system that suits the needs of a welfare audit, rather than rely on systems that were devised for another reason; assessing udder health for example.

Ultimately, hygiene assessment for an animal welfare audit needs to accomplish two main goals: (1) to serve as an indirect measure of health risk; and (2) to provide an assessment of the availability of a dry clean resting area. To that end, hygiene assessment to reflect those goals is best served using an approach to assess the degree of manure and mud contamination of the udder, the lower leg and the upper leg and flank using an adaptation of the system described by Cook and Reinemann (2007) presented in Table 2.2, documenting the proportion of cows scored at each score level for each zone separately.

Table 2.2

A three-point hygiene scoring system for use in animal welfare audits

Zone	Score 1	Score 2	Score 3
Udder			
	Clean udder, <5% of surface area with manure contamination	Small amount of manure (5–25% of surface area) contaminating lower two-thirds of udder	Manure covering >25% of the surface area of the lower two-thirds of the udder
Lower leg			
	Clean lower limb below the hock, <5% of surface area with manure contamination	Small amount of manure (5–25% of surface area) contaminating limb below the hock	Manure covering >25% of the surface area of the limb below the hock
Upper leg and flank			
	Clean upper limb above the hock and flank area behind the ribs, <5% of surface area with manure contamination	Small amount of manure (5–25% of surface area) contaminating upper limb above the hock and flank area behind the ribs	Manure covering >25% of the surface area upper limb above the hock and flank area behind the ribs

Adapted from Cook, N.B., Reinemann, D., 2007. A toolbox for assessing cow, udder and teat hygiene. In: Proceedings of 46th Annual Meeting of the National Mastitis Council. San Antonio, TX. January pp. 21–24.

Using a comparable system, Lombard et al. (2010) found that 10% cows on 491 US farms scored 3 and 41% scored 2, while Cook et al. (2016) found that 12.1% of cows in 66 high-producing freestall-housed herds scored 2 and 3 for the udder zone only, with lower scores for cows bedded on deep loose bedding (8%) compared to mattresses (21%).

2.2.3 Injuries

There is a growing body of literature on the assessment of hock injury with 14 peer reviewed studies since 2000 summarized in Table 2.3, and there is increasing interest in knee (carpus) injuries in dairy cattle, with six studies since 2004 documented in Table 2.4.

Table 2.3

Hock injury prevalence reported in peer reviewed studies since 2000

First author	Date	Country	# herds	Production (kg per lactation)	Housing type	Herd size	All lesions (hair loss and abrasion/swelling) %	All lesion range %	Severe lesions (abrasion/swelling) %	Severe range %	Scoring system used	# Hind limbs scored	Location of scoring	Cow population selected	# observers	Observer reliability
Lombard	2010	USA	297	NR	FS		23.5	NR	3.4	NR	3-pt no lesion, hair loss, swelling	1	pen	up to 100 cows	140	none described
Barberg	2007	USA (MN)	12	10,457	BP	73	25.1	2 to 43.9	1	0 to 3.3	3-pt no lesion, hair loss and swollen	NR	NR	all cows	1	NR
Chapinal	2014	China	34	NR	FS	1380	40	6 to 95	5	0 to 50	3-pt no lesion, hair loss, swelling	1	parlor	high producing cows	2	none described
Potterton	2011	UK	63	NR	FS	162	40.1	NR	9.2 ulcer 25.3 swelling	NR	4-pt no lesion, hair loss <2cm, hair loss 2-2.5 cm, hair loss>2.5-3 cm (0-3) ulceration scored separate, swelling scored separate	2	pen	~50 cows	1	NR
Rutherford	2008	UK	80	7,873	FS/BP	148	37.2 to 49.6	NR	6.5	NR	2-pt no lesion v damage incl. hair loss, abrasion v swelling separate	2	parlor	all cows	>1	Inter-observer reliability 84%
von Keyserlingk	2012	Canada	42	11,734	FS	170	42.3	NR	3.7	NR	3-pt no lesion, hair loss, swelling	1	parlor	high producers	2	PABAK 0.93
Zurbrigg	2005	Canada	317	NR	TS		44	NR	NR	NR	4-pt no lesion, swelling, hair loss, abrasion	1	in tiestall	all cows	>1	>80% agreement with previous scores and other scorers
Brenninkmeyer	2013	Germany/Austria	105	NR	FS	56	50	0 to 100	NR	NR	5 zones - scabs, wounds and swelling	2	parlor or feed bunk	30-50 cows	4	PABAK>0.4
Cook	2016	USA (WI)	66	14,400	FS	851	50.3	3.7 to 97.2	12.2	0 to 80.9	3-pt no lesion, hair loss and swelling	2	parlor	high producing cows	1	NR
von Keyserlingk	2012	USA (CA)	39	12,029	FS	1796	56.2	NR	1.8	NR	3-pt no lesion, hair loss, swelling	1	parlor	high producers	3	PABAK 0.94
Kielland	2009	Norway	232	7,052	FS	39	60.5	NR	7.1	NR	5-pt none, hairless, swollen, wound, open wound	2	NR	10 cows per farm	5	NR
Zaffino-Heyerhoff	2014	Canada	87	NR	FS	151	62	NR	47	NR	4-pt no lesion, hair loss swelling <1cm, hair loss swelling 1-2.5 cm, swelling >3 cm	2	parlor	40 cows 10-120 DIM	?	weighted kappa >0.6
Nash	2016	Canada	100	9,570	TS	66	72	NR	52	NR	4-pt none, hair loss, swelling/scab, swelling>2.5cm	2	in tiestall	40 cows 10-120DIM	10	weighted kappa >0.6
Weary	2000	Canada	20	NR	FS	NR	72.6	NR	NR	NR	3-pt hair loss 5 locations, 1 or 2 severity-based on 10cm² threshold hair loss or trauma plus swelling	2	pen	up to 300	2	NR
Huxley	2004	UK	15	NR	FS/G	NR	78.6	0 to 90	58.3	0 to 100	3-pt hair loss, swelling, ulceration	NR	NR	20% of the herd	1	NR
von Keyserlingk	2012	USA (NY, PA)	40	12,238	FS	826	81.2	NR	5.4	NR	3-pt no lesion, hair loss, swelling	2	parlor	high producers	4	PABAK 0.95

Key: Housing type reported as Bedded Pack (BP), Freestall/cubicle barn (FS), Tiestall (TS), Grazing (G). Not recorded (NR).

Table 2.4

Knee (carpal) injury prevalence reported in peer reviewed studies since 2000

First author	Date	Country	# herds	Production (kg per lactation)	Housing type	Herd size	All lesions (hair loss and abrasion/swelling) %	All lesion range %	Severe lesions (abrasion/swelling) %	Severe range %	Scoring system used	# Fore limbs scored	Location of scoring	Cow population selected	# Observers	Observer reliability
Kielland	2009	Norway	232	7,052	FS	39	35.3	NR	6	NR	5-pt none, hairless, swollen, wound, open wound	2	NR	10 cows per farm	5	NR
Zaffino-Heyerhoff	2014	Canada	87	NR	FS	151	37	NR	24	NR	4-pt no lesion, hair loss swelling <1cm, hair loss swelling 1-2.5 cm, swelling >3 cm	2	In freestall	40 cows 10-120 DIM	NR	weighted kappa >0.6
Huxley	2004	UK	15	NR	FS/G	NR	50	0 to 83.3	NR	NR	3-pt hair loss, swelling, ulceration	NR	NR	NR	NR	NR
Cook	2016	USA (WI)	66	14,400	FS	851	53	7 to 100	6.2	0 to 35.1	3-pt no lesion hair loss and swollen	2	parlor	high producing cows	1	NR
Nash	2016	Canada	100	9,570	TS	66	65	NR	43	NR	4-pt none, hair loss, swelling/scab, swelling>2.5cm	2	in tiestall	40 cows 10-120DIM	10	weighted kappa >0.6
von Keyserlingk	2012	USA (CA)	39	12,029	FS	1796	NR	NR	0.3	NR	2-pt, ok or swollen	2	NR	high producing cows	2	PABAK 0.83
von Keyserlingk	2012	USA (NY, PA)	40	12,238	FS	826	NR	NR	23.1	NR	2-pt, ok or swollen	2	NR	high producing cows	2	PABAK 0.83

Key: Housing type reported as Freestall/cubicle barn (FS), Tiestall (TS), Grazing (G). Not recorded (NR).

While injuries are commonplace on confinement-housed dairy farms, their significance is less well understood when compared to lameness.

Injuries may take the form of hair loss, swelling and skin abrasion/ulceration with a variety of scoring systems used for hock and knee evaluation which vary somewhat in their assessment of the degrees of hair loss and swelling that are included at each score. Across studies, the prevalence of all types of hock and knee injury (including hair loss) average 53% and 48% respectively. Severe injuries involving only abrasion/ulceration and or swelling, average 17% for hocks and 17% for knees. More than half of these studies were performed in North America, mostly in larger freestall herds.

Abrasion/ulceration and swelling present an obvious source of pain and infection risk for the cow and hock injuries have been associated with lameness (Kielland et al., 2009; Potterton et al., 2011). However, the significance of hair loss alone is less well understood. A recent study identified signs of inflammation of the skin in mild lesions, suggesting that these lesions may be a source of pain and risk for further infection (Haager, 2016). Hair loss over the hocks and knees is very common in confinement-housed dairy herds and likely represents loss due to friction as cows rise and lie down on mat or mattress beds, since the presence of lesions is highly correlated with this type of stall surface compared to use of well-managed deep loose-bedded stalls (Weary and Taszkun, 2000; Cook et al., 2016). However, it should also be noted that poorly managed loose-bedded stalls with an exposed rear curb may cause an increase in dorsal hock lesions (Weary and Taszkun, 2000). Injuries to the medial side of the hock have been reportedly caused by poor bedding maintenance and the lying position of the cow—creating a pressure sore as the cow's limb rests over the raised rear concrete curb of the stall bed (Nordlund et al., 2001).

Abrasions or ulcerations on the lateral aspect of the hock are also likely due to a pressure sore or decubitus ulcer, secondary to changes in stall use behavior. We know that lame cows have longer lying bouts than nonlame cows (Ito et al., 2010) and struggle to transition from lying to standing and standing to lying (Cook and Nordlund, 2009). This reluctance to change position and relieve pressure likely contributes to the lesion developing—hence the strong association between lameness and hock injury. This hypothesis is supported by Lim et al. (2013) who noted that lame cows that had recovered in the previous month had greater odds of hock injury than nonlame cows in the current or previous month, suggesting that lameness is not the result of hock injury, but the precursor of it.

Much less is known of the significance of knee injury. However, it seems logical that the etiology follows a similar pattern to hock injury, and some association with stall design and comfort has been recognized (Nash et al., 2016). Anecdotally, we have seen higher rates of knee hair loss on more abrasive bedding surfaces—such as recycled sand bedding, but this appears to be poorly correlated with risk for lameness.

Similar to lameness, in my view, hair loss and mild hock and knee injury should be recorded separately from abrasion/ulceration which represent significantly increased severity. These injuries are complicated by the presence or absence of swelling—which in some scoring systems is scored separately (e.g., Potterton et al., 2011). For simplicity, I recommend a system where hocks and knees are scored normal, with significant hair loss (defined as an area larger than 2.5 cm in diameter), and with significant swelling (defined as >2.5 cm protrusion above the joint) and/or abrasion/ulceration.

Hair loss, swelling and skin abrasion have been noted in other regions of the body—such as the neck, the back, and the area around the hook bones. Neck injuries have been associated with poorly located feed rails at the feed bunk – caused by the cows applying pressure to access feed (Kielland et al., 2010; Zaffino Heyerhoff et al., 2014), or incorrectly located head rails in tiestalls (Zurbrigg et al., 2005b). Both of these issues would be indicative of a welfare problem.

Back and hook injuries are believed to result from stall design and use issues, while tail injuries are most commonly related to poor animal handling and the excessive use of tail jacking. Across five studies since 2004, the mean prevalence of all neck injuries is 20%, with 6% being severe with abrasion and/or swelling (Table 2.5). Zurbrigg et al. (2005b) reported a prevalence of tail breaks in tiestall-housed dairy cattle of 3%.

Table 2.5

Neck and back injury prevalence reported in peer reviewed studies since 2004

First author	Date	Country	# herds	Production (kg per lactation)	Housing type	Herd size	All neck lesions (hair loss and abrasion/swelling) %	Range %	Severe neck lesions (abrasion/swelling) %	Range %	Back injury %	Range %	Scoring system used	Location of scoring	Cow population selected	# Observers	Observer reliability
Zurbrigg	2005	Canada	317	NR	TS	NR	3.8	NR	NR	NR	NR	NR	4-pt no lesion, swelling, hair loss, abrasion	in tiestall	all cows	>1	>80% agreement with previous scores and other scorers
Cook	2016	USA (WI)	66	14,400	FS	851	8.6	0 to 74.3	2	0 to 19.3	3.6	0 to 22.0	3-pt no lesion, hair loss, and swollen	Moving to parlor	high producing cows	1	NR
Zaffino-Heyerhoff	2014	Canada	87	NR	FS	151	16	NR	9	NR	NR	NR	3-pt none, hair loss, swelling and or abrasion	freestall	40 cows 10-120 DIM	NR	weighted kappa >0.6
Kielland	2010	Norway	232	7,053	FS/G	39	21	10 to 100	6	NR	NR	NR	5-pt, none, hair loss, swollen, wound, open wound	NR	10 cows	NR	NR
Huxley	2004	UK	15	NR	FS/G	NR	50	0 to 75	NR	NR	20	0 to 50	NR	NR	NR	1	NR

Key: Housing type reported as Freestall/cubicle barn (FS), Tiestall (TS), Grazing (G). Not recorded (NR).

Other injuries generally occur at low frequencies, but may present as a problem on an individual farm, often related to either an animal handling issue, or a building design problem that would need to be addressed specifically for the farm in question. Observers should be aware of these types of injury and score them separately to address the issue.

2.2.4 Body condition

Body condition score (BCS) is a subjective assessment of the proportion of body fat in an animal and has frequently been adopted by animal welfare audits. In the US it has most commonly been assessed using a five-point scale with 0.25-point increments using the system described by Edmonson et al. (1989).

Matthews et al. (2012), suggest that BCS may reflect historic levels of feed intake and may provide a buffer against physical challenges (e.g., severe cold weather) and numerous studies have demonstrated the importance of managing BCS within a tight range to minimize metabolic disorders (e.g., Roche et al., 2009). Negative impacts on cow health are notable at both high and low body condition scores. For example, over-conditioned cows at calving time appear to be at greater risk for hyperketonaemia in early lactation (McArt et al., 2013), while it has been shown that there is an elevated risk of lameness observed in thin cows with a body condition score <2 (Randall et al., 2015) and a greater risk of mastitis in thin cows (Loker et al., 2012). Given the importance of the avoidance of hunger to animal welfare assessment, Mathews et al. (2012) attempted to examine the time engaged in activities that could serve as a proxy for hunger in thin and over-conditioned cows under extensive grazing management, but failed to show a significant difference in welfare status under these conditions.

Based on the available evidence, industry recommendations for dairy herds are to manage cows at calving with a score of 2.75–3.25 for optimal productivity, fertility and health (Garnsworthy, 2007; Roche et al., 2009).

The full reasoning behind the inclusion of body condition score in welfare audits is unclear and there is little evidence for proven relationships between prevalence assessments of high and low BCS and animal health at the herd level. However, given the relationship between thin cows and elevated health risk, lack of body reserves and the potential for hunger, welfare audits should focus on the avoidance of emaciated cows, typically defined as a body condition score less than or equal to 2.0 using the above scale reported by Edmonson et al. (1989). Based on these guidelines, Fig. 2.1 below summarizes the eight-point body condition evaluation at scores 2.0 or less which would meet the definition of “emaciated.”

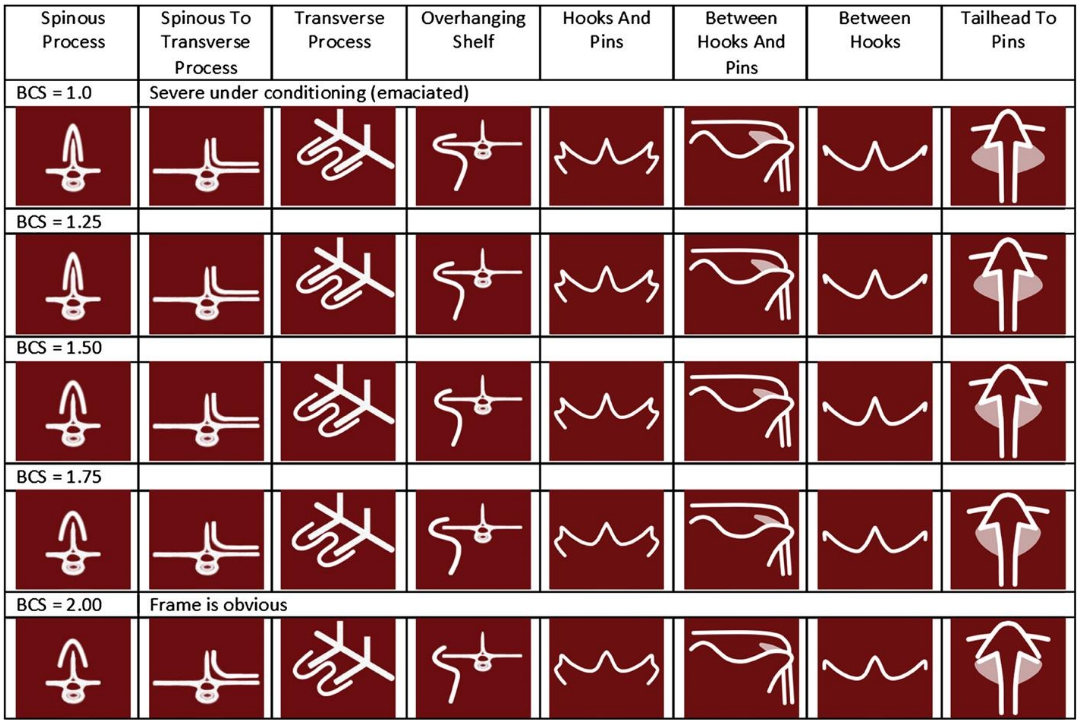


FIGURE 2.1 Body condition score evaluation for scores 1.0–2.0. Adapted from Edmonson et al. (1989).

2.3 Scoring reliability and repeatability

The outcomes discussed so far have been selected by welfare audit systems because they have merit in representing an assessment of the physical welfare of the animal. However, each is assessed using a scoring system with a sliding scale of severity, making them somewhat subjective in their application. Inter- and intra-observer reliability is a potential issue for all the systems available when they are applied across a large number of farms by multiple observers.

While the scoring of body condition has been relatively consistent, with convergence around a five-point system (Edmonson et al., 1989), across cited studies of other welfare outcomes, there is considerable variation in the scoring systems being used, and differences in where the cows are scored on the farm. For lameness, 56% of studies reported in Table 2.1 used a five-point system, 20% used a four-point system and 12% used a three-point system. Seventy percent of studies scored the cows exiting the parlor, while 30% scored the cows in their stall or pen. It can be very challenging keeping track of cows scored in pens as cattle move around and react to the presence of the observer, and gaining an adequate view of the cow can present difficulties. Fifty-four percent of cited studies in Table 2.3 reporting hock lesions used a three-point system, while others used more complex scoring approaches. Half of the studies scored the cows in the parlor, while the others scored the cows in the stall or pen. Sixty percent of studies scored both hocks, while the others scored only one predetermined limb. For other injuries and for hygiene assessment, there is little uniformity in scoring between relatively few studies.

Welfare audits which use producer-gathered data (e.g., Red Tractor) are unlikely to be accurate or reliable, rendering the data unusable. Information must be gathered by 2nd- or 3rd-party auditors who have been adequately trained and assessed for their ability to perform the measurements described.

Inter-observer reliability may be assessed using the percent agreement between observers and calculation of a kappa coefficient—either weighted (Cohen, 1968) and/or prevalence adjusted, bias adjusted (PABAK) (Bryt et al., 1993). The weighted kappa coefficient accounts for the fact that larger disagreement between scores is less desirable than near disagreement, with a goal set generally >0.6 between observers for many studies, while the PABAK is unweighted and only counts agreement when all observers give the same score—it is particularly useful for assessment of lame vs nonlame agreement and scores of 0.4–0.75 would reflect fair to good agreement, while >0.75 reflects excellent agreement (Dippel et al., 2009b).

Vasseur et al. (2013) described a training program to ensure high reliability and repeatability in body condition score assessment, requiring a detailed standard operating procedure using photographs and illustrations, live scoring, and feedback. Scoring cows from behind at the feed bunk or in the stalls was the preferred location. In studies where relatively few, well-trained observers are assessed, high levels for percent agreement between locomotion scores (>80%) and identification of lame vs nonlame can be achieved with PABAK >0.75 (e.g., von Keyserlingk et al., 2012; Hoffman et al., 2013). However, these values may not be as high where larger groups of observers are involved in data collection, where scoring systems are more complex and where data collection occurs in the field rather than from viewing video of the same cow multiple times in the comfort of an office with no time limitation (e.g., Channon et al., 2009).

Some authors have argued for simplified scoring strategies (e.g., lame vs nonlame) to reduce both intra- and inter-observer variability (Channon et al., 2009) and for simpler scoring systems, such as the three-point hock score used by von Keyserlingk et al. (2012), very high PABAK scores can be achieved (0.93). Frequently, studies are reported that use more complex scoring systems, with more than three points, which then only collapse scores to determine reliability using two or three levels. Typically, only one or two levels of affected animals are ultimately reported.

It would seem prudent to start with a collapsed scoring system initially, to simplify the process—since welfare audits are frequently administered by many individual scorers, rather than one or two—increasing the likelihood of less reliable data gathering. I have already attempted to justify the gathering of two levels of lameness and injury—lame vs severe lame, hair loss vs abrasion/ulceration and swelling. I would therefore advocate collapsing all score systems into a three-point process—where 1 is "normal" or "unaffected," a score of 2 represents mildly affected at an easily observable level, and a score of 3 represents severely affected. Each level should be accurately described with multiple pictures and video in the case of lameness, so that the system is administered as accurately as possible.

Locomotion scoring is a particular challenge in tiestall herds, where the observer is unable to assess the cows outside the stall. Some have suggested an alternative system for scoring the cow in her stall (Leach et al., 2009; Gibbons et al., 2014), and while the approach has some merit, it is time consuming to implement and sensitivity of detection suffers and prevalence estimates diverge at lower mean herd lameness prevalence. In tiestall herds, where cows are let out infrequently such an approach may be taken to avoid cow injury, however, it may suffice to record only score 3 severely lame cows using the traditional system, which should still likely be obvious when scored in the stall (Table 2.6).

Table 2.6

Suggested three-point scoring systems for locomotion, hock and knee injury, and neck injuries

Outcome	Score description		
	1	2	3
Locomotion score	Walks without obvious gait asymmetry or weight transfer between limbs and cannot discern which leg is lame after a few strides. Steps may be slightly uneven and may have a flat or subtle arch to the back.	Asymmetric gait with obvious weight transfer and shortening of the stride of the affected limb altering cadence of movement. May also show a head bob, back arch and joint stiffness leading to abduction of the limb.	Able to walk only with extreme difficulty, almost unable to bear weight on the affected limb. Pronounced back arch with rear limb lameness. These animals are frequently in poor body condition and in obvious pain.
Hock score	No obvious hair loss (≤ 2.5 cm in diameter), swelling or abrasion	Hair loss > 2.5 cm in diameter on lateral or medial aspect, or over the tip of the calcaneus, without obvious swelling (>2.5 cm) or abrasion	Abrasion or ulceration with hairloss and/or obvious swelling >2.5 cm of the joint
Knee score	No obvious hair loss (≤ 2.5 cm in diameter), swelling or abrasion	Hair loss > 2.5 cm in diameter without obvious swelling (>2.5 cm) or abrasion	Abrasion or ulceration with hairloss and/or obvious swelling >2.5 cm of the joint
Neck score (can also be used for all other regions of the body)	No obvious hair loss, swelling or abrasion	Hair loss > 2.5 cm in diameter without swelling (>2.5 cm) or abrasion	Abrasion or ulceration with hairloss and/or obvious swelling >2.5 cm and thickening of skin

2.4 How do we set a goal and benchmark the population?

It is important that the goals we set for the outcomes measured are achievable and applicable to the production system in use. This approach implies that we have developed a database from a significant population of herds and benchmarked performance, so that we can determine the range of outcomes observed. Once that has been achieved, a suitable goal can be selected – which may be the mean, median, upper quartile, or top 10th or 20th percentile of herd performance within a given category. While a noble goal, in practice, this approach is very challenging.

There are remarkably few peer-reviewed studies reporting actual benchmarks for a range of herds for the outcomes discussed. Lameness has been most commonly evaluated in the peer-reviewed literature, but even these studies span less than 2000 herds worldwide, with more than half the studies having been performed in North America. While means are frequently reported, the distribution of the data is less well represented amongst these studies, with only 56% even quoting a range. For other welfare outcomes, the situation is even more challenging, with many fewer studies and less-well-defined evaluation systems. In general, the reports also need to accurately describe the population that data were gathered from based on production system, breed, type of housing, management type, etc. These data are important if we are to compare herds with other similar herds. For example, since lameness is assessed quite differently in tiestalls compared to freestalls, it would be unfair to compare benchmarks between the two types of herd.

Obviously, the peer-reviewed literature doesn't solve the problem of setting achievable goals. However, most welfare audits keep proprietary herd databases which may be used to describe the distribution of the data between the different production systems between regions. Provided these databases cover sufficient herds, the approach can work, but it suffers from a lack of transparency, which should be important for the industry going forward.

The approach of comparing a herd with the best herds in the same class and type is also tested in some situations. For example, the prevalence of severe hock injury is remarkably different between herds using deep loose-bedded stalls compared to those using mats or mattresses (Cook et al., 2016). Do we have different standards for the two types of stall base and tolerate very high levels of injury in mattress herds, which clearly do not optimize hock health, or do we set the standard for the best herds across both types of stall base—effectively penalizing the use of mats and mattresses? In this situation, where one type of management and housing is clearly far and away worse than another, I would be in favor of penalizing the system in the hope that the welfare audit could motivate change away from it.

Ultimately, those implementing the audits and storing the data will set the goals, but it will be important in the future to make these benchmarks more transparent and drive the dairy industry toward achieving excellence, rather than tolerating mediocrity, embracing the concept of continuous improvement.

2.5 What is the correct sample size and how do we sample?

If we are to measure an outcome in a herd, make comparison to a goal, and hold the herd accountable for failure to achieve this goal, it is incumbent on the auditor to select an appropriate sample from the at-risk population to ensure adequate reliability in the outcome.

Three main approaches have been taken across different audit systems:

1. random distributed sampling;
2. targeted within-group sampling; and
3. select group sampling and sub-sampling.

2.5.1 Random distributed sampling

The approach taken by Welfare Quality and the DairyFARM program utilizes a random distributed sampling of the herd, or all at-risk groups in the herd, in the belief that this sample will accurately represent the whole herd. For example, Welfare Quality samples between 30 (or the whole herd if herd size is less than 30 cows) and 96 cows for the largest herd sizes for lameness and injury assessment, using a representative sampling approach of cows from different areas of the barn/pen.

Several studies support the approach. Hoffman et al. (2013) applied random sampling of cows to five herds with sizes ranging from 148 to 2744 cows, and found this method to yield estimates of lameness within 5% of the overall herd prevalence in all herds.

While this approach can deliver accurate results, there are questions regarding its applicability in the field—for example; how does the auditor actually perform a random selection of animals?

Hoffman et al. (2013) applied random sampling to data that had already been previously collected from the whole herd or group. For example, locomotion scoring was conducted as cows exited the parlor—an ideal opportunity to gather this type of information, since every cow is available for sampling.

When we apply the approach in the field there are two significant challenges that present:

1. if we use a scoring approach as cows enter and leave the parlor we must attend the entire milking for all cows in the herd;
2. it is unlikely that a single observer can capture all of the lameness and injury scores in one milking—pressing the need to observe the cows at multiple milkings or requiring multiple observers.

These challenges are not insurmountable in smaller herds, but do present significant impediments in larger herds, necessitating being present for 8 or more hours on farm to gather the data, spanning the audit over multiple days and requiring multiple observers—all of which increase the cost and difficulty of delivering a successful audit.

Observations may be performed in the pen—but here too, challenges present. How do we ensure a random sampling of cows in a pen? We know that activity in the pen follows a diurnal pattern (Cook et al., 2005), and that lame cows have abnormal resting behavior and are more likely to be lying down in a stall when the observer enters the pen (Juarez et al., 2003). Sampling for lameness without getting all of the cows out of the stalls would be inherently biased toward the sampling of sound cows—and the alternative would lead to a degree of disruption that producers may not find agreeable.

Of note is also the variation between audits in what qualifies as the "at-risk population." The Welfare Quality program reflects the nature of housing and management of smaller European herds in that they include not only lactating and dry cows, but also pregnant heifers when housed together. Injury and lameness outcomes are likely less prevalent in younger animals (e.g., lameness increases with parity; Espejo et al., 2006), so this approach ensures that the overall prevalence will be lower in these assessments, compared to approaches that focus solely on the population at most risk. The DairyFARM program originally took a similar approach, including youngstock in its evaluations of outcomes such as lameness. The revised program has resolved this issue and now focuses on lactating and dry cows only.

2.5.2 Targeted within-group sampling

A second approach has been suggested, that potentially facilitates the gathering of data from the farm. Main et al. (2010) suggested that from an analysis of milking order in 67 herds where between 29 and 268 cows were assessed for locomotion score, in herds with more than 100 cows, estimating lameness prevalence from a population of a maximum of 100 cows from the middle of the milking order yielded estimates within 5% of the overall herd prevalence on 83% of the farms. However, it should be noted that the herd sizes used in the study were less than 300 cows, and the herd was managed as one group on 55% of the farms. Hoffman et al. (2013) used the quadratic sampling equation developed by Main et al. (2010) to estimate sample size from the middle of each cow pen in five herds with multiple pen groups, where the sample size= $(-0.001\times\text{pen size}^2)+(0.498\times\text{pen size})+6.785$. This approach, when applied to all pens in the herd, yielded estimates within 3% of the overall herd prevalence.

Again, this approach may have merit for smaller herds, but does little to make the gathering of data more efficient in larger herds, since the observer must wait for all groups to be milked.

2.5.3 Select group sampling and sub-sampling

In order to address the particular challenges of auditing large herds, a third approach has been suggested where only select groups are assessed in order to reduce the time and effort commitment required for the audit. Large herds manage cows in multiple pens—grouped by parity, by days in milk, by pregnancy status and groups may specifically be designed for at-risk animals—such as fresh cows, sick cows, and lame cows; ensuring that the prevalence of the outcomes we are attempting to measure will vary widely between groups. In their five-herd comparison, Hoffman et al. (2013) attempted to use the approach applied to the high production, low production and hospital pens and found that the select group approach yielded the most variation of the different sampling strategies tested. One herd in particular distorted the results—suggesting that too few herds were included to fully evaluate the approach, but confirming that pen variation could be a significant issue on certain farms. Endres et al. (2014) also tried to apply the method to four pen sampling approaches in 12 herds, none of which met their criteria for accurate assessment of overall herd prevalence. Again, the sample size was small in this study and it is notable that the approach is one of the more common ones being taken in research studies over the last 5 years.

Attempts have been made to reduce sample sizes not only at the herd level, but also at the pen level, while still maintaining accuracy. For example, Endres et al. (2014) applied very stringent standards for scoring accuracy in 50 herds, where the high-yielding-group pen had been scored for lameness and injury. They found that for higher prevalence conditions (such as lameness), a random sample of 15% of the pen was sufficient to yield an accurate assessment, while for lower prevalence conditions (such as severe lameness and severe hock injury) 30% of the pen required sampling. For rare cases, such as the detection of very thin cows, 70%–80% of the pen required sampling—making the point that there is no one-size-fits-all sample size across all outcomes—which is the current approach being taken by many audits. Pen sampling should always strive to sample as many cows as possible, but there are occasions when that is difficult to achieve. Minimum sample sizes for pen or life-stage scoring can be estimated using sample size calculation software, such as that at http://epitools.ausvet.com.au/content.php?page=1Proportion. These estimates to predict a proportion or prevalence with a specified precision use the formula:

$$n = (Z^2 \times P(1 - P))/e^2$$

where Z=1.96 for 95% confidence limits, P is the expected true prevalence, and e is the desired precision (suggest half the width of the desired confidence interval, i.e. 0.05 or 5%). The sample sizes required to estimate the prevalence of an outcome with 95% confidence at a precision of 5%, where the expected true prevalence is 50%, are shown in Table 2.7 for different group sizes between 30 and 2500 cows.

Table 2.7

Sample size calculator for individual life-stage groups or pens to be assessed for outcomes with an expected true prevalence of 50% with 95% confidence and 5% precision

Group or pen size	Sample size	Group or pen size	Sample size	Group or pen size	Sample Size	Group or pen size	Sample size	Group or pen size	Sample size
<30	All	100	80	200	132	300	169	400	197
30	28	110	86	210	136	310	172	500	218
40	37	120	92	220	140	320	175	600	235
50	45	130	98	230	144	330	178	700	249
60	52	140	103	240	148	340	181	800	260
70	60	150	108	250	152	350	184	900	270
80	67	160	114	260	156	360	187	1000	278
90	73	170	118	270	159	370	189	1500	307
		180	123	280	163	380	192	2000	323
		190	128	290	166	390	194	2500	334

Recently, Heath et al. (2015) have described a sequential sampling approach for use in herds and sub-groups. This approach involves sampling in two stages using a tolerance range (e.g., 10% either side of the expected threshold) to classify herds "good" or "bad" at the end of the first stage if the herd lies outside this range. Evaluators continue to a second stage of sampling if the herd classifies within the tolerance range to gather more data and improve accuracy. They showed that similar accuracy could be achieved with slightly smaller average sample sizes than would normally be collected for the Welfare Quality audit approach.

There are challenges in applying each of the described sampling approaches in the field, and no general agreement has been reached. The Random Distributed Sample technique has merit for smaller herds, less than 200–300 cows, perhaps with a sequential sampling approach, but the reality of delivering the audit at reasonable cost favors the Select Group Sample approach. If the benchmarks that we have available to use apply to the same population across many herds, perhaps the frailties of the approach can be overlooked. Important with this approach would be to include animals segregated into a hospital, sick, or lame cow pen in the assessment population, so that the at-risk population is fully represented.

2.6 Conclusions

There is growing interest in the use of outcome assessment rather than process control in animal welfare audits of beef and dairy cattle worldwide. Lameness/mobility, hygiene/cleanliness, injuries and body condition score are animal measures that are being recorded by different systems with variability in the approach taken between countries and between systems within a country.

There is reasonable scientific evidence to support the collection of such data for the assessment of welfare, but more research is required to justify at what degree of severity we should report and hold herds accountable. Until then, it is prudent to use scoring systems which report mild levels and severe levels independently. These scoring systems need to be simple to use, easy to train and repeatable within and between observers and to that end, I have recommended the use of simple three-point scores.

Assessment should target the at-risk population of animals on the farm and include sufficient sampling to accurately benchmark the herd against other similarly managed herds. The assessment process must also be practical and be completed within a reasonable time-period. This issue arises as larger herds are audited, which may take one or more days to complete the entire process. Currently, it is probably more important to assess a consistent population of animals between farms, and to benchmark the same population, than it is to base the assessment on a statistically derived sample size applied to the entire herd, which may be impractical and challenging to collect, especially in larger herds. Sub-sampling at the pen level may however have merit to set a minimum number of animals to be evaluated in very large pens of cows.

While some benchmarks exist within the peer-reviewed literature for a few outcomes, such as lameness, there is still too great a variation in approaches taken for rigorous comparison between studies, and for some outcomes there is a paucity of data available to understand the true variation in the industry. If herds are to be held accountable when they fail to achieve certain thresholds, there is a need for more accurate benchmarking of well-described herds, using a consistent and transparent approach.

Ultimately, the approach taken should strive for continuous improvement and excellence, rather than settle for the propagation of mediocrity.

References

1. Amory JR, Kloosterman P, Barker ZE, Wright JL, Blowey RW, Green LE. Risk factors for reduced locomotion in dairy cattle on nineteen farms in The Netherlands. *J Dairy Sci.* 2006;89:1509–1515.
2. Barberg AE, Endres MI, Salfer JA, Reneau JK. Performance and welfare of dairy cows in an alternative housing system in Minnesota. *J Dairy Sci.* 2007;90:1575–1583.
3. Barker ZE, Leach KA, Whay HR, Bell NJ, Main DCJ. Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. *J Dairy Sci.* 2010;93:932–941.
4. Bicalho RC, Oikonomou G. Control and prevention of lameness associated with claw lesions in dairy cows. *Livest Sci.* 2013;156:96–105.
5. Bicalho RC, Vokey F, Erb HN, Guard CL. Visual locomotion scoring in the first seventy days in milk: impact on pregnancy and survival. *J Dairy Sci.* 2007;90:4586–4591.
6. Brenninkmeyer C, Dippel S, Brinkmann J, March S, Winckler C, Knierim U. Hock lesion epidemiology in cubicle housed dairy cows across two breeds, farming systems and countries. *Prev Vet Med.* 2013;109:236–245.
7. Bryt T, Bishop J, Carlin JB. Bias, prevalence and kappa. *J Clin Epidemiol.* 1993;46:423–429.
8. Cardoso CS, Hötzel MJ, Weary DM, Robbins JA, von Keyserlingk MAG. Imagining the ideal dairy farm. *J Dairy Sci.* 2016;99:1–9.
9. Channon AJ, Walker AM, Pfau T, Sheldon IM, Wilson AM. Variability of Manson and Leaver locomotion scores assigned to dairy cows by different observers. *Vet Rec.* 2009;164:388–392.
10. Chapinal N, Liang Y, Weary DM, Wang Y, von Keyserlingk MAG. Risk factors for lameness and hock injuries in Holstein herds in China. *J Dairy Sci.* 2014;97:4309–4316.
11. Cohen J. Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit. *Physiol Bull.* 1968;70:213–220.
12. Cook NB. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. *J Am Vet Med Assoc.* 2003;223:1324–1328.
13. Cook NB, Bennet TB, Nordlund KV. Monitoring indices of cow comfort

in free-stall housed dairy herds. *J Dairy Sci.* 2005;88:3876–3885.
14. Cook NB, Hess JP, Foy MR, Bennett TB, Brotzman RL. Management characteristics, lameness and body injuries of dairy cattle housed in high performance dairy herds in Wisconsin. *J Dairy Sci.* 2016;99:5879–5891.
15. Cook NB, Nordlund KV. The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. *Vet J.* 2009;179:360–369.
16. Cook, N.B., Reinemann, D., 2007. A toolbox for assessing cow, udder and teat hygiene. In: Proceedings of 46th Annual Meeting of the National Mastitis Council. San Antonio, TX, January pp. 21–24.
17. Dippel S, Dolezal M, Brenninkmeyer C, et al. Risk factors for lameness in cubicle housed Austrian Simmental dairy cows. *Prev Vet Med.* 2009a;90:102–112.
18. Dippel S, Dolezal M, Brenninkmeyer S, et al. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries. *J Dairy Sci.* 2009b;92:5476–5486.
19. Edmonson AJ, Lean IJ, Weaver LD, Farver T, Webster G. A body condition scoring chart for Holstein dairy cows. *J Dairy Sci.* 1989;72:68–78.
20. Endres MI, Lobeck-Luchterhand KM, Espejo LA, Tucker CB. Evaluation of the sample needed to accurately estimate outcome-based measurements of dairy welfare on farm. *J Dairy Sci.* 2014;97:3523–3530.
21. Espejo LA, Endres MI, Salfer JA. Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. *J Dairy Sci.* 2006;89:3052–3058.
22. Fabian J, Laven RA, Whay HR. The prevalence of lameness on New Zealand dairy farms: A comparison of farmer estimate and locomotion scoring. *Vet J.* 2014;201:31–38.
23. Fregonesi JA, Veira DM, von Keyserlingk MAG, Weary DM. Effects of bedding quality on lying behavior of dairy cows. *J Dairy Sci.* 2007;90:5468–5472.
24. Fulwider WK, Grandin T, Garrick DJ, et al. Influence of freestall base on tarsal joint lesions and hygiene in dairy cows. *J Dairy Sci.* 2007;90:3559–3566.
25. Garnsworthy PC, Wiseman J. *Body condition score in dairy cows:*

Targets for production and fertility. *Recent Advances in Animal Nutrition* Nottingham, UK: Nottingham University Press; 2007;61–85.

26. Gibbons J, Haley DB, Higginson Cutler J, et al. Technical note: A comparison of 2 methods of assessing lameness prevalence in tiestall herds. *J Dairy Sci.* 2014;97:350–353.
27. Gomez A, Cook NB, Rieman J, et al. The effect of digital dermatitis on hoof conformation. *J Dairy Sci.* 2015;98:927–936.
28. Haager D. *Validation of Hock Lesions as Welfare Indicator in Dairy Cows: A Macroscopic, Thermographic and Histological Study, Masters Thesis* Vienna: University of Natural Resources and Life Sciences; 2016.
29. Heath CAE, Main DCJ, Mullan S, Haskell MJ, Browne WJ. Sequential sampling: a novel method in farm animal welfare assessment. *Animal*. 2015;10:349–356.
30. Hoffman AC, Moore DA, Wenz JR, Vanegas J. Comparison of modeled sampling strategies for estimation of dairy herd lameness prevalence and cow-level variables associated with lameness. *J Dairy Sci.* 2013;96:5746–5755.
31. Husfeldt AW, Endres MI. Association between stall surface and some animal welfare measurements in freestall dairy herds using recycled manure solids for bedding. *J Dairy Sci.* 2012;95:5626–5634.
32. Huxley JN, Burke J, Roderick S, Main DCJ, Whay HR. Animal welfare assessment benchmarking as a tool for health and welfare planning in organic dairy herds. *Vet Rec.* 2004;155:237–239.
33. Ito K, von Keyserlingk MAG, LeBlanc SJ, Weary DM. Lying behavior as an indicator of lameness in dairy cows. *J Dairy Sci.* 2010;93:3553–3560.
34. Juarez ST, Robinson PH, DePeters EJ, Proce EO. Impact of lameness on behavior and productivity of lactating Holstein cows. *Appl Anim Behav Sci.* 2003;83:1–14.
35. Kielland C, Ruud LE, Zanella AJ, Osteras O. Prevalence and risk factors for skin lesions on legs of dairy cattle housed in freestalls in Norway. *J Dairy Sci.* 2009;92:5487–5496.
36. Kielland C, Boe KE, Zanella AJ, Osteras O. Risk factors for skin lesions on the necks of Norwegian dairy cows. *J Dairy Sci.* 2010;93:3979–3989.
37. King MTM, Pajor EA, LeBlanc SJ, DeVries TJ. Associations of herd-

level housing, management and lameness prevalence with productivity and cow behavior in herds with automated milking systems. *J Dairy Sci.* 2016;99:9069–9079.
38. Leach KA, Dippel S, Huber J, March S, Winckler C, Whay HR. Assessing lameness in cows kept in tie-stalls. *J Dairy Sci.* 2009;92:1567–1574.
39. Lim, P.Y., Huxley, J.N., Green, M.J., Othman, A.R., Potterton, S.L., Kaler, J., 2013. An investigation into the association between lameness and hair loss on the hock, in a longitudinal study. In: Proceedings of the 17th International Conference on Lameness in Ruminants, 11–14th August 2013, Bristol, UK, pp. 273–274.
40. Lombard JE, Tucker CB, von Keyserlingk MAG, Kopral CA, Weary DM. Associations between cow hygiene, hock injuries, and freestall usage on US dairy farms. *J Dairy Sci.* 2010;93:4668–4676.
41. Loker S, Miglior F, Koeck A, et al. Relationship between body condition score and health traits in first-lactation Canadian Holsteins. *J Dairy Sci.* 2012;95:6770–6780.
42. Nordund, K.V., Peek, S.F., Bennett, T., Emery, K., Gaska, J.G., 2001. Inches from disaster: mastitis and injury problems associated with freestall modifications in a large dairy herd. In: 2nd International Symposium on Mastitis and Milk Quality, Vancouver, BC, pp. 296–300.
43. Main DCJ, Whay HR, Green LE, Webster AJF. Effect of the RSPCA Freedom Food scheme on the welfare of dairy cattle. *Vet Rec.* 2003;153:227–231.
44. Main DCJ, Barker ZE, Leach KA, Bell NJ, Whay HR, Browne WJ. Sampling strategies for monitoring lameness in dairy cattle. *J Dairy Sci.* 2010;93:1970–1978.
45. Matthews LR, Cameron C, Sheahan AJ, Kolver ES, Roche JR. Associations among dairy cow body condition and welfare-associated behavioral traits. *J Dairy Sci.* 2012;95:2595–2601.
46. McArt JAA, Nydam DV, Oetzel GR. Dry period and parturient predictors of early lactation hyperketonemia in dairy cattle. *J Dairy Sci.* 2013;96:198–209.
47. Nash CGR, Kelton DF, DeVries TJ, et al. Prevalence of and risk factors for hock and knee injuries on dairy cows in tiestall housing in Canada. *J Dairy Sci.* 2016;99:6494–6506.
48. Popescu S, Borda C, Diugan EA, Spinu M, Groza IS, Sandru CD. Dairy

cows welfare quality in tie-stall housing system with or without access to exercise. *Acta Vet Scand.* 2013;55:43 http://dx.doi.org/10.1186/1751-0147-55-43.
49. Popescu S, Borda C, Diugan EA, Niculae M, Stefan R, Sandru CD. The effect of the housing system on the welfare quality of dairy cows. *Ital J Anim Sci.* 2014;13:2940 http://dx.doi.org/10.4081/ijas.2014.2940.
50. Potterton SL, Green MJ, Harris J, Millar KM, Whay HR, Huxley JN. Risk factors associated with hair loss, ulceration, and swelling at the hock in freestall-housed UK dairy herds. *J Dairy Sci.* 2011;94:2952–2963.
51. Randall LV, Green MJ, Chagunda MGG, et al. Low body condition predisposes cattle to lameness: An 8-year study of one dairy herd. *J Dairy Sci.* 2015;98:3766–3777.
52. Reneau JK, Seykora AJ, Heins BJ, Endres MI, Farnsworth RJ, Bey RF. Association between hygiene scores and somatic cell scores in dairy cattle. *J Am Vet Med Assoc.* 2005;227:1297–1301.
53. Richert RM, Cicconi KM, Gamroth MJ, Schukken YH, Stiglbauer KE, Ruegg PL. Perceptions and risk factors for lameness on organic and small conventional dairy farms. *J Dairy Sci.* 2013;96:5018–5026.
54. Roche JR, Friggens NC, Kay JK, Fisher MW, Stafford KJ, Berry DP. Invited review: body condition score and its association with dairy cow productivity, health, and welfare. *J Dairy Sci.* 2009;92:5769–5801.
55. Rodriguez-Lainz A, Melendez-Retamal, Hird DW, Read DH, Walker RL. Farm- and host-level risk factors for papillomatous digital dermatitis in Chilean dairy cattle. *Prev Vet Med.* 1999;42:87–97.
56. Rutherford KMD, Langford FM, Jack MC, Sherwood L, Lawrence AB, Haskell MJ. Hock injury prevalence and associated risk factors on organic and nonorganic dairy farms in the United Kingdom. *J Dairy Sci.* 2008;91:2265–2274.
57. Rutherford KMD, Langford FM, Jack MC, Sherwood L, Lawrence AB, Haskell MJ. Lameness prevalence and risk factors in organic and non-organic dairy herds in the United Kingdom. *Vet J.* 2009;180:95–105.
58. Sarjokari K, Kaustell KO, Hurme T, et al. Prevalence and risk factors for lameness in insulated freestall barns in Finland. *Livestock Sci.* 2013;156:44–52.
59. Schreiner DA, Ruegg PL. Relationship between udder and leg hygiene scores and subclinical mastitis. *J Dairy Sci.* 2003;86:3460–3465.

60. Shearer J, Van Amstel S. *Manual of Foot Care in Cattle* 2nd ed. Fort Atkinson, WI: Hoard's Dairyman; 2013; 132pp.
61. Solano L, Barkema HW, Pajor EA, et al. Prevalence of lameness and associated risk factors in Canadian Holstein-Friesian cows housed in freestall barns. *J Dairy Sci.* 2015;98:6978–6991.
62. Vasseur E, Gibbons J, Rushen J, de Passillé AM. Development and implementation of a training program to ensure high repeatability of body condition scoring of dairy cows. *J Dairy Sci.* 2013;96:4725–4737.
63. von Keyserlingk MAG, Barrientos A, Ito K, Galo E, Weary DM. Benchmarking cow comfort on North American freestall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows. *J Dairy Sci.* 2012;95:7399–7408.
64. von Keyserlingk MAG, Martin NP, Kebreab E, et al. Invited review: Sustainability of the US dairy industry. *J Dairy Sci.* 2013;96:5405–5425.
65. Weary DM, Taszkun I. Hock lesions and freestall design. *J Dairy Sci.* 2000;83:697–702.
66. Westin R, Vaughan A, de Passillé AM, et al. Cow- and farm-level risk factors for lameness on dairy farms with automated milking systems. *J Dairy Sci.* 2016;99:3732–3743.
67. Zaffino Heyerhoff JC, LeBlanc SJ, DeVries TJ, et al. Prevalence of and factors associated with hock, knee and neck injuries on dairy cows in freestall housing in Canada. *J Dairy Sci.* 2014;97:173–184.
68. Zurbrigg K, Kelton D, Anderson N, Millman S. Tie-stall design and its relationship to lameness, injury, and cleanliness on 317 Ontario dairy farms. *J Dairy Sci.* 2005a;88:3201–3210.
69. Zurbrigg K, Kelton D, Anderson N, Millman S. Stall dimensions and the prevalence of lameness, injury, and cleanliness on 317 tiestall dairy farms in Ontario. *Can Vet J.* 2005b;46:902–909.

3

Assessment of cattle welfare

approaches, goals, and next steps on farms

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Abstract

Concurrent with increasing concerns about cattle welfare, differently designed on-farm assessment protocols for cattle have been developed during the last decades. These assessment systems serve different purposes, e.g., in terms of on-farm decision support, farm assurance, or assisting other parties in the supply chain in driving changes. Focusing on animal-based measures, this chapter analyzes on-farm welfare-assessment protocols for various cattle categories in terms of number and types of measures included and the main factors shaping the design of such protocols. Addressing the ultimate aim of welfare improvement, I then scrutinize the assessment of resource- and management-based risk factors relevant for targeted interventions and discuss to which extent welfare improvements can be expected following such interventions. Approaches to conveying information on the animals' welfare state and to successfully inducing appropriate changes on farm are finally addressed.

Keywords

Assessment protocols; benchmarking; cattle; continuous improvement; implementation; risk factors

3.1 Introduction

On-farm welfare assessment and management decisions based on its outcomes are important for the producer-animal and the producer–society interface. Understanding the animals' welfare and the underlying influencing factors supports individual farmers in making decisions aimed at improving housing and management and therefore animal welfare. Additionally, as part of farm-assurance welfare assessment may help to safeguard and improve welfare at the industry level and to transparently inform the public. Moreover, it can assist other parties in the supply chain in driving changes, and legislative actors by identifying hot spots of welfare or examining whether legal requirements exert the intended effects.

During the last decades and concurrent with increasing concerns about cattle welfare, substantial efforts have been undertaken to develop valid and reliable animal-based measures of welfare. Depending on the purpose (e.g., labeling, improvement of welfare among the members of a certification scheme, compliance with static minimum requirements, individual farm advice, self-evaluation), and on the resources available for the assessment (mostly regarding time), various assessment protocols have been developed. Protocols using predominantly animal-based measures were first developed for dairy cattle, while protocols addressing calves and rearing heifers as well as beef cattle have only recently received more attention. This focus on dairy cattle may be due to the economic impact of welfare issues such as lameness or mastitis (Bruijnis et al., 2010; Halasa et al., 2011) and the higher public interest in dairy cows than other cattle categories.

A common framework applies to achieving the ultimate goal of continuous welfare improvement: monitoring of pre-defined criteria (welfare assessment) followed by identification of risk factors and interventions in response to the risk factors (preventive and corrective actions) and re-assessment/evaluation (Fig. 3.1). This chapter addresses the different steps involved in this “journey to animal welfare improvement” (Whay, 2007) by

1. analyzing different on-farm welfare-assessment protocols for dairy cows, youngstock/calves, as well as beef cattle;
2. scrutinizing choice and assessment of resource- and management-based risk factors;
3. discussing implementation of measures and welfare improvements thereby achieved; as well as
4. reviewing approaches to conveying information to farmers and inducing change.

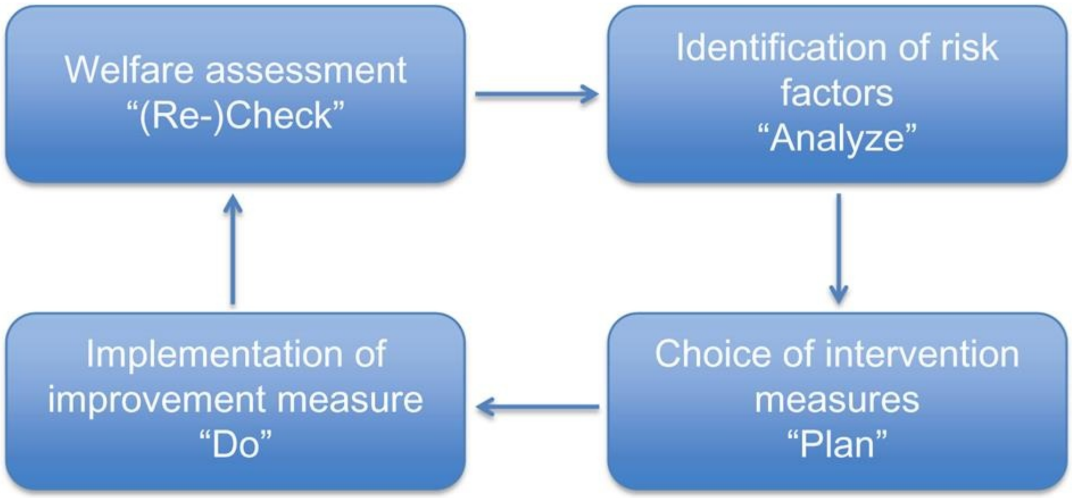

FIGURE 3.1 Key steps in achieving continuous welfare improvement.

It focuses on the assessment on farm, thus excluding welfare audits related to transport or at the slaughter plant. Furthermore, it will neither deal with the validity of the single measures used in the assessment protocols nor with the question where targets for welfare outcome measures should be set. Some of the protocols discussed also contain a limited number of resource-based measures but here the program-specific measurements of this type will not further be discussed.

3.2 Composition of cattle welfare-assessment protocols and respective drivers

Views about the welfare of farm animals differ, but they may be classified into three types according to their emphasis on (1) the biological functioning in terms of health, growth and productivity, (2) the animals’ affective state, and (3) the naturalness of the animals’ life, especially with regard to the ability to perform the normal behavior repertoire (Fraser, 2003). Related to these concepts, according to the Terrestrial Animal Health Code of the World Organisation for Animal Health, a good state of welfare means that an animal is healthy, comfortable, well nourished, safe, able to express innate behavior, and that it is not suffering from unpleasant states such as pain, fear, and distress (OIE (World Organisation for Animal Health), 2016). Beyond the avoidance of unpleasant states, the opportunity for animals to have positive experiences is increasingly recognized as an important component of the overall affective state (Boissy et al., 2007). The definitions of welfare represent a framework to define ideal welfare conditions to work towards. Approaches to on-farm welfare assessment in cattle which have been developed so far, consider these views and recommendations to different extents.

Table 3.1 provides an overview of the animal-based measures used in selected assessment protocols for the husbandry of dairy cows, calves and heifers as well as beef cattle; protocols for veal calves have not been published yet. Within all cattle categories, there is variation in the number and type of measures included. All protocols contain at least some direct (e.g., lameness) and indirect (e.g., body condition) measures of health or other welfare-relevant measures of the physical appearance such as animal cleanliness. They therefore address primarily the biological functioning view of welfare (including the impact health disorders may have on the mental state of animals), while behavioral measures of welfare providing information about affective states such as the level of fearfulness towards humans or on the ability to perform normal behavior are less frequently included.

Table 3.1

Composition of different welfare-assessment protocols for dairy cows, calves, and youngstock as well as beef cattle husbandry

		Dairy cows					Youngstock/calves			Beef cattle				
		WQ	FARM	Assurewel	Ask the cow	Bio Austria	Assurewel	Bio Austria	Ask the cow	WQ	UCD cowcalf[a]	Assurewel	GAP	Bio Austria
Physical appearance/health	Body condition	x	x	x	x	x			x	x	x[a]	x	x	x
	Cleanliness	x		x	x	x			x	x	x	x		x
	Dusty/scuffed neck				x									
	Skin alterations	x[1]	x[2]	x[1]	x[3]	x[1]			x[3]	x	x[a]	x		x
	Ringworm/ectoparasites					x								
	Broken tails			x							x			
	Lameness	x	x	x	x	x			x	x	x[a]	x	x	x
	Claw condition				x	x								x
	Mastitis	x		x										
	Respiratory signs	x							x	x	x	x		x
	Diarrhea/loose feces	x				x		x	x	x	x			x
	Rumen fill				x									
	Bloated rumen									x	x			
	Vulvar discharge	x												
	Downer cows	x												
	Animals needing further care			x								x		
	Runts (calves)							x						
	Mortality: unplanned culls/casualties	x		x		x	x	x		x		x		x
	Planned culls: culling reasons					x								
Behavior	Agonistic behaviors	x			x					x				
	Behavior around resting	x[6]			x[7]					x				
	Human–animal relationship	x[8]		x[9]						x				
	Qualitative behavior assessment	x								x				
	Intersucking							x						
	Behavior before/in/after chute										x[10a]			

WQ, Welfare Quality® Assessment protocol for cattle (http://www.welfarequalitynetwork.net/network/45848/7/0/40); FARM, National Dairy Farmers Assuring Responsible Management Program (http://www.nationaldairyfarm.com/sites/default/files/Version-3-Manual.pdf); Assurewel, Advancing Animal Welfare Assurance, dairy cattle: http://www.assurewel.org/dairycows, beef cattle: http://www.assurewel.org/beefcattle; BioAustria, Leitfaden Tierwohl Rind (Guideline for cattle welfare of the largest Austrian organic farmers association, http://www.bio-austria.at/app/uploads/bio_austria_tierwohl_rind.pdf); Ask the cow, Swedish Dairy Association (https://www.vxa.se/radgivning-och-kurser/analysera-nulaget/analysera-djurhalsan/Fraga-kon/); UCDCowCalf, University of California, Davis Cow-calf Health and Handling Assessment (http://www.ucdcowcalfassessment.com/learn-how-to-assess.html); GAP, Global Animal Partnership: Animal welfare rating standards for beef cattle (http://gapstaging.blob.core.windows.net/standards/5Step®%20Animal%20Welfare%20Rating%20Standards%20for%20Beef%20Cattle%20v1.0.pdf).

[a]Measures marked with the letter ‘a’ are considered “core indicators”; 1: hairloss, lesions, swellings; 2: hock/knee injury; 3: wounds, swellings, inflammation; 4: somatic cell count; 5: treatment incidence; 6: time needed to lie down, lying partly/outside the lying area; 7: rising

behavior, proportion of animals lying/standing in the stalls; 8: avoidance distance towards unknown person; 9: response to stockperson; 10: stumbling, falling, vocalization, balking.

Two major aspects may explain the patterns in the comprehensiveness of the protocols: purpose and availability of resources. The Welfare Quality (WQ) protocols (Welfare Quality, 2009) contain the most comprehensive approach to reflect the different dimensions of welfare. They include the four WQ principles of "Good feeding," "Good housing," "Good health," and "Appropriate behavior" which were defined to accommodate the major areas of scientific and public concern and of importance for good animal welfare (Miele et al., 2011; Keeling et al., 2013). Beyond indicators of physical wellbeing, this approach led to the inclusion of a set of measures addressing social interactions, behavior around resting, and human–animal relationships. Additionally, qualitative behavior assessment, a relatively new method, is used to assess the emotional state of the animals including positive states.

At the other extreme are farm-assurance schemes such as the National Dairy FARM (Farmers Assuring Responsible Management) Program, a collaborative action of dairy farmers, cooperatives and processors in the USA (http://www.nationaldairyfarm.com/sites/default/files/Version-3-Manual.pdf), or animal welfare certification programs such as Global Animal Partnership (GAP, http://www.globalanimalpartnership.org/5-step-animal-welfare-rating-program/standards). These initiatives focus on some of the most important clinical welfare issues (poor body condition, skin lesions, lameness), which explains the very limited number of measures in the protocols. Only the UCD Cow–calf health and handling protocol, a tool to assess health and behavior and stockperson handling in cow–calf ranches, distinguishes between "core" measures and a complete assessment, thus highlighting more import measures of welfare which may be complemented in the full assessment.

Feasibility and reliability are essential for the implementation of assessment protocols, but can also present some of the biggest challenges. Regarding feasibility, the time needed to apply and therefore also economic implications are the most important constraints (e.g., Sørensen et al., 2007; de Vries et al., 2013; Knierim and Winckler, 2009). Often, a maximum "acceptable" time of 1–2 hours per assessment is reported (Metz et al., 2015). At the same time, comprehensiveness of the protocol is closely associated with the time required. For example, the average time needed to assess the animal-based measures of the WQ protocol in Dutch farms (10–211 cows) amounted to about 6 hours. Attempts to reduce the time needed for the full assessment by, e.g., omitting sets of measures while obtaining a similar information on the welfare have not been successful so far (de Vries et al., 2013). An “iceberg indicator” approach as a means of reducing the time taken did similarly not lead to valid results (Heath et al., 2014). Since reliable assessment of behavior requires comparatively more time (e.g., in the WQ protocol for dairy cattle one-third of the measures account for two-thirds of the overall assessment time), behavioral measures are often not or only to a limited extent considered for inclusion.

The design, content and application of assessment protocols also depend on what a program wants to achieve (Table 3.2). For example, one objective could be to address farms with poorer welfare, e.g., belonging to the worst 25% in a population (de Vries et al., 2014). This approach allows more time to be spent using a comprehensive assessment on a smaller number of high-risk farms, instead of reducing the number of measures for a protocol which may be applied in a comparatively short period of time on many farms. In a recent example, identification of farms was made resource-efficient by combining routine herd data with demography, management, milk production and composition as well as fertility information from national databases. This was combined with basic information about housing and management and, together, reduced the number of farm visits required to accurately identify herds with poorer welfare. Depending on the welfare indicator, the reduction ranged from 5% for avoidance distance measures of the human–animal relationship to 37% for severe lameness prevalence (de Vries et al., 2016).

Table 3.2

Goals or purposes of various on-farm welfare assessment programs for dairy cows, calves, and youngstock as well as beef cattle husbandry

Age class and type	Program	Goal
Dairy cows	WQ	Consumer information; producer information
	FARM	Education; continuous improvement
	Assurewel	Farm assurance; producer information
	Ask the cow	Advisory tool
	BioAustria	Self-assessment in organic farms
	Assurewel	Farm assurance; producer information
Youngstock/calves	BioAustria	Self-assessment in organic farms
	Ask the cow	Advisory tool
Beef cattle	WQ	Consumer information; producer information
	UCDcowcalf	Self-assessment; education
	Assurewel	Farm assurance; producer information
	GAP	Labeling program for niche market
	BioAustria	Self-assessment in organic farms

3.3 Towards valid and well-structured risk assessment

For assessments to result in positive change, farmers need information about valid steps that result in improvement. Ideally, the problem is successfully addressed and unintended consequences are avoided. However, do farmers, advisors, or scientists always know which potential risk factors on a given farm or unit are important and what measurable benefits can be expected? From experimental and epidemiological research, a wealth of knowledge is available for a number of welfare issues. For example, extensive studies on lameness in dairy cattle and the underlying leg and claw disorders have resulted in a huge body of evidence regarding influencing factors such as properties of the free-stalls, flooring, feeding, manure scrapers, claw trimming, etc. (e.g., Bernardi et al., 2009; Haufe et al., 2012; van Hertem et al., 2014; Solano et al., 2015). This offers a huge potential, but choosing appropriate measures may not always be straightforward, as knowledge about housing systems and management procedures may change over time. For example, Barker et al. (2012) pointed out that standard measures recommended for reducing claw lesions may not necessarily be beneficial for the animals. For example, in a 3-year on-farm study of lameness, the authors found that increased amounts of sawdust and improved cubicle dimensions were associated with an increased rate of sole ulcers and white line disease, respectively, probably due to the abrasive property of the bedding material. Although there is considerable evidence that softer, more comfortable beds are better for cow comfort, this is a good example of an unintended consequence of a well-meaning recommendation. With regard to mastitis control, a thorough review of the current knowledge found that only 2 out of 21 recommended measures for mastitis control were significantly associated with bulk tank milk cell count, indicating that these measures might not be as effective as assumed (Emanuelson and Nielsen, 2017).

While there is plenty of evidence regarding key farming factors associated with health-related welfare in dairy cattle such as lameness and mastitis, this is much less the case for other welfare issues. Even for commonly used welfare indicators such as hock lesions (e.g., Whay et al., 2003a; Potterton et al., 2011), our understanding of the etiology is limited and relationships between housing design (e.g., cubicle characteristics) and other management factors (e.g., access to pasture) remain unclear (Kester et al., 2014). Factors affecting less prevalent measures or measures less commonly used in cattle assessment protocols such as the incidence of agonistic interactions, behaviors around resting, or human–animal relationships have received even less attention. Similarly, epidemiological studies on welfare concerns in calves and heifers or the cow–calf sector are largely lacking. However, recently Simon et al. (2016a) investigated the relationships of herd-level management, facilities and stockperson handling with beef cattle health and behavior.

Additionally, the external validity of research findings may be limited for at least two reasons. Results of experimental studies may only be valid for the specific conditions under which an experiment was carried out and which may not match with the conditions commonly found in commercial farms. For example, in various experimental settings, overstocking freestalls decreased the time cows lie down and spend standing partially in the stalls (e.g., Fregonesi et al., 2007; Lombard et al., 2010; Krawczel et al., 2012). However, in on-farm research lying time is not consistently affected by stall availability and some studies did not find an association between stocking density and lying behavior (Charlton et al., 2014; Ito et al., 2014; Lombard et al., 2010). Epidemiological research on commercial farms may therefore address the concerns associated with experimental work. However, cross-sectional studies, the most frequently used type of epidemiological research for risk assessment, can only identify associations between outcomes and potential risks. Determination of causal relationships requires controlled intervention studies or longitudinal epidemiological surveys. These limitations may be overcome, at least in part, by integrating scientific evidence with expert knowledge on good agricultural practice originating from stakeholders such as farmers and agricultural and veterinary advisors.

Nevertheless, once welfare problems have been identified using animal-based measures, sufficient knowledge is generally available for targeted interventions. However, well-structured information about the environment (e.g., housing) and management (e.g., feeding, health management or animal handling) is required to identify risks potentially associated with the welfare outcome measures and to provide meaningful recommendations. Farming standards and recommendations (e.g., Code of Practice for the Care and Handling of Dairy Cattle, http://www.nfacc.ca/codes-of-practice/dairy-cattle; Code of Recommendations for the Welfare of Livestock: Cattle, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69 cattle-code-030407.pdf) may serve as a starting point, but the level of detail is often not sufficient to identify relevant influencing variables on individual farms. For example, the latter source only qualitatively describes freestall properties without specifying important details such as the position of the neck rail or the brisket board. Although advisory support is sometimes provided (e.g., http://www.assurewel.org/dairycows/advisorysupport), detailed checklists for housing and management or standard operation protocols, e.g., regarding observations of handling of animals have not or have only rarely been published for the comprehensive assessment of cattle welfare risks. A potential way forward are husbandry advisory tools as they have been developed for the prevention of tail biting in pigs (Taylor et al., 2012; vom Brocke et al., 2015). They provide a risk assessment and improvement procedure based on interviews as well as observations of quantitative and qualitative housing parameters. After entering the collected data in a spreadsheet, a risk profile is calculated which supports an informed decision on which intervention measures to implement.

This profile is based on consultation of expert opinion assigning scores for relative importance to each of the risks included. Such tools are primarily meant to be employed by external veterinarians and farm consultants who play a vital role in advising farmers to implement change based on scientific evidence and professional experience (Whay et al., 2012).

3.4 Implementation of measures and the study of subsequent improvements

Despite the substantial knowledge about many welfare problems and possible ways to address them, surprisingly little work has been done/published on the implementation of measures aiming at improving welfare and the investigation of subsequent changes. A first measure of success is the implementation rate of recommended measures, which may be interpreted as a reduction in welfare risks. In a mastitis control study, an equal number of farms each implemented more than two-thirds, between one and two-thirds, and less than one-third of the preventive measures suggested in the mastitis diagnosis and control plan (Green et al., 2007). Similar orders of magnitude have been found in lameness intervention, ranging from not further specified "less than satisfactory" and therefore presumably low acceptance of recommended measures (Bell et al., 2009) to 73% implementation rate (Brinkmann and March, 2011), or in dairy herd health planning addressing a range of concerns (72%: Brinkmann and March, 2011; 57%: Gratzer, 2011). Much less is known about the propensity of farmers to implement measures directed at improvements of, e.g., behavior. However, in a pilot study that tried to reduce agonistic interactions in dairy herds, six and four out of 14 farms implemented all or parts of the recommended measures, respectively, suggesting that there is a similar potential for the adoption of interventions regarding behavioral indicators of welfare (Tremetsberger and Winckler, 2013).

Intervention studies are scarce, as already pointed out, and the evidence is mixed regarding the actual success of implementing changes in terms of cattle welfare improvements. Mastitis control plan interventions reduced mastitis incidence by about 20% (Green et al., 2007) and the use of antibiotic treatments for mastitis by 30% (Ivemeyer et al., 2008) to 50% (Bennedsgaard et al., 2010). The effects on dairy cattle lameness are more ambiguous. In a 4-year study on German organic dairy herds, lameness prevalence decreased from 33% to 15% in intervention farms as compared to from 19% to 15% in control farms

(Brinkmann and March, 2011), and in a UK study a more pronounced reduction in lameness was found in the support group than in the control group (Main et al., 2012). Other studies, however, did not observe significant change (Bell et al., 2009; Barker et al., 2012). Together with a higher lying time of the cows, lameness prevalence was also lower in farms which made changes to the freestall area after assessment of cow comfort than in farms which did not implement such changes or farms which had never had an assessment of cow comfort. No differences were found for the prevalence of hock and knee injuries (Morabito et al., 2017).

The few publicly accessible investigations that include comprehensive animal health and welfare planning have found that achieving improvement is even more difficult, when simultaneously identifying and addressing several distinct welfare issues, than when tackling a single welfare problem, e.g., lameness, only. For example, in a study of 128 European organic dairy farmers, after assessment, they most frequently addressed metabolic disorders, udder health, and lameness, resulting in a significantly reduced total treatment incidence (Ivemeyer et al., 2012). However, the majority of reduction was related to udder health, while the other areas remained unchanged. In the German subset of 40 farms, again udder health (somatic cell score) but also reproductive health (retained fetal membranes and endometritis) significantly improved in intervention compared to control farms; the pattern of changes regarding metabolic disorders was inconsistent (Brinkmann and March, 2011). To the author's knowledge, the above-mentioned pilot on agonistic interactions is the only study investigating interventions aimed at behavioral measures of welfare. However, after 1 year, the incidence of agonistic interactions remained unaffected in the dairy farms which had implemented measures aimed at reducing social stress (Tremetsberger and Winckler, 2013).

In general, monitoring periods of several years are more likely to reveal significant changes (4 years: Brinkmann and March, 2011; 2 years: Main et al., 2012). While changes in daily management routines are easier and quick to implement, more fundamental modifications, e.g., of the housing system, require longer time periods to be implemented and to become effective. Studies exceeding 2 years are, however, uncommon.

3.5 Conveying information and inducing change: A complex task

Following the assessment, the results have to be reported back to the farmers or farm managers providing sufficiently comprehensive detail about each welfare measure. Such reports should be regarded as problem-oriented decision support tools (Bonde et al., 2001). Benchmarking, i.e. the comparison with peer farms (Whay et al., 2003a; von Keyserlingk et al., 2012; Simon et al., 2016b), demonstrates what might be achievable in similar farming conditions, and may encourage farmers to participate in animal health and welfare planning (Gray and Hovi, 2002). It also serves to increase farmers' awareness of animal welfare issues. It is well known that different welfare concerns are unequally perceived by farmers. For example, lameness prevalence is often underestimated (Leach et al., 2010), partly due to the fact that a certain level of lameness is considered "normal" (Šárová et al., 2011). Inattentional blindness to the farm situation may be overcome by the inclusion of external, independent persons and decisions supported by benchmark-assisted comparisons across farms.

However, it is often questioned at which level of a given welfare issue action should be taken. Such intervention thresholds are usually based on expert opinion (e.g., Whay et al., 2003b), but they may appear too normative and thus impair the propensity of farmers to engage in attempts to improve as long as not taking action is not punished. Alternatively, relative boundaries such as 25% quartiles may be used to identify "poorer" welfare farms (de Vries et al., 2016) which require attention. However, although linked to the idea of benchmarking, such thresholds are arbitrary and may miss a biological or welfare science-based justification.

Ultimately, it is the farmer or farm manager who is to take and ensure action. They are the main stakeholders in promoting welfare, and the actual implementation of intervention measures requires the full inclusion and motivation of all participants on farm. This is especially important as introducing changes to management practices and routine behaviors is difficult, often resulting in a discrepancy between knowing about what should be undertaken and the actual implementation. As long as veterinarians or other agricultural extensionists are involved, the concept of "giving advice" should be scrutinized against this background with the aim of interactively generating farmer-owned decisions in a participatory approach.

The farm-specificity of interventions and feasibility of implementation on the farms (Goeritz et al., 2007; Kristensen and Enevoldsen, 2008) as well as the communication skills and strategies of the veterinary or agricultural consultants (Jansen and Lam, 2012) are important. Early participation allows farmers to provide their own perspective in finding practicable solutions which is essential for the final implementation of changes. For example, a low concordance with lameness control plans was found, when the veterinarian first developed the plan in which the farmers were involved only afterwards and agreed upon it (Bell et al., 2009). On the contrary, facilitating the generation of management action points by the farmers and discussing those with them led to substantial numbers of lameness control actions taken, over and above those initially agreed with a veterinarian (Whay et al., 2012) indicating that such an approach can be at least as beneficial as a direct advisory approach.

Farmer groups engaging in the process of animal health and welfare planning constitute an even more participatory approach. In the so-called “Stable Schools” (Vaarst et al., 2007; Ivemeyer et al., 2015), farmer groups which are guided by a facilitator become jointly involved in setting goals on what to improve and in developing intervention measures. Each of the participants shares and receives information and knowledge at the same time, and the facilitator does not act as an advisor disseminating knowledge.

3.6 Conclusions

The growing number of protocols available for cattle welfare assessment differ in the level of coverage of different dimensions of welfare with the goals of a program and the availability of resources, e.g., time, shaping their design. Given the welfare relevance of animal health and the relative ease of recording, most approaches focus on clinical measures and measures of the physical appearance. Inclusion of behavioral and mental state aspects of welfare would, however, require a more comprehensive approach. Hence, it should always be clearly stated, what can be and is achieved by a given protocol when communicating with stakeholders and the public.

Development of an action plan and subsequent implementation of identified measures and actions are key stages when targeting welfare improvements. Ownership of the problem and farmer-determined generation of action points seem to be crucial for successful implementation. However, farmers need support in starting and sustaining this process. For this purpose, a tool-box of advisory approaches ranging from one-to-one consultation to farmer group discussions seems to be promising.

Future work should consider dairy youngstock and beef cattle to a larger extent. Especially the latter comprise a variety of production systems ranging from extensive cow–calf operations to highly intensive finishing units each exhibiting specific welfare issues which need specific consideration. More research is also required to develop robust and feasible indicators of positive welfare states for the on-farm use.

For valid interventions, an epidemiological approach is warranted, especially with regard to behavioral measures as well as measures of the affective state of animals. Likewise, further controlled studies on the effectiveness of such epidemiologically identified intervention measures in all domains of welfare are needed. Finally, given the crucial role of farm managers in implementing changes for welfare improvement, cattle welfare would greatly benefit from a better understanding of how such changes may be facilitated.

References

1. Barker ZE, Wright JL, Blowey RW, Amory JR, Green LE. Uptake and effectiveness of interventions to reduce claw lesions in 40 dairy herds in the UK. *Anim Welf.* 2012;21:563–576.
2. Bell NJ, Bell MJ, Knowles TG, Whay HR, Main DJ, Webster AJF. The development, implementation and testing of a lameness control programme based on HACCP principles and designed for heifers on dairy farms. *Vet J.* 2009;180:178–188.
3. Bennedsgaard TW, Klaas IC, Vaarst M. Reducing use of antimicrobials: experience from an intervention study in organic dairy herds in Denmark. *Livest Sci.* 2010;131:183–192.
4. Bernardi F, Fregonesi J, Winckler C, Veira DM, von Keyserlingk MAG, Weary DM. The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene. *J Dairy Sci.* 2009;92:3074–3080.
5. Boissy A, Manteuffel G, Jensen MB, et al. Assessment of positive emotions in animals to improve their welfare. *Physiol Behav.* 2007;92:375–397.
6. Bonde M, Rousing T, Sørensen JT. Structure of the welfare assessment report for communication with farmers. *Acta Agric Scand Sect A Anim Sci.* 2001;Supp. 30:58–61.
7. Brinkmann J., March S., 2011. Tiergesundheit in der ökologischen Milchviehhaltung, Status quo sowie (Weiter-) Entwicklung, Anwendung und Beurteilung eines präventiven Konzeptes zur Herdengesundheitsplanung. [Animal Health in Organic Dairy Farming:

Health State as well as Development, Application and Evaluation of a Preventative Herd Health Planning Concept]. PhD Thesis, Georg-August-Universität Göttingen, Göttingen, Germany.
8. Bruijnis MRN, Hogeveen H, Stassen EN. Assessing economic consequences of foot disorders in dairy cattle using a dynamic stochastic simulation model. *J Dairy Sci.* 2010;93:2419–2432.
9. Charlton GL, Haley DB, Rushen J, de Passillé AM. Stocking density, milking duration, and lying times of lactating cows on Canadian freestall dairy farms. *J Dairy Sci.* 2014;97:2694–2700.
10. de Vries M, Engel B, den Uijl I, et al. Assessment time of the Welfare Quality® protocol for dairy cattle. *Anim Welf.* 2013;22:85–93.
11. de Vries M, Bokkers EAM, van Schaik G, Engel B, Dijkstra T, de Boer IJM. Exploring the value of routinely collected herd data for estimating dairy cattle welfare. *J Dairy Sci.* 2014;97:715–730.
12. de Vries M, Bokkers EAM, van Schaik G, Engel B, Dijkstra T, de Boer IJM. Improving the time efficiency of identifying dairy herds with poorer welfare in a population. *J Dairy Sci.* 2016;99:8282–8296.
13. Emanuelson U, Nielsen C. Short communication: weak associations between mastitis control measures and bulk milk somatic cell counts in Swedish dairy herds. *J Dairy Sci.* 2017;100:6572–6576.
14. Fraser D. Assessing animal welfare at the farm and group level: the interplay of science and values. *Anim Welf.* 2003;12:433–443.
15. Fregonesi JA, Tucker CB, Weary DM. Overstocking reduces lying time in dairy cows. *J Dairy Sci.* 2007;90:3349–3354.
16. Goeritz M., Oppermann R., Müller-Arnke I., Rahmann G., March S., Brinkmann J., Schumacher U., 2007. Acceptance of animal health plans: results of a survey at 60 farms. In: Zikeli, S., Claupein, W., Dabbert, S., Kaufmann, B., Müller, T., Valle Zárate, A. (Eds.). Proceedings of the 9th German Scientific Conference on Organic Agriculture, 20–22 March 2007, Hohenheim, Germany, pp. 601–604.
17. Gratzer ET. *Animal Health and Welfare Planning in Austrian Organic Dairy Farms PhD Thesis* Vienna, Austria: University of Natural Resources and Life Sciences; 2011.
18. Gray D., Hovi M., 2002. Animal health plans for organic farms: the UK experience. In: Hovi, M., Vaarst, M. (Eds.), Positive Health: Preventive Measures and Alternative Strategies. Proceedings of the 5th NAHWOA Workshop 11–13 November 2001, Rødding, Denmark, pp. 132–143.

19. Green MJ, Leach KA, Breen JE, Green LE, Bradley AJ. National intervention study of mastitis control in dairy herds in England and Wales. *Vet Rec.* 2007;160:287–293.
20. Halasa T, Huijps K, Østerås O, Hogeveen H. Economic effects of bovine mastitis and mastitis management: a review. *Vet Q.* 2011;29:18–31.
21. Haufe HC, Gygax L, Wechsler B, Stauffacher M, Friedli K. Influence of floor surface and access to pasture on claw health in dairy cows kept in cubicle housing systems. *Prev Vet Med.* 2012;105:85–92.
22. Heath CAE, Browne WJ, Mullan S, Main DCJ. Navigating the iceberg: reducing the number of parameters within the Welfare Quality® assessment protocol for dairy cows. *Animal*. 2014;8:1978–1986.
23. Ito K, Chapinal N, Weary DM, von Keyserlingk MAG. Associations between herd-level factors and lying behavior of freestall-housed dairy cows. *J Dairy Sci.* 2014;97:2081–2089.
24. Ivemeyer S, Maeschli A, Walkenhorst M, et al. Effects of a two-year dairy herd health management programme on udder health, use of antibiotics and longevity. *Schweizer Archiv für Tierheilkunde*. 2008;150:499–505.
25. Ivemeyer S, Smolders G, Brinkmann J, et al. Impact of animal health and welfare planning on medicine use, herd health and production in European organic dairy farms. *Livest Sci.* 2012;145:63–72.
26. Ivemeyer S, Bell NJ, Brinkmann J, et al. Farmers taking responsibility for herd health development—stable schools in research and advisory activities as a tool for dairy health and welfare planning in Europe. *Organic Agric.* 2015;5:135–141.
27. Jansen J, Lam TJGM. The role of communication in improving udder health. *Vet Clin N Am Food Anim Pract.* 2012;28:363–379.
28. Keeling L, Evans A, Forkman B, Kjaernes U. Welfare Quality® principles and criteria. In: Blokhuis H, Miele M, Veissier I, Jones B, eds. *Improving farm animal welfare Science and society working together: The Welfare Quality approach*. Wageningen: Wageningen Academic Publishers; 2013;91–114.
29. Kester E, Holzhauer M, Frankena K. A descriptive review of the prevalence and risk factors of hock lesions in dairy cows. *Vet J.* 2014;202:222–228.
30. Knierim U, Winckler C. On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special

regard to the Welfare Quality® approach. *Anim Welf.* 2009;18:451–458.
31. Krawczel PD, Mooney CS, Dann HM, et al. Effect of alternative models for increasing stocking density on the short-term behavior and hygiene of Holstein dairy cows. *J Dairy Sci.* 2012;95:2467–2475.
32. Kristensen E, Enevoldsen C. A mixed methods inquiry: how dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program. *Acta Vet Scand.* 2008;50:50 http://dx.doi.org/10.1186/1751-0147-50-50.
33. Leach KA, Whay HR, Maggs CM, et al. Working towards a reduction in cattle lameness: 1 Understanding barriers to lameness control on dairy farms. *Res Vet Sci.* 2010;89:311–317.
34. Lombard JE, Tucker CB, von Keyserlingk MAG, Kopral CA, Weary DM. Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms. *J Dairy Sci.* 2010;93:4668–4676.
35. Main DCJ, Leach KA, Barker ZE, et al. Evaluating an intervention to reduce lameness in dairy cattle. *J Dairy Sci.* 2012;95:2946–2954.
36. Metz JHM, Dijkstra T, Franken P, Frankena K. Development and application of a protocol to evaluate herd welfare in Dutch dairy farms. *Livest Sci.* 2015;180:183–193.
37. Miele M, Veissier I, Evans A, Botreau R. Establishing a dialogue between science and society about welfare. *Anim Welf.* 2011;20:103–117.
38. Morabito E, Barkema HW, Pajor EA, Solano L, Pellerin D, Orsel K. Effects of changing freestall area on lameness, lying time, and leg injuries on dairy farms in Alberta, Canada. *J Dairy Sci.* 2017;100:6516–6526.
39. OIE (World Organisation for Animal Health), 2016. Terrestrial Animal Health Code. <http://www.oie.int/en/international-standard-setting/terrestrial-code/access-online/>.
40. Potterton SL, Green MJ, Millar KM, et al. Prevalence and characterisation of, and producers’ attitudes towards, hock lesions in UK dairy cattle. *Vet Rec.* 2011;169 634–634.
41. Šárová R, Stěhulová I, Kratinová P, Firla P, Špinka M. Farm managers underestimate lameness prevalence in Czech dairy herds. *Anim Welf.* 2011;20:201–204.
42. Simon GE, Hoar BR, Tucker CB. Assessing cow–calf welfare Part 2: Risk factors for beef cow health and behavior and stockperson handling.

J Anim Sci. 2016a;94:3488–3500.
43. Simon GE, Hoar BR, Tucker CB. Assessing cow–calf welfare Part 1: Benchmarking beef cow health and behavior, handling; and management, facilities, and producer prespectives. *J Anim Sci.* 2016b;94:3476–3487.
44. Solano L, Barkema HW, Pajor EA, et al. Prevalence of lameness and associated risk factors in Canadian Holstein–Friesian cows housed in freestall barns. *J Dairy Sci.* 2015;98:6978–6991.
45. Sørensen JT, Rousing T, Møller SH, Bonde M, Hegelund L. On-farm welfare assessment systems: what are the recording costs? *Anim Welf.* 2007;16:237–239.
46. Taylor NR, Parker RMA, Mendl M, Edwards SA, Main DCJ. Prevalence of risk factors for tail biting on commercial farms and intervention strategies. *Vet J.* 2012;194:77–83.
47. Tremetsberger L., Winckler C., 2013. Einfluss von Maßnahmen zur Verringerung von agnostischen Verhaltensweisen auf das Sozialverhalten in Milchviehherden. In: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt, Aktuelle Arbeiten zur artgemäßen Tierhaltung 503, ISBN 978-3-941583-87-0, 234–235.
48. van Hertem T, Parmet Y, Steensels M, et al. The effect of routine hoof trimming on locomotion score, ruminating time, activity, and milk yield of dairy cows. *J Dairy Sci.* 2014;97:1–12.
49. Vaarst M, Nissen TB, Østergaard S, Klaas IC, Bennedsgaard TW, Christensen J. Danish stable schools for experiential common learning in groups of organic dairy farmers. *J Dairy Sci.* 2007;90:2543–2554.
50. vom Brocke AL, Madey DP, Gauly M, Schrader L, Dippel S. *Training veterinarians and agricultural advisers on a novel tool for tail biting prevention. Vet Rec Open* 2015; http://dx.doi.org/10.1136/vetreco-2014-000083 2, e000083.
51. von Keyserlingk MAG, Barrientos A, Ito K, Galo E, Weary DM. Benchmarking cow comfort on North American freestall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows. *J Dairy Sci.* 2012;95:7399–7408.
52. Welfare Quality, 2009. Welfare Quality® assessment protocol for cattle. Welfare Quality® Consortium, Lelystad, Netherlands. (updated version available at:

<http://www.welfarequalitynetwork.net/network/45848/7/0/40>).
53. Whay HR. The journey to animal welfare improvement. *Anim Welf.* 2007;16:117–122.
54. Whay HR, Main DCJ, Green LE, Webster AJF. Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. *Vet Rec.* 2003a;153:197–202.
55. Whay HR, Main DCJ, Green LE, Webster AJF. Animal-based measures for the assessment of welfare state of dairy cattle, pigs and lying hens: consensus of expert opinion. *Anim Welf.* 2003b;12:205–217.
56. Whay HR, Barker ZE, Leach KA, Main DCJ. Promoting farmer engagement and activity in the control of dairy lameness. *Vet J.* 2012;193:617–621.

4

Human–animal interactions

Effects, challenges, and progress

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Abstract

In contemporary society, animals and humans interact in a variety of different capacities, as companions, as therapy providers, and as sources of food and fiber. Interactions between animals and their human caretakers play a significant role in the overall welfare of both the livestock and their stewards. For people caring for cattle, it is important to understand how their everyday interactions can affect the health, welfare and performance of the animals. Within the cattle industry, assessments of the human–animal interaction are being incorporated into third-party welfare-verification programs, underlining the importance of finding accurate ways of assessing these interactions. Exploring how the human–animal relationship impacts the caretaker is a novel and relatively less-studied area with potential for future research. The malleability of human–animal interactions is where change and progress in improving cattle and human caretaker welfare is possible within the livestock industry.

Keywords

Animal handling; human caretaker; human–animal interaction; stockmanship; welfare assessment

4.1 Introduction

The lives of humans and animals have been intricately connected for millions of years. The relationship began as a primitive association between predator and prey (early humans as a prey species, then changing into scavengers and finally developing into predators; Mithen, 1999), and the relationship has transformed over the millennia to represent more than a survivalist predator vs prey relationship between early humans and wild animals. While humans were evolving, their relationship with animals changed as they did (Mithen, 1999). Humans as a species have extended their involvement with animals beyond the familiar survivalist relationship into a unique type of interspecies interaction. Humans and animals began to coexist in a more defined way with animal domestication tens of thousands of years ago—for food, for companionship, for rodent control, for protection, among other things. The coexistence was perhaps accidental but began by individuals within both species recognizing a benefit to the slowly transforming human–animal relationship—e.g., humans created refuse to scavenge and dogs provided protection and eventually companionship. There are history books full of descriptions and images of the many ways humans and animals interacted, e.g., how Ancient Egyptians were buried with cats, how dogs became pets, how animals were integral components of cultural mythology, and how sheep herders in the Middle East stayed with their flocks.

In our contemporary society, animals continue to coexist with humans in numerous ways, still as a major source of food and fiber but additionally in companionship, sport, research, therapy, and more. Whereas precontemporary societies probably enjoyed the company of their guard dogs and rodent-control cats, the relationship was more about necessity and use (how does this animal benefit my life in a practical sense?). As societies developed and some of the jobs these animals performed became less of a necessity and perhaps more of a luxury, the relationship between the animals and humans became more of a bond, as opposed to an association based on mutual fulfillment of basic needs.

In countries that are still developing, many of the communities still rely heavily on animals to fulfill bare necessities for food, nutrition and to perform work (e.g., farming and transportation). In countries such as the United States and many European countries, the human–animal bond has developed into something more intricate with a significant focus on the psychological component of the effects animals have on humans in addition to the effects humans have on animals. Animal professions, in particular the veterinary profession, have spent considerable time studying and contemplating this human–animal relationship as it has a significant impact on a veterinarian's job (Fogle, 1999). The American Veterinary Medical Association defines the human–animal bond as "a mutually beneficial and dynamic relationship between people and animals that is influenced by behaviors that are essential to the health and well-being of both" (AVMA, 2016). Veterinarians, particularly those that interact with companion animals, have to navigate the human–animal relationship on a daily basis and they play a key role in the dialogue about the changing role of animals in society (Fogle, 1999).

In the arena of livestock production, the human–animal interaction has significant inter-species effects but it is not as widely discussed or studied outside of the livestock animal welfare niche within which it exists. The majority of the broader population has little to no interaction with livestock and thus the majority of the population is not connected to the food system in a meaningful way for them to consider or experience the details of human–animal interactions with livestock raised for food. Certainly over the past decade, there has been movement of the general non-food-producing public to want to understand how animals are raised at a more detailed level. For many though, this enhanced interest still remains at a high level outlook, not going into detail about exactly how the human–animal relationship is developed, cultivated and/or directly influences the food system. People want to know that animals are treated well by their caretakers—the basic foundation of the human–animal interaction—and if assured that appropriate care is being given, the assumption is that usually that is enough information to satisfy the need to know.

This chapter will demonstrate the complexities of human–animal interactions within the livestock industry. Although the content will focus on cattle, many of the things discussed have also been found in other livestock species. For people caring for cattle, it is important to understand how their everyday interactions can affect the health, welfare, and performance of the animals, and there exists a large body of research to demonstrate these potential effects, both positive and negative. There are many different methods used to assess and measure human–animal interaction and they differ in their ability to capture a true representation of the caretaker–animal relationship. As the industry begins to incorporate assessments of the human–animal interaction as part of third-party welfare-verification programs, it is often cumbersome to navigate through the many different methods that are used between research studies and industry programs. The more traditional perspective of human–animal interactions, i.e. how humans affect animals, has received the most attention from the research community but it is also essential to understand how human–animal interactions also impact the health, welfare, and safety of the caretakers themselves. If animal caretakers can positively impact the behavior of animals during handling, observation and management, the interactions they have with the animals can, in turn, positively influence the caretakers' job satisfaction (Hemsworth and Coleman, 2011). Exploring how the human–animal relationship affects the worker is a novel and relatively less studied area of interest, making it ripe for future research opportunities. Additionally, the human–animal relationship is dynamic, changing and adapting with each interaction, and oftentimes the more traditional research approach and general perspective tends to view the relationship as something stable, i.e. positive or negative, but not fluid. The malleability of human–animal interactions, is where change and progress in improving animal and human caretaker welfare is possible within the cattle industry.

4.2 Human caretaker impact on cattle health and welfare in production settings

In most cattle facilities, animals are in contact with humans to some degree daily making the human–animal interaction, even if brief, a significant and impactful component of animal care. Although perhaps not immediately triggering an image of a strong psychological component that is found between pet owners and companion animals, animal caretakers in cattle facilities often have a similar social bond with the animals under their care. Speculation suggests that on the surface, the relationship that human caretakers have with food animals is somewhat reminiscent of the initial age of domestication when the relationship between animals and humans was symbiotic without intense psychological attachment. On the contrary, learning from personal conversations with animal caretakers, the relationships that human caretakers form with the cattle they look after are often stronger than may be expected. Considering that a caretaker's job is to ensure the cattle survive and thrive, the human–animal bond formed becomes an integral component of the caretaker's job and, hopefully, success. Although many caretakers may not be fully aware of the impacts they can have on the animals they care for, this kind of understanding is potentially an important component of training and education for animal caretakers in the future.

4.2.1 Stockmanship

Stockmanship, sometimes used as a synonym for animal husbandry or stewardship, is a word used within the industry to describe the knowledge and skills that an animal caretaker has and puts into action to raise animals safely, efficiently, effectively, and with minimal stress and discomfort. The term is used broadly to describe aspects of caretaker behavior and personality such as attitude towards animals, approach to handling them, attentiveness to providing proper nutrition, and focus on maintaining animal health. Within the cattle industry, stockmanship is something that is sought after in animal caretakers, whether it be through experience, training, innate ability or a combination of multiple things. Coleman et al. (1998) identified that poor behavior and attitude of a caretaker toward the animals he cares for could in turn reduce the attentiveness to welfare problems in his animals (i.e. poor stockmanship), thus potentially resulting in detrimental impacts on productivity, health, or welfare of the animals in his care.

There exists an ever-growing body of research on the effect of stockmanship (human caretaker attitude and behavior) on animal productivity, health and welfare (see reviews by Hemsworth, 2004; Waiblinger et al., 2006; Hemsworth and Coleman, 2011). P. Hemsworth, a professor at the University of Melbourne, is a leader in this field of animal welfare science, providing a plethora of publications beginning in the early 1980s and continuing currently, exploring the impacts that animal caretakers have on various welfare parameters in a large variety of species (Hemsworth et al., 1981a,b, 1986, 1994, 2000, 2011; Sherwen et al., 2015). Hemsworth and Coleman (2011) have also published a comprehensive book on the human–animal interaction providing insight into the impacts the bond has on both the animals and the human caretakers. Coleman et al. (1998) cited Fishbein's theory of reasoned action (Fishbein and Ajzen, 1975) as the basal theory behind their research on prediction variables of animal caretaker behavior towards pigs. In brief, Fishbein's theory basically states that humans act favorably to things/people they like and unfavorably to things they don't like and these attitudes then dictate actions, i.e. behaviors (Ajzen, 1988). A caretaker's attitude towards the animals it cares for can be predictive of the behavior that the caretaker exhibits towards the animals. A caretaker who has negative feelings towards the animals it cares for will likely act in a negative manner which could elicit fear and stress responses in the animal causing short- and long-term effects on welfare.

4.2.2 Understanding the cattle fear response in the context of human and animal interactions

Animals can respond to interactions with humans in various ways. The discussion of the impact of the human–animal interaction on animal health and welfare usually focuses around the impact of the negative interactions that animals have with their human caretakers, measuring the subsequent short-term and long-term effects on an aspect of animal welfare. A negative interaction between an animal and a human is likely an incident in which the human causes the animal to experience fear or anxiety; fear being the perception of actual danger and anxiety being the reaction to a potential danger (Boissy, 1998). Fear is a primitive emotion of both animals and humans that, when elicited by a stimulus within the environment, is accompanied by physiological and psychological responses that have evolved to help the animal to respond to danger, or perceived danger. A fear response is an adaptive behavior that enables an animal to successfully deal with challenges within its environment with the ultimate goal of survival (Toates, 1980). Although animals that have been domesticated certainly have a reduction in dangers that threaten their survival, i.e. predators, and a reduction in fear towards humans (Price, 1984), they still have the capacity and need to exhibit behavior and physiological changes indicative of a fear response when confronted with situations that cause stress, pain, or frustration, as some general on-farm management practices do. It has been suggested that animals still perceive interactions with humans as predatory encounters (Suarez and Gallup, 1982; Boissy 1998) which could elicit a fear response. Welp et al. (2004) studied the change in vigilance behavior, keeping careful watch for possible danger, in dairy cattle in response to interactions with humans in which the animals had had either aversive or gentle previous encounters. They found that cattle showed more vigilance in response to the person that had treated them in an aversive manner.

Many studies researching an animal's response to an interaction with a caretaker as positive or negative use changes in and occurrence of particular species-specific behaviors or physiology to determine the animal's emotional state. One approach to determining the impact that the human–animal interaction has on cattle welfare is through fear tests, i.e. assessing cattle response to an interaction with a human. de Passillé and Rushen (2005) provide a review of the common methodologies used to measure an animal's fear response to human caretakers. de Passillé and Rushen (2005) discuss the different types of fear measures in the context of the feasibility of incorporating this type of test into an on-farm audit or assessment as a reliable measure of good stockmanship. The authors categorize fear tests into three categories based upon the outcome variable assessed: distance measures (the distance the animal maintains between itself and the human caretaker), handling measures (the animal response to be handled by a human caretaker), and a subjective rating of the animal response to the human. Distance measures are the most common and have been used frequently to assess the impact of human–animal interactions on dairy cow productivity (Breuer et al., 2000; Hemsworth et al., 2000; Waiblinger et al., 2002). Handling measures have been used to assess human interactions and impacts on commercial dairy cows, veal calves, and beef cattle at auction markets (Breuer et al., 2000; Hemsworth et al., 2000; Lanier et al., 2001; Lensink et al., 2001). Subjective measures of cattle response to human–animal interactions in beef cattle have also been used in research studies (Voisinet et al., 1997; Lanier et al., 2001). de Passillé and Rushen (2005) and Waiblinger et al. (2006) provide an extensive review of the reliability and validity of these tests to measure animal fear and stockmanship concluding that this is an area that deserves more research and ultimately standardization, if this type of measure is to become integral in assessments of employee and overall farm performance regarding animal welfare (discussed in a subsequent section).

4.2.3 Changes in cattle health, behavior, and welfare as a result of human caretaker interaction

Fear response tests are not the only metric that can and should be used to assess the impact that human caretaker behavior and/or attitude has on cattle welfare. (It should be noted that many research studies will utilize multiple outcome variables to assess human interaction impact on the animals, i.e. fear tests, behavioral measures, and production/performance variables.) A fear reaction could be a short-term response to a single incident but, if repeated, it could also cause a cascade of other stress responses having potentially chronic impacts on animal health and welfare. In Seabrook, 1972 conducted one of the pioneering studies in assessing the impact of the human–animal interaction on animal production and performance, specifically exploring the relationship of dairy cows with their “cowmen” and how certain personality attributes of the cowmen impacted dairy cow milk production. Seabrook (1980) commented that the dairy cow can have an appropriate environment with regard to housing, food, water, and basic needs, but if there is no level of comfort with the animal caretaker, the cow will still be stressed, which ultimately can impact production.

Much of the literature specific to cattle and their interaction with human caretakers has been focused on commercial dairy cows. Within the United States beef industry, dairy cattle experience the most frequent and most intensive human interaction due to the nature of the production schemes (i.e. calving, milking, handling, etc). There have been several studies exploring negative interactions between cows and their human caretakers and/or fear of humans indicating a negative association with milk production (Seabrook, 1972; Rushen et al., 1999; Breuer et al., 2000; Waiblinger et al., 2002). Raising beef cattle on ranches usually uses a fairly “hands-off” approach to animal management, minimizing the amount of time the cows interact with humans (sometimes making handling more difficult down the production chain due to the cattle’s limited experience with human handlers). Cattle in feedlots will interact with human caretakers primarily during daily health checks conducted by the caretakers. The veal industry is the other segment of the cattle industry in which the animals experience increased levels of human interaction. Fewer studies exist exploring the human–animal interaction impacts within the veal industry. One survey study conducted by Lensink et al. (2000) indicated that, based on self-reported survey results, positive attitudes towards the calves resulted in better productivity as compared with veal producers reporting negative attitudes. Even though certain industry segments may not handle animals to the same degree, it is important to understand the impact of the human–animal interactions as there may be downstream impacts on cattle welfare as the animals move towards more intensely managed systems within the supply chain.

Oftentimes animal behavior can be used to help determine an animal’s response to external stimuli, in the context of this discussion, human-caretaker interactions. Dairy cattle have frequent interactions with human caretakers, one example of an interactive process being milking. One behavioral response of a dairy cow during milking that can be observed and measured is stamping and kicking behavior, previously called the “flinch, step, kick” response (Willis, 1983), which can be a safety issue for the animal caretakers, can interfere with the efficiency of milking and is influenced by the cow’s response to interactions with humans (Hemsworth et al., 1987). Hemsworth et al. (1987) conducted a preliminary study comparing the behavioral responses, “flinch, step, kick” specifically, of dairy cows to human handlers during milking that had been previously handled (during the time of calving) and those that had not been handled. The study demonstrated that the cows that were handled previously had lower incidence of “flinch, step, kick” responses as compared with the cows that weren’t handled. Additionally, cows that were not handled needed more assistance from the human handlers during milking, decreasing the efficiency of the task. Hemsworth et al. (1989) conducted a secondary study to explore the concept further and also found that cows that experienced increased handling during calving had reduced “flinch, step, kick” responses during milking than those that were not handled. This study did not indicate any difference in additional assistance needed as Hemsworth et al. (1987) did, but the secondary study did indicate that cows without handling were slower to move into the milking area when the human experimenter was present. Additionally, the cows without handling had higher milk cortisol concentrations. The conclusion of the authors was that the cows that experienced additional handling by human caretakers had a reduced fear response and thus had lower cortisol concentrations, lower "flinch, step, kick" responses, and were overall easier to handle making a safer more efficient working environment for the human caretakers and a less stressful environment for the animals.

The concept of providing additional positive interactions to cattle to lesser the fear response during intense handling management procedures has been studied by other researchers as well. Tactile interactions between cattle and humans are important in dictating the cattle's behavioral response and positive tactile interactions have been shown to reduce fear of humans in cattle (Boissy and Bouissou, 1988; Boivin et al., 1992; Schmied et al., 2008, 2010). Bertenshaw (2002) conducted a survey of dairies in the United Kingdom exploring how farmers reported and interpreted the behavioral responses of dairy heifers to milking during the adjustment period. The survey respondents reported that heifers take longer to milk, are often more difficult to handle, are reluctant to move into the dairy parlor and often require more use of a kick bar. The farms were categorized by survey response and it was shown that cows that received positive human interaction during rearing had higher milk yield during lactation. Numerous studies have been conducted with dairy cattle exploring the impacts of early positive handling interactions on subsequent interaction with both familiar and unfamiliar humans (de Pasillé et al., 1996; Schütz et al. 2012) and subsequent fear responses (Boissy & Bouissou 1988). Schmied et al. (2008, 2010) have conducted several studies exploring the impacts of stroking different body areas performed by humans on the subsequent behavior of dairy cattle. The studies determined that stroking in certain areas, particularly the neck, reduced avoidance behavior and stress reactions and increased approach behavior in dairy cattle, providing evidence that positive tactile interactions with humans can make a positive impact on routine handling procedures with cattle. Whereas studies often focus on the impact on behavior and production that negative human interactions have on cattle, it is noteworthy to also explore the impact that positive interactions may have so that perhaps intentional positive human–animal interaction can become part of a management routine. Additional research will be needed to determine the optimum time to promote additional positive human–animal interactions (e.g., calving, lactation, weaning).

Another factor that can affect animal welfare, health, productivity and the human–animal relationship is animal temperament. Drugociu et al. (1977) reported that animals with a calm temperament had a 25%–30% increase in milk yield. Voisinet et al. (1997) demonstrated that calmer cattle had higher weight gains. It is difficult to know whether the excitable temperament was caused by negative human–animal interactions or if the excitable animals are just genetically predisposed to exhibiting more fearful, flighty behaviors. Many factors such as age, genetics, breed, and social environment can impact animal temperament, including previous experience with handlers.

4.3 Effects of human–animal interaction on animal caretakers

Although the many effects that the human–animal relationship can have on the animal caretakers themselves is frequently discussed within the livestock industry, there is a paucity of published research in this area. Being an animal caretaker within the cattle industry can be a difficult job, often including unconventional hours, in sometimes unpleasant working conditions (e.g., extreme weather, odorous work environments) and often with little recognition of the demanding nature of the job (Hemsworth and Coleman, 2011). There exists an opportunity to develop the study of the positive and negative impacts that animal interactions can have on the caretaker's physical and mental health and safety. This type of research could potentially improve worker safety, job satisfaction and thus job retention and caretaker stress among other aspects of worker welfare and performance.

4.3.1 Animal caretaker safety

Working with large livestock can sometimes be a safety risk for animal caretakers. Cattle are large and powerful animals that can respond aggressively and quickly when fearful, territorial, threatened, in pain from injury or sickness, or with offspring to protect. Animals that are fearful are often more difficult to handle (Grandin et al., 1987; Boivin et al., 1992). United States Department of Labor statistics indicated that during 2003 and 2007, 5% of the fatalities occurring in the United States in the production of crops and animals were caused by cattle (United States Department of Labor (2003–2007)). A surveillance study, conducted by the Iowa Fatality Assessment and Control Evaluation (IA FACE) and the Great Plains Center for Agricultural Health (GPCAH), assessed data from four cattle-producing states during the same time period and determined that the most common situations surrounding the human fatalities were: working with and treating cattle in enclosed spaces, moving or sorting cattle, loading cattle onto trucks, and working cattle on open pasture (Morbidity and Mortality Weekly Report (MMWR), 2009). Approximately a third of the deaths were caused by cattle that had been previously reported as aggressive. All of the activities occurring around the fatalities were events that involved some type of animal handling, i.e. human–animal interaction. Many of the deaths were caused by blunt force trauma, suggesting that perhaps the animals were potentially responding to fear, manifesting itself in physical assault on their human caretaker. Although livestock behavior cannot always be predicted, it is important to understand how animals may respond to situations to keep a safe working environment when handling livestock. It is important that animal caretaker training programs involve discussions of how to stay safe when working with livestock.

4.3.2 Animal caretaker job satisfaction and retention

Employee retention is linked closely with job satisfaction. As Hemsworth and Coleman (2011) describe, animal caretakers, and employees in general, base the satisfaction of their job on whether or not their expectations are being met. Employee expectations can include numerous factors such as compensation, recognition, job description, available resources, and opportunities to grow. Employee compensation, although not necessarily the first priority for all employees, is definitely a factor for some and traditionally, agricultural workers are usually paid fairly low wages comparatively. The United States Department of Labor, Bureau of Labor Statistics provides national averages for various occupational types of employment. In 2015 statistics indicated that Farm Animal Caretakers made a mean hourly wage of $9.66 USD for performing agricultural jobs, this included non-animal aspects of farming as well, and no prior experience or education requirement was published in this report as required for acquiring this type of employment (United States Department of Labor, 2015a). Non-farm animal workers performing a similar job indicated a 5% higher mean hourly rate but did indicate a high school diploma or equivalent education level requirement (United States Department of Labor, 2015b). Farmers, ranchers, and agricultural ranchers made a significantly higher salary comparatively and the requirement of a high school diploma or equivalent and 5 years of experience in a related field were required (United States Department of Labor, 2015c). Anecdotally, it is often discussed in US industry groups that there is difficulty in finding skilled labor willing to perform the duties associated with caring for animals. Perhaps employers are not requiring the skills, experience level, or providing the equivalent on-the-job training that are truly desired for animal caretaker positions.

4.3.3 Impact of performing psychologically stressful tasks

There are tasks that animal caretakers must perform that have the potential to cause psychological stress. The moral stress of performing euthanasia is something that is discussed in all types of animal care. Requiring a caretaker, who spends her days supporting animals so that they can live, to end an animal's life is a difficult thing for that human to do. Bernard Rollin (2011) writes about this dichotomy as it exists in the veterinary field when veterinarians, who are trained to heal animals, are often required to end life, not always for justifiable reasons, e.g., convenience euthanasia, or in the opposite scenario when euthanasia is the best option but the veterinarian or caretaker is not permitted to end the animal's life in a timely manner. There is evidence suggesting that timely euthanasia within the cattle industry is not practiced as widely as perhaps it should be; permitting animals to die without assistance could certainly be a source of moral stress for their human caretakers. A study conducted by Hoe and Ruegg (2006) indicated that nearly one-third of Wisconsin dairy producers reported that they had not euthanized animals in 3 years, suggesting that perhaps unassisted death may have occurred as an alternative to elective euthanasia. Other studies from Europe and the United States have indicated that between 30% and 84% of culled cows on certain dairies died unassisted (Alvasen et al., 2014; McConnel et al., 2010; Thomsen et al., 2004; Thomsen and Sorenson, 2009; see also Toaff-Rosenstein, 2017; Chapter 8 for further review).

In professions which require people to have constant empathy for the people or animals they work with, such as nurses, veterinarians, shelter workers, animal caretakers, or special needs educators, those individuals can often suffer from something called “compassion fatigue.” This is a condition in which the individuals become apathetic and physically and emotionally exhausted as a result of the constant demands of caring for others. Compassion fatigue can occur with overexposure to traumatic events, in the case of livestock caretakers one of these traumatic events could be euthanasia, and this can be detrimental to the welfare of the animal caretaker and potentially impact job performance. There have been some published articles on understanding compassion fatigue and its impacts on human caretakers in the human and animal medical professions (Mitchener and Ogilive, 2002; Huggard and Huggard, 2008; Mason et al., 2014) but little exists focusing on livestock production.

4.4 Developing, monitoring, and verifying human–animal interactions

4.4.1 Developing the animal caretaker

Taking the understanding that both positive and negative human–animal interactions affect an animal’s emotional response, production performance and day-to-day experiences, and applying it in a practical way to the daily operations of animal production facilities is the challenge for farm managers to overcome. It is easy to provide data demonstrating that the way caretakers interact with animals matters, but it requires attention and focus to transform this knowledge into effective management of employee behavior and understanding on the farm or at the processing facility.

In Hemsworth and Coleman’s (2011) book on the human–animal interaction, the authors spend significant time discussing characteristics of a successful stockperson including skills and knowledge, specific personality traits, work motivation, presence (i.e. absenteeism, turnover), and job satisfaction and motivation. Currently, the United States livestock industry suffers from having a relatively small pool of skilled and motivated potential employees. Working with livestock is difficult and not usually highly paid due to the level of skill required which often leads to difficulty in maintaining a capable and dedicated labor force. Due to the limitations of finding employees for some of the roles with live animals, there is often not a stringent selection process which could potentially lead to hiring people that may not be appropriately suited for the job. Whereas certain veterinary schools use the assessment of attitude towards animals on admittance requirements (Fogle, 1999), it appears that managers in livestock facilities do not often consider that as a top priority, likely because of the vast difference between size and competitiveness of applicant pools. Although animal caretakers are often the key influencers in animal production and welfare at an animal production facility, their jobs, unfortunately, are often underappreciated by both the managers and the employees themselves (English et al., 1992; Hemsworth and Coleman, 2011). While some companies provide significant training and development opportunities for their animal caretakers, others do not. There needs to be focus on the impact these animal caretakers have on animal welfare, health, and performance thus underlining the importance of selecting the correct employees for the job and providing the appropriate training and development to maintain them.

The development of an adept animal caretaker relies on the adequacy of the training that the individual receives. Hemsworth and Coleman (2011) identify "practical experience in the care and maintenance of the animal" as one important factor in determining the performance of the employee. In many livestock production facilities, although past experience is definitely sought after, it is often not a characteristic that many employees have upon hiring. This makes employee training the critical way managers develop animal caretaker skills and knowledge. Despite the importance of employee training, several studies conducted in the 70's and 80's identified that employees working with livestock and poultry received little to no organized training in animal care (Kondos, 1983; Lloyd, 1974; Segundo, 1989). Anecdotally, the focus on training in production facilities has greatly increased.

The definition of training at animal production facilities is quite diverse ranging from a conversation between a manager and an employee describing a procedure to a comprehensive training program including the use of media, quizzes, and a set review schedule throughout the year. All types of training have the potential to provide the employees with the skills and knowledge they need to perform a job so long as the time is taken to truly explain not only how to perform the job but also why it is so important. Simon et al. (2016b) demonstrated that the completion of Beef Quality Assurance training by stockspeople on ranches in California, was protective for cattle-based outcomes, i.e. animals were cleaner and were less likely to be miscaught in the chute during handling, demonstrating the positive impacts animal caretaker training can have on cattle welfare. Demonstration and/or documentation of training has also become a standard parameter audited in most on-farm quality-assurance programs. The majority of third-party animal welfare and handling audits conducted on farms and in packing plants in the United States require proof of some type of employee training regarding animal care. Sometimes the audit tool is prescriptive asking for a specific type of proof of training (i.e. training records, employee questioning, signed standard operating procedures, training in a specific state program) and other times the requirement is fairly nebulous and open to what is produced and shown during the audit. These programs don't often assess the quality of the training programs but do try to include some assessment of employee understanding (BQA, 2016; NPB, 2014). Depending on the specific audit tool, there is often an expectation of retraining, e.g., the North American Meat Institute Animal Care and Handling Audit (NAMI, 2017) requires annual retraining. Many of the various national species trade associations, have entire educational programs focusing on best management practices and one of the main tenants of these programs is training. The National Cattlemen's Beef Association (NCBA), for example, developed the first iteration of the Beef Quality Assurance program in the 1980s and the program has grown and developed over the past several decades. One of the more recent endeavors in the United States cattle industry is the emphasis on the need for a verifiable and robust training program for cattle transporters as this is an area that has not had immense focus in the past several years since the inception of the Master Cattle Transporter Guide via NCBA (Schwartzkopf-Genswein et al., 2016).

In many industries, there are opportunities for employees to grow in their role and develop their skills at a professional level, working towards changing the definition of their work from a "job" to a "career." Hemsworth and Coleman (2011) highlight the need to treat animal caretakers as professionals as their roles in maintaining animal health and welfare are critical; by treating employees as professionals it will increase the self-esteem of the workers and thus promote job performance which ultimately benefits both the human and animal welfare. The United States slaughter industry provides a model example of an industry professionalizing the animal caretaker's role. In the early 2000s, the industry recognized a need to professionalize slaughter plant animal handling and auditing and, as a consequence, the Professional Animal Auditor Certification Organization (PAACO) was developed whose mission, in part, was "to promote the humane treatment of animals through education and certification of animal auditors." PAACO began to provide training and certification for those involved in the animal handling field; the training targeted auditors for third-party companies but additionally, it provided an outlet for advanced training to employees at slaughter facilities who directly impact animal handling, often members of the quality-assurance team or supervisors of the live animal processes. Many companies began to send employees to these training sessions as a means of professional development but also as a key component of some of their animal handling training programs. PAACO has provided an opportunity for plant employees to gain professional development within their area of expertise, an opportunity that didn't necessarily exist prior to PAACO. PAACO continues to facilitate the development of animal care auditing training programs in other areas of livestock production that may help provide more avenues for professional development opportunities for employees in other sectors. Additionally, in recent years, many conferences and seminars have been developed focusing on various aspects of animal care. Attendance at these events can be a way to develop skills, knowledge, and self-esteem of employees working directly with animals. The relatively small monetary investment in these types of activities are also a long-term investment in employees and ultimately the care of animals in the respective companies.

4.4.2 Monitoring and verifying employee behavior

As described, training is an important component to employee success. Training alone however does not ensure appropriate employee behavior. Training needs to be coupled with accountability for one's actions. Working with animals can be tiring and can sometimes try the patience of those employees working with them. Unlike working in a factory with inanimate objects, an animal's behavior is not predictable and they respond to small, sometimes unidentifiable changes in their environment, aspects that make working with animals exciting but simultaneously potentially frustrating.

Several years ago, many of the large commercial slaughter facilities in the United States began to use remote video auditing of the live animal handling areas as a means of training employees on appropriate techniques for working with animals but also as verification of employee adherence to animal handling protocols.

The remote video auditing technology provides management personnel with a tool to measure employee behavior at random moments in time without the employee being aware. This allows management to capture a more realistic impression of how the employee is performing his/her job without the pressure of being observed by an auditor with a clipboard. Being able to capture an employee's behavior on camera has given slaughter plant management tools to help train the employees who handle live animals. Often quality-assurance technicians at the facilities will conduct audits remotely using the live video feed (personal observation). If a deficiency in behavior is noted there will be a protocol in place for communicating with the supervisor in the area who will then counsel the employee. There is often a tendency to solely focus on the deficiencies in behavior but many slaughtering facilities who use the remote video auditing technology have recognized that showing employees when they are performing the behavior correctly is equally as important. Anecdotal observations from slaughter facilities who have used this technology for several years report a significant improvement in animal handling audit scores suggesting improvements in employee behavior. The remote video auditing has provided a feedback mechanism for behavior, has provided a means to assess behavior, and has added an additional level of accountability for job performance. The animal handlers are being held accountable for how they are handling the animals.

The primary company that provides remote video auditing services to the agricultural industry is Arrowsight (www.arrowsight.com). This technology was brought to the slaughtering facilities, not just in the live handling areas but also as a component of food-safety programs. After seeing the success of the technology in improving animal handling at the slaughtering facilities, Arrowsight has branched out into the live animal production arena as well providing similar services to companies who raise animals. With the continuous developments in the technology industry, this area of behavioral monitoring will become an increasingly integral component of livestock production facilities of the future. If this type of technology is not available to a facility, there are still traditional ways of assessing outcomes of employee behavior, i.e. conducting assessments of animal handling, and observing animal response to caretaker interaction.

4.5 Animal welfare assessments and methods to evaluate human–animal interactions

Historically, on-farm animal welfare assessments focused mainly on the physical welfare of animals, i.e. are they provided food and water, are the facilities in good repair, are the animals suffering from an above average level of disease, etc? With the growing concern for farm animal welfare within society, many of the downstream players of the food supply chain began to be interested in understanding more about how animals were being raised; more specifically, retailers wanted to know how the animals they purchased as meat were raised so they could assure the consumers that animal welfare was a high priority on all the farms their animals came from. In light of the contemporary approach of many animal activists groups to capture bad employee behavior at livestock production facilities on video and target specific, large, and influential retailers, many such corporate companies have begun to require on-farm quality-assurance programs as part of their corporate responsibility strategies to ensure animal welfare within their supply chain. In response to the heightened focus on animal treatment on farms, many trade associations have spearheaded projects to develop on-farm animal welfare assessments, if they did not already exist, or spend significant time revising existing standards to be more encompassing of employee interactions with animals (BQA, 2016; NPB, 2014). On-farm quality-assurance programs have begun to more fully recognize the role that farm management factors, such as stockmanship, play in overall farm animal welfare (Rushen, 2003).

In the past decade, many organizations have developed and implemented on-farm assessments to measure and verify that farm animals are receiving a high level of care during their lifetimes. These assessments include the basic tenets of animal care including the provision of food, water and shelter but the majority of the assessments also include some component that considers an aspect of the human–animal interactions that occur regularly at the facility. Some of the assessments measure the human–animal interactions indirectly by auditing the facility's animal handling training program, verifying proof of training documents, but also making direct observations of animal handling. Dr Temple Grandin, a world renowned animal scientist, has been an integral part of the creation process for many of the livestock industry audits. She often teaches that we can only "manage what we measure" making it important to have clear assessment tools that measure the things important to ensuring animal welfare on a farm or at a processing facility and in this case, the human–animal interaction is the focus. It is likely that some type of assessment of the human–animal relationship or employee behavior towards animals will be included in on-farm assessments so it is important to continue to standardize the methods used to measure this parameter.

As discussed, there are many different approaches to measuring the human–animal interaction, most of which can be broadly divided into two categories:

indirect and direct measures. Table 4.1 provides some explanation of indirect and direct measures. Additionally, the table provides information regarding whether the parameter is handler specific, i.e. only assessing one caretaker, and whether or not the parameter is dynamic or static, i.e. does the parameter change over time or does it remain constant. Indirect measures of human–animal interactions are methods such as the distance and handling measures or the subjective rating of animal response described by de Passillé and Rushen (2005). These types of measures focus on the animal's reaction to a human caretaker. Although experiments are designed to account for other variables that may impact an animal's response to a human aside from the interaction being tested, it is difficult to control for all other factors that may impact the outcome of these assessments. Sometimes it seems that the underlying assumption when using these methods is that the human–animal interaction is static, i.e. the cow will always act in this manner to this human. It is recognized that audits and assessments using this type of measure are snapshots in time but these types of methods may not be the most beneficial to assess and ultimately improve animal welfare in livestock facilities long-term. Direct measures of the human–animal interaction focus more on the actions or direct impact of the human. These measures would include things such as electric prod usage, stumbling, and vocalizing during active handling, as used in the NAMI slaughter plant audit (NAMI, 2017), feedyard audits (Woiwode et al., 2015), and cow–calf assessments (Simon et al., 2016a,b). These types of measures put more focus on the human caretaker which ultimately provides feedback and is more promising as the vehicle for change, i.e. improvement in animal welfare and the positive human–animal interaction. While assessing an animal's response to a caretaker can be helpful, it does not provide direct information about the behavior of the caretaker and the caretaker behavior is what can actually be manipulated and ultimately improved more easily. On-farm assessments are snapshots in time as are some of the behavioral tests. It is important to understand how an animal's reaction to a fear test, for example, may change if the test is repeated multiple times, i.e. is the result always consistent and how long would it take to detect improvement if the employee was able to improve skills. Understanding, monitoring and measuring the human caretaker behavior is the key to changing the human–animal interaction as they are active participants in the relationships they build with the animals that they work with.

Table 4.1

Indirect and direct measures used to assess the human–animal interaction in research and in on-farm assessment programs

Type of measure	Positive attributes of measure	Negative attributes of measure	Dynamic or static	Handler specific?
Direct measures of human behavior				
Specific actions by caretaker during animal handling/care (e.g., shouting, electric prod usage, excessive force)	Provides direct measures of a caretaker's behavior that can provide opportunity for improvement (and ability to assess change in behavior)	Only provides a snapshot in time and may not be representative of the overall interactions the individual has with animals	Dynamic	Yes
Personality testing	May assist in determining trends between caretaker personality and animal responses if explored on a large scale	Only provides information about the caretaker and could provide information that is out of context and not applicable	Static	Yes
Incidence of positive interactions between animals and caretakers	Focuses on positive welfare parameters rather than negative	Not as commonly used as a welfare indicator, perhaps needs more exploration	Dynamic	Yes
Self-reported attitude (response to questions regarding interactions)	May assist in determining trends between caretaker and animal responses if explored on a large scale	Information is self-reported by caretaker	Dependent on how it is used	Yes
Indirect measures of human behavior, i.e. animal response				
Fear tests including distance measures (the distance the animal maintains between itself and the human caretaker), handling measures (the animal response to being handled by a human caretaker), and a subjective rating of the animal response to the human	Provides information for researchers and caretakers regarding an animal's interaction with humans, in general	May reflect factors other than human–animal relationship (e.g., quantity of handling, rather than quality). Further exploration needed to verify reliability, repeatability, and standardization of various tests	Dynamic (which is part of the problem as being used as a reliable measure)	Usually tested as a generalized measure, not handler specific
Vigilance	Measure of animal attentiveness to potential danger	Research technique	Dynamic	Yes, tested by researchers that handled cattle in a specific manner
'Flinch, step, kick' or other species-specific behaviors exhibited in response to fear, stress, or pain (e.g., foot stamping, tail flicking, etc.)	Easily measurable and information can be collected in a variety of contexts	Outcomes may be influenced by other factors other than human–animal interaction (e.g. mastitis or teat injury)	Dynamic	No
Change in level of production performance (e.g., milk yield, weight gain)	Provides information regarding physical and physiological state of the animal	Change may be impacted by other factors aside from human–animal interaction. Human–animal interaction may be significant but not cause a change in performance parameters	Dynamic	No
Change in physiological indicators (e.g., cortisol, epinephrine, lactate)	Provides information regarding physiological state and potential short-/long-term stress response of the animal	Sometimes difficult to obtain samples and the process of collecting the sample for testing can affect the outcome	Dynamic	No

4.6 Conclusions

Human–animal interactions play a significant role in the management of farmed animals. Both positive and negative interactions can have an impact on the psychological and physiological state of cattle, thus affecting the welfare, health, and production of animals and their caretakers. More research is needed to understand the psychological impact on the animal caretaker when dealing with difficult procedures such as euthanasia or other on-farm procedures that are a necessity but could cause stress to the animal (such as castration and dehorning). Additional research should also be conducted to explore the impacts of purposefully promoting positive human–animal interactions during the rearing of cattle, i.e. when is the optimum time to interact with an animal to positively influence future interactions with humans as the animal develops and moves through the supply chain?

The research methodology used to assess an animal's response to human–animal interactions also needs to be thoroughly assessed with the goal of identifying a standardized method (or methods) to accurately and precisely capture the true response of the animal to the human caretaker. Currently there does not exist a standard method, making comparisons among studies difficult. Additionally, the repeatability and reliability of many of the tests has been questioned (de Passillé and Rushen 2005). With the continuous development of on-farm quality-assurance programs that want to understand and measure the "stockmanship" on a farm, it is important that the appropriate parameter is captured. It is also necessary to consider the individual animal differences within a herd and how that may affect the test outcomes. There are other measures of production and performance that also aid in explaining the full welfare state of the animal helping to determine the overall management of the animals.

The livestock industry in general over the past several years has recognized the importance of consistent, substantial, and repeated training on how to treat and handle animals properly. By providing animal caretakers with opportunities to grow, there will be an increase in ownership which ultimately will improve job satisfaction, job retention, worker and animal safety, and animal welfare and performance. Part of animal-caretaker training should include demonstrating the direct impact that they have on the animals with which they interact, both in a positive and negative way. Showing a human caretaker how their actions directly affect an animal is essential to developing a competent, compassionate, and motivated stockperson.

References

1. Ajzen I. *Attitudes, Personality, and Behavior* Milton Keynes, United Kingdom: Open University Press; 1988; 178 pp.
2. Alvasen K, Mork MJ, Dohoo IR, Sandgren CH, Thomsen PT, Emanuelson U. Risk factors associated with on-farm mortality in Swedish dairy cows. *Prev Vet Med.* 2014;117:110–120.
3. AVMA American Veterinary Medical Association, 2016. Human–animal Bond. <https://www.avma.org/KB/Resources/Reference/human-animal-bond/Pages/Human-Animal-Bond-AVMA.aspx> (accessed June 2016).
4. Bertenshaw CE. *The Influence of Positive Human–Animal Interaction During Rearing on the Welfare and Subsequent Production of the Dairy Heifer (Ph.D thesis)* Newcastle-upon-Tyne, UK: Newcastle University; 2002.
5. Boissy A. Fear and fearfulness in determining behavior. In: Grandin T, ed. *Genetics and the Behaviour of Domestic Animals*. San Diego, USA: Academic Press; 1998;67–111.
6. Boissy A, Bouissou MF. Effects of early handling on heifers on subsequent reactivity to humans and to unfamiliar situations. *Appl Anim Behav Sci.* 1988;22:259–273.
7. Boivin X, LeNeindre P, Chupin JM. Establishment of cattle-human relationships. *Appl Anim Behav Sci.* 1992;32:325–335.
8. BQA Beef Quality Assurance, 2016. Feedyard Assessment Assessor's Guide. <http://www.bqa.org/resources/assessments> (accessed July 2016).
9. Breuer K, Hemsworth PH, Barnett JL, Matthews LR, Coleman GJ. Behavioural responses to humans and productivity of commercial dairy cows. *Appl Anim Behav Sci.* 2000;66:273–288.
10. Coleman GJ, Hemsworth PH, Hay M. Predicting stockperson behaviour towards pigs from attitudinal and job related variables and empathy. *Appl Anim Behav Sci.* 1998;58:63–75.
11. de Passillé AM, Rushen J, Ladewig J, Petherick C. Dairy calves' discrimination of people based on previous handling. *J Anim Sci.* 1996;74:969–974.
12. de Passillé AM, Rushen J. Can we measure human-animal interactions in on-farm animal welfare assessment?: Some unresolved issues. *Appl Anim Behav Sci.* 2005;92:193–209.
13. Drugociu G, Runceanu L, Nicorici R, Hritcu V, Pascal S. Nervous

typology of cows as a determining factor of gender and productive behaviour. *Anim Breed Abstr.* 1977;45:1262.
14. English P, Burgess G, Segundo R, Dunne J. *Stockmanship: Improving the Care of the Pig and Other Livestock* Ipswich, UK: Farming Press Books; 1992; 220 pp.
15. Fishbein M, Ajzen I. *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research* Reading, MA: Addison-Wesley Publishing Company; 1975; 578 pp.
16. Fogle B. The changing roles of animals in Western society: influences upon and from the veterinary profession. *Anthrozoos*. 1999;12:234–239.
17. Grandin T, Curtis SE, Taylor IA. Toys, mingling and driving reduce excitability in pigs. *J Anim Sci.* 1987;6:230–231.
18. Hemsworth PH. Human-livestock interaction. In: Benson GJ, Rollin BE, eds. *The Welfare of Farm Animals, Challenges and Solutions*. Iowa, USA: Blackwell Publishing; 2004;21–38.
19. Hemsworth, P.H., Coleman, G.J. (Eds.), 2011. Human–Livestock Interactions: The Stockperson and the Productivity and Welfare of Intensively Farmed Animals, 2nd ed. CABI, Oxford, 194 pp.
20. Hemsworth PH, Barnett JL, Hansen C. The influence of handling by humans on the behaviour, growth and corticosteroids in the juvenile female pig. *Horm Behav.* 1981a;15:396–403.
21. Hemsworth PH, Brand A, Willems P. The behavioural response of sows to the presence of human beings and its relation to productivity. *Livestock Prod Sci.* 1981b;8:67–74.
22. Hemsworth PH, Barnett JL, Hansen C. The influence of handling by humans on the behaviour, reproduction and corticosteroids of male and female pigs. *Appl Anim Behav Sci.* 1986;15:303–314.
23. Hemsworth PH, Hansen C, Barnett JL. The effects of human presence at the time of calving of primiparous cows on their subsequent behavioural response to milking. *Appl Anim Behav Sci.* 1987;18:247–255.
24. Hemsworth PH, Barnett JL, Tilbrook AJ, Hansen C. The effects of handling by humans at calving and during milking on the behaviour and milk cortisol concentrations of primiparous dairy cows. *Appl Anim Behav Sci.* 1989;22:313–326.
25. Hemsworth PH, Coleman GJ, Barnett JL. Improving the attitude and behaviour of stockpersons towards pigs and the consequences on the behaviour and reproductive performance of commercial pigs. *Appl*

Anim Behav Sci. 1994;39:349–362.
26. Hemsworth PH, Coleman GJ, Barnett JL, Borg S. Relationships between human–animal interactions and productivity of commercial dairy cows. *J Anim Sci.* 2000;78:2821–2831.
27. Hemsworth PH, Rice M, Karlen MG, et al. Human–animal interactions at abattoirs: relationships between handling and animal stress in sheep and cattle. *Appl Anim Behav Sci.* 2011;135:24–33.
28. Hoe FGH, Ruegg PL. Opinions and practices of Wisconsin dairy producers about biosecurity and animal well-being. *J Dairy Sci.* 2006;89:2297–2308.
29. Huggard PK, Huggard EJ. *When the caring gets tough: Compassion fatigue and veterinary care*. *VetScript* 2008;14–16.
30. Kondos, A.C., 1983. Human resources. In: Proceedings of the 2nd National Pig Production and Marketing Review Conference, Hobart. Standing Committee on Agriculture, Department of Primary Industries and Energy, Canberra, Australian Capital Territory.
31. Lanier JL, Grandin T, Green R, Avery D, McGee K. A note on hair whorl position and cattle temperament in the auction ring. *Appl Anim Behav Sci.* 2001;73:93–101.
32. Lensink BJ, Boissy A, Veissier I. The relationship between farmers' attitude and behavior towards calves, and productivity of veal units. *Ann Zootech*. 2000;49:313–327.
33. Lensink BJ, Raussi S, Boivin X, Pyykkonen M, Veissier I. Reactions of calves to handling depend on housing condition and previous experience with humans. *Appl Anim Behav Sci.* 2001;70:187–199.
34. Lloyd DH. Effective staff management. In: Freedman BM, Boorman KN, eds. *Economic Factors Affecting Egg Production*. Edinburgh, UK: British Poultry Science Ltd; 1974;221–251.
35. Mason VM, Leslie G, Clark K, et al. Compassion fatigue, moral distress and work engagement in surgical intensive care unit trauma nurses: a pilot study. *Dimens Crit Care Nurs*. 2014;33:215–225.
36. McConnel CS, Garry FB, Hill AE, Lombard JE, Gould DH. Conceptual modeling of postmortem evaluation findings to describe dairy cow deaths. *J Dairy Sci.* 2010;93:373–386.
37. Mitchener KL, Ogilvie GK. Understanding compassion fatigue: keys for the caring veterinary health team. *J Am Anim Hosp Assoc.* 2002;38:307–310.

38. Mithen S. The hunter-gatherer prehistory of human–animal interactions. *Antrhrozoos*. 1999;12:195–204.
39. Morbidity and Mortality Weekly Report (MMWR). Fatalities caused by cattle–Four states, 2003–2008. *Centers for Disease Control*. 2009;58:800–804.
40. NAMI, 2017. North American Meat Institute. Recommended Animal Handling Guidelines and Audit Guide: A Systematic Approach to Humane Handling. <http://www.animalhandling.org/ht/d/sp/i/26752/pid/26752> (accessed July 2016).
41. NPB, 2014. National Pork Board. Common Industry Audit. <http://www.pork.org/common-industry-audit/> (accessed July 2016).
42. Price EO. Behavioural aspects of animal domestication. *Q Rev Biol*. 1984;59:1–32.
43. Rollin BE. Euthanasia, moral stress, and chronic illness in veterinary medicine. *Vet Clin N Am Small Anim Pract.* 2011;41:651–659.
44. Rushen J. Changing concepts of farm animal welfare: bridging the gap between applied and basic research. *Appl Anim Behav Sci.* 2003;81:199–214.
45. Rushen J, de Passille AMB, Munksgaard L. Fear of people by cows and effectson milk yield, behaviour and heart rate at milking. *J Dairy Sci.* 1999;82:720–727.
46. Schmied C, Boivin X, Wailblinger S. Stroking different body regions of dairy cows:effects on avoidance and approach behavior toward humans. *J Dairy Sci.* 2008;91:596–605.
47. Schmied C, Boivin X, Scala S, Waiblinger S. Effect of previous stroking on reactions to a veterinary procedure. *Interact Stud.* 2010;11:467–481.
48. Schütz KE, Hawke M, Waas JR, et al. Effects of human handling during early rearing on thebehaviour of dairy calves. *Anim Welf.* 2012;21:19–26.
49. Schwartkopf-Genswein K, Ahola J, Edwards-Callaway L, Hale D, Patterson J. Symposium paper: Transportation issues affecting cattle well-being and considerations for the future. *Profess Anim Sci.* 2016;32:707–716.
50. Seabrook MF. A study to determine the influence of the herdsman's personality on milkyield. *J Agric Labour Sci.* 1972;1:45–59.
51. Seabrook MF. The psychological relationship between dairy cows and

dairy cowmenand its implications for animal welfare. *Int J Study Anim Probl*. 1980;1:295–298.
52. Segundo, R.C., 1989. A Study of Stockpeople and Managers in the Pig Industry With Specialemphasis on the Factors Affecting Their Job Satisfaction (M.Sc. thesis). University of Aberdeen, Aberdeen, Scotland.
53. Sherwen SL, Harvey TJ, Magrath MJL, Butler KL, Fanson KV, Hemsowrth PH. Effects of visual contact with zoo visitors on black-capped capuchin welfare. *Appl Anim Behav Sci*. 2015;167:65–73.
54. Simon GE, Hoar BR, Tucker CB. Assessing cow–calf welfare Part 1:Benchmarking beef cow health and behavior, handling; and management, facilities and producer perspectives. *J Anim Sci*. 2016a;94:3476–3487.
55. Simon GE, Hoar BR, Tucker CB. Assessing cow–calf welfare Part 2: Risk factors for beef cow health and behavior and stockperson handling. *J Anim Sci*. 2016b;94:3488–3500.
56. Suarez SD, Gallup GG. Open-field behaviour in chickens: the experimentier is apredator. *J Compar Physiol Psychol*. 1982;96:432–439.
57. Thomsen PT, Sørensen JT. Factors affecting the risk of euthanasia for cows in Danish dairy herds. *Vet Rec*. 2009;165:43–45.
58. Thomsen PT, Kjeldsen AM, Sørensen JT, Houe H. Mortality (including euthanasia) among Danish dairy cows (1990–2001). *Prev Vet Med*. 2004;62:19–33.
59. Toates FM. *Animal Behaviour – A Systems Approach* Chichester, West Sussex, UK: John Wiley & Sons; 1980; 312 pp.
60. United States Department of Labor, 2003–2007. Bureau of labor statistics. Injuries, Illnesses, and Fataltes. Census of Fatal Occupational Injuries (CFOI)–Current and Revised Data. 2003–2007. Available at <http://www.bls.gov/iif/oshcfoi1.htm>.
61. United States Department of Labor, 2015a. Bureau of labor statistics. Occupational Outlook Handbook. Agricultural Workers. Available at <http://www.bls.gov/ooh/farming-fishingand-forestry/agricultural-workers.htm#tab-4>.
62. United States Department of Labor, 2015b. Bureau of labor statistics. Occupational Outlook Handbook. Animal Care and Service Workers. Available at <http://www.bls.gov/ooh/personal-care-and-service/animal-

care-and-service-workers.htm>.
63. United States Department of Labor, 2015c. Bureau of labor statistics. Occupational Outlook Handbook. Farmers, Ranchers and Other Agricultural Managers. Available at <http://www.bls.gov/ooh/management/farmers-ranchers-and-other-agricultural-managers.htm>.
64. Voisinet BD, Grandin T, Tatum JD, O'Connor SF, Struthers JJ. Feedlot cattlewith calm temperaments have higher average daily gains than cattle with excitable temperaments. *J Anim Sci.* 1997;75:892–896.
65. Waiblinger S, Boivin X, Pedersen V, et al. Assessing the human–animal relationship in farmed species: A critical review. *Appl Anim Behav Sci.* 2006;101:185–242.
66. Waiblinger S, Menke C, Coleman G. The relationship between attitudes, personal characteristics and behaviour of stockpeople and subsequent behaviour of dairy cows. *Appl Anim Behav Sci.* 2002;79:195–219.
67. Welp T, Rushen J, Kramer DL, Festa-Bianchet M, de Passillé AMB. Vigilance as ameasure of fear in dairy cattle. *Appl Anim Behav Sci.* 2004;87:1–13.
68. Willis GL. A possible relationship between the flinch, step and kick response and milk yield in lactating cows. *Appl Anim Ethol.* 1983;10:287–290.
69. Woiwode, R., Grandin, T., Kirch, B., Paterson, J., 2015. Validation of the beef qualityassurance feedyard assessment for cattle handling. In: Proceedings for the Western Section, American Society of Animal Science, vol. 66, Ruidoso, NM.

5

Cattle priorities

Feed and water selection, ability to move freely and to access pasture

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Abstract

Animals' ability to live natural lives and to perform behaviors that are important to them are two major components in animal welfare discussions. The intensive nature of many dairy and beef systems has raised a public concern that the welfare is reduced compared with extensive systems, largely because confinement might restrict the animals' ability to move freely and to perform their full repertoire of natural behaviors, such as grazing. The aim of this chapter is to investigate how systems that differ in the degree of dietary and spatial restriction influence the behavior and welfare of cattle. By reviewing relevant literature, we will provide scientific evidence that it is important to cattle to be able to access appropriate food and water, to move around freely, and to access pasture, focusing largely on factors driving these motivations.

Keywords

Diet selection; forage; roughage; movement; motivation; pasture; water consumption

5.1 Introduction

Societal ethical concerns regarding the welfare of animals can be divided into three overlapping categories: (1) physical functioning, meaning that animals should function well in the sense of good health, and normal growth and development, (2) affective state, which describes how the animal is feeling, and (3) naturalness, meaning that the animals should have the ability to express normal behaviors that they are strongly motivated to perform in an environment with some natural elements (Fraser, 2008). Physical function (e.g., health and production) and negative affective states (e.g., pain and hunger) have historically been the main focus in welfare assessments. It is now, however, generally agreed that welfare assessments also need to take into consideration positive affective states, such as pleasure or being content, and the ability to perform behaviors that are important to the animals. The World Organization for Animal Health (OIE) has included the ability of animals to perform their full repertoire of natural behaviors as a part of their definition of good welfare:

> *Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. (OIE, 2016)*

In light of these developments, the intensive nature of many dairy and beef systems has raised a public concern that animal welfare is reduced compared with extensive systems, largely because confinement restricts the animals' ability to move freely and to carry out natural behaviors, such as grazing. The level of confinement varies from being tethered and with no ability to turn around (e.g., tie-stalls, veal crates), being able to turn around (e.g., individual calf rearing in small pens), being able to take a few steps (e.g., calf rearing in hutches with a small yard), being able to move around a pen or lot (e.g., group-reared calves, indoor feedlots, free-stalls), to being able to move relatively freely (e.g., bedded packs, outdoor feedlots, drylots), and graze (e.g., pastured dairy systems, cow–calf systems) (summarized in Table 5.1). Freedom of movement is an important aspect of animal welfare as it provides opportunities to control the environment, reduce frustration, and to maintain physical health (Gonyou, 1996). For example, cattle with pasture access are able to both move around freely and to graze and have improved health, such as less lameness (Somers et al., 2003; Wells et al., 1999; Hernandez-Mendo et al., 2007), and fewer reproductive and metabolic issues (Washburn et al., 2002). The performance of locomotor behaviors, such as locomotor play in young animals, may also have reinforcing properties, and may therefore be associated with positive feelings (Held and Špinka, 2011). However, the welfare of animals on pasture may be associated with several issues, mainly related to nutritional and climatic challenges (Hemsworth et al., 1995; Fisher et al., 2003; Hernandez-Mendo et al., 2007). Therefore, pasture-based management systems cannot always be considered more welfare friendly than intensive systems (for a review of the welfare of cows in continuously housed and pasture-based dairy production systems, see Arnott et al., 2017).

Table 5.1

Summary of opportunities for undertaking different behaviors by cattle in various management systems

Management system	Self-groom	Turn around	Take several steps	Spend most of day in movement	Run/play	Lie in all positions	Choose where to spend time[a]	Graze	Select diet[b]	Access roughage
Veal crates	No	No	No	No	No	No	No	No	Yes/No[c]	No
Tethered calf stalls	No	No	No	No	No	No	No	No	Yes/No[c]	Yes/No[c]
Individual calf pens	Yes/Limited[d]	Yes/Limited[d]	No	No	No	Limited/No[d]	No	No	Yes/No[c]	Yes/No[c]
Group-housed calves	Yes	Yes	Yes	Yes	Yes	Yes	Yes/Limited[d,e]	No	Yes/No[c]	Yes/No[c]
Calf hutches with small yard	Yes	Yes	Yes/Limited	Limited	No	Yes	Limited	No	Yes/No[c]	Yes/No[c]
Tie-stall without turnout	No	No	No	No	No	No	No	No	Yes	Yes
Free-stall/indoor feedlot	Yes	Yes	Yes	Yes/Limited[e]	Limited[e]	Limited/No[e]	Yes/Limited[e]	No	Yes	Yes/Limited[f]
Bedded pack/outdoor feedlot/drylot	Yes	Yes	Yes	Yes/Limited[e]	Yes	Yes	Yes	No	Yes	Yes/Limited[f]
Pasture (dairy, cow–calf systems)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a]Ability to choose where and when to carry out behavioral activities, such as lying and feeding.

[b]Ability to select from an appropriate diet composition based on preference.

[c]Depending on feeding program used.

[d]Depending on size of pen and calf.

[e]Depending on the quality of the space available.

[f]Limited for fattening diets.

Similarly, systems also vary in their degree of dietary intensiveness, with pasture being at one extreme and systems that involve a diet with little or no roughage, such as veal, fattening, or feedlot rations at the other (Table 5.1). As grazing ruminants, cattle have digestive systems that are equipped to process large amounts of feed substrate over the day. For pasture-fed cattle, this system works well if there is sufficient herbage to consume. Many dairy and beef cattle, raised in more intensive situations (e.g., veal calves, fattening, or drylots), do not graze pasture, but rather eat conserved feeds. Many of those feedstuffs may be less fibrous, and much more rapidly ingested, fermented, and digested, than grasses and other pasturage. While feeding conserved feedstuffs may not necessarily reduce cattle welfare in itself, if animals are limited in terms of their opportunity to spend time eating, particularly accessing roughages, they may exhibit signs of reduced welfare. Cattle also demonstrate much propensity to select dietary components, regardless of whether consuming pasture or when eating a conserved mixed diet (i.e. by "sorting" through them). There is evidence that such selection is not only driven by palatability differences in the feeds provided, but may also be driven by the animal's desire to balance nutrient intake, avoid toxins, and maintain rumen function. Water is the most important essential nutrient that animals consume and water intake is closely related to feed intake. As such, factors that influence water quality and subsequent palatability will affect the willingness of cattle to consume water and optimize their intake of both feed and water.

Whereas many key drivers for animal welfare changes appear to arise from a public concern, to properly care for the welfare of animals and improve management systems and practices, there is a need for scientific evaluation of what behaviors are most important to animals and can be considered a behavioral need, defined in this chapter as "internally-driven behaviors that animals are highly motivated to perform and if restricted in their expression, compromises the individual animal's welfare" (Duncan, 1998; for other definitions and interpretations, see for example Jensen and Pedersen, 2008; Jensen and Toates, 1993).

In this chapter we will investigate how systems that differ in the degree of intensiveness and confinement influence cattle, in terms of how important it is for the animal to be able to access appropriate food and water, to be able to move around freely, and to access pasture. More specifically, we will discuss how important it is to cattle to be able to select their diets, with particular attention to the motivation for accessing and consuming roughage. Further, dietary preferences and selection will be reviewed, focusing on those factors driving them. We will also provide examples of how water consumption is impacted by water quality and palatability. We will then investigate what it means to cattle to be able to move freely in two ways: firstly, by describing animal responses when restrained and when provided with abundant space allowances, and secondly, by discussing how animals respond when they are able to move freely after periods of confinement. Lastly, we will discuss how motivated cattle are to access pasture, focusing largely on factors influencing animal preferences when they are given a free choice between intensive and extensive systems.

5.2 Feed and water preferences

5.2.1 Motivation to forage and access roughage

As ruminants, cattle are herbivores whose digestive tract is highly developed to include a unique mode of digestion, characterized by pre-gastric retention and fermentation by symbiotic microbes, that allows them to efficiently access nutrients from fibrous feeds. Associated with that digestive process is the consummatory behavior that ruminants engage in to fill their rumen with feed to digest. Cattle are grazers, which have the ability to consume large amounts of herbage over the day. In fact, under grazing conditions, cattle will engage in grazing behavior between 6 and 13 hours per 24-h period (Kilgour, 2012). This feeding time is split into a number of smaller meals occurring throughout the day, with the largest meals occurring in the early morning and late afternoon.

While this described feeding behavior holds true for cattle that are kept extensively on pasture and allowed to graze, that is not the reality for all. Many dairy and beef cattle raised in more intensive situations are fed conserved feeds, which often include feedstuffs which are less fibrous, and much more rapidly fermented and digested than grasses and other pasturage. As a result, cattle in these situations are able to consume a larger amount of total feed in a shorter amount of time. For example, dairy cattle fed a total mixed ration (TMR), containing 50% forage (on a dry matter basis), will spend 3–5 hours eating per day, while beef feedlot cattle fed a high-grain finishing diet (<10% forage) will spend less than 2 hours eating per day.

Lindström and Redbo (2000) demonstrated that lactating dairy cows are motivated to orally manipulate (consume) feed even when their rumens are filled artificially, suggesting that cattle may have a behavioral need to perform foraging behavior even when metabolically satiated. Related to that, when cattle are limit-fed, they will display oral stereotypies such as head nodding, tongue rolling, or bar-biting/licking (Redbo et al., 1996; Redbo and Nordblad, 1997; Lindström and Redbo, 2000). These stereotypic behaviors are associated with frustration of feeding motivation and possibly hunger (Bergeron et al., 2006), and thus may be indicative of reduced welfare. In addition to these effects of not spending sufficient time consuming feed, the rapid consumption of feed may also be problematic from a health standpoint. When cattle consume their feed too fast, particularly in large meals with a high proportion of rapidly fermentable carbohydrates, they experience large postprandial drops in rumen pH and are susceptible to ruminal acidosis (Krause and Oetzel, 2006).

The motivation to graze and forage has also been demonstrated in beef cattle. Tuomisto et al. (2008) kept Hereford bulls either in a barn or in forested paddocks and offered them all TMR *ad libitum*. Those researchers found that the paddock bulls grazed and browsed in addition to eating the TMR. While the TMR diet was designed to meet the bulls' nutritional requirements and they consumed the same amount as bulls housed in a barn environment, it was suggested that by grazing and moving in the paddock, the bulls could utilize the opportunities for more diverse behavior and this may have had a positive effect on their welfare (Tuomisto et al., 2008).

In most situations dairy and beef cattle are fed *ad libitum* to maximize nutrient intakes, and thus also production (meat and milk output), however, there are situations where feed or ability to access forage may be limited. The practice of limit-feeding dairy heifers with a high-concentrate ration has been promoted as a way of targeting nutrient intake, while reducing nutrient excretion. This feeding practice results in heifers consuming their feed in 1–2 hours/day (Kitts et al., 2011; Greter et al., 2011), leaving them highly motivated to feed and potentially experiencing negative affective states of hunger and frustration. Greter et al. (2015) demonstrated that under such feeding circumstances, heifers would be willing to pay high prices to obtain supplementary roughage by pushing a weighted gate; those heifers pushed 5% of their body weight (BW) immediately after consuming their daily allotment of nutrient-dense TMR, and 10% of their BW following a 21-h period of time after feed consumption. Those researchers also demonstrated, in a separate study, that such limit-fed heifers had a higher preference for long-particle supplementary straw compared to that with short particles (Greter et al., 2013). The authors suggested that the preference may have been driven by a number of factors, including the desire to: (1) increase physical fill that was felt by consumption of the longer, bulky fiber of long straw, (2) ameliorate any drop in postprandial pH encountered through consumption of the nutrient-dense, limit-fed TMR, or (3) spend more time foraging, masticating, and ruminating the long particles, which may, as described above, have helped the animals to satisfy a behavioral need to forage.

Veal calves are often fed diets consisting of only milk, with or without supplemental grain concentrate, and little to no forage. Similar to the work in limit-fed heifers, Webb et al. (2014) demonstrated that veal calves, fed a high-energy diet comprised of milk replacer and concentrate, were motivated to work for roughage (by pressing panels). Further, those calves also showed a preference for long hay particles, as compared to chopped hay. Those authors suggested that their findings provide support for the idea that cattle are not only able to make food choices based on rumen function, but also potentially on their high motivation and, thus, need to forage.

Dairy heifer calves are also often raised to the point of weaning off milk without the provision of forage. While there is concern that forage may displace concentrate intake and, consequently, impair rumen papillae development in young calves, there is evidence to suggest that forage provision does not reduce concentrate intake and may have a positive impact on the rumen environment (Khan et al., 2011; Castells et al., 2012). Further, provision of hay to dairy calves has been shown to reduce the occurrence of non-nutritive oral behaviors (Castells et al., 2012), suggesting that it satisfies a need to exercise foraging behavior in those neonates. Further support for this was recently provided by Costa et al. (2016), who demonstrated that dairy calves primarily fed calf starter, preferentially sorted a supplementary allotment of TMR for the long roughage particles. It is not surprising, then, that when dairy calves are offered a choice of concentrate and hay, across multiple studies they have been shown to select a proportion of hay ranging between 5 and 30% of their total dry matter intake (Castells et al., 2012; Miller-Cushon et al., 2013; Khan et al., 2011).

Beef feedlot cattle are another example of a limited opportunity to forage. During the finishing phase, these cattle are typically provided diets with only 5–10% forage, despite an apparent desire to consume fiber. Evidence for that desire was demonstrated by DeVries et al. (2014a); in that study beef heifers fed a backgrounding diet consisting of 60% forage (on a dry matter basis) sorted against the longest, most-fibrous, ration particles. After transitioning heifers to a high-grain diet (with 9% forage), the heifers changed their selection pattern, sorting for the longest, most-fibrous ration particles. While this change in dietary selection indicates a desire to consume fibrous feedstuffs when they are provided in a limited amount, there is little research to assess the strength of the motivation to access roughage when beef cattle are fed high-grain, feedlot finishing diets. Van Os et al. (2017) recently demonstrated that cattle fed a high-grain finishing diet were highly motivated to consume roughage. In that study, beef heifers pushed nearly half of their body weight and worked to obtain hay immediately after its delivery and 98% sooner than those fed an all forage diet. This, again, suggests that these beef animals fed a high-grain diet are exhibiting a behavioral need to forage. It is interesting to note, however, that those heifers with unrestricted access to hay also pushed considerable weight to access a small additional portion of hay. Those researchers suggested that this is the first demonstration of contrafreeloading in cattle, which may indicate the potential importance for the heifers of performing foraging behavior, expressing control over their environment, or gathering information about available food sources.

5.2.2 Dietary preferences and selection

Regardless of the feeding situation, cattle demonstrate the ability and desire to preferentially consume certain feedstuffs or components of feedstuffs. As described by Rutter (2006), it is important to differentiate between what cattle want to eat (i.e. preference) and what they actually consume given the circumstances in which the feed is presented to them in (i.e. selection). This means that when provided the opportunity to select from different feeds, cattle will select what they prefer, however, there may be environmental circumstances that limit the animals' ability to express that preference. For grazing cattle, their ability and propensity to preferentially consume is dictated by the types and abundance of plant species available to them. As reviewed by Rutter (2006), when preference for legumes and grasses are tested with grazing cattle, they typically consume a mixed diet, with a preference for consuming legumes in the morning, and greater proportion of grasses over the course of the day; in addition lactating cattle may show greater preference for legumes. Rutter (2006) also summarized the theories for the biological basis underpinning these preferences, including the desire to balance nutrient intake, maintain rumen function, avoid toxins, and avoid predators.

For cattle that are fed conserved feeds (e.g., hay, silage, grain), there is much empirical evidence to suggest that they too will show strong dietary preference, selecting for various feed types and components under a variety of different feeding conditions. This selective consumption is observed, despite feed often being provided as a TMR, with the aim of promoting consistency in nutrient intake and limiting of ability to select individual feed components (Coppock, 1977). In lactating dairy cattle, selection is typically against longer forage particles and in favor of the smaller, highly fermentable particles (Leonardi and Armentano, 2003; DeVries et al., 2007a); this results in an unbalanced intake of nutrients and reduces the nutritive value of the ration remaining available to the group of animals for the rest of the day (DeVries et al., 2005).

As with grazing situations, the dietary selection of mixed rations composed of conserved feeds is influenced by a number of factors. For the most part, palatability (i.e. acceptance of food based on flavor) of individual ration components is the major factor driving feed sorting of mixed rations. The most commonly reported direction of feed sorting, with cattle sorting for smaller, highly fermentable, particles and thus discriminating against longer forage components, is typically ascribed to the selection in favor of the most palatable ration components. For rations including a grain component, this pattern of sorting is consistent with a preference for sweet flavors exhibited by cattle (Nombekela et al., 1994). While less researched, preferences for particular feed components are clearly present in young calves. Miller-Cushon et al. (2014a) found that dairy calves prefer certain feed components commonly included in starter rations, including soybean meal and wheat meal, whereas less preference was demonstrated for corn gluten meal and rapeseed meal. While some of these feed ingredients may be less preferable due to aversive flavors, such as the bitter flavor of glucosinolates in rapeseed meal, the factors influencing the preference for others has yet to be established. It is also interesting to note that many feed preferences appear to be innate (as opposed to learned), as these preferences are apparent in previously inexperienced calves (Miller-Cushon et al., 2014a). In a study by Miller-Cushon et al. (2014b), calves were offered a choice of two mixed pelleted diets, similar in nutrient content, for the duration of the milk-feeding stage: one containing a low-protein base starter pellet and a high-protein soybean meal pellet, and the other contained a low-protein base starter pellet and a high-protein canola meal pellet. Calves exhibited a preference for the mixed diet containing the soybean pellet and, further, sorted within the soybean pellet mixture for protein and sorted within the canola meal pellet mixture against protein. These results suggest this feed selection was driven, to a greater extent, by palatability than nutrient requirements. It follows, therefore, that any deviations from this typical direction of feed sorting at the individual level may be due to other feedback mechanisms or requirements, overriding an innate sensory driven preference for certain flavors or feed components.

It is well established that ruminant dietary preferences may be influenced by forming associations (i.e. learning) between sensory properties of feed and postingestive feedback. Preferences for feeds may develop through positive postingestive feedback, by ingesting foods paired with nutrients, such as glucose (Burritt and Provenza, 1992) and aversions for feeds may develop through negative postingestive feedback resulting from toxins, such as lithium chloride (Burritt and Provenza, 1989), or excess amounts of a nutrient, such as urea (Kertz et al., 1982). There is evidence in dairy cows that both positive and negative postingestive feedback may influence dietary preferences and selection. Dohme et al. (2008) subjected TMR-fed dairy cows to a ruminal acidosis challenge, by restricting feed intake followed by provision of a large quantity of rapidly fermentable grain; this challenge was repeated three times at 14-day intervals. Those researchers found that with each subsequent challenge, dairy cows became less willing to consume the grain, as a result of negative postingestive feedback. Interestingly, in that same study, DeVries et al. (2008) found that upon experience of the bout of acidosis, cows altered their sorting behavior of a TMR to select in favor of long forage particles, rather than against these particles as they typically would. These researchers also provided some evidence to suggest that both the severity of acidosis, and repeated experience, influenced the extent by which the cows would sort their TMR to attenuate low ruminal pH. These data provide evidence that those cows were able to make a positive association with consumption of more fibrous particles and the alleviation of the symptoms of ruminal acidosis. Similarly, DeVries et al. (2014a) demonstrated that beef cattle, fed a high-grain, low-forage, feedlot diet will increase their sorting for the forage component of their diet upon experiencing a bout of acidosis. Those researchers also found that the degree to which they altered their sorting for the most fibrous dietary components was directly related to the degree of acidosis incurred (Fig. 5.1; DeVries et al., 2014b). These studies provide evidence that cattle may exhibit "nutritional wisdom" in response to altered rumen environments. It is unknown, however, what level of experience and, thus, postingestive feedback, is needed to make those associations and alterations in dietary selection.

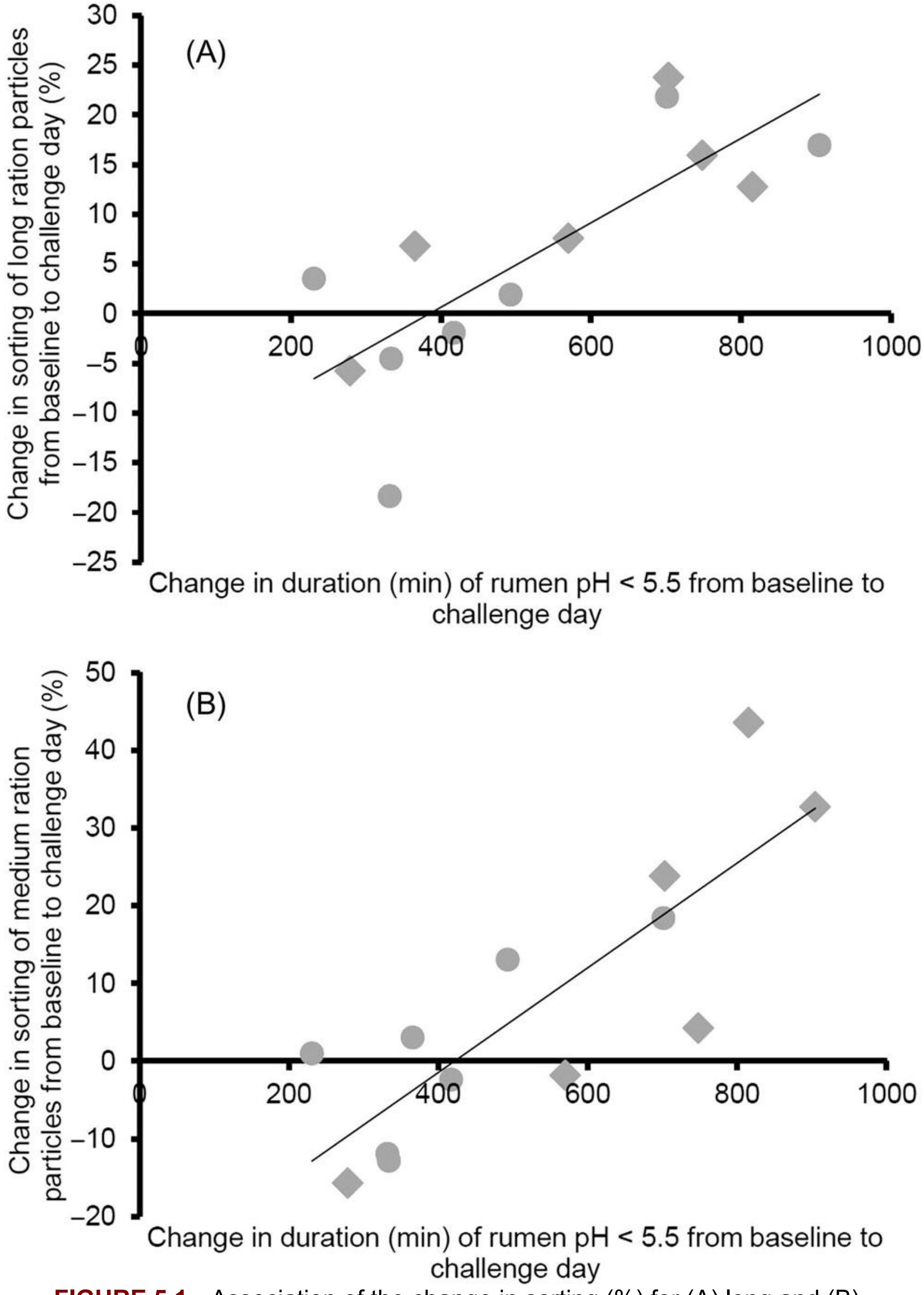

FIGURE 5.1 Association of the change in sorting (%) for (A) long and (B) medium ration particles with the change in duration (min) of rumen pH<5.5 from the baseline period to challenge day. Data are for beef heifers either long-adapted (circles) or short-adapted (diamonds) to a high-grain feedlot diet (9% forage). *Source:* Adapted from DeVries et al., 2014b.

Alterations in dietary selection in cattle may not only be limited to disrupted rumen function, but also to changing nutrient demands. In a study by DeVries et al. (2011), the changes in feed sorting behavior of lactating dairy cows in response to lactation demands were studied. Those researchers found that at peak milk production, when cows were mobilizing body reserves, cows were sorting against acid-detergent fiber (ADF) and for crude protein (CP) in their ration. DeVries et al. (2011) suggested that, in response to their nutrient demands for production, cows were sorting to maximize the digestibility of the feed consumed (i.e. by sorting against ADF) and their nutrient intake (i.e. by sorting for CP). Further research is needed to determine how changing physiological demands (associated with growth, lactation, and pregnancy) may influence the dietary selection of dairy cattle across time.

Research with dairy calves has provided support for the idea that changing physiological demands and experience may alter feed selection patterns. Miller-Cushon et al. (2013) found that calves provided a mixed diet (70% grain and 30% chopped hay) selected in favor of hay during the milk-feeding stage, but selected in favor of grain after weaning. Those authors suggested that sorting for the nutrient-dense grain portion of the ration may have been influenced by an increased reliance on solid feed for nutrients following removal of milk. Similarly, Miller-Cushon and DeVries (2011) exposed calves to either concentrate or hay prior to weaning, and found that they sorted a mixed diet (of that same concentrate and hay) in favor of the familiar feed component initially after weaning, but differences in sorting patterns did not persist, with all calves beginning to sort in favor of concentrate and against hay within 4 weeks after weaning. That change in sorting was likely related to the fact that calves needed to consume greater proportions of concentrate to meet their nutrient requirements for growth at that stage of life. More recently, Costa et al. (2016) demonstrated similar results; they offered calves access to both a TMR (containing roughly 51% silage and dry hay and 49% concentrate) and calf starter from birth. Ten days after weaning, calves in that study selected in favor of the long forage particles in the TMR and against the small particles. Interestingly, this pattern of sorting changed when the calf starter was removed from the diet, with calves sorting in favor of the smallest particles of the TMR, again suggesting that calves were now sorting in an effort to meet their nutrient requirements.

5.2.3 Water consumption and palatability

Water is essential for life and is thus the most important dietary nutrient for ruminants. Water consumption is positively associated with feed intake in both beef (Brew et al., 2011) and dairy (Stockdale and King, 1983) cattle. Factors which limit the desire of cattle to drink water, in particular its quality and palatability, have the potential to not only reduce welfare, but also to limit growth and production. The most studied influences on the quality and palatability of water include concentrations of dissolved minerals, microbial contamination, particularly from fecal matter, and temperature. Willms et al. (2002) suggested that high salt content of water can influence its consumption level, and thus also feed intake and growth rates of beef cattle. Similarly, Grout et al. (2006) demonstrated that when water contains high levels of sulfates, particularly magnesium sulfate, palatability and quality is decreased and beef cattle will decrease their water consumption, even to the point of indication of dehydration. Similar observations are made when considering fecal contamination of water. Willms et al. (2002) demonstrated that beef cattle will, when given a choice of clean water, avoid water that is contaminated with feces (0.05 mg/g water). In that same study, when testing the impact of only consuming contaminated water, they observed that water consumption was reduced at fecal concentrations above 2.5 mg/g water, followed by a reduction in feed consumption at concentrations greater than 5 mg/g water. Lardner et al. (2005) demonstrated similar results in a study when they tested different ways of treating contaminated water for beef cattle. In that study, as well as that by Willms et al. (2002), growth rates were linked to improvements in the palatability and quality of the water, and as a result cattle drank more and consumed more solid feed.

Another aspect of water provision which may influence cattle acceptability and consumption levels is its temperature. Although the literature is not completely consistent on this topic, there is evidence that reducing the temperature of drinking water (10°C vs 27–28°C) can reduce heat load by reducing body temperature and respiration rate in warm weather (with ambient temperature ranging from 20°C to 35°C) (Stermer et al., 1986; Wilks et al., 1990). Chilled drinking water has been shown to increase feed intake and milk production in dairy cattle (Milam et al., 1986; Wilks et al., 1990) and liveweight gains in beef cattle (Ittner et al., 1951; Lofgreen et al., 1975). Interestingly, despite these apparent benefits, particularly in warm climates, when given a choice cattle seem to prefer to consume water close to ambient temperatures (Wilks et al., 1990) and drink less chilled water (Ittner et al., 1951; Lofgreen et al., 1975). It is also noteworthy that these results may not always apply in cooler climates. In a Canadian study by Osborne et al. (2002), it was reported that water intake was 3–6% greater in all four seasons when cattle were offered heated water versus ambient drinking water (30–33°C vs 7–15°C). Feed intake increased by 4.5% during the summer when cattle consumed the heated water. However, it was also found in that study that milk yield was greater when the cattle consumed the ambient temperature water in both spring and summer. In contrast, in a Swedish study (with a mean temperature of 15.3°C, ranging from 10°C to 24°C), water consumption of dairy cows was lower when the cows were offered 24°C water than for 3°C, 10°C, or 17°C water (Andersson, 1985). Those researchers did not detect any impact of water temperature on dry matter intake, but did find that milk production was decreased when 3°C water was offered; it is possible that the energy required to warm the water within the cow limited resources required to sustain production.

Overall, the literature is consistent in terms of the beneficial impacts of providing cattle with clean, highly palatable water in terms of the intake, and subsequent production. However, the exact temperature water needs to be, in particular in relation to ambient conditions, to maximize acceptability and consumption is not yet known, and is an area for further research.

5.3 Freedom of movement

5.3.1 Effects of space restriction

Management systems that severely restrict normal behavior, such as freedom of movement including the ability to turn around, and self-grooming, are associated with both behavioral and physiological responses indicative of acute and chronic stress in both young calves and in adult dairy cattle. Even though there are systems where calves are group-reared and able to spend most of the day in movement (e.g., at least 1.5 m^2/calf for young group-reared calves in New Zealand), many calves raised for milking herd replacements, veal, or dairy beef are individually reared in varying levels of confinement, such as tethered where they are unable to turn around, in pens where the animals can only turn around depending on size of pen and calf (Fig. 5.2), or in hutches with a small yard where more movement is possible but still limited (e.g., taking a few steps). In hutches with small yards, however, the calves have a certain degree of control over their environment, e.g., to stay in sun or shade and ability to lie in different positions. Calves in close confinement (tied in stalls and in small individual pens) show physiological and behavioral indicators of chronic stress, reduced immune function (Cummins and Brunner, 1991; Friend et al., 1985; Le Neindre, 1993), and impaired locomotor ability, such as higher incidents of falls and stumbles when released into an open-field arena after a period of confinement compared to calves reared with more space or in group pens (Dellmeier et al., 1985; Sisto and Friend, 2001). The physiological evidence of chronic stress associated with movement restriction are largely reversed when calves were moved into less restrictive housing, i.e. moving from 0.56×1.2 m stalls to hutches (1.2×1.2×2.4 m long) (Friend et al., 1987). In a recent study, increasing the space allowance from 1.23 m^2 (conventional housing) to 1.85 m^2 and 3.71 m^2/calf improved some measures of performance, health, and respiratory immune competence of male Holstein calves reared for beef (Calvo-Lorenzo et al., 2016). Even though Tapkı et al. (2006) found no improvement of daily live weight gain in newborn dairy calves raised individually with more space (1.5 m^2, 2.25 m^2, and 4 m^2), behavioral differences suggested that the welfare of calves are better in the larger pens; calves spent more time eating, ruminating, walking, and playing in the bigger pens. More play behavior was also observed in the larger pens in an earlier study investigating the same space allowances (Jensen and Kyhn, 2000).

FIGURE 5.2 Individual housing of dairy calves in California. *Source:* Anonymous.

Severe restriction of movement by tethering of adult dairy cattle is still common practice in many parts of the world. Tethering limits or prevents dairy cattle from carrying out many of their natural behaviors, such as grazing, self-, and social grooming, other types of social interactions, and the ability to lie in all positions (e.g., lying on the side with extended legs, lying with the head supported) in a preferred or chosen location. Tethered dairy cattle show oral stereotypies, likely caused by a combination of restricted movement and feeding behavior, which are reversed when the animals are transferred from tie-stalls to pasture or loose housing (Redbo, 1990, 1992). Restriction through tethering also influenced the physiological stress response, by enhancing the adrenocortical activity and modification of the hypothalamus–pituitary–adrenal axis (Higashiyama et al., 2007; Ladewig and Smidt, 1989; Redbo, 1993). Part of the stress response may be due to animals having problems lying down in tie-stalls with concrete floors (Ladewig and Smidt, 1989; Jensen 1999a). For example, tethered heifers on partially slatted floors started to show the first intention to lie down 65 minutes before completing the movement, and had higher heart rates at this time, compared to 8.5 seconds by heifers on deep straw (Müller et al., 1989). The lack of movement and exercise is also associated with several negative health effects. Exercise promotes good health as it improves blood circulation and develops the muscular system (Davidson and Beede, 2009; Gustafson, 1993; Gustafson and Lund-Magnussen, 1995; Popescu et al., 2013). Cows with regular exercise demonstrate reduced lameness and have fewer hoof disorders, hock lesions, and teat injuries compared to cows in tie-stalls with no or limited exercise (Bielfeldt et al., 2005; Keil et al., 2006; Loberg et al., 2004; Regula et al., 2004). There is also some evidence suggesting that exercise reduces blood levels of non-esterified fatty acids (NEFA), thus potentially reducing the risk of metabolic and digestive disorders (Adewuyi et al., 2006). In addition, locomotor behavior in young animals, often expressed as play behavior, is hypothesized by many to be involved in muscle and brain development, and enhance physical and cognitive skills (reviewed in Held and Špinka, 2011).

5.3.2 Motivation to move freely

Calves that are managed on pasture (Wood-Gush et al., 1984) or housed indoors with abundant space perform vigorous locomotor play behavior, including galloping, bucking, and buck kicking (Jensen, et al., 1998; Jensen, 1999b; Jensen and Kyhn, 2000, Fig. 5.3). In most conventional dairy housing systems, however, calves are housed under low space allowances, either individually or in small group pens, where the opportunity for grooming, to lie in different positions, and to perform locomotor behaviors is very limited (Le Neindre, 1993; Jensen, 1999b). The effects of space restrictions and the motivation for movement have been studied by observing the behavior of previously confined calves and adults in an open-field or "exercise" area. Calves and heifers that are managed with low space allowance will often engage in vigorous play behavior after being released from confinement (Dellmeier et al., 1985; Jensen, 1999b; Jensen and Kyhn, 2000) and vocalize more during play (Dellmeier et al., 1985), than animals managed with more space available. When calves were given a free choice between two pen sizes (2.4 vs 21 m^2), they showed a preference for the large pen over the small pen (Jensen, 1999b). In the same study, calves confined in a small pen (1.5 m^2) for 4, 2, or 1 week performed more locomotor play when released into a large arena than animals managed with more space (6.3 m^2), however, there was no effect of the confinement duration (Jensen, 1999b). The author suggested that the internal motivation to perform locomotor play increases within a few days or hours of confinement. This was confirmed in a later study, where the motivation to perform locomotor play increased with the duration of relatively short periods of confinement (0, 1, or 3 days, Jensen 2001). The play behavior shown in arena tests could partly be due to novelty (de Passillé et al., 1995; Mintline et al., 2012) and other experimental conditions, such as the size and shape of the arena (Mintline et al., 2012). In a recent study, calves in more confined housing (conventional veal stalls) showed more locomotor play in an arena test than those in larger pens, however, no evidence was found that this effect was mediated by fearful or exploratory responses to novelty (there was no difference in sniffing, vocalization, and defecation behavior; Rushen and de Passillé, 2014), thus supporting the idea that there is an internal build-up of motivation over time.

FIGURE 5.3 Locomotor play in dairy calves. *Source:* Photo courtesy of AgResearch Ltd.

Surprisingly few studies have investigated the motivation for movement in adult dairy cows. Tethered heifers gallop and buck more when released in a large arena, compared to animals that were managed in a large pen (Jensen, 1999b), demonstrating that adult animals show a similar rebound effect in play behavior to that seen in calves. In a study by Veissier et al. (2008), cows that were tied with no access to exercise displayed greater locomotor activity (walking and trotting) in a test arena after only 1 day of restraint. When the cows were able to exercise more regularly, the activity levels in the arena reverted back to levels observed when the cows were loose-housed. In another study by Loberg et al. (2004) where tethered cows had access to an outdoor paddock once daily, 2 days per week, 1 day per week, or no access, cows with less regular access to the paddock moved around more when given more space.

Cows also use this turnout, or release from tethering, for other activities such as exploring, social contact, playing, and self-grooming, particularly grooming body parts that could not be reached when tied (Loberg et al., 2004), indicating that freedom of movement is important for other behavioral reasons than for health and exercise. After release from a 4-h restraint in a self-locking stanchion, dairy cows spent more time grooming than unrestrained animals, and grooming was one of the first behaviors performed after restraint (Bolinger et al., 1997). Indeed, cows will groom with brushes, if given the opportunity. For example, group-housed dairy cattle that had access to a mechanical cow brush were grooming (scratching), on average, 9.7 times per day compared to 3.0 events by cows without the brush; 80% of those events were visits to the mechanical brush, particularly grooming body parts that were hard to reach by the cow (DeVries et al., 2007b). Dairy cattle will also use regular contact to maintain dominance relationships among each other; fighting will occur in some breeds when turnout becomes less frequent (Castro et al., 2011). Together, these studies indicate that cows are motivated to move freely after a relatively short period of restraint. To more precisely assess the strength of this motivation, however, other methodology is required, such as operant techniques as described by, for example, Jensen et al. (2004), Jensen and Pedersen (2008), and von Keyserlingk et al. (2017), and we encourage further research into this area.

Beef feedlots and dairy drylots confine cattle to environments where they are not able to move freely over large distances, but are able to move around in the pen. Not surprisingly, cattle were reported to take fewer steps when confined to a feedlot (9 m^2/animal), than in a pasture environment (>1700 m^2/animal; Lee et al., 2017). In another study, pastured cattle spent most of their time grazing (51%), 32% of their time resting, and 14% walking during daylight hours (Kilgour et al., 2012). The findings indicate that the increased activity is most likely due to grazing to meet energy requirements when on pasture.

5.3.3 Motivation to access pasture

The concept of natural living is a main component in modern-day animal welfare discussions and is a major concern for consumers. Most people would probably agree that grazing cattle on pasture represents a more natural life compared to intensive systems. Pasture is a more complex environment compared to many other systems and provides plenty of space and opportunities to graze, explore, and engage in social activities. It also provides animals with a certain degree of control and choice over their lives, or "agency," something that is increasingly considered important to animals. Indeed, Webster (2016) suggested that the fifth of the five Freedoms (the freedom to express normal behavior; FAWC, 1993) should instead be expressed as "Freedom of Choice." This incorporates freedom to express natural behavior with regard to choice of diet, environment, social contact, comfort, and security (Webster, 2016).

Dairy cattle worldwide are mostly managed in indoor systems with no or limited access to pasture (often only during the summer months). For example, in the United States 19.9% of lactating cows and 34.0% of dry cows have some pasture access (USDA, 2016) whereas in the United Kingdom, it has been estimated that 92% of dairy holdings included grazing as part of their management system (March et al., 2014). In Sweden, both dairy and beef cattle are required by law to have access to pasture (or other type of outdoors for beef cattle) for up to 120 days (24 hours) during the grazing period (April to October) depending on the region (Swedish Board of Agriculture, 2017). In contrast, cows are predominantly managed outdoors all year around in pasture-based dairy systems, such as in New Zealand. The health benefits to cattle that have access to pasture are well documented, but how important is pasture to the animals? Most researchers who have investigated cattle preferences for pasture over indoor or feedlot conditions have found a partial preference for pasture, however, it is clear that many factors influence what location animals choose, such as where the feed is provided, time of day, weather conditions, and the distance they would need to walk to access it. For example, Angus beef cattle preferred the feedlot during the day (61% preference), where they demonstrated a distinct diurnal feeding pattern with two feeding peaks, one in the morning and one in the afternoon (Lee et al., 2013). The general diurnal pattern of feeding and rest is well described in the literature as grazing cattle are known to be crepuscular, i.e. they are most active at sunrise and again at sunset and they show peaks of grazing in the early morning and late afternoon (Kilgour et al., 2012).

Similarly, in a study by Charlton et al. (2011a), Holstein dairy cows in a free-stall system with limited previous exposure to pasture, spent more than 90% of their time indoors where the TMR was provided, and this preference was particularly strong for high-yielding cows. From this study, it seemed like high-producing cows make their choices largely based on nutritional requirements and that pasture may not always meet those demands (Fike et al., 2003).

However, the literature about the effect of feed location, feed type and amount is mixed. Some researchers find location and type of feed matters (Charlton et al., 2011a; Lee et al., 2013, 2014) which drives a daytime preference for the more intensive options, indoor in a dairy and a feedlot for beef cattle. However, this result has not been replicated by Motupalli et al. (2014) who found a preference for pasture, even when TMR was only offered indoors and regardless of herbage mass of the grass offered. To complicate matters further, others find that cattle prefer pasture only once TMR is moved outside (Charlton et al., 2011b).

Interestingly, numerous studies have demonstrated a preference for pasture during the night, both in dairy (Charlton et al., 2011b, 2013; Legrand et al., 2009; Falk et al., 2012; Motupalli et al., 2014) and in beef cattle (Lee et al., 2013). Cattle spend most of their time resting at night time and the partial preference for pasture during the night could possibly suggest that cattle perceive pasture as a more attractive place to rest. This idea is supported by Lee et al. (2013) where Angus cattle preferred the pasture environment over a feedlot at night, where they spent around 90% of their time, of which 80% was spent lying (Fig. 5.4). The preference to lie on pasture (over indoor conditions, Krohn et al., 1992; Ketelaar-de Lauwere et al., 1999, 2000) could partly be due to pasture providing animals with more space to choose a preferred lying location and to lie in all positions compared to other systems, such as free-stalls, and tie-stalls. For example, Krohn and Munksgaard (1993) observed more lateral lying with the head supported on pasture, than in a deep-bedded loose housing system in one group of cattle. Having the head supported plays an important part in quality of sleep, as rapid eye movement (REM) sleep in cattle only occurs when the head is supported (Ternman et al., 2014). Finally, cattle also face other trade-offs when making their choices between indoor and pasture, such as the distance animals have to walk to get to grass, which likely contributes to some of the variation in studies investigating pasture preference (e.g., Charlton et al., 2011a,b, 2013). Cows spent less time on pasture when they had to walk further to access it (Spörndly and Wredle, 2004; Charlton et al., 2013; Motupalli et al., 2014), however, interestingly, not at night time (Charlton et al., 2013; Motupalli et al., 2014).

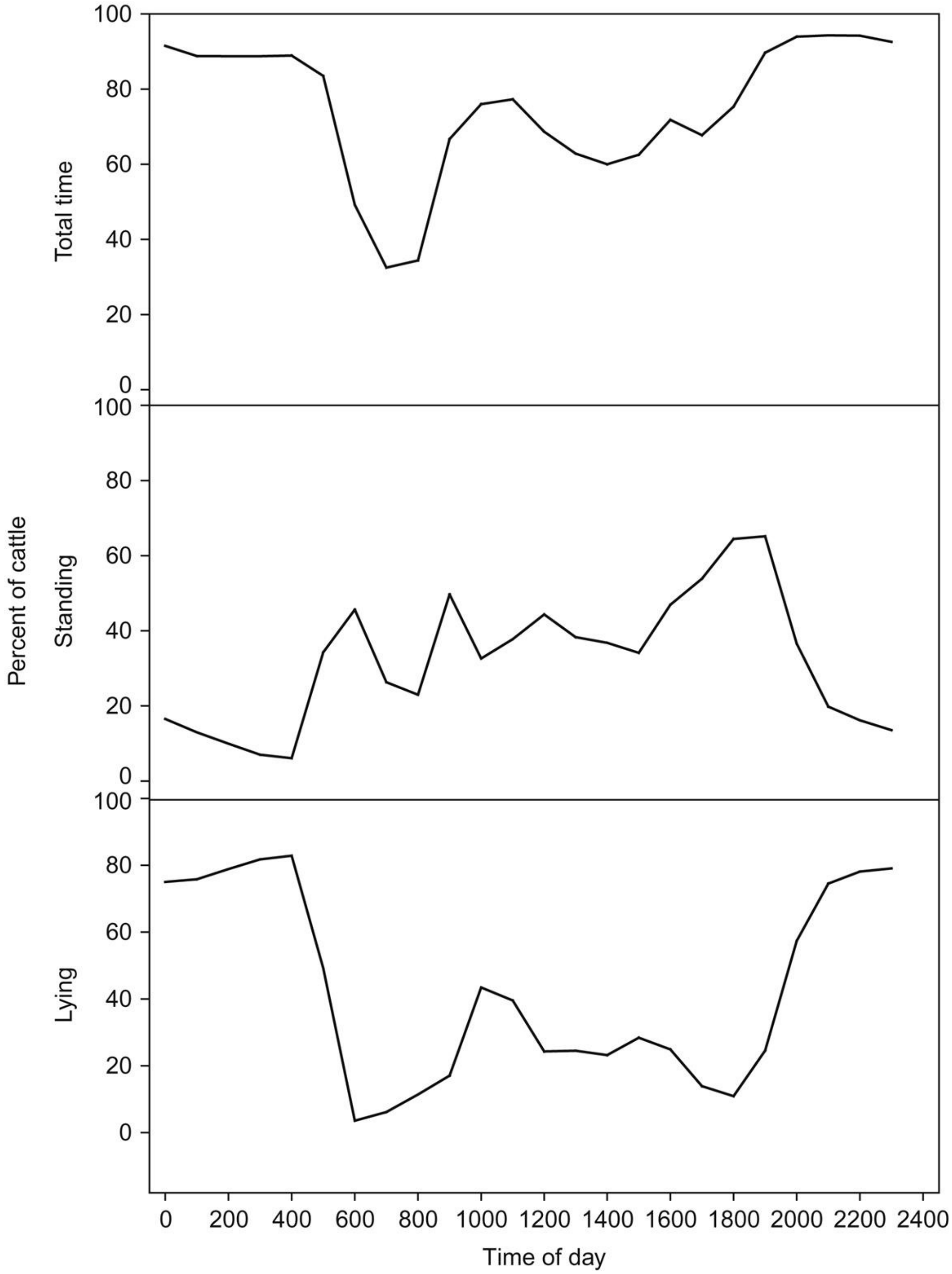

FIGURE 5.4 Mean daily profile of percentage of time steers spent at pasture and their behavior while at pasture. Standing and lying times sum

to the total time in pasture. The data are an average of all animals at 1-h intervals for a 24-h period. *Source:* Adapted from Lee et al., (2013).

Many of the previously discussed studies have used preference testing to allow cattle to express their own priorities, however, it is clear that preference testing seldom is straightforward as animals' choices vary with circumstances and previous experience (Keeling and Jensen, 2002). For example, indoor-reared dairy cows showed a greater preference for an indoor environment when given a choice (Charlton et al., 2011a). In order to fully understand how important pasture is to animals, motivational testing using operant techniques is required to assess the strength of preference, alternatively studies of affective states would tell us more about how the animals perceive pasture. Strength of preference has been studied in two recent experiments. Charlton et al. (2013) used motivational methodology to assess the strength of pasture preference at different times of the day. Those authors made the cows walk different distances to access the pasture, so that the longer distance the cows were willing to walk, the more motivated they were considered to be. At night time, the cows were willing to walk all distances tested to access the pasture (i.e. they were willing to pay a high price to access the pasture), whereas they only spent more time at pasture during the day when the distance was short. In another recent study, cows were trained to push on a weighted push door to get access to pasture; by gradually adding weight to the door it was measured how much the animal is prepared to work to get access to the resource (the more weight the animals were prepared to push the greater the motivation is considered to be). Those researchers found that the motivation to access pasture was as strong as to access fresh feed (von Keyserlingk et al., 2017). The motivation to access pasture was also stronger in the afternoon which agrees with the idea that pasture is the preferred location at night time.

The literature seems to suggest that having access to pasture is important to cattle, however, since the pasture environment provides cattle with a more complex environment that offers opportunities to undertake a wide range of behaviors (such as exploration, grazing, and to engage in social interactions), as well as abundant space simultaneously, it is difficult to determine exactly what it is about pasture that is attractive to cattle. It is also unclear how important it is to animals to be able to choose where to spend their time, lie down, feed, etc., i.e. to have choices and a certain degree of control over their environment and also to be able to engage in more diverse behaviors.

Being outdoors also means that the animals are exposed to a range of conditions and situations where the animals' perception of their environment might vary. For example, when outdoors, cattle seek protection from inclement weather both in windy, rainy (Vandenheede et al., 1995; Tucker et al., 2007; Webster et al., 2008; Schütz et al., 2010), and warm conditions, especially with high levels of solar radiation (Schütz et al., 2008, 2009; Tucker et al., 2008). This response to adverse weather conditions may in part explain why cows chose indoors over pasture both during rainfall (Ketelaar-de Lauwere et al., 1999; Spörndly and Wredle, 2004; Legrand et al., 2009; Charlton et al., 2011a, 2013; Falk et al., 2012), and in warm weather (Legrand et al., 2009; Falk et al., 2012), and may also explain why cattle sometimes prefer pasture during the night. Preference for pasture varied with season in the study by Charlton et al. (2011b) as cows spent more time on pasture as the temperature–humidity index increased (Northern hemisphere autumn). Ambient weather conditions will also influence the surface quality of pasture and outdoor feedlot conditions and thus the available, comfortable space for lying and walking. For example, in summer, the ground can be very hard and dry and may not be a comfortable surface to walk or lie down on. There is convincing evidence that outdoor conditions during wet weather and in winter sometimes do not offer a comfortable lying surface. Cows spent more time lying on pasture in summer than in winter compared to an indoor deep bedding system, whereas the opposite was true in winter (Krohn et al., 1992). Dairy cattle in off-pasture situations prefer to spend more time lying on soft, well-bedded (Tucker et al., 2003; Tucker and Weary, 2004; Drissler et al., 2005; Tucker et al., 2009; Schütz and Cox, 2014), and dry (Fregonesi et al., 2007; Reich et al., 2010) surfaces. When managed on pasture or in uncovered feedlots, underfoot conditions can quickly become muddy in wet weather as shown in Fig. 5.5. Muddy conditions might impose constraints on animals' ability to move and find a comfortable place to lie down and thus reduce lying times. Lying time is an important welfare indicator in cattle, with higher lying times indicative of a more comfortable lying surface (Haley et al., 2000). The effects of reduced lying time can accumulate over time and result in alterations in pituitary-adrenal axis function, an indicator of chronic stress (Fisher et al., 2002). Several studies of dairy cows have reported severely reduced lying times on muddy surfaces by 50% to 75% compared to dry surfaces (Chen et al., 2016; Fisher et al., 2003; Muller et al., 1996). The effects of reduced lying times on mud might be even more evident at colder temperatures (Fisher et al., 2003; Muller et al., 1996), possibly due to thermoregulatory challenges associated with cold, wet surfaces (Morrison et al., 1970; Holmes et al., 1978), which in turn will increase metabolic requirements (Degen and Young, 1993; Tucker et al., 2007).

Muddy feedlots were reported to be one of the greatest hindrances to cattle performance (weight gain and efficiency) in the nonsummer months in US feedlots (Mader, 2011; Morrison et al., 1970). When varying levels of mud in the feedlot were examined, there was no influence on cattle preference for the feedlot or pasture environment (Lee et al., 2017), however, cattle had a preference for pasture in the afternoon similar to that shown by Lee et al. (2013). Those authors found that more time was spent lying when at pasture (Lee et al., 2017), which may reflect the need to compensate for the time spent in the muddy feedlot where lying may have been less comfortable. Muddy conditions may also affect how much space animals have available as more energy is required to walk in mud compared to on concrete (Dijkman and Lawrence, 1997), and animals may be hesitant to move around in mud because of the risk of slipping. This is true for all management systems. Walking surface characteristics for indoor housing have been extensively studied, and it has been demonstrated that the degree of, for example, slipperiness, hardness, and abrasiveness significantly influence cattle welfare (Rushen and de Passillé, 2006; Telezhenko and Bergsten, 2005). Not much is known about the effects of outdoor muddy surfaces on the way animals move and utilize the available space, but it is clear that the quality of the underfoot condition and space influence how animals perceive their environment.

FIGURE 5.5 Muddy conditions in (A) an Australian feedlot experiment and in (B) a pasture-based dairy system (overwintering of non-lactating, pregnant dairy cattle in New Zealand). *Source:* (A) Photo courtesy of Jim Lea. (B) Photo courtesy of Grant Shackell.

5.4 Conclusions

Beef and dairy cattle are managed in a range of systems that vary in the level of dietary and space intensiveness. These systems are likely to meet the animals' dietary requirements and behavioral motivations to different degrees, which are summarized in Fig. 5.6. Cattle are particularly motivated to be able to manipulate their feed and select their diet, particularly to access roughage. Dietary preferences and resultant selection in cattle may be driven by palatability of different feedstuffs, however, it can also be influenced by the need to balance nutrient intake, avoid toxins, and maintain rumen function. Further research is needed to determine how changing physiological demands associated with growth, lactation, and pregnancy may influence dietary selection across time. In relation to this, voluntary water consumption, which is vital for maintaining feed intake and health, is affected by water quality and its palatability, however, there is a need for more research investigating potential welfare and production consequences by providing free access to clean water.

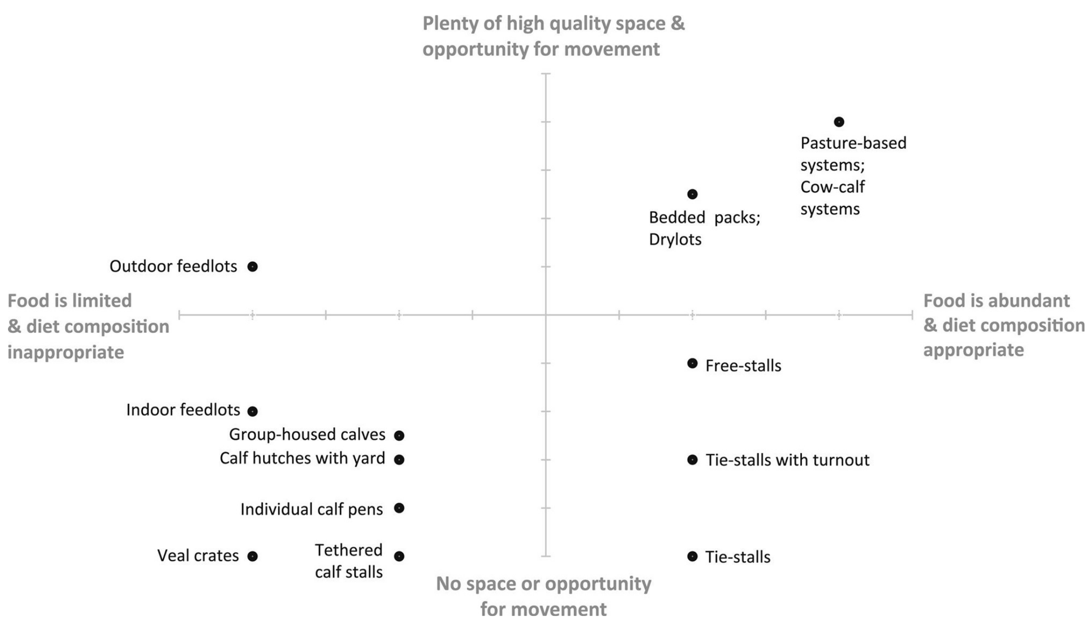

FIGURE 5.6 Summary of how different cattle management systems meet the animals' dietary requirements and ability to move freely in high-quality space.

Severe constraint of movement has negative effects on the welfare of cattle, whereas freedom to move is associated with good health and a range of normal behaviors, such as grooming. Both young and adult dairy cattle are highly motivated to be able to move freely and to undertake other behavioral activities, such as self-grooming, exploration, and play. Freedom of movement can therefore be considered a behavioral need of cattle. This motivation seems to build up after a relatively short period of severe confinement, however, research is needed to assess how the motivation to move freely is influenced by housing systems that vary in their level of confinement, such as free-stall, drylot, and feedlot systems, that provide greater opportunities for movement than tie-stalls, but not to the same extent as pasture-based systems. Similarly, more work is also needed to understand the affective state of cattle in various housing systems.

Even though recent evidence has shown that cattle are highly motivated to access pasture, the choices animals make depend on many different factors, such as where the feed is provided, weather conditions, time of day, and how far the animals have to walk to access it. The motivation to access pasture is particularly strong at night time and may suggest that pasture is a more attractive place to lie down on, possibly due to more space available and a more comfortable lying surface. Does it have to be pasture? Whereas cattle seek opportunities to engage in grazing and foraging behavior, there is to date no scientific evidence showing the strength of this motivation, and we encourage research in this area to be able to determine what it is about pasture that is attractive to cattle.

Finally, while there is evidence that cattle seek opportunities to graze and forage, select their diet, in particular to access roughage, and to be able to move freely and access pasture to undertake different behavior activities, future research should also address what it means to cattle to live in a complex environment with plenty of opportunities for choice and control.

References

1. Adewuyi AA, Roelofs JB, Gruys E, Toussaint MJM, van Eerdenburg FJCM. Relationship of plasma nonesterified fatty acids and walking activity in postpartum dairy cows. *J Dairy Sci.* 2006;89(8):2977–2979.
2. Andersson M. Effects of drinking water temperatures on water intake and milk yield of tied-up dairy cows. *Livest Prod Sci.* 1985;12:329–338.
3. Arnott G, Ferris CP, O'Connell NE. Review: welfare of dairy cows in continuously housed and pasture-based production systems. *Animal*. 2017;11:261–273.
4. Bergeron R, Badnell-Waters AJ, Lambton S, Mason G. Stereotypic oral behaviour in captive ungulates: foraging, diet and gastrointenstinal function. In: Mason G, Rushen J, eds. *Stereotypic Animal Behaviour Fundamentals and Applications to Welfare*. second ed. Wallingford,

UK: CABI Publishing, CAB International; 2006;19–57.

5. Bielfeldt JC, Badertscher R, Tölle KH, Krieter J. Risk factors influencing lameness and claw disorders in dairy cows. *Livest Prod Sci.* 2005;95:265–271.
6. Bolinger DJ, Albright JL, Morrow-Tesch J, Kenyon SJ, Cunningham MD. The effects of restraint using self-locking stanchions on dairy cows in relation to behavior, feed intake, physiological parameters, health, and milk yield. *J Dairy Sci.* 1997;80:2411–2417.
7. Brew MN, Myer RO, Hersom MJ, et al. Water intake and factors affecting water intake of growing beef cattle. *Livest Sci.* 2011;140:297–300.
8. Burritt EA, Provenza FD. Food aversion learning: ability of lambs to distinguish safe from harmful foods. *J Anim Sci.* 1989;67:1732–1739.
9. Burritt EA, Provenza FD. Lambs form preferences for nonnutritive flavors paired with glucose. *J Anim Sci.* 1992;70:1133–1136.
10. Calvo-Lorenzo MS, Hulbert LE, Fowler AL, et al. Wooden hutch space allowance influences male Holstein calf health, performance, daily lying time, and respiratory immunity. *J Dairy Sci.* 2016;99:4678–4692.
11. Castells L, Bach A, Araujo G, Montoro C, Terré M. Effect of different forage sources on performance and feeding behavior of Holstein calves. *J Dairy Sci.* 2012;95:286–293.
12. Castro IML, Gygax L, Wechsler B, Hauser R. Increasing the interval between winter outdoor exercise aggravates agonistic interactions in Hérens cows kept in tie-stalls. *Appl Anim Behav Sci.* 2011;129:59–66.
13. Charlton GL, Rutter SM, East M, Sinclair LA. Preference of dairy cows: Indoor cubicle housing with access to a total mixed ration vs access to pasture. *Appl Anim Behav Sci.* 2011a;130(1–2):1–9.
14. Charlton GL, Rutter SM, East M, Sinclair LA. Effects of providing total mixed rations indoors and on pasture on the behavior of lactating dairy cattle and their preference to be indoors or on pasture. *J Dairy Sci.* 2011b;94:3875–3884.
15. Charlton GL, Rutter SM, East M, Sinclair LA. The motivation of dairy cows for access to pasture. *J Dairy Sci.* 2013;96:4387–4396.
16. Chen JM, Stull CL, Ledgerwood DN, Tucker CB. Muddy conditions reduce hygiene and lying time in dairy cattle and increase time spent on concrete. *J Dairy Sci.* 2016;100:2090–2103.
17. Coppock CE. Feeding methods and grouping systems. *J Dairy Sci.*

1977;60:1327–1336.
18. Costa JHC, Adderley NA, Weary DM, von Keyserlingk MAG. Effect of diet changes on sorting behavior of weaned dairy calves. *J Dairy Sci.* 2016;99:5635–5639.
19. Cummins KA, Brunner CJ. Effect of calf housing on plasma ascorbate and endocrine and immune function. *J Dairy Sci.* 1991;74:1582–1588.
20. Davidson JA, Beede DK. Exercise training of late-pregnant and nonpregnant dairy cows affects physical fitness and acid-base homeostasis. *J Dairy Sci.* 2009;92:548–562.
21. Degen AA, Young BA. Rate of metabolic heat production and rectal temperature of steers exposed to simulated mud and rain conditions. *Can J Anim Sci.* 1993;73:207–210.
22. Dellmeier GR, Friend TH, Gbur EE. Comparison of four methods of calf confinement II Behavior. *J Anim Sci.* 1985;60:1102–1109.
23. de Passillé AM, Rushen J, Martin F. Interpreting the behaviour of calves in an open-field test: a factor analysis. *Appl Anim Behav Sci.* 1995;45:201–213.
24. DeVries TJ, von Keyserlingk MAG, Beauchemin KA. Frequency of feed delivery affects the behavior of lactating dairy cows. *J Dairy Sci.* 2005;88:3553–3562.
25. DeVries TJ, Beauchemin KA, von Keyserlingk MAG. Dietary forage concentration affects the feed sorting behavior of lactating dairy cows. *J Dairy Sci.* 2007a;90:5572–5579.
26. DeVries TJ, Vankova M, Velra DM, von Keyserlingk MAG. Short communication: usage of mechanical brushes by lactating dairy cows. *J Dairy Sci*. 2007b;90:2241–2245.
27. DeVries TJ, Dohme F, Beauchemin KA. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: Feed sorting. *J Dairy Sci.* 2008;91:3958–3967.
28. DeVries TJ, Holsthausen L, Oba M, Beauchemin KA. Effect of parity and stage of lactation on feed sorting behavior of lactating dairy cows. *J Dairy Sci.* 2011;94:4039–4045.
29. DeVries TJ, Schwaiger T, Beauchemin KA, Penner GB. The duration of time that beef cattle are fed a high-grain diet affects feed sorting behavior, both prior to and after acute ruminal acidosis. *J Anim Sci.* 2014a;92:1728–1737.
30. DeVries TJ, Schwaiger T, Beauchemin KA, Penner GB. Impact of

severity of ruminal acidosis on feed sorting behaviour of beef cattle. *Anim Prod Sci.* 2014b;54:1238–1242.
31. Dijkman JT, Lawrence PR. The energy expenditure of cattle and buffaloes walking and working in different soil conditions. *J Agric Sci.* 1997;128:95–103.
32. Dohme F, DeVries TJ, Beauchemin KA. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: ruminal pH. *J Dairy Sci.* 2008;91:3554–3567.
33. Drissler M, Gaworski M, Tucker CB, Weary DM. Free-stall maintenance: Effects on lying behavior of dairy cattle. *J Dairy Sci.* 2005;88:2381–2387.
34. Duncan IJH. Behavior and behavioral needs. *Poult Sci.* 1998;77:1766–1772.
35. Falk AC, Weary DM, Winckler C, von Keyserlingk MAG. Preference for pasture versus free-stall housing by dairy cattle when stall availability indoors is reduced. *J Dairy Sci.* 2012;95:6409–6415.
36. Farm Animal Welfare Council (FAWC). *Second Report on Priorities for Research and Development in Farm Animal Welfare* London, UK: DEFRA; 1993.
37. Fike JH, Staples CR, Sollenberger LE, Macoon B, Moore JE. Pasture forages, supplementation rate, and stocking rate effects on dairy cow performance. *J Dairy Sci.* 2003;86:1268–1281.
38. Fisher AD, Verkerk GA, Morrow CJ, Matthews LR. The effects of feed restriction and lying deprivation on pituitary-adrenal axis regulation in lactating cows. *Livest Prod Sci.* 2002;73:255–263.
39. Fisher AD, Stewart M, Verkerk GA, Morrow CJ, Matthews LR. The effects of surface type on lying behaviour and stress responses of dairy cows during periodic weather-induced removal from pasture. *Appl Anim Behav Sci.* 2003;81:1–11.
40. Fraser D. *Understanding Animal Welfare: The Science in Its Cultural Context* Oxford, UK: Wiley-Blackwell; 2008.
41. Fregonesi JA, Veira DM, von Keyserlingk MAG, Weary DM. Effects of bedding quality on lying behavior of dairy cows. *J Dairy Sci.* 2007;90:5468–5472.
42. Friend TH, Dellmeier GR, Gbur EE. Comparison of four methods of calf confinement I Physiology. *J Anim Sci.* 1985;60:1095–1101.
43. Friend TH, Dellmeier GR, Gbur EE. Effects of changing housing on

physiology of calves. *J Dairy Sci.* 1987;70:1595–1600.
44. Gonyou HW. Design criteria: Should freedom of movement be retained? *Acta Agric Scand Sect A, Anim Sci.* 1996;27:36–39.
45. Greter AM, Kitts BL, DeVries TJ. Limit feeding dairy heifers: Effect of feed bunk space and provision of a low-nutritive feedstuff. *J Dairy Sci.* 2011;94:3124–3129.
46. Greter AM, Prinsen M, Duffield TF, McBride BW, Widowski TM, DeVries TJ. Growing dairy heifers prefer supplementary long straw when fed a nutrient-dense ration in a limited amount. *J Dairy Sci.* 2013;96:3950–3958.
47. Greter AM, Miller-Cushon EK, McBride BW, Widowski TM, Duffield TF, DeVries TJ. Limit feeding affects behavior patterns and feeding motivation of dairy heifers. *J Dairy Sci.* 2015;98:1248–1254.
48. Grout AS, Veira DM, Weary DM, von Keyserlingk MAG, Fraser D. Differential effects of sodium and magnesium sulfate on water consumption by beef cattle. *J Anim Sci.* 2006;84:1252–1258.
49. Gustafson GM. Effects of daily exercise on the health of tied dairy cows. *Prev Vet Med.* 1993;17:209–223.
50. Gustafson GM, Lund-Magnussen E. Effect of daily exercise on the getting up and lying down behaviour of tied dairy cows. *Prev Vet Med.* 1995;25:27–36.
51. Haley DB, Rushen J, de Passillé AM. Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. *Can J Anim Sci.* 2000;80:257–263.
52. Held S, Špinka M. Animal play and animal welfare. *Anim Behav.* 2011;81:891–899.
53. Hemsworth PH, Barnett JL, Beveridge L, Matthews LR. The welfare of extensively managed dairy cattle: A review. *Appl Anim Behav Sci.* 1995;42:161–182.
54. Hernandez-Mendo O, von Keyserlingk MAG, Veira DM, Weary DM. Effects of pasture on lameness in dairy cows. *J Dairy Sci.* 2007;90:1209–1214.
55. Higashiyama Y, Nashiki M, Narita H, Kawasaki M. A brief report on effects of transfer from outdoor grazing to indoor tethering and back on urinary cortisol and behaviour in dairy cattle. *Appl Anim Behav Sci.* 2007;102:119–123.
56. Holmes CW, Christensen R, McLean NA, Lockyer J. Effects of winter

weather on the growth rate and heat production of dairy cattle. *New Zeal J Agr Res.* 1978;21:549–556.
57. Ittner NR, Kelly CF, Guilbert HR. Water consumption of Hereford and Brahman cattle and the effect of cooled drinking water in a hot climate. *J Anim Sci.* 1951;10:742–751.
58. Jensen MB. Adaptation to tethering in yearling dairy heifers assessed by the use of lying down behaviour. *Appl Anim Behav Sci.* 1999a;62:115–123.
59. Jensen MB. Effects of confinement on rebounds of locomotor behaviour of calves and heifers and the spatial preferences of calves. *Appl Anim Behav Sci.* 1999b;62:43–56.
60. Jensen MB. A note on the effect of isolation during testing and length of previous confinement on locomotor behaviour during open-field test in dairy calves. *Appl Anim Behav Sci.* 2001;70:309–315.
61. Jensen MB, Kyhn R. Play behaviour in group-housed dairy calves, the effect of space allowance. *Appl Anim Behav Sci.* 2000;67:35–46.
62. Jensen MB, Pedersen LJ. Using motivation tests to assess ethological needs and preferences. *Appl Anim Behav Sci.* 2008;113:340–356.
63. Jensen P, Toates FM. Who needs 'behavioural needs'? Motivational aspects of the needs of animals. *Appl Anim Behav Sci.* 1993;37:161–181.
64. Jensen MB, Vestergaard KS, Krohn CC. Play behaviour in dairy calves kept in pens: the effect of social contact and space allowance. *Appl Anim Behav Sci.* 1998;56:97–108.
65. Jensen MB, Tuomisto L, Pederson LJ. Locomotor behaviour in dairy calves, the use of demand functions to assess the effect of deprivation. *Appl Anim Behav Sci.* 2004;86:3–14.
66. Keeling L, Jensen P. Behavioural disturbances, stress and welfare. In: Jensen P, ed. *The Ethology of Domestic Animals: An Introductory Text*. Wallingford, UK: CABI Publishing, CAB International; 2002.
67. Keil NM, Wiederkehr TU, Friedli K, Wechsler B. Effects of frequency and duration of outdoor exercise on the prevalence of hock lesions in tied Swiss dairy cows. *Prev Vet Med.* 2006;74:142–153.
68. Kertz AF, Koepke MK, Davidson LE, et al. Factors influencing intake of high urea-containing rations by lactating dairy cows. *J Dairy Sci.* 1982;65:587–604.
69. Ketelaar-de Lauwere CC, Ipema AH, van Ouwerkerk ENJ, et al.

Voluntary automatic milking in combination with grazing of dairy cows: Milking frequency and effects on behaviour. *Appl Anim Behav Sci.* 1999;64:91–109.
70. Ketelaar-de Lauwere CC, Ipema AH, Lokhorst C, et al. Effect of sward height and distance between pasture and barn on cows' visits to an automatic milking system and other behaviour. *Livest Prod Sci.* 2000;65:131–142.
71. Khan MA, Weary DM, von Keyserlingk MAG. Hay intake improves performance and rumen development of calves fed higher quantities of milk. *J Dairy Sci.* 2011;94:3547–3553.
72. Kilgour RJ. In pursuit of "normal": A review of the behaviour of cattle at pasture. *Appl Anim Behav Sci.* 2012;138:1–11.
73. Kilgour RJ, Uetake K, Ishiwata T, Melville GJ. The behaviour of beef cattle at pasture. *Appl Anim Behav Sci.* 2012;138:12–17.
74. Kitts BL, McBride BW, Duncan IJH, DeVries TJ. Effect of the provision of a low-nutritive feedstuff on the behavior of dairy heifers fed a high-concentrate ration in a limited amount. *J Dairy Sci.* 2011;94:940–950.
75. Krause KM, Oetzel G. Understanding and preventing subacute ruminal acidosis in dairy herds: a review. *Anim Feed Sci Technol.* 2006;126:215–236.
76. Krohn CC, Munksgaard L. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie-stall) environments II Lying and lying-down behaviour. *Appl Anim Behav Sci.* 1993;37:1–16.
77. Krohn CC, Munksgaard L, Jonasen B. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie-stall) environments 1 Experimental procedure, facilities, time budgets-diurnal and seasonal conditions. *Appl Anim Behav Sci.* 1992;34:37–47.
78. Ladewig J, Smidt D. Behavior, episodic secretion of cortisol, and adrenocortical reactivity in bulls subjected to tethering. *Horm Behav.* 1989;23:344–360.
79. Lardner HA, Kirychuk BD, Braul L, Willms WD, Yarotski J. The effect of water quality on cattle performance on pasture. *Aust J Agr Res.* 2005;56:97–104.
80. Le Neindre P. Evaluating housing systems for veal calves. *J Anim Sci.* 1993;71:1345–1354.
81. Lee C, Fisher AD, Colditz IG, Lea JM, Ferguson DM. Preference of beef cattle for feedlot or pasture environments. *Appl Anim Behav Sci.*

2013;145:53–59.
82. Lee, C., Lea, J., Colditz, I., Fisher, A., Ferguson, D., 2014. Assessing cattle motivation for access to pasture or feedlot environments. Final Report, Meat and Livestock Australia.
83. Lee, C., Lea, J., Thomson, P., Pool, K., Colditz, I., 2017. The effect of mud on cattle motivation for feedlot or pasture environments. Final Report, Meat and Livestock Australia.
84. Legrand AL, von Keyserlingk MAG, Weary DM. Preference and usage of pasture versus free-stall housing by lactating dairy cattle. *J Dairy Sci.* 2009;92:3651–3658.
85. Leonardi C, Armentano LE. Effect of quantity, quality, and length of alfalfa hay on selective consumption by dairy cows. *J Dairy Sci.* 2003;86:557–564.
86. Lindström T, Redbo I. Effect of duration and rumen fill on behaviour in dairy cows. *Appl Anim Behav Sci.* 2000;70:83–97.
87. Loberg J, Telezhenko E, Bergsten C, Lidfors L. Behaviour and claw health in tied dairy cows with varying access to exercise in an outdoor paddock. *Appl Anim Behav Sci.* 2004;89:1–16.
88. Lofgreen GP, Givens RL, Morrison SR, Bond TE. Effect of drinking water temperature on beef cattle performance. *J Anim Sci.* 1975;40:223–229.
89. Mader, T., 2011. Mud effects on feedlot cattle. In: Nebraska Beef Rep. No. MP94. University of Nebraska-Lincoln, Lincoln.
90. March MD, Haskell MJ, Chagunda MGG, Langford FM, Roberts DJ. Current trends in British dairy management regimes. *J Dairy Sci.* 2014;97:7985–7994.
91. Milam KZ, Coppock CE, West JW, et al. Effects of drinking water temperature on production responses in lactating Holstein cows in summer. *J Dairy Sci.* 1986;69:1013–1019.
92. Miller-Cushon EK, DeVries TJ. Effect of early feed type exposure on diet-selection behavior of dairy calves. *J Dairy Sci.* 2011;94:342–350.
93. Miller-Cushon EK, Bergeron R, Leslie KE, Mason GJ, DeVries TJ. Effect of early exposure to different feed presentations on feed sorting of dairy calves. *J Dairy Sci.* 2013;96:4624–4633.
94. Miller-Cushon EK, Montoro C, Ipharraguerre IR, Bach A. Dietary preference in dairy calves for feed ingredients high in energy and protein. *J Dairy Sci.* 2014a;97:1634–1644.

95. Miller-Cushon EK, Terré M, DeVries TJ, Bach A. The effect of palatability of protein source on dietary selection in dairy calves. *J Dairy Sci.* 2014b;97:4444–4454.
96. Mintline EM, Wood SL, de Passillé AM, Rushen J, Tucker CB. Assessing calf play behavior in an arena test. *Appl Anim Behav Sci.* 2012;141:101–107.
97. Morrison SR, Givens RL, Garrett WN, Bond TE. Effects of mud-wind-rain on beef cattle performance in feed lot. *Calif Agric.* 1970;24:6–7.
98. Motupalli PR, Sinclair LA, Charlton GL, Bleach EC, Rutter SM. Preference and behavior of lactating dairy cows given free access to pasture at two herbage masses and two distances. *J Anim Sci.* 2014;92:5175–5184.
99. Müller C, Ladewig J, Thielscher HH, Smidt D. Behaviour and heart rate of heifers housed in tether stanchions without straw. *Physiol Behav.* 1989;46:751–754.
100. Müller CJC, Botha JA, Smith WA. Effect of confinement area on production, physiological parameters and behaviour of Friesian cows during winter in a temperate climate. *S Afr J Anim Sci.* 1996;26:1–5.
101. Nombekela SW, Murphy MR, Gonyou HW, Marden JI. Dietary preferences in early lactation cows as affected by primary tastes and some common feed flavors. *J Dairy Sci.* 1994;77:2393–2399.
102. OIE, 2016. Article 1.1.1. in Terrestrial Animal Health Code. <http://www.oie.int> (accessed 23.11.16.).
103. Osborne VR, Hacker RR, McBride BW. Effects of heated drinking water on the production responses of lactating Holstein and Jersey cows. *Can J Anim Sci.* 2002;82:267–273.
104. Popescu S, Borda C, Diugan EA, Spinu M, Groza IS, Sandru CD. Dairy cows welfare quality in tie-stall housing system with or without access to exercise. *Acta Vet Scand.* 2013;43 http://doi.org/10.1186/1751-0147-55-43.
105. Redbo I. Changes in duration and frequency of stereotypies and their adjoining behaviours in heifers, before, during and after the grazing period. *Appl Anim Behav Sci.* 1990;26:57–67.
106. Redbo I. The influence of restraint on the occurrence of oral stereotypies in dairy cows. *Appl Anim Behav Sci.* 1992;35:115–123.
107. Redbo I. Stereotypies and cortisol secretion in heifers subjected to tethering. *Appl Anim Behav Sci.* 1993;38:213–225.

108. Redbo I, Nordblad A. Stereotypies in heifers are affected by feeding regime. *Appl Anim Behav Sci.* 1997;53:193–202.
109. Redbo I, Emanuelson M, Lundberg K, Oredsson N. Feeding level and oral stereotypies in dairy cows. *Anim Sci.* 1996;62:199–206.
110. Regula G, Danuser J, Spycher B, Wechsler B. Health and welfare of dairy cows in different husbandry systems in Switzerland. *Prev Vet Med.* 2004;66:247–264.
111. Reich LJ, Weary DM, Veira DM, von Keyserlingk MAG. Effects of sawdust bedding dry matter on lying behavior of dairy cows: A dose-dependent response. *J Dairy Sci.* 2010;93:1561–1565.
112. Rushen J, de Passillé AM. Effects of roughness and compressibility of flooring on cow locomotion. *J Dairy Sci.* 2006;93:2965–2972.
113. Rushen J, de Passillé AM. Locomotor play of veal calves in an arena: are effects of feed level and spatial restriction mediated by responses to novelty? *Appl Anim Behav Sci.* 2014;155:34–41.
114. Rutter SM. Diet preference for grass and legumes in free-ranging domestic sheep and cattle: Current theory and practice. *Appl Anim Behav Sci.* 2006;97:17–35.
115. Schütz KE, Cox NR. Effects of short-term repeated exposure to different flooring surfaces on the behavior and physiology of dairy cattle. *J Dairy Sci.* 2014;97:2753–2762.
116. Schütz KE, Cox NR, Matthews LR. How important is shade to dairy cattle? Choice between shade or lying following different levels of lying deprivation. *Appl Anim Behav Sci.* 2008;114:307–318.
117. Schütz KE, Rogers AR, Cox NR, Tucker CB. Dairy cows prefer shade that offers greater protection against solar radiation in summer: Shade use, behaviour, and body temperature. *Appl Anim Behav Sci.* 2009;116:28–34.
118. Schütz KE, Clark KV, Cox NR, Matthews LR, Tucker CB. Responses to short-term exposure to rain and wind by dairy cattle: time budgets, shelter use, body temperature and feed intake. *Anim Welf.* 2010;19:375–383.
119. Sisto AM, Friend T. The effect of confinement on motivation to exercise in young dairy calves. *Appl Anim Behav Sci.* 2001;73:83–91.
120. Somers JGCJ, Frankena K, Noordhuizen-Stassen EN, Metz JHM. Prevalence of claw disorders in dutch dairy cows exposed to several floor systems. *J Dairy Sci.* 2003;86:2082–2093.

121. Spörndly E, Wredle E. Automatic milking and grazing—effects of distance to pasture and level of supplements on milk yield and cow behavior. *J Dairy Sci.* 2004;87:1702–1712.
122. Stermer RA, Brasington CF, Coppock CE, Lanham JK, Milam KZ. Effect of drinking water temperature on heat stress of dairy cows. *J Dairy Sci.* 1986;69:546–551.
123. Stockdale CR, King KR. A note on some of the factors that affect the water consumption of lactating dairy cows at pasture. *J Anim Prod.* 1983;36:303–306.
124. Swedish Board of Agriculture, <www.Jordbruksverket.se/amnesomraden/djur/olikaslagsdjur/notkreatur/ (accessed 15.03.17.).
125. Tapkı İ, Şahin A, Önal AG. Effect of space allowance on behaviour of newborn milk-fed dairy calves. *Appl Anim Behav Sci.* 2006;99:12–20.
126. Telezhenko E, Bergsten C. Influence of floor type on the locomotion of dairy cows. *Appl Anim Behav Sci.* 2005;93:183–197.
127. Ternman E, Pastell M, Agenäs S, et al. Agreement between different sleep states and behaviour indicators in dairy cows. *Appl Anim Behav Sci.* 2014;160:12–18.
128. Tucker CB, Weary DM. Bedding on geotextile mattresses: How much is needed to improve cow comfort? *J Dairy Sci.* 2004;87:2889–2895.
129. Tucker CB, Weary DM, Fraser D. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. *J Dairy Sci.* 2003;86:521–529.
130. Tucker CB, Rogers AR, Verkerk GA, Kendall PE, Webster JR, Matthews LR. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. *Appl Anim Behav Sci.* 2007;105:1–13.
131. Tucker CB, Rogers AR, Schütz KE. Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. *Appl Anim Behav Sci.* 2008;109:141–154.
132. Tucker CB, Weary DM, von Keyserlingk MAG, Beauchemin KA. Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. *J Dairy Sci.* 2009;92:2684–2690.
133. Tuomisto L, Ahola L, Martiskainen P, Kauppinen R, Huuskonen A. Comparison of time budgets of growing Hereford bulls in an uninsulated barn and in extensive forest paddocks. *Livest Sci.*

2008;118:44–52.
134. USDA, 2016. <https://www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dai (accessed 15.03.17.).
135. Vandenheede M, Nicks B, Shehi R, et al. Use of shelter by grazing fattening bulls: effect of climatic factors. *Anim Sci.* 1995;60:81–85.
136. Van Os JM, Mintline EM, DeVries TJ, Tucker CB. Feedlot cattle are motivated to obtain roughage and show contrafreeloading. In: Jensen MB, Herskin MS, Malmkvist J, eds. *Proceedings of the 51st Congress of the International Society for Applied Ethology*. Wageningen, The Netherlands: Wageningen Academic Publishers; 2017.
137. Veissier I, Andanson S, Dubroeucq H, Pomiès D. The motivation of cows to walk as thwarted by tethering. *J Anim Sci.* 2008;86:2723–2729.
138. von Keyserlingk MAG, Cestari AA, Franks BA, Fregonesi JA, Weary DM. Dairy cows value access to pasture as highly as fresh feed. *Sci Rep.* 2017;7:44953 http://dx.doi.org/10.1038/srep44953.
139. Washburn SP, White SL, Green JT, Benson GA. Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. *J Dairy Sci.* 2002;85:105–111.
140. Webb LE, Jensen MB, Engel B, et al. Chopped or long roughage: what do calves prefer? Using cross point analysis of double demand functions. *PLoS One*. 2014;9:e88778 Available from: https://doi.org/10.1371/journal.pone.0088778.
141. Webster J. Animal welfare: freedoms, dominions and “a life worth living”. *Animals*. 2016;6 http://dx.doi.org/10.3390/ani6060035.
142. Webster JR, Stewart M, Rogers AR, Verkerk GA. Assessment of welfare from physiological and behavioural responses of New Zealand dairy cows exposed to cold and wet conditions. *Anim Welf.* 2008;17:19–26.
143. Wells SJ, Garber LP, Wagner BA. Papillomatous digital dermatitis and associated risk factors in US dairy herds. *Prev Vet Med.* 1999;38:11–24.
144. Wilks DL, Coppock CE, Lanham JK, et al. Responses of lactating Holstein cows to chilled drinking water in high ambient temperatures. *J Dairy Sci.* 1990;73:1091–1099.
145. Willms WD, Kenzie OR, McAllister TA, et al. Effects of water quality on cattle performance. *J Range Manage.* 2002;55:452–460.
146. Wood-Gush DGM, Hunt K, Carson K, Dennison SGC. The early

behaviour of suckler calves in the field. *Biol Behav.* 1984;9:295–306.

6

The role of social behavior in cattle welfare

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Abstract

Social behavior is learned early in life; it enables calves to adapt to later challenges, and rearing with the dam or with peers improves calf welfare compared to individual rearing. When calves are dam-reared, breaking the maternal–filial bond is stressful, but partial separation prior to final separation may mitigate this. Cattle form social bonds and perceive isolation as aversive. Social contact buffers adverse experiences, but living in a group also means competing for resources. This competition depends on resource availability; however, sharing resources may be facilitated by social stability. Regrouping is an animal welfare challenge because it implies breaking existing social bonds and establishing new dominance relations through aggressive behavior. However, maintaining some bonds may provide social buffering and reduce adverse effects of regrouping. At parturition, the cow's social priorities change, and allowing her to seek seclusion may be important for cow welfare. To advance animal welfare, housing and management should stimulate normal social development and allow cattle to adapt to their social environment through affiliative behavior.

Keywords

Social behavior; animal welfare; cattle; group housing; cow-calf contact

6.1 Introduction

6.1.1 Overview of social behavior of cattle

Under natural conditions, cattle form groups of females and young, while males disperse. This is the general picture emerging from the few existing studies of feral domestic cattle (Bouissou et al., 2001). In a near-natural social environment, a social bond is established between mother and young (von Keyserlingk and Weary, 2007), and preferential social relationships develop between similar-aged calves (Reinhardt and Reinhardt, 1982; Raussi et al., 2010). These preferential relationships are expressed through more time in close proximity or through social grooming (Val-Laillet et al., 2009). Extensively reared beef calves thus live in near-natural social groups until they are weaned at 5–6 months of age. On the other hand, intensively reared dairy calves are typically separated from the dam at birth and spend the first 1–2 months of life alone and with limited contact with peers. Cattle form preferential social relationships, but living in a group also involves conflicts, especially if resources are limited. Dominance relations determine access to limited resources. Under near-natural conditions, sub-adults are frequently assessing each other's strength. Therefore, dominance relations among heifers and young bulls are unstable (Reinhardt and Reinhardt, 1978), while the social status of elder cows typically remains unchallenged (Reinhardt and Reinhardt, 1978; Šárová et al., 2013). Under intensive conditions, frequent regroupings challenge the establishment and maintenance of preferential social relationships, as well as dominance relations, and may result in a high level of aggression. This is exacerbated if space allowances are low and stocking densities of feed and resting places are high.

6.1.2 Animal welfare concerns

Is rearing in isolation, breaking of social bonds and social housing under competitive conditions associated with animal welfare problems? There are three different concerns for animal welfare emphasizing natural living, animals' affective states and animals' biological functioning, respectively, and Fraser et al. (1997) proposed a model that integrates these three concerns. According to this model, challenges to animal welfare may arise because the animals have natural adaptations that are not required in the current environment. For instance, isolation of a socially motivated animal is associated with fear (a negative affective state), and this is a problem even if this does not impair health (a measure of biological functioning). Animal welfare may also be compromised because the environment has challenges for which the animals are not adapted. For instance, if low-ranking individuals in a group are unable to avoid aggression and cannot access resources, this may result in both negative affective states and impaired health.

6.1.3 Goals of this chapter

Animal welfare problems relating to social behavior may be due to social isolation, but they may also be due to instability of relationships and competition. But what is important about being social, having social contact and performing social behavior? The chapter aims to answer this question and to illustrate how knowledge of cattle's social behavior may be used to suggest housing and management that improve cattle welfare.

6.2 Social bonds, separation, and isolation

6.2.1 The maternal–filial bond

Under natural conditions, the calf's first social contact is with the dam. The dam licks the calf intensively during the first hours after birth (Edwards and Broom, 1982; Lidfors, 1996; Jensen, 2012) which stimulates the calf to stand and search for the udder, and which plays a role in the establishment of the social bond between dam and calf (von Keyserlingk and Weary, 2007). The maternal licking is associated with low-pitched vocalization (Edwards and Broom, 1982) which may play a role in the calf's recognition of the dam, as calves responded preferentially to calls of the dam after 24 hours together (Barfield et al., 1994; Marchant-Forde et al., 2002). Ingestion of colostrum is important for the bonding of lambs to their dam (Val-Laillet et al., 2004), but little is known about the role of nursing for bonding in cattle. Results from Johnsen et al. (2015a) suggest that dairy calves form a preferential bond to their dam even in the absence of nursing. The duration of social contact between dam and calf declines during the first few weeks of the calf's life (Jensen, 2011). During this period, calves associate increasingly with other calves of similar age (Reinhardt, 1980; Wood-Gush et al., 1984; Sato et al., 1987). Nevertheless, when dam and calf are kept together, the dam represents the calf's primary social bond, and the calf remains a preferential conspecific even after the birth of the next calf (Veissier et al., 1990).

6.2.1.1 Separation from the dam in dairy production

Most dairy calves in conventional production systems are separated from their dam within hours or days after birth and artificially fed milk or replacer until weaned off milk at 6–12 weeks of age. One argument for separating the calf from the dam at birth is prevention of vertical disease transmission (mainly *Salmonella Dublin* and Paratuberculosis). During the first hours after separation, dam and calf show only subtle responses to this (Hopster et al., 1995; Lidfors, 1996), likely because the calf naturally lies out hidden in vegetation between nursing, i.e. for hours at the time. However, both dam and calf respond to separation, and a peak response is seen at 9–21 hours following this process (Weary and Chua, 2000). The maternal bond is formed during the first hours after birth (Hudson and Mullord, 1977; Marchant-Forde et al., 2002), and a series of studies suggest that the bond is strengthened within the first 24 hours, as the behavioral responses to separation were stronger when the dam and calf had spent more than 24 hours together in an individual maternity pen. For instance, among calves, a stronger behavioral response to separation (more time standing, moving and placing head out of pen) was seen after 4 days together with the dam compared to 24 or 6 hours together (Weary and Chua, 2000), after 4 or 7 days together compared to 24 hours together (Stěhulová et al., 2008), and after 14 days together compared to 24 hours together (Flower and Weary, 2001; Table 6.1). Also, among cows, the behavioral response to separation was stronger the longer time the two had spent together; after 4 days together, the dam vocalized more and louder than after 24 or 6 hours together (Weary and Chua, 2000), and cows called more, moved more and placed the head out of the pen more when they had spent 7 days with their calf compared to 1 or 4 days (Stěhulová et al., 2008), and when they had spent 14 days compared to 24 hours together (Flower and Weary, 2001).

Table 6.1

Behavioral responses of calves to separation from the cow. An overview of timing or method of separation, timing or method that elicits the stronger response as well as responses affected is given in experimental studies on dairy and beef cattle, respectively

Timing or method of separation	Method that elicits the stronger response	Responses affected	Reference
Dairy			
Immediate versus 4 days	4 days	Lie Oral behavior	Lidfors (1996)
24 hours versus 4 or 7 days	4 and 7 days	Stand Move in pen Place head out of pen Sniff wall or bedding Heart rate	Stěhulová et al. (2008)
24 hours versus 14 days	14 days	Move in pen Place head out of pen	Flower and Weary (2001)
6 hours, 24 hours, or 4 days	4 days	Stand Move in pen Place head out of pen	Weary and Chua (2000)
Abrupt versus nose flap (1st step)	Abrupt	Vocalize Walk Sniff pen Social behavior	Loberg et al. (2008)
Beef			
25 days versus 45 days	25 days	Lie Vocalize	Pérez-Torres et al. (2016)
6 months versus 8 months	6 months	Lie Vocalize	Lambertz et al. (2015b)
Abrupt versus fence (1st step)	Abrupt	Vocalize Walk Lie Feed	Price et al. (2003)
Abrupt versus nose flap (1st step)	Abrupt	Vocalizations Walk Stand Feed	Haley et al. (2005)
Nose flap versus fence (1st step)	Fence	Vocalizations Fence pacing Seeking	Enriquez et al. (2010)
Nose flap versus fence (2nd step)	Nose-flap	Vocalizations Walking Fence pacing Seeking	Enriquez et al. (2010)
Abrupt versus fence	No significant differences	None	Solano et al. (2007)

Behavioral responses of dam and calf to separation are affected by the degree of contact allowed. Cows called less and were less restless if they could not see or hear the calf after the separation, while the effect of this on calves' responses was minimal (when separated within the first week after calving; Stěhulová et al., 2008). On the other hand, allowing visual and physical contact, while preventing nursing by partial separation (a fence), resulted in a reduced vocal response in 8-week-old calves compared to when calves could hear but not see and touch the dam, while no effects on dams' responses were found (Johnsen et al., 2015b). Thus, making separation a gradual process may be more beneficial to the calf than to the dam when calves are approx. 2 months old. For the calf, removing the milk alone is also associated with a negative affective state due to hunger which is illustrated by 5- to 6-week-old dairy calves vocalizing intensively as a response to abrupt weaning off milk (Thomas et al., 2001; Budzynska and Weary, 2008). When calves are separated from the dam and weaned off milk simultaneously, part of the calves' affective response may also reflect hunger. One way to reduce the stress of separation from the dam is to first prevent nursing while allowing continued social contact to the dam and then subsequently to cut off all contact between the two. Loberg et al. (2008) showed that 10-week-old dairy calves that stayed with their foster cow, but were prevented from nursing by fitting a nose-flap (Fig. 6.1), vocalized less than controls that were abruptly removed from their foster cow. Similarly, the foster cows' response to cessation of suckling was reduced by this procedure (Loberg et al., 2007). However, when nose-flap calves were separated from their foster cows 2 weeks later, both calves and cows showed another vocal response. Both the responses to the first and the second step of separation need to be considered when evaluating the welfare consequences of a two-step procedure. Two-step separation procedures, including partial separation by fence-line and prevention from nursing by nose-flaps, for a few days before complete separation of dam and calf have been studied in more detail in beef calves (see below).

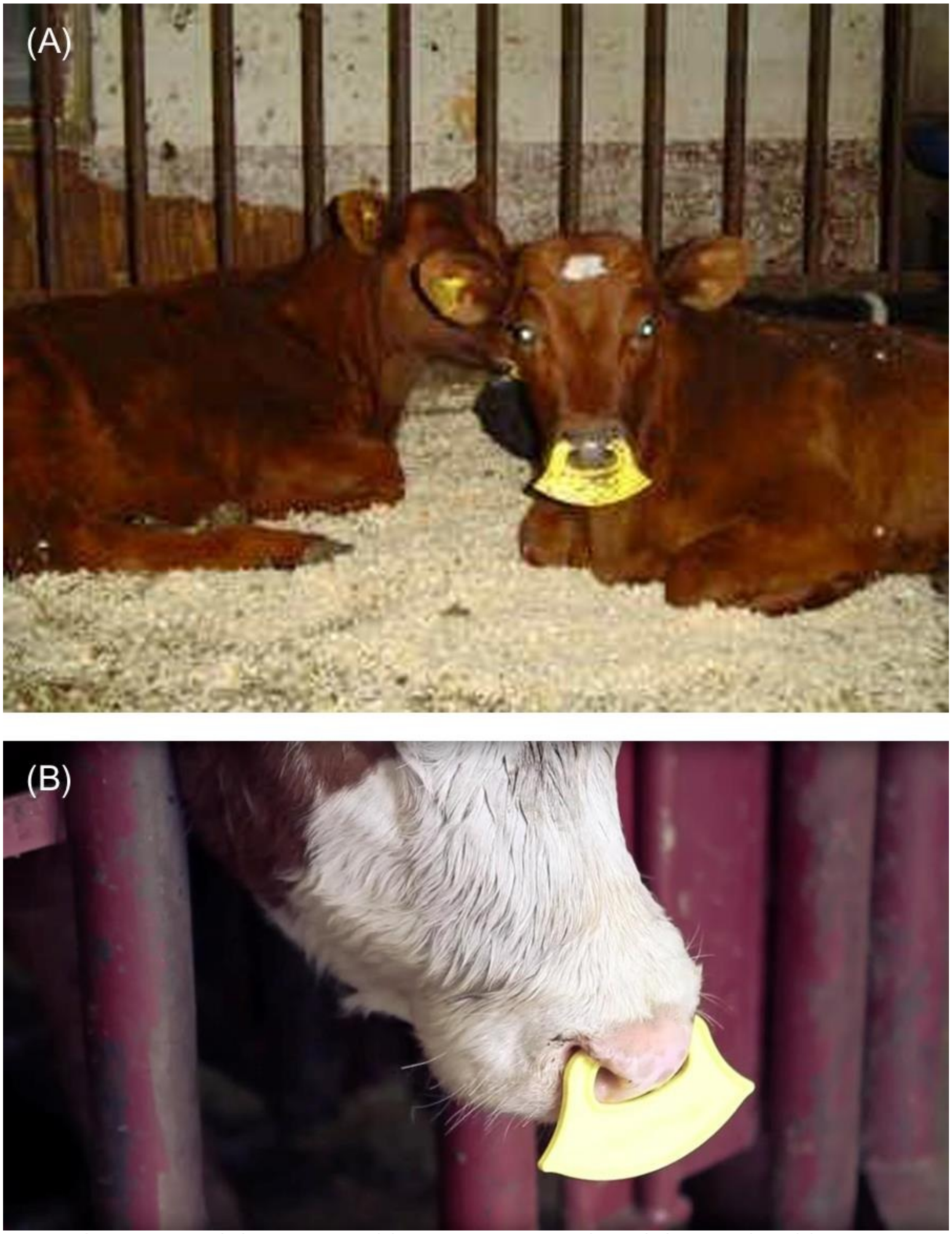

FIGURE 6.1 (A) A dairy calf fitted with a nose-flap. (B) A beef calf fitted with a nose-flap (www.quietwean.com). The flap prevents the calf from nursing. *Source:* (A) Photo courtesy of Jenny Loberg, Swedish University of Agricultural Sciences. (B) Photo courtesy of Derek Haley, University of Guelph.

There is evidence that dam and calf experience negative affective states during separation. The intensity of calls by dam and calf reflects the arousal of the negative affective state caused by the separation as well as the strength of the motivation to reunite (Weary et al., 2008; Watts and Stookey, 2000). Animals' judgement of their chance of success in achieving a goal reflects their affective state: a pessimistic response bias being associated with a negative affective state (Mendl et al., 2010). In support of juveniles experiencing a negative affective state after separation, 6-week-old calves evaluated their chance of success in a standardized test situation more negatively following separation from the dam than before (Daros et al., 2014).

The management choice between providing the benefit of early dam–calf contact and imposing the disadvantage of separation appears to represent a dilemma. As the maternal bond is formed within hours after birth (Hudson and Mullord, 1977; Marchant-Forde et al., 2002), it may be argued that the two should be separated as soon after birth as possible to minimize the stress of separation. However, we know little about the positive affective experiences of the dam while performing maternal behavior and of the calf while receiving early maternal care (e.g., being licked and nursed), and it is difficult to make the trade-off between these presumably positive effects against the negative affective states experienced following separation. In support of extended cow–calf contact are also later positive effects on calves' social behavior. For instance, dam-rearing for 14 days affected calves' social responses when measured 4 weeks later (Flower and Weary, 2001) in a similar way to how social contact with other calves affects calves' social responses (see Section 6.3.1). Furthermore, calves reared with the dam for 6–13 weeks attained higher dominance rank (Le Neindre, 1989), more often displayed submissive behavior in response to a threat of an unfamiliar cow (Buchli et al., 2017), and were better at avoiding aggression when introduced to the cow herd as heifers (Wagner et al., 2012). Currently, there is an interest (e.g., in organic dairy production) in systems allowing extended dam–calf contact. Restricted suckling systems allowing contact only to nurse are known from extensive dairy production systems (e.g., Fröberg et al., 2007). However, there is also some experience in intensive systems with unrestricted dam–calf contact for the first 8 weeks (Fröberg and Lidfors, 2009) or dam–calf contact restricted to part of the 24 hours, for example during the night between afternoon and morning milking (Johnsen et al., 2015a). At present, restricting dam–calf contact to only part of the day, for example during the day or the night, is evaluated as the most feasible approach (Johnsen et al., 2016), partly because calves attain a certain degree of both social and nutritional independence of the dam before weaning and separation at 2–3 months of age. However, even though a few weeks, or months, of maternal contact has positive effects on animal welfare as outlined above, breaking the bond at this early stage has adverse effects, and identifying dam–calf management that minimizes these effects in dairy production, represents an important future challenge.

6.2.1.2 Separation from dam in beef production

Calves from beef breeds are typically dam-reared on pasture until weaned by abruptly separating them from the dam at 5–6 months of age (Enriquez et al., 2011). This is typically before the dam would have weaned her calf off milk, which naturally occurs between 7 and 14 months of age (Hall, 1979; Reinhardt and Reinhardt, 1981). During natural weaning, the dam gradually reduces the calf's opportunity to suckle while maintaining social contact (Veissier et al., 1990). In contrast, weaning by abrupt separation from the dam also implies abruptly breaking the social bond.

After abrupt separation from the dam, 6-month-old beef calves vocalize for days, and this calling is associated with increased walking (Enríquez et al., 2010; Price et al., 2003; Haley et al., 2005), reduced lying time (Price et al., 2003; Haley et al., 2005), and increased levels of plasma cortisol (Lay et al., 1998; Hickey et al., 2003). These responses to separation were reduced by partial separation, i.e. prevention of nursing, while cow and calf maintain auditory, visual and, in some studies, physical contact. Calves prevented from nursing by a fence-line for 7 days showed less vocalization, spent less time walking and more time lying down when subsequently separated from the dam than calves separated and weaned abruptly (Price et al., 2003). Fitting calves with nose-flaps (Fig. 6.1) means that calves are prevented from nursing, but they may maintain close proximity and social interaction with the dam, and calves fitted with nose-flaps for 3 and 14 days also displayed fewer behavioral signs of anxiety when separated from the dam compared to calves weaned abruptly (Haley et al., 2005). The behavioral responses of the dam to separation from the calf were reduced when the calf had been weaned by wearing a nose-flap beforehand compared to when calves were separated abruptly. Cows also spent more time grazing and less time pacing and vocalizing when separated from calves wearing nose-flaps than when calves were weaned and separated at the same time (Ungerfeld et al., 2015, 2016).

These studies illustrate that the second step (complete separation) is less stressful once the calves have gone through the first step and are weaned off milk. However, the first step preventing nursing may also be stressful as outlined for dam–calf separation in dairy production. Although the intensity of each of the two steps may be lower than abrupt separation, it has to be considered how the prolonged impact of a two-step separation affects the calves' overall affective state and for a two-step separation to improve calf welfare; overall, the two steps together should be less stressful than the abrupt separation. To investigate this, Enriquez et al. (2010) compared fence-line, nose-flap (both for 17 days) and abrupt separation and found that the behavioral responses of fence-line calves were strongest after the first step, while the responses of nose-flap calves were strongest after separation from the dam, i.e. the second step (Table 6.1). The nose-flap thus appeared the least effective of the two methods in weakening the dam–calf bond, which may be due to the continued close proximity of the two and because nose-flap calves attempt to nurse irrespective of the flap (Enriquez et al., 2010; Hötzel et al., 2010; Haley et al., 2005). During natural weaning, calves increasingly interact with peers as the attachment to the dam is reduced (Veissier et al., 1990), but 6-month-old calves separated from the dam stayed in closer proximity of and interacted more with peers than calves kept with the dam prevented from nursing by an udder net (Veissier and Le Neindre, 1989). This supports the fact that partial separation (e.g., by fence-line) may be more efficient than merely preventing nursing (e.g., by nose-flap) in weakening the maternal bonds as well as facilitating strengthening of the attachment to peers. One study reports injury to the nostrils caused by the nose-flap procedure (Lambertz et al., 2015a), but the type of nose-flaps and the length of time calves carry them likely affect this. Furthermore, the flap may thwart intake of feed and water, which is suggested by a lower daily gain of nose-flap calves compared to fence-line calves (Enriquez et al., 2010). When fence-line weaning was compared to abrupt weaning and transporting the calves a long distance, only feeding (and not walking, lying, and vocalizing) was affected in the study by Price et al. (2003). Solano et al. (2007) also found no differences between fence-line, abrupt or total separation when 3-month-old calves were temporarily separated from their dam for 3 days. This suggests that auditory contact between dam and calf may increase the stress when beef calves are abruptly weaned without opportunity to have tactile contact. This is similar to what was found in week-old dairy calves (Stěhulová et al., 2008). Temporary separation of dam and calf is sometimes used to stimulate the first postpartum ovulation, and calves that were separated from their dam by a 50-m-wide wire-fenced pasture at 25 days and again at 45 days of age showed a stronger vocal response during the first separation than during the second (Pérez-Torres et al., 2016). The lower response during the second separation may be due to a lower nutritional and social dependence on the dam as well as experience. Indeed, calves that had experienced a 3-day-period of partial separation from the dam using nose-flaps at 10 weeks of age had a lower behavioral response to weaning at 6 months of age than controls (Hötzel et al., 2012). Nutritional and social independence increases with increasing calf age, and calves that were abruptly weaned at 6 months of age vocalized more throughout the first 3 days following separation than calves weaned abruptly at 8 months of age (Lambertz et al., 2015b). Also following abrupt weaning, cows that were separated from calves that were younger (age range 5–9 months) and calves that were more nutritionally dependent (as indicated by higher growth rates) vocalized more than other cows, while calves that were more nutritionally dependent vocalized more (Stěhulová et al., 2017). Thus, the relation between dam and calf is sensitive to the physical state of each of the two, and the dam appears to balance her own body condition to the needs of the calf (Bateson, 1994). Interestingly, pregnant cows called their calf less following separation than nonpregnant cows (Stěhulová et al., 2017), which emphasizes this point.

The extended dam-calf contact commonly practiced in beef cattle bears much resemblance to natural living. However, reduced weaning age and temporary weaning are increasingly practiced to increase productivity. Future studies are encouraged to investigate the animal welfare consequences of this practice and of the ways it may be imposed.

6.2.2 Responses to brief periods of separation from the group and social isolation

In cattle of all age classes, separation and isolation from the herd are accompanied by behavioral and physiological signs of fear. In heifers and cows, these signs include high-frequency vocalization to localize peers, attempts to escape or reunite with peers (Boissy and Le Neindre, 1997), as well as increased heart rate (Boissy and Le Neindre, 1997; Rushen et al., 2001), and increased plasma cortisol concentrations (Boissy and Le Neindre, 1997; Herskin et al., 2004; 2007). Animals of dairy and beef breeds respond in the same way although the responses of beef breeds are more severe (Le Neindre, 1989; Boissy and Le Neindre, 1997). In artificially reared milk-fed dairy calves, responses to separation from peers and isolation in a novel test area have been studied to assess effects of social and physical environment on animals' fear and exploratory responses (see Section 6.3.1), and calves also respond to isolation with increased adrenocortical and heart rate responses (Van Reenen et al., 2005). Physical activity is also a typical response to a novel arena test, but increasing heart rates were unrelated to the physical activity (Jensen et al., 1997; Jensen and Larsen, 2014) supporting the fact that an elevated heart rate is due to fear in this situation.

If animals are separated from their group together with one to two peers rather than alone, this reduces the responses to separation. For instance, calves placed in a novel room in the company of a peer vocalized less and were more explorative than calves placed there alone (Færevik et al., 2006; Duve and Jensen, 2011), and heifers more readily approached a human and ate more when in the company of peers in a novel place (Veissier and Le Neindre, 1992). This is known as social buffering; i.e. the presence of a peer reduces the negative effect of a stressful event (Rault, 2012). In heifers, the mere sight of conspecifics reduces the behavioral responses to isolation regardless of peer identity (Veissier and Le Neindre, 1992; Boissy and Le Neindre, 1997), while in calves, familiar calves tended to provide better social buffering than unfamiliar calves (Færevik et al., 2006). Cattle may have to be separated from herd mates as part of standard management routines, but rather than isolating animals, handling them in pairs or small groups not only improved the animals' welfare but also made them easier to handle (e.g., Duve et al., 2012; Grignard et al., 2000).

6.3 Individual housing

6.3.1 Milk-fed dairy calves in pens and hutches

Individual rearing of calves is common practice in dairy production, and this sometimes involves prolonged isolation. More than 70% of milk-fed dairy calves are housed individually in Canada (Vasseur et al., 2010), Brazil (Hötzel et al., 2014), and the United States (USDA, 2008). However, in European countries like Germany, The Netherlands, Sweden, and Denmark, pair and group housing of milk-fed dairy calves (Fig. 6.2) is becoming more common (Marcé et al., 2010). The main argument for keeping calves individually is that it is easy to monitor feed intake and health and that calves are protected from pathogens. However, calves have a high motivation for social contact (Holm et al., 2002), and individual housing is associated with impaired social and learning abilities (see Costa et al., 2016, for review).

FIGURE 6.2 Calves housed as a pair in an outdoor hutch. Photo courtesy of Linda Rosager Duve, Aarhus University, Denmark.

Calves housed in pairs or small groups are more confident in a standard social test and more readily approach and interact with an unfamiliar calf (de Paula et al., 2012; Jensen et al., 1997) than individually housed calves. Individually housed calves are not only more reluctant to approach an unfamiliar calf; once they have made contact, these calves engage in more agonistic social interactions, while socially reared calves remain calm (de Paula et al., 2012; Duve and Jensen, 2011; Jensen and Larsen, 2013). Allowing tactile contact between neighboring individual pens did not affect social responses (Jensen at al., 1999; Jensen and Larsen, 2013), and individually housed calves' inability to respond appropriately during social interactions suggests that social skills are only developed in pair and group housing where full social interaction is possible (Fig. 6.3). In line with this suggestion, calves from individual pens were involved in more aggressive and less nonagonistic interactions when grouped compared to when group-housed calves were regrouped (Veissier et al., 1994). Group-housed calves also had access to concentrates for longer (Duve et al., 2012) and attained higher rank (Veissier et al., 1994) after (re)-grouping than individually housed calves, supporting the fact that full social contact is a prerequisite for development of social skills and competitive abilities.

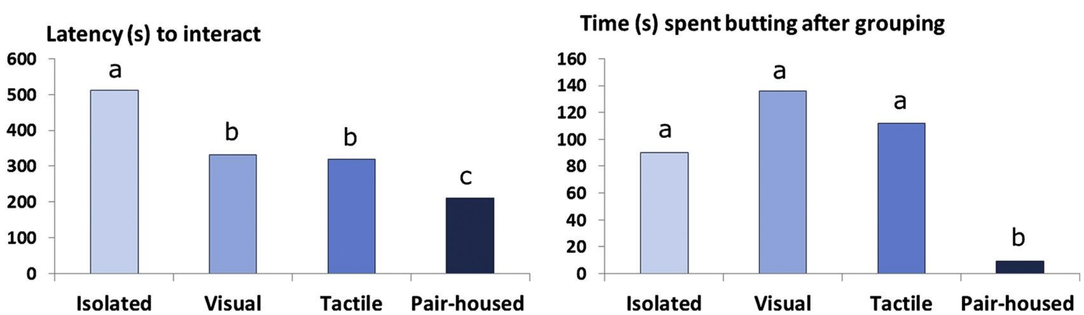

FIGURE 6.3 Left: the latency to interact with an unfamiliar calf (seconds) of calves that were individually housed and isolated, individually housed with visual contact, individually housed with tactile contact, and of calves that were housed in pairs (Jensen and Larsen, 2014). Right: the frequency of butting during the first 6 hours after regrouping with unfamiliar calves at 6 weeks of age by calves that had previously been individually housed and isolated, individually housed with visual contact, individually housed with tactile contact, and by calves that had been previously housed in pairs (Jensen and Larsen, 2013).

Calves in individual pens will associate with neighboring calves if the design of the pens allows tactile social contact. Individually housed calves in open pens sniffed and licked the neighboring calf's head through partitions already at the age of 12 days, although the level of social behavior performed was lower than that of similar pair-housed calves that could push, butt, sniff, and lick each other (Duve and Jensen, 2012). Providing some social contact between neighboring, individual pens does affect calves' fear responses in novel environments. Calves isolated in closed individual pens that allowed only auditory social contact responded more fearfully in novel situations than calves housed in individual pens with open sides that allowed visual and tactile social contact (Jensen et al., 1999). In another study, calves with only auditory contact were the most fearful ones in a novel environment, and pair-housed calves were the least fearful ones, while individually housed calves with tactile or visual contact were intermediate (Jensen and Larsen, 2014). However, only pair or group housing improved calves' social responses as outlined above.

Being able to respond appropriately during social interactions is an advantage when calves are weaned off milk and have to compete for access to solid feed. Another advantage of social housing pre-weaning is that it provides social support and reduces the stress at weaning off milk (de Paula Vieira et al., 2010; Bolt et al., 2017). Finally, social housing facilitates the transition from milk to solids by stimulating intake of solid feed. This has been shown in calves fed limited amounts of milk (Babu et al., 2004; Phillips, 2004; Hepola et al., 2006; Tapki, 2007) as well as in ad-libitum-fed calves (de Paula Vieira et al., 2010). In one study with ad-libitum-fed calves, pair housing prevented weight loss in the week following weaning off milk (Chua et al., 2002). In a recent study, the positive effect of pair housing on concentrate intake and weight gain was found in calves fed a high milk allowance (9 L/day) and not in calves fed a low milk allowance (5 L/day) (Jensen et al., 2015a). This is likely due to low-fed calves being hungrier and more motivated to consume any feed accessible, regardless of the social stimulation facilitating feeding. Pair housing has also been found to improve learning ability as assessed in a reversal learning task (Gaillard et al., 2014) which may also aid in finding and ingesting solid feed prior to weaning. Social skills are possibly more easily and more rapidly learned at younger ages although individually reared veal calves that were group housed from 3 months of age could still learn the social behavior at this stage (Veissier et al., 1994). However, calves form social bonds from an early age; they prefer a pen mate to an unfamiliar calf after 3 weeks of housing together (Færevik et al., 2006), and in 6-week-old calves, this preference was stronger if they had been housed together from birth rather than from 3 weeks of age (Duve and Jensen, 2011). Furthermore, for socially naïve calves, the stress of grouping likely adds to the stress of weaning off milk.

Studies that have compared individual housing with dam rearing have found similar effects on social responses (Flower and Weary, 2001; Wagner et al., 2013) and learning ability (Meagher et al., 2015). Although the presence of a peer does not substitute the dam, this may suggest that social housing with peers mitigates some of the adverse effects of early separation from the dam.

One concern about group housing milk-fed calves is group size. In the above studies, calves were pair-housed or housed in groups of three to six calves. However, when group-housed calves are fed milk via a computer-controlled feeder, group sizes may be as high as 20–30, and calves may be introduced to a group of this size when only a few days old. However, housing in large groups (Svensson et al., 2003), as well as early introduction to the group (Svensson and Liberg, 2006), has been reported to increase the risk of respiratory disease. Furthermore, calves introduced to a large group at 6 days of age were less explorative and required more assistance to learn to use the milk feeder than calves introduced at 14 days of age (Rasmussen et al., 2006; Jensen, 2007). Fujiwara et al. (2014) also found that younger calves spent more time learning to use a milk feeder than older calves. Therefore, even though social contact has several beneficial effects on calf welfare, keeping calves in groups of more than 10–12 is cautioned due to adverse effects on heath and increased competition (see also Section 6.4.1).

6.3.2 Use of tether stalls

Individual housing of cows in tether stalls has largely been replaced by loose housing, as farm size has increased in most western countries. However, tether stalls are still commonly used in small-sized dairy farms. The tethers and stall dividers limit cows' opportunities for social contact to merely sniffing and licking the head and neck of neighboring individuals. However, housing in tether stalls has traditionally been combined with summer grazing allowing cows the opportunity for full social contact while on pasture. Access to social contact during the winter may be given by releasing the cows into a yard on a regular basis, which is practiced, for example, in European organic dairy herds if they have tether stalls. Constantly tethered cows perform less social behavior than cows on pasture (Krohn, 1994), but when tethered dairy cows were let out into an outdoor yard for 1 hour, they performed the range of social behavior during this time, including both affiliative and agonistic behavior (Krohn, 1994; Loberg et al., 2004). Looking at the rebound of affiliative social behavior following various length of tethering may give some guidance as to how frequent free access to social contact should be given to avoid adverse effects of preventing affiliative behavior. On the other hand, increased aggressive social behavior may suggest that tethering prevents cattle from maintaining their dominance relations. In dairy cows, there was no increase in social behavior with more days between yard access (daily, twice weekly, or once weekly; Loberg et al., 2004). However, cows of the dual-purpose Hérens breed fought more when the interval between yard accesses exceeded 3 days (1–5 days; Castro et al., 2011, 2012), suggesting that tethering prevented cows of this breed from maintaining dominance relations. Tethering inhibits social behavior, but it also inhibits self-grooming and places much restriction on cattle's lying behavior (see Schütz et al., 2017, Chapter 5), and this housing is presently being phased out in countries like Denmark and Sweden.

6.4 Group housing–competition and aggression

6.4.1 Effects of group size, group composition, and regrouping

6.4.1.1 Group size

On rangelands, beef cows in herds of 27–240 cows split into subgroups of three to seven cows while grazing (Stephenson et al., 2016), but group size while grazing increased from six to 11 cows as forage availability increased (Muller et al., 1976). This suggests that when resources are limited, animals split into smaller groups. Such subgrouping may be based on preferential relations. In herds of 40 cows or less, the composition of grazing groups of beef cows did not differ from random, but in herds of 53–240 cows there was evidence of cows grazing with preferred individuals (Stephenson et al., 2016), suggesting that subgrouping based on preferential relations occurred in herds of more than 40 cows. In newly formed groups, familiar individuals are certainly preferred. During the first month on communal pastures (in a group of 70 or 118 cows), cows with two to four familiar peers (i.e. originating from the same farm) stayed in closer proximity and were involved in more social grooming and less agonistic interactions than cows with none or only one familiar peer (Takeda et al., 1999). However, even in smaller herds, the group size plays a role. Rind and Phillips (1999) found that dairy cows stayed closer together on pasture when in groups of four cows than when in groups of eight or 16 cows and that the level of aggression was highest in groups of 16 cows.

When cattle are housed indoors, subgrouping may not be possible, and large group sizes may represent an animal welfare concern if available resources, or space, is limited. There are, however, only a few studies on the effects of keeping cattle in large groups on social behavior under production conditions, and these offer little evidence of subgrouping. For instance, dairy cows in a large group (110 cows) kept in a straw yard (9.5 m^2 per cow) associated more with cows of a similar age, but cows did not appear to subgroup as such; i.e. they belonged to one social cluster (Boyland et al., 2016). In herds of 24–43 dairy cows, Gygax et al. (2010) found that dairy cows were less synchronized and kept a greater distance between them with increasing herd size. However, herd size and barn area were confounded in this study, and the given barn area may have prevented cows from subgrouping.

Other studies investigating the effect of group size while keeping constant access to resources have compared much smaller group sizes, and here the evidence is mixed. For instance, in dairy cows, there was less aggression the first day after introduction to a postpartum group of six cows than of 24 cows (Jensen and Proudfoot, 2017), while no effect of group size on aggression was found among lactating dairy cows in groups of six or 12 (Telezhenko et al., 2012). Among veal calves, group sizes of two, four, or eight calves did not affect affiliative or agonistic behavior (Abdelfattah et al., 2013). However, increased competition indicated by increased rate of milk ingestion from individual teat buckets was evident when increasing group size from two to six calves (Jensen and Budde, 2006), suggesting that increasing group size did increase competition for milk in milk-fed calves. Group composition may explain the lack of consistent effects of group size.

6.4.1.2 Group composition

Under natural conditions, cattle live in age-heterogeneous herds, and young individuals may benefit from the companionship of the dam as well as older calves. In support of this, dairy calves reared with older companions had enhanced food intake (de Paula Vieira et al., 2012), and calves reared in dam–calf groups were less neophobic (Costa et al., 2014) and performed better in learning tests (Meagher et al., 2015) compared to individually reared calves. However, under production conditions, social competition impacts younger individuals more than older ones, and it may be advantageous to maintain animals in a homogeneous group. In dairy heifers, aggressive interactions were higher in weight-heterogeneous groups of 10 than in homogeneous groups of five, and light heifers in the larger heterogeneous groups gained less weight than light heifers in the smaller homogeneous groups, especially when concentrates were offered separately and not as part of a total mixed ration (TMR; Hindhede et al., 1999). Similarly, among weaned calves in age-heterogeneous groups, the younger calves gained less weight than similar-aged calves in age-homogeneous groups (Færevik et al., 2010). First parity dairy cows kept in a separate group had a higher feed intake and higher milk yield than first parity cows grouped with later parity cows, and the effect on feed intake was more pronounced for feed offered restrictively than for feed offered ad libitum (Krohn and Kongaard, 1979). This illustrates that heterogeneity creates problems, especially when limited resources are defendable. Also on pasture, first parity cows kept in a separate group were involved in fewer aggressive interactions and spent more time grazing than first parity cows grouped with later parity cows (Philips and Rind, 2001). If herd size is small and first parity cows cannot be kept in a separate group, it may be an advantage to house nulliparous dairy cows with multiparous animals prior to calving for the dominance relations to be established before calving rather than after. For instance, Boyle et al. (2013) found that such primiparous cows received less aggression and spent more time at the feed after calving if they had been housed with multiparous dry cows during the precalving period.

Another group of cattle that may need to be kept separately and protected from competition is sick or injured animals. Sick or injured dairy cows have reduced competitive abilities (Gonzalez et al., 2008), but also motivational priorities may change. Studies primarily on rodents have shown that animals become inactive, lose appetite, and avoid social interactions during systemic disease (Dantzer and Kelley, 2007). Postpartum dairy cows diagnosed with an infectious disease, and with a fever, spent more time isolating behind an opaque barrier in an individual maternity pen than healthy cows (Proudfoot et al., 2014a). Moreover, group-housed cows diagnosed with a uterine infection interacted less with other cows and avoided competition at the feed manger (Huzzey et al., 2007), suggesting that also dairy cows with a systemic disease avoid social interactions. On the other hand, dairy cows diagnosed with a non-infectious hoof disease, and no fever, spent most of their time in visual contact with and proximity of animals in a neighboring pen (Jensen et al., 2015b). More knowledge of the effect of various diseases on social motivation of different age classes would be beneficial to determine when animals should have the opportunity to isolate when sick and when they should not be isolated but merely protected from competition to aid their recovery.

6.4.1.3 Regrouping

Under intensive production conditions, where cattle are grouped according to age, sex and (re)productive status, regrouping often occurs. Regrouping means that new dominance relationships have to be established, and regrouping typically results in a period of increased agonistic interactions. Dairy cows that were regrouped by being individually introduced into an established social group of 11 cows were displaced from the feeding area 2.5 times more often on the first day after regrouping as compared to in their original group (von Keyserlingk et al., 2008). Beef cows introduced in pairs to a group of eight cows received more and initiated less aggression compared to resident cows (Mench et al., 1990), but introducing more individuals at the time into an established group may reduce the amount to aggression received by each individual. On dairy farms with groups of 22–44 cows, heifers introduced to the herd together with a familiar heifer were involved in fewer agonistic interactions during the first 3 days after introduction than heifers introduced alone (Neisen et al., 2009). This may be because the pairs synchronized their activity, and this enabled them to avoid aggressive encounters. Resident animals also experience a change in group composition when new individuals are introduced. In studies where regrouping is conducted by replacing half of the individuals of an original group with individuals from another group, it was shown that relocation and regrouping is a larger challenge than regrouping in the home pen. For instance, cows with a high dominance value could maintain this after regrouping if they stayed in their home pen but not if they were relocated to a novel pen (Hasegawa et al., 1997). Furthermore, cows that were both relocated and regrouped initiated more displacements from feed than cows that were only regrouped (Schirmann et al., 2011), suggesting that these cows had more difficulties in accessing the feed.

Regrouping also often means breaking preferential social relationships (Bouissou et al., 2001; Raussi et al., 2010), and these preferential relationships likely play a role in reducing adverse effects of competition. Generally, the earlier in life dairy heifers are reared together, the more affiliative behavior and the less aggression at the feed manger are observed among them (Færevik et al., 2007; Bouissou et al., 2001). Regrouping of 9-month-old bulls resulted in more aggressive behavior, more mounting (Mounier et al., 2005) and more competition at the feed manger (Mouier et al., 2006) than if group composition remained unchanged. However, more affiliative behavior, more tolerance and less aggression among those individuals that had previously been grouped together support the fact that opportunity to maintain contact with previous group mates reduces the adverse effects of regrouping (Mounier et al., 2005, 2006). Possibly, it has to be specifically preferred partners to obtain this effect. For instance, Patison et al. (2010) showed that steers were more likely to move away from the herd to feed when with a familiar rather than an unfamiliar peer. Furthermore, Færevik et al. (2007) regrouped calves into groups of four, eight or 16 so that half of the calves in each group came from the same previous group of eight. On the first day after regrouping, the number of displacements from the feed manger was higher in groups of four than in the larger groups. This may be due to each calf in groups of 16 having all previous partners in the new group, while each calf in groups of four only had one. One way of always maintaining some familiarity in groups of calves and young stock might be to create new groups by combining previous and smaller groups.

Dairy cows also preferred familiar cows; i.e. cows that they had been grouped with either during rearing, during previous lactations or during the most recent dry period (Gutmann et al., 2015). In this study, cows spent more time feeding next to familiar individuals, and these preferred partners interacted more socially (agonistic as well as nonagonistic). Val-Laillet et al. (2009) found that those cows that were frequently feeding together were also displacing each other more in situations with high competition. However, these dyads were also grooming each other more, and together, these two studies suggest that cows choose to compete, and to share, with preferred individuals. Furthermore, Šárová et al. (2016) saw that most social grooming in a stable herd was exchanged between dominant cows, supporting that social grooming mainly serves to ensure social stability. Therefore, group management that prioritizes keeping familiar cows together likely contributes to increased animal welfare through increased social stability and social support.

Aggression occurs even after many regroupings, and heifers did not show signs of habituation to repeated regrouping (Raussi et al., 2005). The level of aggression after regrouping and repeated regrouping was low in calves under the age of 5 months. However, calves having experienced several pair regroupings were more reluctant to sniff an unfamiliar calf and spent less time drinking milk in the presence of an unfamiliar calf, indicating that repeated regrouping results in increased social fear (Veissier et al., 2001). Furthermore, 18-day-old calves responded to individual introduction into a dynamic group fed milk via an automated feeder with a transient reduction in milk intake and an increase in drinking rate (O'Driscoll et al., 2006), suggesting that also milk-fed calves have problems competing for resources after regrouping. Reducing the stocking of cubicles from one to two cubicles per cow reduced aggression after regrouping in a study where six unfamiliar cows were added to a core group of six cows (Talebi et al., 2014), and increasing resource availability when regrouping may also be a way of mitigating the negative effects of regrouping and improving animal welfare.

6.4.2 Effect of space allowance

When cattle are housed indoors, the total space allowance and the stocking density of the feed manger and lying areas are important determinants of the level of competition for space, feed and access to rest, respectively. Reducing access to these resources leads to increased aggression and attempts to counteract the reduced access. This is particularly obvious when the stocking density of the feed manager is increased.

Increased stocking density of the feed manger results in more aggressive displacements from the feed and an increased feeding rate. This is found both with ad libitum and restrictive feeding, but the effects are greatest with restrictive feeding. For instance, a reduction in feeding space from 1.08 m per cow (one feed bin per cow) to 0.27 m per cow (one feed bin per four cows) with ad libitum feeding resulted in a four-fold increase in the number of displacements and a reduction of 19% in feeding time. The same reduction in feeding space with restrictive feeding resulted in a 10-fold increase in the number of displacements and a reduction of 50% in feeding time (Olofsson, 1999). Most dairy cows are fed a TMR for ad libitum intake and, in cubicle housing, the feed manger is typically fitted with a post and rail or headlocks. Among cows fed at a pendulous rail, a reduction in available feed space from 1.0 to 0.5 m per cow resulted in more than a doubling of aggressive interactions during the first 1.5 hours after the provision of fresh feed (DeVries et al., 2004). Among cows fed at a headlock feed manger, a reduction in available feed space from 0.61 m to 0.49 m per cow resulted in an increase of 40% in the number of displacements (Lobeck-Luchterhand et al., 2015). In a study including a range of allowances, an exponential increase in the number of displacements and a concurrent decline in feeding time with a reduction in feed manger space from 0.81, 0.61, 0.41 to 0.21 m per cow were found in the case of both post and rail and headlocks (one headlock was 0.61 m). A marked increase in displacement and reduction in feeding time was seen when there was less than 0.61 m per cow, and the effect of reducing feed manger space to 0.21 m per cow was dramatic (Huzzey et al., 2006).

Headlocks offered more protection from displacements than a post and rail and, when there was only 0.21 m per cow, more displacements were seen with post and rail than with headlocks (Huzzey et al., 2006; Endres et al., 2005). Nevertheless, headlocks do not prevent displacements, and considerable protection is required to prevent displacements. For instance, placing barriers covering the front of the cows between 0.87-m-wide feeding spaces reduced displacements from the manger markedly (DeVries and von Keyserlingk, 2006). Similarly, fitting barriers between milk buckets eliminated displacements in dairy calves when the barriers covered the calves' heads and shoulders (Jensen et al., 2008).

Overstocking the feed manger increases aggression and reduces feeding time and, in turn, feeding rate is increased to counteract this (Nielsen, 1999). When lying areas are overstocked, low-ranking animals have reduced access to lying down (Winckler et al., 2015; Nielsen et al., 1997), but animals have no means of counteracting reduced access to rest (Munksgaard et al., 2005). Among dairy cows in cubicle housing, overstocking of cubicles increased displacements form these lying spaces (Wierenga, 1990; Fregonesi et al., 2007; Winckler et al., 2015) compared to 100% stocking. On the other hand, understocking reduced the number of displacements from cubicles, suggesting that cows were competing for certain preferred lying spaces (Winckler et al., 2015) or attempting to keep a larger individual distance when resting than what is possible in neighboring cubicles at 100% stocking of cubicles.

In some instances, the floor space is equal to lying space. Among pasture-kept dairy cows (approx. 500 kg live weight) that were temporarily taken off pasture for 18 hours each day, increasing the space allowance from 3.0 to 4.5 m^2 per cow reduced the number of aggressive interactions by 35%, while a smaller reduction was seen in the interval from 4.5 to 10.5 m^2 per cow (Schütz et al., 2015). Among young stock (250–500 kg live weight) that were permanently housed in pens with fully slatted floors, increasing the space allowance in the range between 1.5 and 3.0 m^2 per animal increased social grooming (Fisher et al., 1997) and reduced the frequency of lying displacements (Lidfors, 1992). When young stock is housed in pens with fully slatted floors, they are typically kept at a low space allowance. A total space allowance of minimum 3 m^2 per animal and the provision of softer lying surfaces are now recommended in the EU (Wechsler, 2011). However, also in pens with a total space of 5 m^2 per animal and a separate straw-bedded lying area, increasing the lying area from 1.8 m^2 to 2.7 and 3.6 m^2, resulted in fewer aggressive interactions and lying displacements among heifers weighing up to 480 kg (Nielsen et al., 1997). This illustrates the beneficial effects of increasing space in the softer lying area but also questions whether a total area of 3 m^2 per animal is an appropriate minimum for cattle up to 500 kg live weight to safeguard animal welfare.

6.4.3 Social priorities around parturition

As the cow approaches calving, her social priorities change. Among beef cows kept on open pasture, pregnant cows were more often seen within 20 m of other pregnant cows than maternal cows (i.e. cows that had recently calved), while maternal cows were most often seen within this range of other maternal cows (Finger et al., 2014). However, the time that cows spent within 4 m of other cows decreased from approx. 10 minutes per day at 50 days before calving to 1 minutes on the day of calving and remained at approx. 2–3 minutes for 50 days after calving (Swain et al., 2015). The reduced social contact on the day of calving likely reflects a motivation to isolate from the herd. Also among beef cows kept at open pasture, 88% of the cows moved more than 100 m away from the feeding area (where the main herd stayed) to calve (Flörcke et al., 2014). Apparently, the tendency to isolate from the herd at calving depends on the environment. Domestic cattle kept in areas with natural vegetation have been reported to separate from the herd to calve in a sheltered area covered with trees or bushes, and with a dry surface, while among cattle kept on open pasture calving often occurred within the herd (Lidfors et al., 1994). Although the cow may be motivated to isolate prior to calving, a conflict arises if there are no suitable hiding places offering protection from predators, and this may explain the above results. When dairy cows were given the opportunity to hide behind a 1.5-m-wide opaque barrier in an individual maternity pen (Fig. 6.4), 80% of the cows calved behind this barrier and visually isolated from pregnant cows in a neighboring group pen, while cows in open maternity pens chose their calving site at random (Proudfoot et al., 2014a). In the maternity pens with a barrier, the cows sought isolation approx. 1 hour before calving (Proudfoot et al., 2014a), but under near-natural conditions (Lidfors et al., 1994), and when housed in large experimental maternity pens (Proudfoot et al., 2014b), cows sought isolation 12–8 hours prior to calving. The timing of isolation seeking, as well as the propensity of cows to seek isolation, may depend on the design of and distance to the hide, and much is still to be learnt about the importance of being able to make these special social priorities for cow welfare. However, cows are often moved late in relation to calving, and it has been shown that dairy cows that were moved late in relation to calving had prolonged duration of the second stage of calving (Proudfoot et al., 2013). Because prolonged calving may be associated with increased pain, inflammation and risk of dystocia (Mainau and Manteca, 2011), enabling the cows to separate from the herd on their own and well in time before calving has a great potential for improving cow welfare. Furthermore, management at calving may also be important for management of extended dam-calf contact in dairy production. For instance, some time together in an individual maternity pen may be beneficial to ensure that the maternal bond is formed before the two enter a larger group of cows with their calves.

FIGURE 6.4 A cow with her new-born calf in an individual maternity pen with a 1.5-m-wide opaque barrier covering half of the side facing the group pen with pregnant cows. Photo courtesy of Maria Vilain Rørvang, Aarhus University, Denmark.

6.4.4 Abnormal social behavior in group housing

6.4.4.1 Cross-sucking

Artificially reared dairy calves that are housed in groups may direct their sucking behavior towards other calves' heads and bodies (cross-sucking; Lidfors, 1993). Cross-sucking may be directed towards any body part but most commonly mouth, ears, navel, scrotum, prepuce and udder are sucked (Fig. 6.5), and this may cause loss of hair and inflammation (see reviews by de Passillé (2001) and Jensen (2003)). The abnormal behavior may persist as inter-sucking after weaning off milk, and the behavior is also a risk factor for development of milk stealing among dairy cows (Keil and Langhans, 2001; Keil et al., 2000) which may discourage dairy farmers from group-housing milk-fed calves (Lidfors and Isberg, 2003).

FIGURE 6.5 Five calves in a group pen; the calves have just been fed milk in open buckets, and all calves are performing cross-sucking of mouth, ear or under the belly. Photo courtesy of Marlene Budde, Aarhus University, Denmark.

Cross-sucking in milk-fed calves may be reduced if calves are fed milk via a teat (e.g., teat buckets or automated milk feeders) instead of in open buckets and troughs. When calves are fed milk via a teat, they spend more time ingesting the milk, they suck the teat after the milk is ingested, and they perform less cross-sucking (Jensen and Budde, 2006). Reducing the milk flow rate, and thus prolonging the milk meal and the provision of artificial teat to suck after the milk meal (Jung and Lidfors, 2001), also reduces the occurrence of cross-sucking. When computer-controlled milk feeders are used, there are often more than 20 calves per milk feeder and there is much aggression around it, and displacement from the feeder is seen (Jensen, 2004); however, although much cross-sucking was observed at the milk feeder, the behavior could not be related to aggression (Laukkanena et al., 2010). Sucking behavior is elicited by the ingestion of milk (de Passillé et al., 1992) and, after weaning, most calves stop cross-sucking. However, some calves intensify the behavior around the time of weaning, especially if they are weaned early and abruptly (Nielsen et al., 2008; Sweeney et al., 2010) and if their energy intake is low (de Passillé et al., 2010). Most calves attempt to avoid being cross-sucked, but calves that intensify cross-sucking at weaning often also allows other calves to cross-suck themselves, and specific pairs of mutually cross-sucking calves have been observed sometime after weaning (Špinka, 1992; de Passillé et al., 2011). Milk-feeding via a teat and ensuring energy intake around weaning are measures to prevent the abnormal behavior, but, once established, separating mutually cross-sucking pairs may be the simplest cure if the abnormal behavior persists between certain calves (Vaughan et al., 2016).

6.4.4.2 Excessive mounting behavior

Excessive mounting behavior is reported among young bulls housed in pens with little space and among steers kept in large groups in feedlots. Among young bulls housed in small group pens with fully slatted floors, increasing the space allowance in the range between 1.5 m^2 and 3.0 m^2 per animal reduced the frequency of mounting (Wierenga, 1987; Lidfors, 1992) and head resting (Fisher et al., 1997), which indicates an intention to mount. Mounting is likely related to dominance. At regrouping, both aggression and mounting increased, and the two declined at the same rate with time after regrouping (Tennesen et al., 1985; Kenny and Tarrant, 1987). More mounting at low space allowances may be due to the mounted animals not having enough space to move away or to turn around to retaliate.

In feedlots, where several hundreds of steers are grouped together, excessive mounting is reported and described as the “buller steer syndrome” where one individual is repeatedly mounted and ridden by its pen mates until exhaustion and injury, including hair loss, swelling, trauma and broken bones (Tucker et al., 2015). Risk factors for this behavior are group sizes of more than 200–250 animals, regrouping, and warm weather (reviewed by Blackshaw et al., 1997), but the use of anabolic hormone implantation may also play a role (Tucker et al., 2015). If an animal is a victim of excessive mounting behavior, the resulting exhaustion and injury make removal from the group the only way to avoid further injury, and, when victims are grouped together, only little or no mounting is reported (Blackshaw et al., 1997). Excessive mounting is a damaging social behavior that appears to be a symptom of a social environment, which the animals have no behavioral means to adapt to, either due to little space or due to a large group size and group instability or both. In the natural situation, males would disperse into small bachelor groups, and keeping males in small stable groups may be one solution to this problem.

6.5 Conclusions

What do we know, and where do we need to know more about social behavior to advance animal welfare in cattle production?

6.5.1 Cow–calf separation: Understanding risk associated with separation at various ages and knowing more about ways to mitigate that risk

In beef production, calves experience a complex social environment until they are weaned at 5–6 months of age. This separation is before natural weaning age and is associated with negative affective states, but partial separation before final separation reduces the calf’s responses to separation in beef production. The maternal bond is formed within the hours after birth, and an increased response to separation the longer the two are kept together is used as an argument for separating dam and calf at birth in dairy production. However, also in dairy calves, recent research suggests that partial separation before final separation may reduce behavioral responses to separation. These effects were mainly found in calves, and a two-step procedure may be more beneficial for the calf than for the dam, especially if the two are separated after a few weeks, as in dairy production. Therefore, future research should focus on management that reduces the responses to separation in both calf and dam at various calf ages. In addition to stepwise separation, experiencing short periods of separation before the final separation may be a way to weaken the maternal bond gradually such that dam and calf can benefit from early contact, while adverse effects of separation are reduced. Social contact may buffer an adverse experience, and the potential for the presence of peers to reduce the negative effect of separating dam and calf, as well as other adverse management procedures, should be investigated further.

6.5.2 Calf housing: Pairs versus more complex options

In dairy production, social rearing with similar-aged peers in pairs or small groups has several beneficial effects on calf welfare; calves develop cognitive and social skills, intake of solid food is stimulated, and calves are better prepared for the social and nutritional changes encountered at weaning off milk. Similar short-term effects of pair housing, group housing, and dam rearing have been found, and thus it appears that pair housing provides sufficient social contact to obtain these short-term effects. However, studies on long-term effects of early social environment are few, and the question arises as to whether growing up in a complex social environment, including the dam, is superior to being housed with just one other calf. Research to investigate the effects of complexity of the early social environment, as well as the effect of duration and timing of maternal and other social contact, on social and cognitive abilities in adulthood is needed to answer this question.

6.5.3 Buffering effects of social contact during regrouping across ages

Living in a group means competing for resources. This competition depends on resource availability, and research to show how increasing availability of feeding and lying spaces to dairy cows reduces this competition exists. Recent research suggests that cows compete and share with preferred individuals, and future research should explore whether the sharing of resources is facilitated by early social experiences and by social stability of the group. Incorporating such knowledge in group management may potentially improve animal welfare, because it enables cattle to adapt to their social environment through affiliative behavior. Heterogeneous group composition creates problems, especially when limited resources are defendable, and keeping groups stable and homogeneous appears to have animal welfare benefits. Regrouping is a challenge to animal welfare because it may imply breaking existing social bonds and always implies establishing new dominance relations. Letting animals maintain at least some social bonds when new groups are formed may provide social buffering, but the extent to which this may mitigate the negative effects of regrouping needs to be investigated. Furthermore, the effect of giving disadvantaged individuals the benefits of straying in the familiar environment, as well as the effect of increasing space and availability of other resources for a period after regrouping, on reducing the negative effects of regrouping should be explored. Groups of special focus could be newly weaned calves, postpartum cows, and sick or injured animals. To the parturient cow, the opportunity to avoid social interaction and to calve (and bond to her calf) on her own may potentially increase her welfare, but, overall, more focus on preferential relationships and cattle's affiliative social behavior is encouraged.

6.5.4 Group composition and abnormal behavior

Under some conditions, abnormal behavior develops during social housing. One type of abnormal behavior is cross-sucking, and although the cause of this behavior lies in milk feeding management, social factors appear to play a role in the persistence of this behavior and, here, certain pairs of mutual cross-sucking individuals may have to be separated post-weaning. Another abnormal behavior is excessive mounting among males. This damaging behavior is related to aggression and appears to be a symptom of too little space or too large groups where victims of the behavior have no opportunities to either retaliate or escape. In the natural situation, males would disperse into small bachelor groups, and an apparent lower risk at higher space allowance and smaller group size suggests that future research should look there for solutions to this problem.

References

1. Abdelfattah EM, Schutz MM, Lay DC, Marchant-Forde JN, Eicher SD. Effect of group size on behavior, health, production, and welfare of veal calves. *J Anim Sci.* 2013;91:5455–5465.
2. Babu LK, Pandey HN, Sahoo A. Effect of individual versus group rearing on ethological and physiological responses of crossbred calves. *Appl Anim Behav Sci.* 2004;87:177–191.
3. Barfield CH, Tang-Martinez Z, Trainer JM. Domestic calves recognize

their own mother by auditory cues. *Ethology*. 1994;97:257–264.
4. Bateson P. The dynamics of parent offspring relationships in mammals. *Trends Ecol Evol.* 1994;9:399–403.
5. Blackshaw JK, Blackshaw AW, Mcglone JJ. Buller steer syndrome review. *Appl Anim Behav Sci.* 1997;54:97–108.
6. Boissy A, Le Neindre P. Behavioral, cardiac and cortisol responses to brief peer separation and reunion in cattle. *Physiol Behav.* 1997;61:693–699.
7. Bolt SL, Boyland NK, Mlynski DT, James R, Croft DP. Pair housing of dairy calves and age at pairing: effects on weaning stress, health, production and social networks. *PLoS ONE*. 2017;12:e0166926 https://doi.org/10.1371/journal.pone.0166926.
8. Bouissou MF, Boissy A, Le Neindre P, Veissier I. Social behaviour of cattle. In: Keeling L, Gonyou H, eds. *The Social Behaviour of Farm Animals*. Wallingford, UK: CABI Publishing; 2001;113–145.
9. Boyland NK, Mlynski DT, James R, Brent LJN. The social network structure of a dynamic group of dairy cows: from individual to group level patterns. *Appl Anim Behav Sci.* 2016;174:1–10.
10. Boyle AR, Ferris CP, O'Connell NE. Does housing nulliparous dairy cows with multiparous animals prior to calving influence welfare- and production-related parameters after calving? *Appl Anim Behav Sci.* 2013;143:1–8.
11. Buchli C, Raselli A, Bruckmaier R, Hillmann E. Contact with cows during the young age increases social competence and lowers the cardiac stress reaction in dairy calves. *Appl Anim Behav Sci.* 2017;187:1–7.
12. Budzynska M, Weary DM. Weaning distress in calves: effects of alternative weaning procedures. *Appl Anim Behav Sci.* 2008;112:33–39.
13. Castro IML, Gygax L, Wechsler B, Hauser R. Increasing the interval between winter ourdoor exercise aggravates agonistic interactions in Hérens cows kept in tie-stalls. *Appl Anim Behav Sci.* 2011;129:59–66.
14. Castro IML, Gygax L, Wechsler B, Hauser R. Effects of short or long periods of separation on agonistic behaviour, injuries and stress in Hérens cows kept in loose housing. *Appl Anim Behav Sci.* 2012;136:96–103.
15. Chua B, Coenen E, van Delen J, Weary DM. Effects of pair versus individual housing on the behavior and performance of dairy calves. *J*

Dairy Sci. 2002;85:360–364.
16. Costa JHC, Daros RR, von Keyserlingk MAG, Weary DM. Complex social housing reduces food neophobia in dairy calves. *J Dairy Sci.* 2014;97:7804–7810.
17. Costa JHC, von Keyserlingk MAG, Weary DM. Invited review: effects of housing of dairy calves on behaviour, cognition performance, and health. *J Dairy Sci.* 2016;99:2453–2467.
18. Dantzer R, Kelley KW. Twenty years of research on cytokine induced sickness behavior. *Brain Behav Immun.* 2007;21:153–160.
19. Daros R, Costa JHC, von Keyserlingk MAG, Hötzel MJ, Weary DM. Separation from the dam causes negative judgement bias in dairy calves. *PLoS ONE*. 2014;9:e98429 http://dx.doi.org/10.1371/journal.pone.0098429.
20. de Passillé AMB, Metz JHM, Mekking P, Wiepkema PR. Does drinking milk stimulate sucking in young calves? *Appl Anim Behav Sci.* 1992;34:23–36.
21. de Passillé AM. Sucking motivation and related problems in calves. *Suckling Appl Anim Behav Sci.* 2001;72:175–187.
22. de Passillé AM, Sweeney B, Rushen J. Cross-sucking and gradual weaning of dairy calves. *Appl Anim Behav Sci.* 2010;124:11–15.
23. de Passillé AM, Borderas FT, Rushen J. Cross-sucking by dairy calves may become a habit or reflect characteristics of individual calves more than milk allowance or weaning. *Appl Anim Behav Sci.* 2011;133:137–143.
24. de Paula Vieira A, von Keyserlingk MAG, Weary DM. Effects of pair versus single housing on performance and behaviour of dairy calves before and after weaning from milk. *J Dairy Sci.* 2010;93:3079–3085.
25. de Paula Vieira A, von Keyserlingk MAG, Weary DM. Presence of an older weaned companion influences feeding behaviour and improves performance of dairy calves before and after weaning from milk. *J Dairy Sci.* 2012;95:3218–3224.
26. DeVries TJ, von Keyserlingk MAG. Feed stalls affect the social and feeding behavior of lactating dairy cows. *J Dairy Sci.* 2006;89:3522–3531.
27. DeVries TJ, von Keyserlingk MAG, Weary DM. Effect of feeding space on the inter-cow distance, aggression and feeding behaviour of free-stall housed lactating dairy cows. *J Dairy Sci.* 2004;87:1432–1438.

28. Duve LR, Jensen MB. The level of social contact affects social behaviour in pre-weaned dairy calves. *Appl Anim Behav Sci.* 2011;135:34–43.
29. Duve LR, Jensen MB. Social behavior of young dairy calves housed with limited or full social contact with a peer. *J Dairy Sci.* 2012;95:1–10.
30. Duve LR, Weary DM, Halekoh U, Jensen MB. The effects of social contact and milk allowance on the response to handling, play behavior and social behavior in young dairy calves. *J Dairy Sci.* 2012;95:6571–6581.
31. Edwards S, Broom D. Behavioural interactions of dairy cows with their newborn calves and the effects of parity. *Anim Behav.* 1982;30:525–535.
32. Endres MI, DeVries TJ, von Keyserlingk MAG, Weary DM. Effect of feed barrier design on the behavior of loose housed lactating dairy cows. *J Dairy Sci.* 2005;88:2377–2380.
33. Enriquez DH, Ungerfeld R, Quintans G, Guidoni AL, Hötzel MJ. The effects of alternative weaning methods on behaviour in beef calves. *Livest Sci.* 2010;128:20–27.
34. Enriquez D, Hötzel MJ, Ungerfeld R. Minimising the stress of weaning of beef calves: a review. *Acta Vet Scand.* 2011;53:28 http://actavetscand.biomedcentral.com/articles/10.1186/1751-0147-53-28.
35. Færevik G, Jensen MB, Bøe KE. Dairy calves' social preferences and the significance of a companion during separation from the group. *Appl Anim Behav Sci.* 2006;99:205–221.
36. Færevik G, Andersen IL, Jensen MB, Bøe K. Increased group size reduces conflicts and strengthens the preference for familiar group mates in dairy calves (*Bos Taurus*). *Appl Anim Behav Sci.* 2007;108:215–228.
37. Færevik G, Jensen MB, Bøe K. The effect of group composition and age on social behavior and competition in groups of weaned dairy calves. *J Dairy Sci.* 2010;93:4274–4279.
38. Finger A, Patison KP, Heath BM, Swain DL. Changes in the group associations of free-ranging beef cows at calving. *Anim Prod Sci.* 2014;54:270–276.
39. Fisher A, Crowe MA, Prendiville DJ, Enright W. Indoor space allowance: effects on growth, behaviour, adrenal and immune response

of finishing beef heifers. *Anim Sci.* 1997;64:53–62.
40. Flörcke C, Grandin T. Separation behaviour for parturition of red angus beef cows. *Open J Anim Sci.* 2014;4:43–50.
41. Flower F, Weary DM. Effects of early separation on the dairy cow and calf: 2 Separation at 1 day and 2 weeks after birth. *Appl Anim Behav Sci*. 2001;70:275–284.
42. Fraser D, Weary DM, Pajor EA, Milligan BN. A scientific conception of animal welfare that reflects ethical concerns. *Anim Welf.* 1997;6:187–205.
43. Fregonesi JA, Tucker CB, Weary DM. Overstocking reduces lying time in dairy cows. *J Dairy Sci.* 2007;90:3349–3354.
44. Fröberg S, Lidfors L. Behaviour of dairy calves suckling the dam in a barn with automatic milking or being fed milk substitute from an automatic feederin a group pen. *Appl Anim Behav Sci.* 2009;117:150–158.
45. Fröberg S, Aspegren-Guldorff A, Olsson I, et al. Effect of restricted suckling on milk yield, milk composition and udder health in cows and behaviour and weight gain in calves, in dual-purpose cattle in the tropics. *Trop Anim Health Prod.* 2007;39:71–81.
46. Fujiwara M, Rushen J, de Passillé AM. Dairy calves' adaptation to group housing with automated feeders. *Appl Anim Behav Sci.* 2014;158:1–7.
47. Gaillard C, Meagher RK, von Keyserlingk MAG, Weary DM. Social housing improves dairy calves' performance in two cognitive tests. *PLoS ONE*. 2014;9:e90205 http://dx.doi.org/10.1371/journal.pone.0090205.
48. González LA, Tolkamp BJ, Coffey MP, Ferret A, Kyriazakis I. Changes in feeding behavior as possible indicators for the monitoring of health disorders in dairy cows. *J Dairy Sci.* 2008;91:1017–1028.
49. Grignard L, Boissy A, Boivin X. The social environment influences the behavioural responses of beef cattle to handling. *Appl Anim Behav Sci.* 2000;68:1–11.
50. Gutmann AK, Špinka M, Winckler C. Long-term familiarity creates preferred social partners in dairy cows. *Appl Anim Behav Sci.* 2015;169:1–8.
51. Gygax L, Neisen G, Wechsler B. Socio-spatial relationships in dairy cows. *Ethology*. 2010;116:10–23.
52. Haley D, Bailey D, Stookey J. The effects of weaning beef calves in two

stages on their behavior and growth rate. *J Anim Sci.* 2005;83:2205–2214.

53. Hall SJG. *Breed of the month. Studying the Chillingham Wild Cattle.* 6 Ark 1979;72–79.
54. Hasegawa N, Nishiwaki A, Sugaware K, Ito I. The effects of social exchange between two groups of lactating primiparous heifers on milk production, dominance order and adrenocortical response. *Appl Anim Behav Sci.* 1997;51:15–27.
55. Hepola H, Hänninen L, Pursiainen P, et al. Feed intake and oral behavior of dairy calves housed individually or in groups in warm or could buildings. *Livest Sci.* 2006;105:94–104.
56. Herskin MS, Munksgaard L, Ladewig J. Effects of acute stressors on behavior, adrenocortical responses and hypoalgesia in dairy cows. *Physiol Behav.* 2004;83:411–420.
57. Herskin MS, Munksgaard L, Andersen JB. Effects of social isolation and restraint on adrenocortical responses and hypoalgesia in loose housed dairy cows. *J Anim Sci.* 2007;85:240–247.
58. Hickey M, Drennan M, Earley B. The effect of abrupt weaning of suckler calves on the plasma concentrations of cortisol, catecholamines, leukocytes, acute-phase proteins and in vitro interferon-gamma production. *J Anim Sci.* 2003;81:2847–2855.
59. Hindhede J, Mogensen L, Sørensen JT. Effect of group composition and feeding systems on behaviour, production and health of dairy heifers in deep bedding systems. *Acta Agric Scand., Sect A, Animal Sci.* 1999;49:211–220.
60. Holm L, Jensen MB, Jeppesen LL. Calves' motivation for access to two different types of social contact measured by operant conditioning. *Appl Anim Behav Sci.* 2002;79:175–194.
61. Hopster H, Oconnell JM, Blokhuis HJ. Acute effects of cow–calfseparation on heart-rate, plasma cortisol and behavior in mutliparousdairy-cows. *Appl Anim Behav Sci.* 1995;44:1–8.
62. Hötzel M, Ungerfeld R, Quintans G. Behavioural responses of 6-month old beef calves prevented from suckling: influence of dam's milk yield. *Anim Prod Sci*. 2010;50:909–915.
63. Hotzel MJ, Longo C, Balcao LF, Cardoso CS, Costa JHC. A survey of management practices that influence performance and welfare of dairy calves reared in Southern Brazil. *PLoS ONE*. 2014;9:e114995

http://dx.doi.org/10.1371/journal.pone.0114995.
64. Hötzel MJ, Quintas G, Ungerfeld R. Behaviour response to two-step weaning is dismissed in beef calves previously submitted to temporary weaning with nose flaps. *Livest Sci.* 2012;149:88–95.
65. Hudson SJ, Mullord MM. Investigations of maternal bonding in dairy cattle. *Appl Anim Ethol.* 1977;3:271–276.
66. Huzzey JM, DeVries TJ, Valois P, von Keyserlingk MAG. Stocking density and feed barrier design affects feeding and social behavior of dairy cattle. *J Dairy Sci.* 2006;89:126–133.
67. Huzzey JM, Veira DM, Weary DM, von Keyserlingk MAG. Behavior and intake measures can identify cows at risk for metritis. *J Dairy Sci.* 2007;90 3320–3233.
68. Jensen MB, Vestergaard KS, Krohn CC, Munksgaard L. Effect of single versus group housing and space allowance on responses of calves during open-field test. *Appl Anim Behav Sci.* 1997;54:109–121.
69. Jensen MB, Mogensen L, Munksgaard L, Krohn C. Effects of housing in different social environments on open-field and social responses of female dairy calves. *Acta Agric Scand Sect A, Anim Sci.* 1999;49:113–120.
70. Jensen MB. The effects of feeding method, milk allowance and social factors on milk feeding behaviour and cross-sucking in group housed dairy calves. *Appl Anim Behav Sci.* 2003;80:191–206.
71. Jensen MB. Computer controlled milk feeding of dairy calves: The effects of number of calves per feeder and number of milk portions on use of feeder and social behavior. *J Dairy Sci.* 2004;87:3428–3438.
72. Jensen MB, Budde M. The effect of milk feeding method and group size on feeding behavior and cross-sucking in group-housed dairy calves. *J Dairy Sci.* 2006;89:4778–4783.
73. Jensen MB. Age at introduction to the group affects dairy calves’ use of a computer-controlled milk feeder. *Appl Anim Behav Sci.* 2007;107:22–31.
74. Jensen MB, de Passillé AM, von Keyserlingk MAG, Rushen J. A barrier can reduce competition over teats in pair-housed milk-fed calves. *J Dairy Sci.* 2008;91:1607–1613.
75. Jensen MB. Early behaviour of cow and calf in an individual calving pen. *Appl Anim Behav Sci.* 2011;134:92–99.
76. Jensen MB. Behaviour around the time of calving in dairy cows. *Appl*

Anim Behav Sci. 2012;139:195–202.
77. Jensen, M.B., Larsen L.E., 2013. The effect of social contact in dairy calves on behaviour and health. In: Proceedings of the 47th International Congress of the ISAE, Florianopolis, Brazil, p. 63.
78. Jensen MB, Larsen LE. Effects of level of social contact on dairy calf behavior and health. *J Dairy Sci J Dairy Sci.* 2014;97:5035–5044.
79. Jensen MB, Duve LR, Weary DM. Pair housing and enhanced milk allowance increase play behavior and improve performance in dairy calves. *J Dairy Sci.* 2015a;98:2568–2575.
80. Jensen MB, Herskin MS, Thomsen P, Forkman B, Houe H. Preferences of lame cows for type of surface and level of social contact in hospital pens. *J Dairy Sci.* 2015b;98:4552–4559.
81. Jensen, M.B., Proudfoot, K.L. 2017. Effect of group size and health status on behavior and feed intake of multiparous dairy cows in early lactation J.Dairy Sci. In Press https://doi.org/10.3168/jds.2017-13035.
82. Johnsen JF, de Passille AM, Mejdell CM, et al. The effect of nursing on the cow–calf bond. *Appl Anim Behav Sci.* 2015a;163:50–57.
83. Johnsen JF, Ellingsen K, Grøndahl AM, Bøe KE, Lidfors L, Mejdell CM. The effect of physical contact between dairy cows and calves during separation on their post-separation behavioural response. *Appl Anim Behav Sci.* 2015b;166:11–19.
84. Johnsen JF, Zipp KA, Kälber T, et al. Is rearing calves with the dam a feasible option?–Current and future research. *Appl Anim Behav Sci.* 2016;181:1–11.
85. Jung, J., Lidfors, L., 2001. Effects of amount of milk, milk flow and access to a rubber teat on cross-sucking and non-nutritive sucking in dairy calves. Appl. Anim. Behav. Sci. 72, 201–213.
86. Keil NM, Langhans W. The development of intersucking in dairy calves around weaning. *Appl Anim Behav Sci.* 2001;72:295–308.
87. Keil NM, Audigé L, Langhans W. Factors associated with intersucking in Swiss dairy heifers. *Prev Vet Med.* 2000;45:305–323.
88. Kenny FJ, Tarrant PV. The behaviour of young Friesian bulls during social regrouping at an abattoir Influence of an overhead electrified wire grid. *Appl Anim Behav Sci.* 1987;18:233–246.
89. Krohn CC. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie-stall) environments III Grooming, exploration and abnormal behaviour. *Appl Anim Behav Sci.* 1994;42:73–

86.
90. Krohn CC, Kongaard SP. Effects of isolating first lactation cows from older cows. *Livest Prod Sci.* 1979;6:137–146.
91. Lambertz C, Bowen PR, Erhard G, Gauly M. Effects of weaning beef cattle in two stages or by abrupt separation on nasal abrasions, behaviour, and weight gain. *Anim Prod Sci.* 2015a;55:786–792.
92. Lambertz C, Farke-Rover A, Gauly M. Effects of sex and age on behavior and weight gain in beef calves after abrupt weaning. *Anim Sci J.* 2015b;86:345–350.
93. Laukkanena H, Rushen J, de Passillé AM. Which dairy calves are cross-sucked? *Appl Anim Behav Sci.* 2010;125:91–95.
94. Lay DC, Friend TH, Randel RD, et al. Effects of restricted nursing on physiological and behavioral reactions of Brahman calves to subsequent restraint and weaning. *Appl Anim Behav Sci.* 1998;56:109–119.
95. Le Neindre P. Influence of cattle rearing conditions and breed on social relationships of mother and young. *Appl Anim Behav Sci.* 1989;23:117–127.
96. Lidfors, L., 1992. Behaviour of Bull Calves in Two Different Housing Systems: Deep Litter in an Uninsulated Building Versus Slatted Floor in an Insulated Building. Thesis. Sveriges Landbruksuniversitet, V Veterinærmedicinske fakulteten. Institution för Husdjurhygien, Skara. Rapport 30, 108 pp.
97. Lidfors L. Cross-sucking in group-housed dairy calves before and after weaning off milk. *Appl Anim Behav Sci.* 1993;38:15–24.
98. Lidfors LM. Behavioural effects of separating the dairy calf immediately or 4 days post-partum. *Appl Anim Behav Sci.* 1996;49:269–283.
99. Lidfors L, Isberg L. Intersucking in dairy cattle–review and questionnaire. *Appl Anim Behav Sci.* 2003;80:207–231.
100. Lidfors LM, Moran D, Jung J, Jensen P, Castren H. Behaviour at calving and choice of calving place in cattle kept in different environments. *Appl Anim Behav Sci.* 1994;42:11–28.
101. Lobeck-Luchterhand KM, Silva PRB, Chebel RC, Endres MI. Effect of stocking density on social, feeding, and lying behavior of prepartum dairy animals. *J Dairy Sci.* 2015;98:240–249.
102. Loberg JM, Telezhenko E, Bergsten C, Lidfors L. Behaviour and claw health in tied dairy cows with varying access to exercise in an outdoor paddock. *Appl Anim Behav Sci.* 2004;89:1–16.

103. Loberg JM, Hernandez CE, Thierfelder T, Jensen MB, Berg C, Lidfors L. Reaction of foster cows to the prevention of suckling from and separation from four calves simultaneously or in two steps. *J Anim Sci.* 2007;85:1522–1529.
104. Loberg JM, Hernandez CE, Thierfelder T, Jensen MB, Berg C, Lidfors L. Weaning and separation in two steps – a way to decrease stress in dairy calves suckled by foster cows. *Appl Anim Behav Sci.* 2008;111:222–234.
105. Mainau E, Manteca X. Pain and discomfort caused by parturition in cows and sows. *Appl Anim Behav Sci.* 2011;135:241–251.
106. Marcé C, Guatteo R, Bareille N, Fourichon C. Dairy calf housing systems across Europe and risk for calf infectious diseases. *Animal*. 2010;4:1588–1596.
107. Marchant-Forde JN, Marchant-Forde RM, Weary DM. Responses of dairy cows and calves to each other's vocalisations afterearly separation. *Appl Anim Behav Sci.* 2002;78:19–28.
108. Meagher RK, Daros RR, Costa JHC, von Keyserlingk MAG, Hötzel MJ, Weary DM. Effects of degree and timing of social housing on reversal learning and response to novel objects in dairy calves. *PLoS ONE*. 2015;10:e0132828 http://dx.doi.org/10.1371/journal.pone.0132828.
109. Mench JA, Swanson JC, Stricklin WR. Social stress and dominance among group members after mixing beef cows. *Can J Anim Sci.* 1990;70:345–354.
110. Mendl, et al. An integrative and functional framework for the study of animals emotion and mood. *Proc R Soc B.* 2010;277:2595–2904.
111. Mounier L, Veissier I, Boissy A. Behavior, physiology and performance of bulls mixed at the onset of finishing to form uniform body weight groups. *J Anim Sci.* 2005;83:1696–1704.
112. Mounier L, Veissier I, Andanson S, Deval E, Boissy A. Mixing at the beginning of fattening moderates social buffering in beef bulls. *Appl Anim Behav Sci.* 2006;96:185–200.
113. Muller WJ, Low WA, Lendon C, Dudzinski ML. Variation in grazingpatterns of free-ranging cattle in a semi-arid area. *Proc Aust Soc Anim Prod.* 1976;11:461–464.
114. Munksgaard L, Jensen MB, Pedersen LJ, Hansen SW, Matthews L. Quantifying behavioural priorities-effects of time constraints on

behaviour of dairy cows. *Appl Anim Behav Sci.* 2005;92:3–14.
115. Neisen G, Wechler B, Gygax L. Effects of introduction of single heifers or pairs of heifers into dairy-ciw herds on the temporal and spatial associations of heifers and cows. *Appl Anim Behav Sci.* 2009;119:127–136.
116. Nielsen BL. On the interpretation of feeding behaviour measures and the use of feeding rate as an indicator of social constraint. *Appl Anim Behav Sci.* 1999;63:79–91.
117. Nielsen LH, Mogensen L, Krohn C, Hindhede J, Sørensen JT. Resting and social behaviour of dairy heifers housed in slatted floor pens with different sized bedded lying areas. *Appl Anim Behav Sci.* 1997;54:307–316.
118. Nielsen P, Jensen MB, Lidfors LM. Milk allowance and weaning method affect the use of a computer controlled milk feeder and the development of cross-sucking in dairy calves. *Appl Anim Behav Sci.* 2008;109:223–237.
119. O'Driscoll K, von Keyserlingk MAG, Weary DM. Effects of mixing on drinking and competitive behaviour of dairy calves. *J Dairy Sci.* 2006;89:229–233.
120. Olofsson J. Competition for total mixed diets fed for ad libitum intake using one or four cows per feeding station. *J Dairy Sci.* 1999;82:69–79.
121. Patison KP, Swain DL, Bishop-Hurley GJ, Pattison P, Robins G. Social companionship versus food: The effect of the presence of familiar and unfamiliar conspecifics on the distance steers travel. *Appl Anim Behav Sci.* 2010;122:13–20.
122. Pérez-Torres L, Orihuela A, Corro M, Rubio I, Alonso MA, Galina CS. Effects of separation time on behavioral and physiological characteristics of Brahman cows and their calves. *Appl Anim Behav Sci.* 2016;179:17–22.
123. Phillips CJC. The effects of forage provision and group size on the behavior of calves. *J Dairy Sci.* 2004;87:1380–1388.
124. Phillips CJC, Rind MI. The effects on production and behavior of mixing uniparous and multiparous cows. *J Dairy Sci.* 2001;84:2424–2429.
125. Price EO, Harris JE, Borgwardt RE, Sween ML, Connor JM. Fenceline contact of beef calves with their dams at weaning reduces the negative effects of separation on behavior and growth rate. *J Anim Sci.*

2003;81:116–121.

126. Proudfoot KL, Jensen MB, Heegaard PMH, von Keyserlingk MAG. Effect of moving dairy cows at different stages of labor on behavior during parturition. *J Dairy Sci.* 2013;96:1638–1646.

127. Proudfoot KL, Jensen MB, Weary DM, von Keyserlingk MAG. Dairy cows seek isolation at calving and when ill. *J Dairy Sci.* 2014a;97:2731–2739.

128. Proudfoot KL, Weary DM, von Keyserlingk MAG. Maternal isolation behavior of Holstein dairy cows kept indoors. *J Anim Sci.* 2014b;92:277–281.

129. Rasmussen L, Jensen MB, Jeppesen LL. The effect of age at introduction and number of milk-portions on calves responses to integration into a dynamic group of dairy calves fed by computer controlled milk feeder. *Appl Anim Behav Sci.* 2006;100:153–163.

130. Rault. Friends with benefits: Social support and its relevance for farm animal welfare. *Appl Anim Behav Sci.* 2012;136:1–14.

131. Raussi S, Boissy A, Delaval E, Pradel P, Kaihilahti J, Veissier I. Does repeated regrouping alter the social behaviour of heifers. *Appl Anim Behav Sci.* 2005;93:1–12.

132. Raussi S, Niskanen S, Siivonen J, et al. The formation of preferential relationships at early age in cattle. *Behav Process.* 2010;84:726–731.

133. Reinhardt V. *Untersuchung zum Sozialverhalten des Rindes* Verlag, Basel: Birkhäuser; 1980; 89 pp.

134. Reinhardt V, Reinhardt A. Natural sucking performance and age of weaning in zebu cattle (*Bos indicus*). *J Agric Sci.* 1981;96:309–312.

135. Reinhardt V, Reinhardt A. Mock fighting in cattle. *Behaviour*. 1982;81:1–13.

136. Reinhardt V, Mutiso FM, Reinhardt A. Social behaviour and social relationships between female and male prepubertal bovine calves (*Bos Indicus*). *Appl Anim Ethol.* 1978;4:43–54.

137. Rind MI, Phillips CJC. The effect of group size on the ingestive and social behaviour of grazing dairy cows. *Anim Sci.* 1999;68:589–596.

138. Rushen J, Munksgard L, Marnet PG, de Passillé AM. Human contact and the effect of acute stress of cows at milking. *Appl Anim Behav Sci.* 2001;73:1–14.

139. Šárová R, Špinka M, Stěhulová I, Ceacero F, Simecková M, Kotrba R. Pay respect to the elders: age, more than body mass, determines

dominance in female beef cattle. *Anim Behav.* 2013;86:1315–1323.
140. Šárová R, Gutmann AK, Špinka M, Stěhulová I, Wickler C. Important role of dominance in allogrooming behaviour in beef cattle. *Appl Anim Behav Sci.* 2016;181:41–48.
141. Sato S, Wood-Gush DGM, Wetherill G. Observations on crèche behavior in suckler calves. *Behav Process.* 1987;15:333–343.
142. Schirmann K, Chapinal N, Weary DM, Heuwueser W, von Keyserlingk MAG. Short-term effects of regrouping on behaviour of prepartum dairy cows. *J Dairy Sci.* 2011;94:2312–2319.
143. Schütz K, Huddart FJ, Sutherland MA, Stewart M, Cox NR. Effects of space allowance on the behaviour and physiology of cattle temporarily managed on rubber mats. *J Dairy Sci.* 2015;98:6226–6235.
144. Solano J, Orihuela A, Galina CS, Aguirre V. A note on behavioral responses to brief cow–calf separation and reunion in cattle (*Bos indicus*). *J Vet Behav Clin Appl Res.* 2007;2:10–14.
145. Špinka M. Intersucking in dairy heifers during the first two years of life. *Behav Process*. 1992;28:41–49.
146. Stěhulová I, Lidfors L, Špinka M. Response of dairy cows and calves to early separation: Effect of calf age and visual and auditory contact after separation. *Appl Anim Behav Sci.* 2008;110:144–165.
147. Stěhulová I, Valníčková B, Šárová R, Špinka M. Weaning reactions in beef cattle are adaptively adjusted to the state of the cow and the calf. *J Anim Sci.* 2017;95:1023–1029.
148. Stephenson MB, Bailey DW, Jensen D. Association patterns of visually-observed cattle on Montana, USA foothill rangelands. *Appl Anim Behav Sci.* 2016;178:1–75.
149. Svensson C, Liberg P. The effect of group size on health and growth rate of Swedish dairy calves in pens with automatic milk feeders. *Prev Vet Med.* 2006;73:43–53.
150. Svensson C, Lundborg K, Emanuelson U, Olsson SO. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Prev Vet Med.* 2003;58:179–197.
151. Swain DL, Patison KP, Heath BM, Bishop-Hurley GJ, Finger A. Pregnant cattle associations and links to maternal reciprocity. *Appl Anim Behav Sci.* 2015;168:10–17.
152. Sweeney BC, Rushen J, Weary DM, de Passillé AM. Duration of

weaning, starter intake, and weight gain of dairy calves fed large amounts of milk. *J Dairy Sci.* 2010;93:148–152.
153. Takeda K, Sato S, Sugawara K. The number of farm mates influences social and maintenance behaviours of Japanese Black cows in a communal pasture. *Appl Anim Behav Sci.* 1999;67:181–192.
154. Talebi A, von Keyserlingk MAG, Telezhenko E, Weary DM. Reduced stocking density mitigates the negative effects of regrouping in dairy cattle. *J Dairy Sci.* 2014;97:1358–1363.
155. Tapki I. Effects of individual or combined housing systems on behavioural and growth responses of dairy calves. *Acta Agric Scand.* 2007;57:55–60 http://dx.doi.org/10.1080/09064700701464405.
156. Telezhenko E, von Keyserlingk MAG, Talebi A, Weary DM. Effect of pen size, group size, and stocking density on activity in freestall-housed dairy cows. *J Dairy Sci.* 2012;95:3064–3069.
157. Tennessen T, Price MA, Berg RT. The social interactions of young bulls and steers after re-grouping. *Appl Anim Behav Sci.* 1985;14:37–47.
158. Thomas TJ, Weary DM, Appleby MC. Newborn and 5-week old calves vocalise in response to milk deprivation. *Appl Anim Behav Sci.* 2001;74:165–173.
159. Tucker CB, Coetzee JF, Stookey JM, Thomson DU, Grandin T, Schwartzkopf-Genswein KS. Beef cattle welfare in the USA: identification of priorities for future research. *Anim Health Res Rev.* 2015;16:107–124.
160. Ungerfeld R, Quintans G, Hötzel MJ. Minimizing cows' stress when calves were early weaned using the two-step method with nose flaps. *Animal*. 2016;10:1871–1876.
161. Ungerfeld R, Hötzel MJ, Quintans G. Changes in behaviour, milk production and bodyweight in beef cows subjected to two-step or abrupt weaning. *Anim Prod Sci.* 2015;55:1281–1288.
162. USDA, 2008. Dairy 2007 Part III: Reference of the dairy cattle health and management practices in the United States, 2007. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.), Fort Collins, CO.
163. Val-Laillet D, Simon M, Nowak R. A full belly and colostrum: Two major determinants of filial love. *Dev Psychobiol.* 2004;45:163–173.
164. Val-Laillet D, Guesdon V, von Keyserlingk MAG, de Passillé AM, Rushen J. Allogrooming in cattle: relationships between social preferences, feeding displacements and social dominance. *Appl Anim*

Behav Sci. 2009;116:141–149.
165. van Reenen CG, O'Connell NE, van der Werf JTN, et al. Responses of calves to acute stress: individual consistency and relations between behavioural and physiological measures. *Physiol Behav.* 2005;85:557–570.
166. Vasseur E, Borderas F, Cue RI, et al. A survey of dairy calf management practices in Canada that affect animal welfare. *J Dairy Sci.* 2010;93:1307–1316.
167. Vaughan A, Miguel-Pacheco GG, de Passillé AM, Rushen J. Reciprocated cross sucking between dairy calves after weaning off milk does not appear to negatively affect udder health or production. *J Dairy Sci.* 2016;99:5596–5603.
168. Veissier I, Le Neindre P. Weaning in calves: its effect on social organization. *Appl Anim Behav Sci.* 1989;24:43–54.
169. Veissier I, Le Neindre P. Reactivity of Aubrac heifers exposed to a novel environment alone or in groups of four. *Appl Anim Behav Sci.* 1992;33:11–15.
170. Veissier I, Le Neindre P, Garel JP. Decrease in cow-calf attachment after weaning. *Behav Process.* 1990;21:95–105.
171. Veissier I, Gesmier V, Le Neindre P, Gautier JY, Bertrand G. The effect of rearing in individual crates on subsequent social behaviour of veal calves. *Appl Anim Behav Sci.* 1994;41:199–210.
172. Veissier I, Boissy A, de Passillé AM, et al. Calves' responses to repeated social regrouping and relocation. *J Anim Sci.* 2001;79:2580–2593.
173. von Keyserlingk MAG, Weary DM. Maternal behaviour in cattle. *Horm Behav.* 2007;52:106–113.
174. von Keyserlingk MAG, Olineck D, Weary DM. Acute behavioral effects of regrouping dairy cows. *J Dairy Sci.* 2008;91:1011–1016.
175. Wagner K, Barth K, Palme R, Futschik A, Waiblinger S. Integration into the dairy cow herd: long-term effects of mother contact during the first twelve weeks of life. *Appl Anim Behav Sci.* 2012;141:117–129.
176. Wagner K, Barth K, Hillmann E, Palme R, Futschike A, Waiblinger S. Mother rearing of dairy calves: Reactions to isolation and to confrontation with an unfamiliar conspecific in a new environment. *Appl Anim Behav Sci.* 2013;147:43–54.
177. Watts JM, Stookey JM. Vocal behaviour in cattle: the animal's commentary on its biological processes and welfare. *Appl Anim Behav*

Sci. 2000;67:15–33.
178. Weary DM, Chua B. Effects of early separation on the dairy cow and calf: 1 Separation at 6 h, 1 day and 4 days after birth. *Appl Anim Behav Sci*. 2000;69:177–188.
179. Weary DM, Jasper J, Hötzel MJ. Understanding weaning distress. *Appl Anim Behav Sci.* 2008;110:24–41.
180. Wechler B. Floor quality and space allowance in intensive beef production: a review. *Anim Welf.* 2011;20:497–503.
181. Wierenga, H.K., 1987. Behavioural problems in fattening bulls. In Schlichting, M.C. & Smidt, D. (Eds.), Welfare aspects of housing systems for veal calves and fattening bulls. EEC-seminar, Mariensee, Report EUR 10777, pp. 105–122.
182. Wierenga HK. Social dominance in dairy cattle and the influences of housing and management. *Appl Anim Behav Sci.* 1990;27:201–229 201.
183. Winckler C, Tucker CB, Weary DM. Effects of under- and overstocking freestalls on dairy cattle behaviour. *Appl Anim Behav Sci.* 2015;170:14–19.
184. Wood-Gush DGM, Hunt K, Carson K, Dennison SGC. The early behaviour of suckler calves in the field. *Biol Behav.* 1984;9:295–306.

7

Painful procedures

When and what should we be measuring in cattle?

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Abstract

Pain research in cattle has focused on the first few hours or days following the procedure, and few studies have looked at the progression of pain during and, possibly, after healing. Broadening our understanding of pain to include not just the acute nociceptive response, but also longer-term inflammatory and neuropathic conditions will be critical for ensuring best practice in pain management. In addition, the acute pain associated with procedures other than castration and disbudding/dehorning is currently understudied and, as a result, is often undertreated. Future research on ways to effectively identify and manage this pain is needed. Pharmacological agents, as well as nonpharmacological adjuvants, that are safe, long-acting, cost-effective, and convenient to administer should be explored. Finally, factors that modulate the pain experience, such as age, previous pain and stress experiences, concurrent procedures, and states of attention and arousal, could impact assessment and treatment outcomes and deserve consideration.

Keywords

Cattle; analgesia; nociceptive pain; inflammatory pain; neuropathic pain; pain assessment; animal welfare

7.1 Introduction

Pain is a multifaceted phenomenon that can be broadly dissociated into three types: (1) acute nociceptive pain in response to the initial tissue damage; (2) inflammatory pain which can persist for days or weeks until the tissue damage is resolved; and (3) neuropathic pain which occurs when the somatosensory nervous system itself is damaged and which can last indefinitely. The duration, intensity, and quality of the pain experience depend on many factors beyond the extent and nature of the tissue damage itself. These include, nonexhaustively, an individual's previous and concurrent experiences with pain and stress; cognitive, social, and emotional modulators; the quality and duration of analgesics given before, during, and after the procedure; as well as the presence or absence of complementary nonpharmacological interventions.

Pain can occur through natural processes (e.g., injury or disease) or husbandry practices. In this chapter, we focus on pain arising from the latter category. The most common husbandry procedures in cattle are castration, disbudding/dehorning, and identification marking (e.g., branding, ear notching). Surgery may also be performed to treat disease or injury (e.g., left displaced abomasal correction, claw disorders, cancer eye, teat laceration, liver biopsy).

Our objective for this chapter is to offer a broader perspective on which procedures we should be looking at and when, and what we should be looking for, in pain research in cattle. In the first three sections, we review the current status of scientific knowledge concerning acute, inflammatory, and neuropathic pain associated with husbandry procedures in cattle. The last section discusses some key factors driving individual differences in pain, and their implications for pain recognition and management. We focus on cattle research, but draw on literature from other species when needed.

7.2 Acute nociceptive pain (intraoperative phase)

7.2.1 Neurobiology

Noxious stimuli are detected by a specialized class of sensory neurons located in the skin and deep tissue. These neurons, termed nociceptors, respond selectively to high-intensity thermal, mechanical, and/or chemical stimuli that produce actual or potential injury. Nociceptors may be sub-classified by their type of afferent fiber: (1) fast-conducting, thinly myelinated A-fiber afferents; or (2) slow-conducting, unmyelinated C-fiber afferents. The sharp, first pain that alerts us to injury is signaled by A-fiber nociceptors, while C-fibers evoke a more delayed, diffuse, duller sensation (second pain) (Ringkamp et al., 2013).

Proteins in the membrane of the nociceptor convert the energy of the noxious stimulus into a depolarizing electrical potential that travels along the afferent fibers to the dorsal horn of the spinal cord. The release of neurotransmitters (e.g., glutamate, substance P) from the central terminals of nociceptive afferents activates dorsal horn neurons that then relay information to various structures in the brain for central processing. In addition, spinally mediated withdrawal reflexes may be generated before the pain signal has reached the brain. Activity along all of these neural pathways is subject to modulation (inhibitory or excitatory) by descending projections from the brainstem (Ringkamp et al., 2013).

Information is relayed from the spinal cord to the brain via several ascending nociceptive pathways, the targets of which contribute to the sensory-discriminative and affective-motivational components of pain. Information about the sensory-discriminative aspects (i.e., the location, intensity, and quality of the noxious stimulus) is relayed through the lateral thalamus to the somatic sensory cortex, whereas the subjective experience of unpleasantness is processed by several regions, notably the limbic areas, anterior cingulate cortex, prefrontal cortex, and insular cortex.

7.2.2 Management methods

Intraoperative pain can be inhibited or minimized using a variety of pharmacological options, such as local anesthesia, general anesthesia, and sedation, administered before the procedure occurs (Anderson and Edmondson, 2013). Nonpharmacological adjuvants, such as cognitive modulation and electroacupuncture, have received less attention.

7.2.2.1 Local anesthesia

Local anesthesia achieves a temporary loss of sensation in the target area by blocking nerve conduction. The variety of techniques for administering local anesthetics are described by Anderson and Edmondson (2013). The most commonly used local anesthetic in cattle, lidocaine hydrochloride (2%), is effective at reducing acute behavioral and physiological pain responses during routine husbandry procedures, such as disbudding (Stock et al., 2013) and castration (Coetzee, 2013a). However, injection of lidocaine can itself be painful. The sting of injection can be mitigated by adding sodium-bicarbonate to reduce the acidity of the solution (McKay et al., 1987). As an alternative to lidocaine, bupivicaine offers a longer duration of action (up to 6 hours compared to 1–2 hours for lidocaine), but there is a higher risk of toxicity when given intravenously (Anderson and Edmondson, 2013). Ethanol administered as a cornual nerve block achieves desensitization at the site of hot-iron disbudding for at least 3 days, and thus may be a promising novel agent for treating postoperative pain as well, although further studies are needed to evaluate the efficacy and potential side effects of this technique before it can be recommended (Tapper et al., 2011).

Topical application of local anesthetics may present a lower-stress alternative to injectable administration. However, topical anesthetics, in general, have proven ineffective at inducing analgesia in clinical practice (Anderson and Edmondson, 2013). Intact bovine skin is resistant to penetration, thus limiting topical anesthetics for preprocedural use. However, immediate postprocedural application to open wounds may facilitate absorption and rapid analgesia. A topical anesthetic formulation containing lidocaine, bupivacaine, adrenaline and an antiseptic, originally formulated for controlling mulesing pain in lambs, decreased pain-related behavior, and wound sensitivity (Lomax and Windsor, 2013), but not plasma cortisol concentrations (McCarthy et al., 2016) after surgical castration in beef calves. A modification of the same formulation reduced wound sensitivity after scoop dehorning as early as 1 minute postapplication and remained effective for up to 5 hours (Espinoza et al., 2013, 2016). The efficacy of topical anesthetic depends on the nature of the wound. In contrast to the exposed blood vessels produced by surgical castration and scoop dehorning, hot-iron disbudding cauterizes the wound, sealing off blood vessels, thereby inhibiting absorption. Indeed, topical anesthetics have limited use in treating full-thickness burns in humans and rodents (Summer et al., 2007).

7.2.2.2 General anesthesia

When extended periods of immobility or highly invasive procedures are required, general anesthesia may be considered (Abrahamsen, 2013). General anesthesia causes a state of unconsciousness resulting in a complete loss of sensation. General anesthesia can be induced and maintained via intravenous infusion of drugs such as a combination of xylazine, ketamine, and guaifenesin (e.g., triple drip method), or via inhalation of halogenated anesthetic agents (e.g., isoflurane). Regurgitation is a common enough occurrence in cattle under prolonged recumbency that an endotracheal tube is always required (Greene, 2003). Other side effects include hypoventilation and bloat, as well as hypothermia in calves. Although effective general anesthesia prevents the immediate perception of pain, it may not abolish nociceptive input during surgery (Pascoe, 2000). For example, stellar sea lions under isoflurane anesthesia had elevated heart rates, breathing rates and increased trembling and head and shoulder movements during hot-iron branding compared to sham-branded animals, suggesting the general anesthesia may not have eliminated pain (Walker et al., 2011). In cats, supplementing general anesthesia with a local block to abolish nociceptive input at the site of operation reduced postoperative pain and lowered the dose of anesthetic required to maintain unconsciousness (e.g., Zilberstein et al., 2008).

7.2.2.3 Sedation

Sedation can be an easier, less expensive alternative to general anesthesia for shorter, less invasive procedures. Sedatives depress the central nervous system while maintaining partial preservation of consciousness. The chemical restraint produced by sedatives makes handling easier and enhances the efficiency and safety of the operator. The α2-adrenergic agonist, xylazine, is the most frequently used sedative in cattle (Abrahamsen, 2013). In addition to their supraspinally mediated sedative effects, α2-adrenergic agonists produce spinal analgesia. Activation of α2-adrenergic receptors inhibits transmitter release from the central terminals of primary afferent nociceptors, thereby suppressing nociceptive input to the spinal dorsal horn (Pertovaara, 2006).

Xylazine was not sufficient for controlling pain during hot-iron disbudding as assessed by the presence of head, ear, and leg movements during the procedure (Stilwell et al., 2010). In contrast, Caray et al. (2015) did not observe struggling when calves receiving xylazine were disbudded with a hot iron. The authors suggest this may be because their behavioral definitions excluded the subtle movements recorded by Stilwell et al. (2010). Diminished distress behavior under sedation has been used as evidence of analgesia (e.g., Coetzee et al., 2010a; Rizk et al., 2012). However, the absence of pain-related behavior under sedation should be interpreted guardedly, as the muscle relaxant properties of α2-adrenergic agonists limit the animal's ability to move and thus the lack of behavioral indicators does not preclude the possibility of pain and/or distress occurring. In addition, xylazine itself has been shown to elicit a stress response, potentially due to the cardiorespiratory depression that accompanies sedation, or to the psychological distress induced by being unable to avoid human contact (Stafford et al., 2003; Stilwell et al., 2010). Further studies are needed to determine whether sedation improves welfare during painful procedures. Regardless of its poorly understood impact, xylazine is not an anesthetic and should be supplemented with local anesthesia to ensure adequate pain relief during a procedure (Greene, 2003).

Xylazine can also be supplemented with a low dose of ketamine, an *N*-methyl-D-aspartate receptor antagonist, which produces dissociative anesthesia that is characterized by hypnosis, analgesia, and increased sympathetic nervous system activity (Sleigh et al., 2014). Administering an opioid (e.g., butorphanol, morphine) in conjunction with xylazine and ketamine (known as the "ketamine stun" technique) produces a potent cocktail that is thought to augment the quality of analgesia in cattle (Abrahamsen, 2013).

7.2.2.4 Cognitive modulation

The pain response depends both on the qualities of the noxious stimulus and the context in which it occurs. Traditional pain relief focuses on dampening ascending signals arising from the stimulus, but the importance of context in modulating pain perception through descending control systems is increasingly recognized in human medicine, although it continues to receive little attention in farm animals. It is well known that positive mood states and distractions can exert analgesic effects, whereas negative mood states and attending to the pain generally increase its perception (Villemure and Bushnell, 2002). The potency of these cognitive effects should not be underestimated; in children, for example, distractions are often preferred over topical anesthetics during immunization (Cohen et al., 1999). Provision of an oral insert reduced the amount of struggling by steers in a headgate, presumably by diverting attention away from the physical restraint (Aitken et al., 2013). Providing positive reinforcers (e.g., food, teats for calves, visual and/or tactile contact with conspecifics, massage) before, during, and after a painful procedure could also improve emotional state. After multiple procedures, "counter-conditioning" may occur, a phenomenon in which the animal forms an association between the repeated aversive stimulus (e.g., operator, chute) and a reward, leading to reduced pain unpleasantness and distress (Westlund, 2015). Low-stress handling techniques could also diminish pain perception by reducing negative emotional states, such as fear or anxiety. Less anxious animals require lower doses to achieve adequate sedation or general anesthesia, minimizing the side effects and financial cost of pharmacological techniques (Abrahamsen, 2013). In summary, the manipulation of context can be a powerful, cost-effective analgesic and should be considered as part of a comprehensive approach to pain management.

7.2.2.5 Electroacupuncture

Pain perception can also be modulated nonpharmacologically by electrical stimulation. Electroacupuncture, in which an electrical current is applied to specific anatomical regions to elicit analgesia, is minimally invasive and has few adverse side effects. Its analgesic effects are mediated by induction of endogenous opioids and the descending pain control pathways from the brain and spinal cord (Fry et al., 2014). Electroacupuncture stimulation has been used to produce surgical analgesia in horses (Sheta et al., 2015) and cattle (Kim et al., 2004). It should be noted that electroimmobilization, in which an electrical current is pulsed through the body to contract and relax the skeletal muscle, is highly aversive to cattle and is not considered a humane method of restraint (Pascoe, 1986; Pascoe and McDonell, 1986).

7.2.2.6 Multimodal therapy

A combination of different classes of drugs (e.g., local anesthetics, α2-adrenergic agonists, *N*-methyl-D-aspartate receptor antagonists, opioids), as well as nonpharmacological interventions where appropriate, achieves more effective analgesia than each alone. The choice of therapy matters not only insofar as it prevents immediate pain perception during the procedure, but also in the degree to which it decreases pain and analgesic consumption in the postoperative period. In humans, multimodal preventive analgesia started preoperatively and continued postoperatively is more effective for controlling postoperative pain and reducing analgesic consumption than sole administration of preemptive analgesia before the procedure (Vadivelu et al., 2014). Preventive analgesia administered to humans throughout the perioperative period has prolonged beneficial effects, such as reducing pain sensitivity during healing and possibly mitigating the risk of developing chronic pain (Lavand'homme et al., 2005).

7.2.3 What we do and don’t know about acute pain

The immediate pain associated with disbudding/dehorning and castration is by the far the best documented among bovine procedures and was recently reviewed by Stock et al. (2013) and Coetzee (2013a), respectively. Thus, this section will focus on our (limited) knowledge regarding immediate pain during other management and therapeutic surgical procedures.

7.2.3.1 Identification marking

Branding can be performed with a hot or cold iron. Both methods produce immediate pain-related responses, including tail flicking, exertion of force on the headgate and squeeze chute, and head movements (Schwartzkopf-Genswein et al., 1997b, 1998); escape-avoidance reactions (Lay et al., 1992b); as well as elevated plasma cortisol concentrations (Lay et al., 1992a; Schwartzkopf-Genswein et al., 1997a) and heart rate compared to controls (Lay et al., 1992a). These effects were most pronounced when a hot iron was used, suggesting freeze branding is less painful, but the latter is time-consuming to perform. To our knowledge, no studies have assessed the use of local anesthetics for preventing acute branding pain.

Studies evaluating pain associated with other forms of identification, such as ear tagging and notching, as well as potentially less painful newer electronic methods (electronic ear tag, injectable transponder, ruminal bolus) are needed.

7.2.3.2 Electroejaculation

Electroejaculation is an effective means for collecting semen for breeding soundness evaluation or artificial insemination, but is considered painful for the bull (Palmer, 2005; but see Whitlock et al., 2012). Electroejaculated bulls given caudal epidural anesthesia showed reduced elevations in progesterone (Falk et al., 2001; Etson et al., 2004), cortisol (Falk et al., 2001), and heart rate (Mosure et al., 1998), and a lowered frequency of struggling, escape attempts, and vocalizations (Pagliosa et al., 2015), as compared to those electroejaculated without anesthesia. However, in some of these studies the observed reduction of these parameters only tended towards statistical significance (Mosure et al., 1998; Falk et al., 2001). Justification for the continued use of electroejaculation over potentially less painful, albeit less reliable, alternatives (e.g., transrectal massage, artificial vagina) hinges on developing an effective pain management strategy for this procedure. Transrectal massage may also be sufficiently aversive to demand pain relief, as suggested by increased levels of progesterone in bulls (Falk et al., 2001) and cardiac responses during rectal palpation in cows (Kovács et al., 2014), although pharmacological manipulations are needed to determine whether these responses reflect pain or a stress response to handling.

7.2.3.3 Abdominal surgery

Abdominal surgery is a highly invasive procedure that is perceived to cause significant pain in cattle (Huxley and Whay, 2006; Hewson et al., 2007; Fajt et al., 2011). Although use of local or regional anesthesia during abdominal surgeries in adult cattle, such as left displaced abomasum corrections, ovariectomies, and cesarean sections, is more or less universal (Huxley and Whay, 2006; Hewson et al., 2007; Fajt et al., 2011), no studies have looked at whether these practices effectively mitigate pain responses during the operation.

In calves, abdominal surgery may be performed to correct umbilical hernias or infections. Offinger et al. (2012) found that caudal epidural anesthesia reduced cortisol concentrations during umbilical surgery compared to inhalation and injectable anesthesia, but the authors note that the endocrine stress response may be attributable to the side effects of the anesthetic rather than pain sensation per se. Conversely, calves under inhalation anesthesia exhibited fewer spontaneous movements during the procedure, but this effect can likely be attributed to the ataxic effects of the anesthesia rather than the quality of analgesia (Offinger et al., 2012). Thus, it cannot be concluded from this study which, if any, anesthetic procedure was effective at controlling pain during umbilical surgery.

7.2.3.4 Claw surgery

Some veterinarians treat claw disorders with claw-preserving surgical procedures or amputation of the digit in more severe cases, although prognosis is poor for cows undergoing the latter surgery (Bicalho et al., 2006). Intravenous regional anesthesia is the preferred method for surgery of the bovine digit (Heppelmann et al., 2009). However, Rizk et al. (2012) found that intravenous regional anesthesia alone or in combination with preoperative xylazine did not abolish the elevation in cortisol concentrations in dairy cows undergoing claw surgery, suggesting pain and/or distress was still present to some extent and further investigation of the most effective analgesic regime for this procedure is warranted.

7.2.3.5 Liver biopsy

During liver biopsy, cattle showed increased restlessness, head shaking, and decreased rumination, despite the fact they received procaine, a local anesthetic (Molgaard et al., 2012). Procaine has a longer onset, shorter duration of action, and lower potency than lidocaine (Anderson and Edmondson, 2013). Multiple samples of liver were required to obtain sufficient tissue in the study, perhaps contributing to the low analgesic efficacy of the anesthetic during the procedure.

7.2.3.6 Eye surgery

In certain cases, ocular disease or injury may require surgical intervention (Shaw-Edwards, 2010). For example, ocular squamous cell carcinoma can be treated using traditional surgical techniques (e.g., eyelid resection or enucleation of the eye) or, if extensive invasion has not occurred, cancer cells can be destroyed by freezing or heating (Tsujita and Plummer, 2010). To the best of our knowledge, no study has addressed pain responses to ocular therapies in any species.

7.2.3.7 Teat surgery

A combination of sedation and anesthesia has been recommended for controlling pain during teat laceration repair (Couture and Mulon, 2005; Nichols, 2008). However, we are not aware of any studies investigating pain associated with treating this type of injury or other teat surgeries (e.g., extra teat removal).

7.2.3.8 Injections

Dairy calves find injections more aversive when given intramuscularly than via the subcutaneous or intranasal route (Ede et al., 2017). In addition to the route of administration, several other factors can contribute to injection pain, including needle size, injection speed and volume, and type of substance administered (e.g., lidocaine, hormones for estrus synchronization, rBST). This type of pain is poorly understood and deserves investigation.

7.2.4 Future directions

Pain associated with experimental or therapeutic surgical procedures is understudied in cattle and, as a result, is often undertreated. Future research on ways to effectively identify and manage this pain is needed.

In contrast to the surgical procedures described above, for acute pain associated with dehorning and castration, considerable research already exists to inform best practice and policy-making. Unfortunately, current practice does not fully reflect scientific understanding of pain management for these procedures. For example, it is well established that a combination of local anesthetic and NSAID mitigates acute dehorning and castration pain. However, despite irrefutable evidence that these procedures are painful, they are routinely performed without pain relief in many countries (Huxley and Whay, 2006;

Coetzee et al., 2010b; Fajt et al., 2011; Cozzi et al., 2015; Kling-Eveillard et al., 2015; Robbins et al., 2015; Cardoso et al., 2016). Several challenges may explain the limited uptake of pain relief, including the cost of analgesia (Newton and O'Connor, 2013), time required to administer analgesia and the delay in the onset of analgesic activity (Coetzee, 2013b), inadequate knowledge about the importance of and options for pain relief (Whay and Huxley, 2005), as well as restricted access to pain relief in some countries (e.g., USA: Smith, 2013).

7.3 Inflammatory pain (healing stage)

7.3.1 Neurobiology

In addition to evoking acute nociceptive pain, tissue injury causes prolonged inflammatory pain after the noxious stimulus has been removed that can persist until the wound is healed, which may take anywhere from a few days for incisional skin injuries to several weeks or months for burns. A consistent feature of tissue injury and inflammation is increased pain sensitivity to a noxious or ordinarily nonnoxious stimulus, a phenomenon referred to as hyperalgesia (Sandkühler, 2013). Hyperalgesia can occur at the site of injury (primary hyperalgesia) as well as in the surrounding and distant uninjured tissues (secondary hyperalgesia). Primary hyperalgesia is due, at least in part, to sensitization of primary afferent nociceptors in the periphery and may be characterized by a decreased threshold for response, increased response to suprathreshold stimuli, and/or ongoing spontaneous activity (Ringkamp et al., 2013). These effects are due to the interaction of nociceptors with an "inflammatory soup" of substances released locally from neuronal and nonneuronal cells at the time of injury. These inflammatory mediators include prostaglandins, serotonin, histamine, substance P, bradykinin, cytokines, chemokines, protons, purines, and neurotrophic factors, all of which act directly or indirectly to augment the nociceptive response.

In addition to primary hyperalgesia, secondary hyperalgesia may be induced via an assortment of centrally acting mechanisms, which contribute to the phenomenon referred to as central sensitization. Spinal signaling substances released by neuronal and nonneuronal cells trigger various forms of plasticity in excitatory and inhibitory nociceptive pathways of the spinal dorsal horn, ultimately leading to a long-lasting amplification of pain sensation. Alterations in the descending control from the brainstem may also contribute to the development of secondary hyperalgesia (Sandkühler, 2013).

The specific neural pathways underlying hyperalgesia depend on the type of stimulus. For example, mechanical hyperalgesia can be elicited by stroking the skin with a normally innocuous stimulus such as a cotton swab ("stroking hyperalgesia" or "allodynia") or by punctate stimuli, such as von Frey monofilaments ("punctate hyperalgesia"). Stroking hyperalgesia arises due to diminished inhibition between nonnociceptive, low-threshold mechanoreceptors that convey touch sensation and normally nociceptive-specific neurons, giving rise to a sensation of pain (Sandkühler, 2013). Meanwhile, punctate hyperalgesia appears to be mediated by increased excitability of primary afferent nociceptors synapsing with neurons in the dorsal horn (Ringkamp et al., 2013).

7.3.2 Management methods

7.3.2.1 NSAIDs

Nonsteroidal antiinflammatory drugs (NSAIDs) act by inhibiting prostaglandin production through blockade of two cyclooxygenases, COX-1 and COX-2. Prostaglandins contribute to inflammatory-mediated pain sensitization, but are also involved with maintaining homeostasis. COX-1 provides the tonic supply of prostaglandins required for "housekeeping" functions, whereas COX-2 is primarily responsible for the inflammatory response. The classic NSAIDS, such as flunixin, phenylbutazone, and salicylates, inhibit both cyclooxygenases. This nonselective inhibition accounts for their unwanted side effects, including impaired renal function and gastrointestinal toxicity. Newer NSAIDs, including carprofen and meloxicam, have been developed that selectively inhibit COX-2 and have fewer adverse side effects (Zeilhofer and Brune, 2013). Studies evaluating the effects of nonselective or selective NSAIDs on wound healing in rodents and/or humans have found no effect on tendon and ligament healing (Chen and Dragoo, 2013), a detrimental effect on bone healing (Chen and Dragoo, 2013), and mixed effects for cutaneous wounds (Fairweather et al., 2015).

The beneficial effects of NSAIDs for pain alleviation after disbudding/dehorning and castration are well-documented. A combination of NSAID and local anesthetic administered before castration or disbudding/dehorning is more effective at mitigating pain, as determined by a significant reduction in cortisol response, than either drug in isolation (Coetzee, 2013a; Stock et al., 2013). In general, the benefits of a single dose of NSAID do not last beyond the immediate hours or day following the procedure. However, the physiological and behavioral effects of a single preoperative dose of the longer-acting NSAID, meloxicam, have been shown to persist for several days after hot-iron disbudding (Theurer et al., 2012; Allen et al., 2013).

A few studies have evaluated the effectiveness of NSAIDs for controlling postoperative pain for surgical procedures other than castration and disbudding/dehorning. Meloxicam increased lying time following cesarean section (Barrier et al., 2014) and reduced cortisol, lameness scores, and body temperature after claw surgery (Offinger et al., 2013). Meloxicam administered before liver biopsy had only a minor effect on postoperative pain behavior (Beausoleil and Stafford, 2012), although the same group was unable to identify postbiopsy pain behavior in calves receiving either local anesthetic and meloxicam or local anesthetic only in a later study (Barrett et al., 2016). Ketoprofen alleviated some, but not all, postsurgical pain after rumen fistulation surgery (Newby et al., 2014), but had negligible effects following surgical correction of a left displaced abomasum (Newby et al., 2013). Wound sensitivity, surface temperature, and healing following hot-iron branding were not affected by a single injection of flunixin meglumine (Tucker et al., 2014a).

7.3.2.2 Opioids

Endogenous and exogenous opioids activate three receptor sub-types—mu, delta, and kappa—located predominantly on the central terminals of primary nociceptive afferents in the spinal cord. Activation of opioid receptors inhibits presynaptic release of pro-nociceptive transmitters, leading to potent antinociceptive effects (Dickenson and Kieffer, 2013). Opioids can also produce local analgesia through receptors located on the peripheral terminals of nociceptors. In addition to their spinally and peripherally mediated analgesic effects, opioids act supraspinally, notably in brainstem structures (i.e. the periaqueductal gray and the rostroventral medulla), to enhance the activity of inhibitory descending pathways. Opioid activity in the brainstem leads to undesirable effects in humans, including cough suppression, nausea and vomiting, while activity at peripheral receptors produces constipation.

Opioid-induced analgesia is under-researched in cattle, possibly due to disappointing clinical experience in ruminants (Stafford et al., 2006), economic constraints (Anderson and Edmondson, 2013), or “opiophobia”, a phenomenon in which irrational concern over the risks associated with opioids leads to their underutilization (Schug, 2013). The mode of administration affects the outcome of opioid use. A wide range of routes are available for administration, including oral, inhalation, subcutaneous and transdermal uptake, and deserve exploration in cattle. Small doses administered locally can produce potent analgesia while minimizing the side effects of systemically administered opioids (Stein and Lang, 2009).

7.3.2.3 When and for how long is pain relief needed?

Preventive pain management throughout the perioperative period minimizes postoperative pain and facilitates long-term recovery in humans and rodents. The goal of preventive analgesia is to block the barrage of nociceptive input before, during, and after surgery in order to reduce peripheral and central sensitization, thereby lowering the requirement for analgesics in the postoperative period and the risk of developing neuropathy (Katz et al., 2011). Human medical trials have established that this approach is much more effective than treating pain only after it has developed. Thus, administering analgesics on a regular schedule, rather than on an "as-needed" basis, may be optimal for postoperative pain management. However, the deleterious effects of multiple dosing should be considered; multimodal analgesia can help achieve an appropriate balance of benefits and risks.

The need for therapeutic treatment during the postoperative period typically declines as healing progresses. However, clinical observations of human burn patients suggest that the late stage of healing, immediately preceding re-epithelialization, is very painful (Summer et al., 2007), possibly due to the involvement of the pro-nociceptive substance, calcitonin gene-related peptide, which is suggested to mediate both pain sensation and the healing process (Henderson et al., 2006). Studies are needed to determine the phases of recovery when pain is most intense for different procedures. Furthermore, the clinical indications for postoperative analgesia and the appropriate schedule and route of administration require investigation. Time and cost factors should also be considered in order to develop a protocol that can be implemented on the farm. To this end, more convenient novel formulations are being developed, such as a topical preparation of flunixin meglumine, which is rapidly absorbed and has a longer half-life compared to when it is administered intravenously (Kleinhenz et al., 2016).

7.3.3 What we do and don't know about

inflammatory pain

7.3.3.1 Castration

Studies on the long-term effects (≥24 hours) of physical castration are plentiful (Table 7.1), but largely focus on cortisol, immune response measures, and production parameters (e.g., feed intake, weight gain). Large discrepancies in findings are observed across studies, with some reporting no effects of castration on these parameters, while others find effects persisting for weeks (Table 7.1). Interpretation of these parameters as pain indicators is confounded by the concurrent decrease in testosterone, which is known to suppress glucocorticoid expression (Bangasser and Valentino, 2012), exert antiinflammatory activities (Fijak et al., 2015), and stimulate appetite and weight gain (Asarian and Geary, 2006).

Table 7.1

Summary of studies examining the effect of Burdizzo, ring/band, and/or surgical castration on measures collected for ≥24 hours postoperation. Values in bold represent effects that were still significant at the end of the observation period and thus may have lasted beyond the duration indicated.

Measure[a]	Procedure	Duration of effect[b]	Reference
Substance P	Ring/band	NS	Repenning et al. (2013)
Restlessness	Burdizzo	2.5 hours	Thuer et al. (2007)
	Ring/band	NS	Marti et al. (2010)
		2 hours	Thuer et al. (2007)
Vitals	Burdizzo	NS	Pieler et al. (2013)
		2–3 days	Pang et al. (2006)
		4–5 days	Ting et al. (2003a)
	Ring/band	NS	Marti et al. (2010)
		2–3 days	Pang et al. (2006)
	Surgical	NS	Pieler et al. (2013), Roberts et al. (2015), Brown et al. (2015)
Lying time	Burdizzo	NS	Lambertz et al. (2015)
	Ring/band	NS	Fisher et al. (2001)
	Surgical	NS	Fisher et al. (2001)
		5 days	Devant et al. (2012)
		7 days	Brown et al. (2015)
Cortisol	Burdizzo	NS	Pieler et al. (2013)
		1.5 hours	Thuer et al. (2007)
		1–2 days	Pang et al. (2011)
		1–3 days	Ting et al. (2003a)
		2 days	Stilwell et al. (2008b)
		3 days	Pang et al. (2006)
	Ring/band	NS	Fisher et al. (2001)
		2–4 hours	Gonzalez et al. (2010)
		6 hours	Thuer et al. (2007)
		1–2 days	Pang et al. (2011)
		1–3 days	Pang et al. (2006)
		1–4 days	Fell et al. (1986)
		2–5 days	Chase et al. (1995)
	Surgical	NS	Pieler et al. (2013)
		1.5–2.5 hours	Ballou et al. (2013)
		4–5 hours	Roberts et al. (2015)
		12–24 hours	Fisher et al. (1997), Ting et al. (2003b)
		1–4 days	Fell et al. (1986)
		2–5 days	Chase et al. (1995)
		7 days	Faulkner et al. (1992)
		14 days	Fisher et al. (2001)
Wound-directed behavior	Burdizzo	NS	Pieler et al. (2013)
	Ring/band	14–21 days	Marti et al. (2010)
	Surgical	NS	Pieler et al. (2013)
Eating/rumination	Burdizzo	NS	Pieler et al. (2013), Lambertz et al. (2015)
	Ring/band	NS	Marti et al. (2010), Warnock et al. (2012)
		5 hours	Fisher et al. (2001)
		28–35 days	Gonzalez et al. (2010)
	Surgical	NS	Pieler et al. (2013), Warnock et al. (2012), Webster et al. (2013)
		5 hours	Fisher et al. (2001)
		14 days	Devant et al. (2012), Earley and Crowe (2002)
		26 days	Ting et al. (2003b)
Locomotion/stride length	Burdizzo	NS	Lambertz et al. (2015)
	Ring/band	NS	Fisher et al. (2001)
		28 days	Gonzalez et al. (2010)
	Surgical	NS	Fisher et al. (2001)
		24 hours	Currah et al. (2009)
Temperament	Burdizzo	NS	Pieler et al. (2013)
	Ring/band	**28 days**	Repenning et al. (2013)
	Surgical	NS	Pieler et al. (2013)
Immune response	Burdizzo	NS	Pieler et al. (2013), Pang et al. (2011)
		3–7 days	Ting et al. (2003a)
		14–21 days	Pang et al. (2006)

(Continued...)

Measure[a]	Procedure	Duration of effect[b]	Reference
	Ring/band	NS	Marti et al. (2010), Pang et al. (2011)
		2–5 days	Chase et al. (1995)
		4–7 days	Fisher et al. (2001)
		15 days	Warnock et al. (2012)
		35 days	Pang et al. (2006)
	Surgical	6–24 hours	Sutherland et al. (2013)
		3 days	Pieler et al. (2013)
		2–5 days	Chase et al. (1995)
		3–7 days	Faulkner et al. (1992), Brown et al. (2015)
		4–7 days	Fisher et al. (2001)
		9–12 days	Warnock et al. (2012)
		7–14 days	Ting et al. (2003b)
		3 days	Fisher et al. (1997), Roberts et al. (2015)
		35 days	Earley and Crowe (2002)
Weight gain	Burdizzo	NS	Pieler et al. (2013), Pang et al. (2006), (Lambertz et al., 2015)
		7 days	Ting et al. (2003a)
	Ring/band	NS	Pang et al. (2006), Chase et al. (1995), Fell et al. (1986)
		21–28 days	Gonzalez et al. (2010)
		28 days	Warnock et al. (2012)
		28 days	Repenning et al. (2013)
		49 days	Marti et al. (2010)
	Surgical	NS	Pieler et al. (2013), Webster et al. (2013), Fell et al. (1986)
		7 days	Fisher et al. (1997), Ting et al. (2003b), Earley and Crowe (2002)
		14 days	Devant et al. (2012), Warnock et al. (2012), Brown et al. (2015)
Wound sensitivity	Burdizzo	NS	Ting et al. (2010)
		15 days	Thuer et al. (2007)
	Ring/band	50 days	Thuer et al. (2007)
		11–84 days	Becker et al. (2012)
	Surgical	**24 hours**	Lomax and Windsor (2013)
Abnormal posture	Burdizzo	1–7 days	Thuer et al. (2007)
	Ring/band	14–21 days	Marti et al. (2010)
		10–84 days	Thuer et al. (2007)
Healing/inflammation	Burdizzo	15 days	Molony et al. (1995)
		28 days	Thuer et al. (2007)
		92 days	Stafford et al. (2002)
	Ring/band	37–65 days	Thuer et al. (2007)
		54–77 days	Becker et al. (2012)
		51 days	Molony et al. (1995)
		56 days	Fisher et al. (2001)
		58–92 days	Stafford et al. (2002)
	Surgical	9 days	Molony et al. (1995)
		48–63 days	Stafford et al. (2002)
		28–56 days	Fisher et al. (2001)
		28–63 days	Mintline et al. (2014)

[a]Measures are listed in ascending order by maximum duration of effect across all procedures.

[b]The duration that each measure was affected by the procedure is based on comparisons between castrated and sham-castrated animals (steers or bulls). In the absence of a control treatment, measures were compared to baseline values (with the exception of healing/inflammation measures, which were not compared to a sham treatment or baseline). NS indicates a nonsignificant effect.

Among the three methods (Burdizzo, rubber-ring/band, surgical removal of testes), surgical wounds heal fastest (Table 7.1), although this technique produces the greatest acute pain (Stafford, 2007). Behavioral effects (e.g., abnormal posture, scrotal sensitivity, temperament) are seen for several weeks in rubber-ring castrated calves, whereas these parameters return to control levels within the first month after Burdizzo castration. Given the delayed, yet prolonged pain associated with rubber-ring/bands, the adverse welfare effects of this method may be sufficiently great to justify discontinuing its use in favor of the other methods.

7.3.3.2 Disbudding/dehorning

Little is known about how long pain associated with disbudding or dehorning persists. To date, studies have focused on the first few days following the procedure, with the longest follow-up period not exceeding 1 week (Allen et al., 2013; Glynn et al., 2013; Table 7.2). With some exceptions, wound-directed behavior, activity budgets (e.g., eating, lying, locomotion), and plasma cortisol concentrations return to baseline or control levels within 24 hours (Table 7.2), suggesting that any pain occurring during the healing process is of a different intensity or quality than that of the acute response. It is likely that primary hyperalgesia is present for several weeks, as hot-iron disbudding wounds and wounds of similar severity from hot-iron branding remain sensitive for at least 1 week (Allen et al., 2013) or 10 weeks (Tucker et al., 2014a, b), respectively.

Table 7.2

Summary of studies examining the effect of chemical disbudding, hot-iron disbudding, or scoop dehorning on measures collected for ≥24 hours postoperation. Values in bold represent effects that were still significant at the end of the observation period and thus may have lasted beyond the duration indicated.

Measure[a]	Procedure	Duration of effect[b]	Reference
Locomotion	Scoop	NS	Sylvester et al. (2004)
Standing time	Hot-iron	NS	Doherty et al. (2007)
Substance P	Hot-iron	NS	Stock et al. (2015)
	Scoop	NS	Glynn et al. (2013)
Eating/rumination	Hot-iron	NS	Doherty et al. (2007)
	Scoop	2–6 hours	Sylvester et al. (2004)
		4–6 hours	McMeekan et al. (1999)
Lying time	Chemical	NS	Morisse et al. (1995)
	Hot-iron	NS	Morisse et al. (1995)
		NS	Doherty et al. (2007)
	Scoop	NS	Sylvester et al. (2004)
		4–6 hours	McMeekan et al. (1999)
Vitals	Hot-iron	**24 hours**	Heinrich et al. (2009), Stock et al. (2015)
Restlessness	Scoop	6–24 hours	McMeekan et al. (1999)
		6–26 hours	Sylvester et al. (2004)
Play	Hot-iron	3–27 hours	Mintline et al. (2013)
Cortisol	Chemical	1–3 hours	Stilwell et al. (2009)
		1–4 hours	Morisse et al. (1995)
		3–6 hours	Stilwell et al. (2008a)
	Hot-iron	1 hours	Stock et al. (2015)
		1–3 hours	Stilwell et al. (2012)
		4–6 hours	Doherty et al. (2007)
		24 hours	Heinrich et al. (2009), Morisse et al. (1995)
	Scoop	15 hours	Sutherland et al. (2002)
		6–24 hours	Ballou et al. (2013)
		36 hours	Sylvester et al. (1998)
Wound-directed behavior	Chemical	3–6 hours	Stilwell et al. (2008a)
		6–24 hours	Stilwell et al. (2009)
	Hot-iron	3–6 hours	Stilwell et al. (2012)
		2 days	Heinrich et al. (2010)
	Scoop	6–24 hours	McMeekan et al. (1999)
		6–26 hours	Sylvester et al. (2004)
Immune response	Hot-iron	NS	Doherty et al. (2007)
	Scoop	6–24 hours	Sutherland et al. (2013)
		7 days	Glynn et al. (2013)
Wound sensitivity	Hot-iron	**24 hours**	Stock et al. (2015)
		3 days	Mintline et al. (2013)
		7 days	Allen et al. (2013)
	Scoop	**24 hours**	Espinoza et al. (2013, 2016)

[a]Measures are listed in ascending order by maximum duration of effect across all procedures.

[b]The duration that each measure was affected by the procedure is based on comparisons between disbudded/dehorned and sham-operated animals. In the absence of a control treatment, measures were compared to baseline values. NS indicates a nonsignificant effect.

The duration, quality, and intensity of pain depends on the method used (chemical disbudding, hot-iron disbudding, scoop dehorning), as tissue damage is generated by distinct molecular processes depending on the energy form of the stimulus (Lee and Astumian, 1996). Burn and excision injuries of equivalent extent produce distinct profiles of inflammatory mediators in mice, and these differences persist for at least several weeks after the initial trauma (Valvis et al., 2015). In humans, thermal burn pain manifests differently from surgical pain, and may increase over time while surgical pain subsides gradually (Summer et al., 2007). The extent of tissue damage will also vary between methods, with scoop dehorning wounds likely taking longer to heal due to more extensive damage, although healing time has not been investigated for any of the three methods. Even within techniques, significant variation may occur. For example, the tip dimensions, heat capacity of the iron, duration of application, and amount of pressure applied during hot-iron disbudding likely affect study outcomes. More detailed descriptions of techniques should be included in future investigations to refine standard operating procedures and facilitate comparisons between studies.

Caustic paste disbudding has been recommended as a less painful alternative to hot-iron disbudding, as sedated calves disbudded with caustic paste had fewer head shakes and transitions in the 12 hours following the procedure than calves disbudded with a hot iron using both a sedative and local anesthetic (Vickers et al., 2005). However, potential longer-term consequences (inflammatory pain, scurring, injuries from chemical run-off) of this method have not been evaluated. In addition, caustic paste disbudding requires physical isolation for several hours following the procedure in order to avoid other animals coming into contact with the paste. The distress associated with this extended isolation should be considered when weighing the merits and pitfalls of the two techniques for group-housed calves.

7.3.3.3 Other procedures

Abdominal surgeries, including cesarean section, rumen fistulation surgery, left displaced abomasum correction, and flank ovariectomy, but not liver biopsy, produce behavioral and physiological alterations that persist for at least several days (Table 7.3). Therapeutic surgeries to treat an existing ailment (e.g., left displaced abomasum, claw disorders) ameliorated symptoms of the underlying condition (e.g., ketosis in left displaced abomasum, lameness in claw disorder), but increased cortisol, heart rate, and respiratory rates in the postoperative period (Table 7.3). Flank ovariectomy results in more behavioral and physiological changes than the trans-vaginal method, suggesting the latter may be more humane, although further research is required (Table 7.3). Studies investigating postoperative pain (≥24 hours) associated with other procedures, including umbilical, ocular, and teat surgeries, and electroejaculation, are needed.

Table 7.3

Summary of studies examining the effect of procedures other than castration and disbudding/dehorning on measures collected for ≥24 hours postoperation. Values in bold represent effects that were still significant at the end of the observation period and thus may have lasted beyond the duration indicated.

Procedure	Measure[a]	Duration of effect[b]	Reference
Cesarean section[c]	Reaction to noise	NS	Kolkman et al. (2010)
	Eating/rumination	1–3 days	Kolkman et al. (2010)
	Locomotion/stride length	1–3 days	Kolkman et al. (2010)
	Lying time	1–3 days	Kolkman et al. (2010)
	Restlessness	1–3 days	Kolkman et al. (2010)
	Standing time	1–3 days	Kolkman et al. (2010)
	Wound sensitivity	**14 days**	Kolkman et al. (2010)
Claw surgery	Milk yield	NS	Offinger et al. (2013)
	Cortisol	1–2 days	Offinger et al. (2013)
	Vitals	1–2 days	Offinger et al. (2013)
	Eating/rumination	**7 days**	Offinger et al. (2013)
	Lameness[d]	**7 days**	Offinger et al. (2013)
Fistulation surgery	Lying time	NS	Newby et al. (2014)
	Healing/inflammation	**7 days**	Newby et al. (2014)
	Immune response	**7 days**	Newby et al. (2014)
	Vitals	**7 days**	Newby et al. (2014)
	Wound–directed behavior	24 hours	Newby et al. (2014)
	Eating/rumination	**6 days**	Newby et al. (2014)
	Milk yield	**6 days**	Newby et al. (2014)
Flank ovariectomy	Ketosis	NS	Petherick et al. (2011, 2013)
	Locomotion/stride length	NS	Petherick et al. (2013)
	Cortisol	6–8 hours	Petherick et al. (2011)
	Eating/rumination	**3 days**	Petherick et al. (2013)
	Standing time	**3 days**	Petherick et al. (2013)
	Wound–directed behavior	**3 days**	Petherick et al. (2013)
	Cortisol	**4 days**	Petherick et al. (2013)
	Immune response	**4 days**	Petherick et al. (2011, 2013)
	Muscle damage	**4 days**	Petherick et al. (2013)
	Healing/inflammation	**42 days**	Petherick et al. (2011, 2013)
Freeze branding	Temperament	NS	Schwartzkopf-Genswein et al. (1997b)
	Healing/inflammation	6–7 days	Schwartzkopf-Genswein and Stookey (1997)
Hot-iron branding	Lying time	NS	Tucker et al. (2014b)
	Temperament	NS	Schwartzkopf-Genswein et al. (1997b)
	Weight gain	NS	Tucker et al. (2014b)
	Weight gain	1–2 days	Tucker et al. (2014a)
	Healing/inflammation	**7 days**	Schwartzkopf-Genswein and Stookey (1997)
	Healing/inflammation	**56–70 days**	Tucker et al. (2014a, b)
	Wound sensitivity	**70 days**	Tucker et al. (2014a,b)
LDA correction	Eating/rumination	**3 days**	Wittek et al. (2008)
	Milk yield	**3 days**	Wittek et al. (2008)
	Eating/rumination	**9 days**	Newby et al. (2013)
	Ketosis	**9 days**	Newby et al. (2013)
	Vitals	**9 days**	Newby et al. (2013)
Liver biopsy	Eating/rumination	NS	Barrett et al. (2016)
	Locomotion	NS	Barrett et al. (2016)
	Lying time	NS	Barrett et al. (2016)
	Restlessness	NS	Barrett et al. (2016)
	Wound-directed behavior	NS	Barrett et al. (2016)
Trans-vaginal ovariectomy	Immune response	NS	Petherick et al. (2011)
	Ketosis	NS	Petherick et al. (2011, 2013)
	Locomotion/stride length	NS	Petherick et al. (2013)
	Muscle damage	NS	Petherick et al. (2011)
	Wound-directed behavior	NS	Petherick et al. (2013)
	Cortisol	6–8 hours	Petherick et al. (2011)
	Eating/rumination	8–24 hours	Petherick et al. (2013)
	Cortisol	24 hours	Petherick et al. (2013)
	Muscle damage	24 hours	Petherick et al. (2013)
	Standing time	**3 days**	Petherick et al. (2013)

(Continued...)

Procedure	Measure[a]	Duration of effect[b]	Reference
	Immune response	**4 days**	Petherick et al. (2013)

[a]Measures are listed in ascending order by their duration of effect for each procedure.

[b]The duration that each measure was affected by the procedure is based on comparisons between operated and nonoperated animals. In the absence of a control treatment, measures were compared to baseline values (with the exception of healing/inflammation measures, which were not compared to a sham treatment or baseline). NS indicates a nonsignificant effect.

[c]Compared to natural calving.

[d]Improvement after surgery.

7.3.4 Future directions

Progress in understanding inflammatory pain in cattle is constrained both by the observation period and what is being measured. As stated earlier, pain may not decline in a linear fashion. A short observation period could therefore increase the likelihood of false negatives (i.e. failing to detect signs of pain in a suffering animal) if the pain peaks only after data collection is finished. Longer observation periods are preferable since they not only provide a more comprehensive picture of pain progression, but also lower the chances of prematurely concluding that the animal is no longer in pain (Fig. 7.1).

FIGURE 7.1 Healing progression of hot-iron disbudding and surgical castration wounds at 3 days (top panels), 3 weeks (middle panels), and 10 weeks (bottom panels) after the procedure. It is possible that the degree of inflammatory pain fluctuates through the healing period (top and middle panels), depending on the nature of the injury (e.g., burn vs surgical). In addition, neuropathic pain may develop during healing and persist after the wound has healed (bottom panels). Photos on the left courtesy of Adcock and Tucker (in preparation); photos on the right from Mintline et al., 2014.

The literature unequivocally indicates that wounds remain sensitive to mechanical stimuli throughout healing. However, it is unclear whether pain is experienced independent of external stimuli, as there is reason to believe that the mechanisms underlying hypersensitivity and spontaneous (nonevoked) pain are dissociable (Mogil and Crager, 2004). Given its important implications for cattle welfare, novel sensitive and reliable indicators of spontaneous pain are needed to address this knowledge gap. To date, behavioral measures of spontaneous pain have consisted largely of wound-directed behaviors and activity (e.g., lying, feeding, ruminating, locomotion) (Viñuela-Fernández et al., 2011). Changes in these measures following a painful procedure rarely persist beyond the first few days, potentially leading to erroneous conclusions about the duration and intensity of pain experienced by the animal. Indeed, spontaneous pain behaviors may be rare in prey species such as cattle, since they would signal vulnerability to a predator and would be weeded out by natural selection (although this theory has never been empirically tested). The development of more sensitive pain assays and indicators of positive welfare will be critical in reducing cases of false-negative results. Several models of spontaneous pain have been validated in rodents, including the conditioned place preference and avoidance paradigms, and analgesic self-administration (Mogil, 2009). Adoption of similar operant measures for cattle may yield significant insight into the animal's ongoing affective state.

7.4 Neuropathic pain (posthealing)

7.4.1 Neurobiology

As wounds heal, the hyperalgesia induced by peripheral and central sensitization typically subsides, and pain thresholds return to normal. However, when the somatosensory nervous system itself has been damaged, pain can persist after healing is complete, a chronic condition referred to as neuropathic pain. Neuropathic pain can be associated with a peculiar combination of loss-of-function symptoms, such as partial or complete numbness at the site of injury due to denervation, and gain-of-function symptoms, including spontaneous abnormal sensations, hyperalgesia, and persistent pain (Devor, 2013). These paradoxical symptoms can be explained by the development of electrical hyperexcitability in damaged/severed nerve ends. When an axon is severed during injury, a predictable cascade of events is initiated that ultimately leads to the restoration of normal nerve function in the original peripheral target. However, when axonal re-growth is impaired, the proximal stumps and aborted sprouts of damaged axons form a tangled knot of nerve tissue, known as a nerve-end neuroma. Ectopic firing originating in the neuroma leads to spontaneous and stimulus-evoked pain, explaining how these sensations can arise in the skin when the epidermis is denervated. This aberrant electrical activity in the periphery induces and maintains central sensitization, which plays a key role in neuropathic pain (Devor, 2013).

Neuropathic pain is associated with increased activity in the prefrontal cortex and amygdala, which may reflect the more elaborated accompanying psychological state. In addition, neuropathic pain can produce structural brain changes, notably a reduction in gray matter, as well as decreased activity of the opioidergic and dopaminergic neurotransmitter systems (Apkarian et al., 2013). In humans, neuropathic pain is often accompanied by comorbidities, including depression (Dickens et al., 2002), anxiety disorders (McWilliams et al., 2004), sleep disturbance (Fishbain et al., 2010), and cognitive impairment (Moriarty et al., 2011).

7.4.2 Management methods

To our knowledge, neuropathic pain has not been described in cattle. The vast majority of what we know about neuropathic pain and its management comes from rodent models and human clinical trials. Since there is no cure for neuropathic pain, management focuses on relief of pain symptoms. As with acute and inflammatory pain, a single mode of therapy is rarely sufficient. In humans, drugs used to treat neuropathic pain fall into four categories: (1) anticonvulsants; (2) antidepressants; (3) opioids; and, less frequently, (4) cannabinoids. Although NSAIDs are often used to treat neuropathic pain (Vo et al., 2009), this class of medication is generally considered ineffective for this purpose and receives no mention in neuropathic pain treatment guidelines for humans (O'Connor and Dworkin, 2009; Attal et al., 2010; Dworkin et al., 2010; Moulin et al., 2014).

7.4.2.1 Anticonvulsants

The antiepileptic drug, gabapentin, is a primary agent for treating neuropathic pain. It exerts its analgesic properties via indirect blockade of voltage-gated calcium channels, leading to decreased excitatory neurotransmitter release (Morisset et al., 2013). The few studies that have evaluated its use in cattle have focused on its efficacy at treating postsurgical pain during the inflammatory stage (Fraccaro et al., 2013; Glynn et al., 2013). Oral administration of gabapentin (15 mg/kg) at the time of scoop dehorning did not affect cortisol, haptoglobin, prostaglandin E_2 levels, or wound sensitivity in the following days

(Fraccaro et al., 2013; Glynn et al., 2013). Following induction of lameness, calves treated with gabapentin combined with meloxicam demonstrated increased force applied to the lame claw compared with placebo-treated controls (Coetzee et al., 2014). Gabapentin's ability to manage pathophysiological pain states in cattle is unknown.

7.4.2.2 Antidepressants

In human medicine, tricyclic antidepressants are an effective first-line treatment for neuropathic pain. They exert analgesic actions separate from the antidepressant effect primarily via reinforcement of the pain-inhibiting system that descends from the brainstem to the spinal cord (Dharmshaktu et al., 2012). To our knowledge, no studies have evaluated these drugs for pain management in farm animals. A case report in dogs diagnosed with neuropathic pain demonstrated that treatment with the tricyclic antidepressant, amitriptyline, resulted in dramatic improvement of clinical signs (Cashmore et al., 2009).

7.4.2.3 Opioids

In addition to managing acute pain, opioids are recommended for treating neuropathic pain in humans (O'Connor and Dworkin, 2009; Attal et al., 2010; Dworkin et al., 2010). Tramadol, a μ-opioid receptor agonist and serotonin reuptake inhibitor, has antinoceptive effects in rodent models of neuropathic pain (Apaydin et al., 2000; Kaneko et al., 2014), although a single dose can produce cognitive impairments (Hosseini-Sharifabad et al., 2016). Evaluation of opioids for management of neuropathic pain in other animals is limited. In horses with chronic laminitis, treatment with tramadol alone provided limited pain relief, and more effective analgesia was evident when ketamine was coadministered (Guedes et al., 2012). The potential for tolerance, dependence, and withdrawal should be considered when administering long-term opioid therapy.

7.4.2.4 Cannabinoids

The therapeutic effects of plant-derived cannabinoids have been known for millennia, but they have been underappreciated in human and veterinary medicine until recently, as increasing evidence for their analgesic efficacy emerges (e.g., Moulin et al., 2014). In parallel with the opioid system, endogenously released "endocannabinoids" are involved in nociceptive processing via interaction with receptors located in the brain, spinal cord, and peripheral nervous system. Exogenously administered cannabinoids target these endocannabinoid binding sites and have proven efficacious at inducing analgesia in animal models of neuropathic pain (Hohmann and Rice, 2013). Low doses of cannabinoids could be a promising adjuvant therapy due to their ability to increase the analgesic effectiveness of opioids (Gerak and France, 2016) and reduce gastrointestinal complications from other drugs (Kinsey and Cole, 2013). Intravenous infusion of cannabinoids was shown to produce an immediate, transient decrease in pain sensitivity in calves, although the sample size was small and the observed hypoalgesia may have been due to nonspecific stressor effects from the injection (Zenor et al., 1999). The adverse effects (e.g., psychotropic properties) and milk/meat withholding times associated with long-term cannabinoid therapy in cattle are unknown.

7.4.2.5 Euthanasia

Long-term analgesic therapy may be unrealistic when the animal is severely affected and significant improvement is unlikely, in which case euthanasia may be the preferred option (Cockcroft, 2015).

7.4.3 What we do and don’t know about neuropathic pain

Given our limited understanding of acute nociceptive and inflammatory pain as described in the previous sections, it is not surprising that we know virtually nothing about pathophysiological states associated with painful procedures in cattle, or most other animals for that matter. The absence of validated neuropathic pain scales for children is telling of the challenges we face in diagnosing this condition in our own species, let alone others (von Baeyer and Spagrud, 2007; Howard et al., 2014).

Neuromas have been found in docked tails of dogs (Gross and Carr, 1990), lambs (French and Morgan, 1992), piglets (Herskin et al., 2015), and heifers (Eicher et al., 2006), as well as the trimmed beaks of hens (Breward and Gentle, 1985). It is possible that castration and disbudding/dehorning, as well as other surgical procedures, could lead to neuroma development. In humans, approximately half of burn patients report neuropathic-like pain symptoms that persist for over a year (Schneider et al., 2006), or a decade in the case of severe, widespread injury (Dauber et al., 2002). Even minor burn injuries that cover 4%

of the total body surface area can produce profound, sustained systemic decreases in skin innervation (Anderson et al., 2010). Whether the third-degree burns produced by hot-iron disbudding or branding have similar long-term consequences is unknown.

Phantom pain, a neuropathic condition in which pain is perceived in a missing body part, occurs in the majority of limb amputees (Jackson and Simpson, 2004), but is poorly documented in nonhuman animals. Phantom pain could conceivably occur in cattle following some surgeries, such as digital amputation or eye enucleation (Hope-Stone et al., 2015).

7.4.4 Future directions

Sensitive and reliable indicators of neuropathic pain are needed to understand its prevalence and consequently, its welfare implications, in cattle. Overt behavioral signs of spontaneous neuropathic pain are difficult to observe (e.g., aggression, locomotion, food intake, posture, grooming, scratching), as they tend to habituate or dissipate over time and are subject to high inter-individual variability (Mogil, 2009). Facial grimace scales have been used to detect acute pain, but neuropathic pain was not associated with a pain face in mice (Langford et al., 2010). Evoked responses to mechanical and thermal stimuli may offer insight into the presence of neuropathic pain, but should not be relied on in isolation; in humans, neuropathic pain may be characterized by spontaneous pain in the absence of evoked pain due to heat or touch (Backonja and Stacey, 2004).

In addition to evoked and spontaneous pain, the emotional effects of neuropathic pain are equally, if not more so, deserving of attention. In humans with neuropathic pain, the high prevalence of psychiatric co-morbidities indicates that psychological factors are key players in the experience, maintenance, and exacerbation of pain, regardless of whether they are causes, effects, or, likely, both. Treatments targeted at alleviating emotional distress in humans produce a modest reduction in neuropathic pain severity comparable to that of traditional pharmacological methods (Turk et al., 2010). Anxiety- and/or depression-related behaviors have also been reported in rodent models of neuropathic pain (reviewed in Yalcin et al., 2014) and addition of physical enrichment (e.g., access to exercise, more space, toys) and social enrichment (e.g., more cagemates) improves pain outcomes (reviewed in Bushnell et al., 2015). Although our toolkit for assessing emotional states—and, especially, emotional valence (whether the state is positive or negative)—is limited for animals, promising indicators have emerged in recent years. In particular, cognitive bias tasks offer a means to detect the valence of emotional experiences (Mendl et al., 2009). For example, Neave et al. (2013) found that calves are more likely to evaluate ambiguous stimuli as negative in the immediate hours following disbudding, indicating that pain produces a "pessimistic" state. Similar operant conditioning paradigms may prove useful for investigation of neuropathic pain states.

7.5 Inter-individual differences in pain

Individuals differ in many aspects of the pain experience, including their sensitivity to noxious stimuli, susceptibility to developing neuropathic pain after injury, and their analgesic response to pharmacological therapy (Mogil, 2012). An understanding of the underlying basis of these differences in cattle would improve our ability to recognize and manage pain effectively through all its stages. Here, we focus on the developmental, environmental, and cognitive factors most relevant to cattle, including: (1) age; (2) neonatal pain and stress experiences; (3) concurrent painful procedures; and (4) states of attention and arousal. The genetic contributions to inter-individual pain differences have been reviewed elsewhere (Mogil, 1999, 2012; Lacroix-Fralish and Mogil, 2009) and will not be considered here, except to note that they are an integral piece of the puzzle, both in terms of their unique effects and in their interactions with environmental factors (e.g., diet: Shir and Seltzer, 2001).

7.5.1 Age

Performing procedures early in life may offer a practical strategy for mitigating pain; less tissue is damaged and growth rates are steepest in young animals, in theory promoting faster wound closure. Unfortunately, many organizations permit painful procedures without pharmacological analgesia in animals under a certain age, despite a notable lack of empirical evidence to support this allowance. For example, the European Convention, which applies to 47 countries, recommends pain relief be used when disbudding calves over 4 weeks of age (Council of Europe, 1988). Similarly, the New Zealand and Australian standards do not require pain relief in calves surgically castrated or dehorned under 6 months (NAWAC, 2005; AHA, 2016). There are no regulations requiring analgesia at any age in the United States, to our knowledge.

There is a widespread misconception that neonates have an absent or diminished awareness of pain. This assumption is not restricted to nonhumans; the question of whether human infants can experience pain has been a source of immense controversy in the medical community. A review of neonatal pain management in 2009 found that 60% of infants do not receive any pharmacological analgesia during painful procedures (Roofthooft et al., 2014). This is troubling given the fact that a noxious stimulus activates the same brain regions encoding the sensory and affective components of pain in adults and newborns (Goksan et al., 2015). Fortunately, concerted efforts are being made to improve pain management in this population. This issue has also received increasing attention in farm animals. Not only is there ample evidence that neonates feel pain (e.g., Boesch et al., 2008; Guesgen et al., 2011; Caray et al., 2015), but it has been speculated that pain may be experienced more intensely at younger ages due to the rapid activation of awareness soon after birth (Mellor and Stafford, 2004). However, some studies in lambs and calves have demonstrated a reduced electroencephalographic response to painful procedures at younger ages (Johnson et al., 2005a; Johnson et al., 2009; Dockweiler et al., 2013). Nonetheless, a pain response was observed in the younger age group, justifying the provision of pain relief for all ages.

The ability for neonates to feel pain has implications for the management of fetuses during slaughter of pregnant animals. Indeed, the European Food Safety Authority is currently reviewing the welfare concerns regarding the slaughter of pregnant animals (EFSA, 2016). Electroencephalographic activity suggests that consciousness in a precocial species requires the onset of breathing and arises in the first few minutes after birth (Mellor and Diesch, 2006; Diesch et al., 2008). Thus, it has been proposed that if a fetus dies before drawing its first breath it will not suffer. In accordance with this idea, the World Organization for Animal Health recommends that fetuses should not be removed from the uterus of a slaughtered pregnant dam until unconscious or dead (Shimshony and Chaudry, 2005). However, more recently it has been argued that, following the precautionary principle, protection should be extended to prenatal animals as there is at least a scientific possibility that suffering can occur before exiting the womb (Campbell et al., 2014). In fact, US lab animal guidelines for neuroscience and behavioral research advise that anesthesia for potentially painful procedures be provided for late-term fetuses (National Research Council, 2003).

7.5.2 Neonatal adverse experiences

The influence of early adverse events on developing nociceptive pathways has received considerable attention in human and experimental animal models. Painful experiences in neonates can lead to heightened sensitivity to injury later in life in both altricial (humans: Taddio et al., 1997; rodents: Beggs et al., 2012) and precocial species (sheep: McCracken et al., 2010). This hypersensitivity may have a delayed onset, not emerging until adolescence in some cases (Vega-Avelaira et al., 2012). Importantly, the "priming" effect of early pain experiences is diminished by local anesthetic, indicating that sensory activity is necessary to trigger long-term changes in pain sensitivity (Taddio et al., 1997; Walker et al., 2009). This finding has important implications for the quality of analgesic therapy used for neonatal procedures in cattle.

In addition to tissue damage, early life stress can evoke long-lasting alterations in pain perception. For example, neonatal maternal separation induces hyperalgesia in rats (Coutinho et al., 2002). Conversely, prenatal stress attenuated nociceptive responses in piglets (Sandercock et al., 2011). Prenatal stress is also associated with a dysfunctional stress response that increases susceptibility to chronic pain (Blackburn-Munro, 2004). Intriguingly and rather alarmingly, effects lasting across generations have been reported; ewes exposed to a simulated infection at 2–3 days of age gave birth to lambs with hypoalgesia (Clark et al., 2014). The impact of reduced pain sensitivity on welfare is unclear. On the one hand, a high tolerance for pain may reduce suffering during routine procedures. On the other hand, injury is more likely to go undetected, leading to deleterious effects in the long-term.

Emphasis is often placed on early life adversity that predisposes individuals to pain, but it is conceivable that positive early experiences (e.g., maternal contact, play) may serve a protective function. For example, rat pups exposed to enriched environments have reduced stress reactivity (Belz et al., 2003) and pain sensitivity (Rossi and Neubert, 2008) and increased opioid sensitivity (Smith et al., 2003, 2005). Promisingly, environmental enrichment at later stages of development has been shown to offset the effects of early trauma on stress reactivity in rats (Francis et al., 2002; Morley-Fletcher et al., 2003). However, it should be noted that caution is needed when translating findings from an altricial species (e.g., rats) to a precocial one (e.g., cattle), as the latter are born in a more advanced developmental state and undergo less neurologic development postnatally (Wood et al., 2003). The long-term effects, positive and negative, of early-life experiences on pain sensitivity in cattle, as well as the effective management of these experiences, represent an important area for investigation.

7.5.3 Concurrent procedures

Although research focuses on examining pain responses to a single procedure, multiple procedures are often performed concurrently in practice. In the USA, for example, over 90% of bovine veterinarians dehorn male beef calves at the time of castration (Coetzee et al., 2010b). A large body of data in rodents and humans indicates noxious stimulation applied to one part of the body diminishes the perceived intensity of another stimulus applied to a remote body part. This seemingly paradoxical phenomenon, known as "diffuse noxious inhibitory control", occurs through widespread descending inhibition from the brainstem (Le Bars et al., 1979; Youssef et al., 2016) and is independent of a distraction effect in humans (Moont et al., 2010). This endogenous analgesia may provide a compelling reason for performing procedures at the same time. The two studies that have evaluated the effects of concurrent castration and dehorning in 3-month-old Holstein calves have produced equivocal results; Ballou et al. (2013) reported an additional increase in cortisol concentrations in calves subjected to both procedures compared to castration alone, but an additive effect was not observed by Mosher et al. (2013). In the latter study, the authors suggest that a ceiling effect may have occurred, such that cortisol reaches its maximum concentration and stops increasing beyond a certain level of pain.

The effects of concurrent procedures on healing in cattle need investigation. Thermal injuries in mice have been shown to markedly delay healing and suppress the inflammatory response at a distal excisional wound site incurred immediately following the burn (Schwacha et al., 2008). Thus, it is possible that disbudding and/or branding at the time of castration may increase healing time.

7.5.4 States of attention and arousal

Although the link between cognition and pain has received little attention in cattle, human and rodent studies provide compelling evidence that attention and arousal are powerful modulators of pain perception. This cognitive role can be exploited to achieve a degree of analgesia, as discussed in the first section of this chapter, but can also profoundly impact the outcomes of pain assessments. When different motivations compete for attention, the brain assigns priority to the most salient drive, overriding lower-priority ones. Thus, pain can be suppressed when a threat is encountered (e.g., predator: Kavaliers, 1988; social isolation and restraint: Herskin et al., 2004, 2007; unfamiliar conspecific: Langford et al., 2011; human observer: Sorge et al., 2014), as well as in less dire situations, when an animal has a strong urge to feed (Wright et al., 2015) or urinate (Baez et al., 2005), for example. Grooming has also been shown to inhibit sensitivity to mechanical stimulation in mice, presumably by acting as a distraction (Callahan et al., 2008). Conversely, hyperalgesia can occur in mice exposed to a familiar conspecific in a similar pain state (Langford et al., 2006). The presence of threats, distractions, and conspecifics (or lack thereof) while conducting pain assays represents a serious confound, which can be minimized by testing under homogenous conditions with minimal disruption to the animal, or if that is not possible, by including putative attentional modulators as covariates in the analysis. Neuroimaging and electroencephalography techniques could provide insight into the animal's subjective experience when behavioral and physiological responses are confounded with contextual factors (e.g., Johnson et al., 2005b; Gibson et al., 2007; Bergamasco et al., 2011). Further investigation of cognitive states and their effect on pain perception in cattle is merited.

7.6 Conclusions

Pain management is widely acknowledged as a top priority for cattle welfare, yet progress in this area lags behind advances made in other species, namely rodents, companion animals, and humans. Current research, legislation, and recommendations on the use of pain relief in cattle focus on the immediate response to painful procedures, namely castration and disbudding/dehorning, and neglect other procedures and the long-term consequences of injury. Broadening our understanding of pain to include inflammatory and neuropathic conditions will be critical for ensuring best practice in pain management, as these factors may tip the balance when deciding whether the potential benefits of a procedure are sufficient to justify its negative effects. The narrow focus to date may be explained, at least in part, by the lack of sensitive and reliable measures needed to accurately identify pain. Our pain assessment toolkit for cattle has stagnated over the last two decades, and novel measures and standardized protocols will do much to advance the field. Finally, the development of practical, safe, and cost-effective pain-management strategies will improve the translation of research into practice. A vast selection of adjuvant/alternative therapies have been described in the companion animal and human medicine literature, yet receive little attention in cattle, where the focus has been largely on local anesthetics, NSAIDs, or a combination of the two. There is no doubt that increasing the amount of cross-talk between animal welfare science and other disciplines, particularly human medicine and psychology, will broaden our perspectives on pain and reveal fresh insights into identifying and alleviating this undesirable affective state in cattle.

References

1. Abrahamsen EJ. Chemical restraint and injectable anesthesia of ruminants. *Vet Clin N Am Food Anim Pract.* 2013;29:209–227.
2. AHA, 2016. Australian Animal Welfare Standards and Guidelines for Cattle. <http://www.animalwelfarestandards.net.au/files/2016/02/Cattle-Standards-and-Guidelines-Endorsed-Jan-2016-250116.pdf> (accessed 5.09.16.).
3. Aitken BL, Stookey JM, Noble S, Watts J, Finlay D. The effects of an oral distraction on cattle during a painful procedure. *Can Vet J.* 2013;54:588–590.
4. Allen KA, Coetzee JF, Edwards-Callaway LN, et al. The effect of timing of oral meloxicam administration on physiological responses in calves after cautery dehorning with local anesthesia. *J Dairy Sci.* 2013;96:5194–5205.
5. Anderson DE, Edmondson MA. Prevention and management of surgical pain in cattle. *Vet Clin N Am Food Anim Pract.* 2013;29:157–184.
6. Anderson JR, Zorbas JS, Phillips JK, et al. Systemic decreases in cutaneous innervation after burn injury. *J Investig Dermatol.* 2010;130:1948–1951.
7. Apaydin S, Uyar M, Karabay NU, Erhan E, Yegul I, Tuglular I. The antinociceptive effect of tramadol on a model of neuropathic pain in rats. *Life Sci.* 2000;66:1627–1637.
8. Apkarian AV, Bushnell MC, Schweinhardt P. Representation of pain in the brain. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
9. Asarian L, Geary N. Modulation of appetite by gonadal steroid hormones. *Philos Trans R Soc B Biol Sci.* 2006;361:1251–1263.

10. Attal N, Cruccu G, Baron R, et al. EFNS guidelines on the pharmacological treatment of neuropathic pain: 2010 revision. *Eur J Neurol.* 2010;17:e1113–e1188.
11. Backonja M-M, Stacey B. Neuropathic pain symptoms relative to overall pain rating. *J Pain*. 2004;5:491–497.
12. Baez MA, Brink TS, Mason P. Roles for pain modulatory cells during micturition and continence. *J Neurosci.* 2005;25:384–394.
13. Ballou MA, Sutherland MA, Brooks TA, Hulbert LE, Davis BL, Cobb CJ. Administration of anesthetic and analgesic prevent the suppression of many leukocyte responses following surgical castration and physical dehorning. *Vet Immunol Immunopathol.* 2013;151:285–293.
14. Bangasser DA, Valentino RJ. Sex differences in molecular and cellular substrates of stress. *Cell Mol Neurobiol.* 2012;32:709–723.
15. Barrett LA, Beausoleil NJ, Benschop J, Stafford KJ. Pain-related behavior was not observed in dairy cattle in the days after liver biopsy, regardless of whether NSAIDs were administered. *Res Vet Sci.* 2016;104:195–199.
16. Barrier AC, Coombs TM, Dwyer CM, Haskell MJ, Goby L. Administration of a NSAID (meloxicam) affects lying behaviour after caesarean section in beef cows. *Appl Anim Behav Sci.* 2014;155:28–33.
17. Beausoleil NJ, Stafford KJ. Is a nonsteroidal anti-inflammatory drug required to alleviate pain behavior associated with liver biopsy in cattle? *J Vet Behav Clin Appl Res.* 2012;7:245–251.
18. Becker J, Doherr MG, Bruckmaier RM, Bodmer M, Zanolari P, Steiner A. Acute and chronic pain in calves after different methods of rubber-ring castration. *Vet J.* 2012;194:380–385.
19. Beggs S, Currie G, Salter MW, Fitzgerald M, Walker SM. Priming of adult pain responses by neonatal pain experience: Maintenance by central neuroimmune activity. *Brain*. 2012;135:404–417.
20. Belz EE, Kennell JS, Czambel RK, Rubin RT, Rhodes ME. Environmental enrichment lowers stress-responsive hormones in singly housed male and female rats. *Pharmacol Biochem Behav.* 2003;76:481–486.
21. Bergamasco L, Coetzee JF, Gehring R, Murray L, Song T, Mosher RA. Effect of intravenous sodium salicylate administration prior to castration on plasma cortisol and electroencephalography parameters in calves. *J Vet Pharmacol Ther.* 2011;34:565–576.

22. Bicalho RC, Cheong SH, Warnick LD, Nydam DV, Guard CL. The effect of digit amputation or arthrodesis surgery on culling and milk production in Holstein dairy cows. *J Dairy Sci.* 2006;89:2596–2602.
23. Blackburn-Munro G. Hypothalamo-pituitary-adrenal axis dysfunction as a contributory factor to chronic pain and depression. *Curr Pain Headache Rep.* 2004;8:116–124.
24. Boesch D, Steiner A, Gygax L, Stauffacher M. Burdizzo castration of calves less than 1-week old with and without local anaesthesia: Short-term behavioural responses and plasma cortisol levels. *Appl Anim Behav Sci.* 2008;114:330–345.
25. Breward J, Gentle MJ. Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry. *Experientia.* 1985;41:1132–1134.
26. Brown AC, Powell JG, Kegley EB, et al. Effect of castration timing and oral meloxicam administration on growth performance, inflammation, behavior, and carcass quality of beef calves. *J Anim Sci.* 2015;93:2460–2470.
27. Bushnell MC, Case LK, Ceko M, et al. Effect of environment on the long-term consequences of chronic pain. *Pain*. 2015;156:S42–S49.
28. Callahan BL, Gil ASC, Levesque A, Mogil JS. Modulation of mechanical and thermal nociceptive sensitivity in the laboratory mouse by behavioral state. *J Pain*. 2008;9:174–184.
29. Campbell MLH, Mellor DJ, Sandøe P. How should the welfare of fetal and neurologically immature postnatal animals be protected? *Anim Welf*. 2014;23:369–379.
30. Caray D, de Boyer des Roches A, Frouja S, Andanson S, Veissier I. Hot-iron disbudding: Stress responses and behavior of 1- and 4-week-old calves receiving anti-inflammatory analgesia without or with sedation using xylazine. *Livest Sci.* 2015;179:22–28.
31. Cardoso CS, von Keyserlingk MAG, Hötzel MJ. Trading off animal welfare and production goals: Brazilian dairy farmers' perspectives on calf dehorning. *Livest Sci.* 2016;187:102–108.
32. Cashmore RG, Harcourt-Brown TR, Freeman PM, Jeffery ND, Granger N. Clinical diagnosis and treatment of suspected neuropathic pain in three dogs. *Aust Vet J.* 2009;87:45–50.
33. Chase CC, Larsen RE, Randel RD, Hammond AC, Adams EL. Plasma cortisol and white blood cell responses in different breeds of bulls: A

comparison of two methods of castration. *J Anim Sci.* 1995;73:975–980.
34. Chen MR, Dragoo JL. The effect of nonsteroidal anti-inflammatory drugs on tissue healing. *Knee Surg Sports Traumatol Arthroscopy*. 2013;21:540–549.
35. Clark C, Murrell J, Fernyhough M, O'Rourke T, Mendl M. Long-term and trans-generational effects of neonatal experience on sheep behaviour. *Biol Lett.* 2014;10:20140273.
36. Cockcroft PD. Pain Management in Cattle Practice. In: Cockcroft PD, ed. *Bovine Medicine*. Chichester, UK: John Wiley & Sons, Ltd; 2015.
37. Coetzee JF. Assessment and management of pain associated with castration in cattle. *Vet Clin N Am Food Anim Pract.* 2013a;29:75–101.
38. Coetzee JF. A review of analgesic compounds used in food animals in the United States. *Vet Clin N Am Food Anim Pract.* 2013b;29:11–28.
39. Coetzee JF, Gehring R, Tarus-Sang J, Anderson DE. Effect of sub-anesthetic xylazine and ketamine ('ketamine stun') administered to calves immediately prior to castration. *Vet Anaesth Analg.* 2010a;37:566–578.
40. Coetzee JF, Nutsch AL, Barbur LA, Bradburn RM. A survey of castration methods and associated livestock management practices performed by bovine veterinarians in the United States. *BMC Vet Res.* 2010b;6:12.
41. Coetzee JF, Mosher RA, Anderson DE, et al. Impact of oral meloxicam administered alone or in combination with gabapentin on experimentally induced lameness in beef calves. *J Anim Sci.* 2014;92:816–829.
42. Cohen LL, Blount RL, Cohen RJ, Schaen ER, Zaff JF. Comparative study of distraction versus topical anesthesia for pediatric pain management during immunizations. *Health Psychol.* 1999;18:591–598.
43. Council of Europe, 1988. Recommendation concerning cattle. <http://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety_and_use_of_animals/farming/Rec%20cattle (accessed 5.09.16.).
44. Coutinho SV, Plotsky PM, Sablad M, et al. Neonatal maternal separation alters stress-induced responses to viscerosomatic nociceptive stimuli in rat. *Am J Physiol Gastrointestinal Liver Physiol.* 2002;282:G307–G316.
45. Couture Y, Mulon PY. Procedures and surgeries of the teat. *Vet Clin N Am Food Anim Pract.* 2005;21:173–204.

46. Cozzi G, Gottardo F, Brscic M, et al. Dehorning of cattle in the EU Member States: A quantitative survey of the current practices. *Livest Sci.* 2015;179:4–11.
47. Currah JM, Hendrick SH, Stookey JM. The behavioral assessment and alleviation of pain associated with castration in beef calves treated with flunixin meglumine and caudal lidocaine epidural anesthesia with epinephrine. *Can Vet J.* 2009;50:375–382.
48. Dauber A, Osgood PF, Breslau AJ, Vernon HL, Carr DB. Chronic persistent pain after severe burns: A survey of 358 burn survivors. *Pain Med.* 2002;3:6–17.
49. Devant M, Marti S, Bach A. Effects of castration on eating pattern and physical activity of Holstein bulls fed high-concentrate rations under commercial conditions. *J Anim Sci.* 2012;90:4505–4513.
50. Devor M. Neuropathic Pain: Pathophysiological Response of Nerves to Injury. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
51. Dharmshaktu P, Tayal V, Kalra BS. Efficacy of antidepressants as analgesics: A review. *J Clin Pharmacol.* 2012;52:6–17.
52. Dickens C, McGowan L, Clark-Carter D, Creed F. Depression in rheumatoid arthritis: A systematic review of the literature with meta-analysis. *Psychosom Med.* 2002;64:52–60.
53. Dickenson AH, Kieffer BL. Opioids: Basic Mechanisms. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
54. Diesch TJ, Mellor DJ, Johnson CB, Lentle RG. Responsiveness to painful stimuli in anaesthetised newborn and young animals of varying neurological maturity (wallaby joeys, rat pups and lambs). *Altern Anim Test Exp.* 2008;14:549–552.
55. Dockweiler JC, Coetzee J, Edwards-Callaway L, et al. Effect of castration method on neurohormonal and electroencephalographic stress indicators in Holstein calves of different ages. *J Dairy Sci.* 2013;96:4340–4354.
56. Doherty TJ, Kattesh HG, Adcock RJ, et al. Effects of a concentrated lidocaine solution on the acute phase stress response to dehorning in dairy calves. *J Dairy Sci.* 2007;90:4232–4239.
57. Dworkin RH, O'Connor AB, Audette J, et al. Recommendations for the

pharmacological management of neuropathic pain: An overview and literature update. *Mayo Clinic Proc.* 2010;85:S3–S14.
58. Earley B, Crowe MA. Effects of ketoprofen alone or in combination with local anesthesia during the castration of bull calves on plasma cortisol, immunological, and inflammatory responses. *J Anim Sci.* 2002;80:1044–1052.
59. Ede T, von Keyserlingk MAG, Weary DM. Intramuscular injections induce conditioned place aversion in calves. In: Jensen MB, Herskin MS, Malmkvist J, eds. *Proceedings of the 51st International Congress of the International Society of Applied Ethology*. Denmark: Aarhus; 2017;154.
60. EFSA, 2016. <http://registerofquestions.efsa.europa.eu/roqFrontend/mandateLoader?mandate=M-2015-0178> (accessed 14.11.16.).
61. Eicher SD, Cheng HW, Sorrells AD, Schutz MM. Short communication: Behavioral and physiological indicators of sensitivity or chronic pain following tail docking. *J Dairy Sci.* 2006;89:3047–3051.
62. Espinoza C, Lomax S, Windsor P. The effect of a topical anesthetic on the sensitivity of calf dehorning wounds. *J Dairy Sci.* 2013;96:2894–2902.
63. Espinoza CA, McCarthy D, White PJ, Windsor PA, Lomax SH. Evaluating the efficacy of a topical anaesthetic formulation and ketoprofen, alone and in combination, on the pain sensitivity of dehorning wounds in Holstein-Friesian calves. *Anim Prod Sci.* 2016;56:1512–1519.
64. Etson CJ, Waldner CL, Barth AD. Evaluation of a segmented rectal probe and caudal epidural anesthesia for electroejaculation of bulls. *Can Vet J.* 2004;45:235–240.
65. Fairweather M, Heit YI, Buie J, et al. Celecoxib inhibits early cutaneous wound healing. *J Surg Res.* 2015;194:717–724.
66. Fajt VR, Wagner SA, Norby B. Analgesic drug administration and attitudes about analgesia in cattle among bovine practitioners in the United States. *J Am Vet Med Assoc.* 2011;238:755–767.
67. Falk AJ, Waldner CL, Cotter BS, Gudmundson J, Barth AD. Effects of epidural lidocaine anesthesia on bulls during electroejaculation. *Can Vet J.* 2001;42:116–120.
68. Faulkner DB, Eurell T, Tranquilli WJ, et al. Performance and health of

weanling bulls after butorphanol and xylazine administration at castration. *J Anim Sci.* 1992;70:2970–2974.

69. Fell LR, Wells R, Shutt DA. Stress in calves castrated surgically or by the application of rubber rings. *Aust Vet J.* 1986;63:16–18.
70. Fijak M, Damm LJ, Wenzel JP, et al. Influence of testosterone on inflammatory response in testicular cells and expression of transcription factor Foxp3 in T cells. *Am J Reprod Immunol.* 2015;74:12–25.
71. Fishbain DA, Cole B, Lewis JE, Gao J. What is the evidence for chronic pain being etiologically associated with the DSM-IV category of sleep disorder due to a general medical condition? A structured evidence-based review. *Pain Med.* 2010;11:158–179.
72. Fisher AD, Crowe MA, O'Nualláin EM, et al. Effects of cortisol on in vitro interferon-gamma production, acute-phase proteins, growth, and feed intake in a calf castration model. *J Anim Sci.* 1997;75:1041–1047.
73. Fisher AD, Knight TW, Cosgrove GP, et al. Effects of surgical or banding castration on stress responses and behaviour of bulls. *Aust Vet J.* 2001;79:279–284.
74. Fraccaro E, Coetzee JF, Odore R, et al. A study to compare circulating flunixin, meloxicam and gabapentin concentrations with prostaglandin E_2 levels in calves undergoing dehorning. *Res Vet Sci.* 2013;95:204–211.
75. Francis DD, Diorio J, Plotsky PM, Meaney MJ. Environmental enrichment reverses the effects of maternal separation on stress reactivity. *J Neurosci.* 2002;22:7840–7843.
76. French NP, Morgan KL. Neuromata in docked lambs' tails. *Res Vet Sci.* 1992;52:389–390.
77. Fry LM, Neary SM, Sharrock J, Rychel JK. Acupuncture for analgesia in veterinary medicine. *Top Companion Anim Med.* 2014;29:35–42.
78. Gerak LR, France CP. Combined treatment with morphine and Δ9-tetrahydrocannabinol in rhesus monkeys: Antinociceptive tolerance and withdrawal. *J Pharmacol Exp Therap.* 2016;357:357–366.
79. Gibson TJ, Johnson CB, Stafford KJ, Mitchinson SL, Mellor DJ. Validation of the acute electroencephalographic responses of calves to noxious stimulus with scoop dehorning. *N Z Vet J.* 2007;55:152–157.
80. Glynn HD, Coetzee JF, Edwards-Callaway LN, et al. The pharmacokinetics and effects of meloxicam, gabapentin, and flunixin in postweaning dairy calves following dehorning with local anesthesia. *J*

Vet Pharmacol Ther. 2013;36:550–561.
81. Goksan S, Hartley C, Emery F, et al. fMRI reveals neural activity overlap between adult and infant pain. *eLife*. 2015;4:e06356.
82. González LA, Schwartzkopf-Genswein KS, Caulkett NA, et al. Pain mitigation after band castration of beef calves and its effects on performance, behavior, *Escherichia coli*, and salivary cortisol. *J Anim Sci*. 2010;88:802–810.
83. Greene SA. Protocols for anesthesia of cattle. *Vet Clin N Am Food Anim Pract.* 2003;19:679–693.
84. Gross TL, Carr SH. Amputation neuroma of docked tails in dogs. *Vet Pathol Online*. 1990;27:61–62.
85. Guedes AGP, Matthews NS, Hood DM. Effect of ketamine hydrochloride on the analgesic effects of tramadol hydrochloride in horses with signs of chronic laminitis-associated pain. *Am J Vet Res.* 2012;73:610–619.
86. Guesgen MJ, Beausoleil NJ, Minot EO, Stewart M, Jones G, Stafford KJ. The effects of age and sex on pain sensitivity in young lambs. *Appl Anim Behav Sci.* 2011;135:51–56.
87. Heinrich A, Duffield TF, Lissemore KD, Squires EJ, Millman ST. The impact of meloxicam on postsurgical stress associated with cautery dehorning. *J Dairy Sci.* 2009;92:540–547.
88. Heinrich A, Duffield T, Lissemore K, Millman S. The effect of meloxicam on behavior and pain sensitivity of dairy calves following cautery dehorning with a local anesthetic. *J Dairy Sci.* 2010;93:2450–2457.
89. Henderson J, Terenghi G, McGrouther DA, Ferguson MWJ. The reinnervation pattern of wounds and scars may explain their sensory symptoms. *J Plast Reconstr Aesth Surg.* 2006;59:942–950.
90. Heppelmann M, Kofler J, Meyer H, Rehage J, Starke A. Advances in surgical treatment of septic arthritis of the distal interphalangeal joint in cattle: a review. *Vet J.* 2009;182:162–175.
91. Herskin MS, Munksgaard L, Ladewig J. Effects of acute stressors on nociception, adrenocortical responses and behavior of dairy cows. *Physiol Behav.* 2004;83:411–420.
92. Herskin MS, Munksgaard L, Andersen JB. Effects of social isolation and restraint on adrenocortical responses and hypoalgesia in loose-housed dairy cows. *J Anim Sci.* 2007;85:240–247.

93. Herskin MS, Thodberg K, Jensen HE. Effects of tail docking and docking length on neuroanatomical changes in healed tail tips of pigs. *Animal*. 2015;9:677–681.
94. Hewson CJ, Dohoo IR, Lemke KA, Barkema HW. Canadian veterinarians' use of analgesics in cattle, pigs, and horses in 2004 and 2005. *Can Vet J.* 2007;48:155–164.
95. Hohmann AG, Rice ASC. Cannabinoids. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
96. Hope-Stone L, Brown SL, Heimann H, Damato B, Salmon P. Phantom eye syndrome: Patient experiences after enucleation for uveal melanoma. *Ophthalmology*. 2015;122:1585–1590.
97. Hosseini-Sharifabad A, Rabbani M, Sharifzadeh M, Bagheri N. Acute and chronic tramadol administration impair spatial memory in rat. *Res Pharmaceut Sci.* 2016;11:49–57.
98. Howard RF, Wiener S, Walker SM. Neuropathic pain in children. *Arch Dis Child.* 2014;99:84–89.
99. Huxley JN, Whay HR. Current attitudes of cattle practitioners to pain and the use of analgesics in cattle. *Vet Rec.* 2006;159:662–668.
100. Jackson MA, Simpson KH. Pain after amputation Contin Educ Anaesth Crit Care Pain. *Crit Care Pain*. 2004;4:20–23.
101. Johnson CB, Stafford KJ, Sylvester SP, Ward RN, Mitchinson S, Mellor DJ. Effects of age on the electroencephalographic response to castration in lambs anaesthetised using halothane in oxygen. *N Z Vet J.* 2005a;53:433–437.
102. Johnson CB, Wilson PR, Woodbury MR, Caulkett NA. Comparison of analgesic techniques for antler removal in halothane-anaesthetized red deer (*Cervus elaphus*): Electroencephalographic responses. *Vet Anaesth Analg*. 2005b;32:61–71.
103. Johnson CB, Sylvester SP, Stafford KJ, Mitchinson SL, Ward RN, Mellor DJ. Effects of age on the electroencephalographic response to castration in lambs anaesthetized with halothane in oxygen from birth to 6 weeks old. *Vet Anaesth Analg.* 2009;36:273–279.
104. Kaneko K, Umehara M, Homan T, Okamoto K, Oka M, Oyama T. The analgesic effect of tramadol in animal models of neuropathic pain and fibromyalgia. *Neurosci Lett.* 2014;562:28–33.
105. Katz J, Clarke H, Seltzer Z. Review article: Preventive analgesia: quo

vadimus? *Anesth Analg.* 2011;113:1242–1253.
106. Kavaliers M. Brief exposure to a natural predator, the short-tailed weasel, induces benzodiazepine-sensitive analgesia in white-footed mice. *Physiol Behav.* 1988;43:187–193.
107. Kim DH, Cho SH, Song KH, et al. Electroacupuncture analgesia for surgery in cattle. *Am J Chin Med.* 2004;32:131–140.
108. Kinsey SG, Cole EC. Acute Δ(9)-tetrahydrocannabinol blocks gastric hemorrhages induced by the nonsteroidal anti-inflammatory drug diclofenac sodium in mice. *Eur J Pharmacol.* 2013;715:111–116.
109. Kleinhenz MD, Van Engen NK, Gorden PJ, et al. The pharmacokinetics of transdermal flunixin meglumine in Holstein calves. *J Vet Pharmacol Ther.* 2016; http://dx.doi.org/10.1111/jvp.12314.
110. Kling-Eveillard F, Knierim U, Irrgang N, Gottardo F, Ricci R, Dockès AC. Attitudes of farmers towards cattle dehorning. *Livest Sci.* 2015;179:12–21.
111. Kolkman I, Aerts S, Vervaecke H, et al. Assessment of differences in some indicators of pain in double muscled Belgian Blue cows following naturally calving vs caesarean section. *Reprod Domestic Anim.* 2010;45:160–167.
112. Kovács L, Tözsér J, Szenci O, et al. Cardiac responses to palpation per rectum in lactating and nonlactating dairy cows. *J Dairy Sci.* 2014;97:6955–6963.
113. Lacroix-Fralish ML, Mogil JS. Progress in genetic studies of pain and analgesia. *Annu Rev Pharmacol Toxicol.* 2009;49:97–121.
114. Lambertz C, Farke-Rover A, Moors E, Gauly M. Effects of castration and weaning conducted concurrently or consecutively on behaviour, blood traits and performance in beef calves. *Animal*. 2015;9:122–129.
115. Langford DJ, Crager SE, Shehzad Z, et al. Social modulation of pain as evidence for empathy in mice. *Science*. 2006;312:1967–1970.
116. Langford DJ, Bailey AL, Chanda ML, et al. Coding of facial expressions of pain in the laboratory mouse. *Nat Methods*. 2010;7:447–449.
117. Langford DJ, Tuttle AH, Briscoe C, et al. Varying perceived social threat modulates pain behavior in male mice. *J Pain*. 2011;12:125–132.
118. Lavand'homme P, De Kock M, Waterloos H. Intraoperative epidural analgesia combined with ketamine provides effective preventive analgesia in patients undergoing major digestive surgery.

Anesthesiology. 2005;103:813–820.
119. Lay DC, Friend TH, Bowers CL, Grissom KK, Jenkins OC. A comparative physiological and behavioral study of freeze and hot-iron branding using dairy cows. *J Anim Sci*. 1992a;70:1121–1125.
120. Lay DC, Friend TH, Grissom KK, Bowers CL, Mal ME. Effects of freeze or hot-iron branding of Angus calves on some physiological and behavioral indicators of stress. *Appl Anim Behav Sci*. 1992b;33:137–147.
121. Le Bars D, Dickenson AH, Besson JM. Diffuse noxious inhibitory controls (DNIC) I Effects on dorsal horn convergent neurones in the rat. *Pain*. 1979;6:283–304.
122. Lee RC, Astumian RD. The physicochemical basis for thermal and non-thermal ‘burn’ injuries. *Burns*. 1996;22:509–519.
123. Lomax S, Windsor PA. Topical anesthesia mitigates the pain of castration in beef calves. *J Anim Sci*. 2013;91:4945–4952.
124. Marti S, Velarde A, de la Torre JL, et al. Effects of ring castration with local anesthesia and analgesia in Holstein calves at 3 months of age on welfare indicators. *J Anim Sci*. 2010;88:2789–2796.
125. McCarthy D, Lomax S, Windsor PA, White PJ. Effect of a topical anaesthetic formulation on the cortisol response to surgical castration of unweaned beef calves. *Animal*. 2016;10:150–156.
126. McCracken L, Waran N, Mitchinson S, Johnson CB. Effect of age at castration on behavioural response to subsequent tail docking in lambs. *Vet Anaesth Analg*. 2010;37:375–381.
127. McKay W, Morris R, Mushlin P. Sodium bicarbonate attenuates pain on skin infiltration with lidocaine, with or without epinephrine. *Anesth Analg*. 1987;66:572–574.
128. McMeekan C, Stafford KJ, Mellor DJ, Bruce RA, Ward RN, Gregory N. Effects of a local anaesthetic and a non-steroidal anti-inflammatory analgesic on the behavioural responses of calves to dehorning. *N Z Vet J*. 1999;47:92–96.
129. McWilliams LA, Goodwin RD, Cox BJ. Depression and anxiety associated with three pain conditions: results from a nationally representative sample. *Pain*. 2004;111:77–83.
130. Mellor DJ, Diesch TJ. Onset of sentience: The potential for suffering in fetal and newborn farm animals. *Appl Anim Behav Sci*. 2006;100:48–57.
131. Mellor DJ, Stafford KJ. Animal welfare implications of neonatal

mortality and morbidity in farm animals. *Vet J.* 2004;168:118–133.
132. Mendl M, Burman OHP, Parker RMA, Paul ES. Cognitive bias as an indicator of animal emotion and welfare: Emerging evidence and underlying mechanisms. *Appl Anim Behav Sci.* 2009;118:161–181.
133. Mintline EM, Stewart M, Rogers AR, et al. Play behavior as an indicator of animal welfare: Disbudding in dairy calves. *Appl Anim Behav Sci.* 2013;144:22–30.
134. Mintline EM, Varga A, Banuelos J, et al. Healing of surgical castration wounds: A description and an evaluation of flunixin. *J Anim Sci.* 2014;92:5659–5665.
135. Mogil JS. The genetic mediation of individual differences in sensitivity to pain and its inhibition. *Proc Natl Acad Sci.* 1999;96:7744–7751.
136. Mogil JS. Animal models of pain: Progress and challenges. *Nat Rev Neurosci.* 2009;10:283–294.
137. Mogil JS. Pain genetics: Past, present and future. *Trends Genet.* 2012;28:258–266.
138. Mogil JS, Crager SE. What should we be measuring in behavioral studies of chronic pain in animals? *Pain*. 2004;112:12–15.
139. Molgaard L, Damgaard BM, Bjerre-Harpoth V, Herskin MS. Effects of percutaneous needle liver biopsy on dairy cow behaviour. *Res Vet Sci.* 2012;93:1248–1254.
140. Molony V, Kent JE, Robertson IS. Assessment of acute and chronic pain after different methods of castration of calves. *Appl Anim Behav Sci.* 1995;46:33–48.
141. Moont R, Pud D, Sprecher E, Sharvit G, Yarnitsky D. ‘Pain inhibits pain’ mechanisms: Is pain modulation simply due to distraction? *Pain*. 2010;150:113–120.
142. Moriarty O, McGuire BE, Finn DP. The effect of pain on cognitive function: A review of clinical and preclinical research. *Prog Neurobiol.* 2011;93:385–404.
143. Morisse JP, Cotte JP, Huonnic D. Effect of dehorning on behaviour and plasma cortisol responses in young calves. *Appl Anim Behav Sci.* 1995;43:239–247.
144. Morisset V, Davis JB, Tate SN. Mechanism of action of anticonvulsants as analgesic drugs. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.

145. Morley-Fletcher S, Rea M, Maccari S, Laviola G. Environmental enrichment during adolescence reverses the effects of prenatal stress on play behaviour and HPA axis reactivity in rats. *Eur J Neurosci.* 2003;18:3367–3374.
146. Mosher RA, Wang C, Allen PS, Coetzee JF. Comparative effects of castration and dehorning in series or concurrent castration and dehorning procedures on stress responses and production in Holstein calves. *J Anim Sci.* 2013;91:4133–4145.
147. Mosure WL, Meyer RA, Gudmundson J, Barth AD. Evaluation of possible methods to reduce pain associated with electroejaculation in bulls. *Can Vet J.* 1998;39:504–506.
148. Moulin DE, Boulanger A, Clark AJ, et al. Pharmacological management of chronic neuropathic pain: Revised consensus statement from the Canadian Pain Society. *Pain Res Manag.* 2014;19:328–335.
149. National Research Council. *Guidelines for the Care and Use of Mammals in Neuroscience and Behavioral Research* Washington, D.C: National Academies Press; 2003.
150. NAWAC, 2005. Animal Welfare (Painful Husbandry Procedures) Code of Welfare. <http://www.mpi.govt.nz/protection-and-response/animal-welfare/codes-of-welfare/> (accessed 5.09.16).
151. Neave HW, Daros RR, Costa JHC, von Keyserlingk MAG, Weary DM. Pain and pessimism: Dairy calves exhibit negative judgement bias following hot-iron disbudding. *PLoS ONE*. 2013;8:e80556 http://doi.org/10.1371/journal.pone.0080556.
152. Newby NC, Pearl DL, LeBlanc SJ, Leslie KE, von Keyserlingk MAG, Duffield TF. The effect of administering ketoprofen on the physiology and behavior of dairy cows following surgery to correct a left displaced abomasum. *J Dairy Sci.* 2013;96:1511–1520.
153. Newby NC, Tucker CB, Pearl DL, et al. An investigation of the effects of ketoprofen following rumen fistulation surgery in lactating dairy cows. *Can Vet J.* 2014;55:442–448.
154. Newton HP, O’Connor AM. The economics of pain management. *Vet Clin N Am Food Anim Pract.* 2013;29:229–250.
155. Nichols S. Teat laceration repair in cattle. *Vet Clin N Am Food Anim Pract.* 2008;24:295–305.
156. O'Connor AB, Dworkin RH. Treatment of neuropathic pain: An overview of recent guidelines. *Am J Med.* 2009;122:S22–S32.

157. Offinger J, Meyer H, Fischer J, Kastner SBR, Piechotta M, Rehage J. Comparison of isoflurane inhalation anaesthesia, injection anaesthesia and high volume caudal epidural anaesthesia for umbilical surgery in calves; metabolic, endocrine and cardiopulmonary effects. *Vet Anaesth Analg.* 2012;39:123–136.
158. Offinger J, Herdtweck S, Rizk A, et al. Postoperative analgesic efficacy of meloxicam in lame dairy cows undergoing resection of the distal interphalangeal joint. *J Dairy Sci.* 2013;96:866–876.
159. Pagliosa RC, Derossi R, Costa DS, Faria FJ. Efficacy of caudal epidural injection of lidocaine, xylazine and xylazine plus hyaluronidase in reducing discomfort produced by electroejaculation in bulls. *J Vet Med Sci.* 2015;77:1339–1345.
160. Palmer CW. Welfare aspects of theriogenology: Investigating alternatives to electroejaculation of bulls. *Theriogenology.* 2005;64:469–479.
161. Pang WY, Earley B, Sweeney T, Crowe MA. Effect of carprofen administration during banding or burdizzo castration of bulls on plasma cortisol, in vitro interferon- gamma production, acute-phase proteins, feed intake, and growth. *J Anim Sci.* 2006;84:351–359.
162. Pang WY, Earley B, Murray M, Sweeney T, Gath V, Crowe MA. Banding or Burdizzo castration and carprofen administration on peripheral leukocyte inflammatory cytokine transcripts. *Res Vet Sci.* 2011;90:127–132.
163. Pascoe PJ. Humaneness of an electroimmobilization unit for cattle. *Am J Vet Res.* 1986;47:2252–2256.
164. Pascoe PJ. Perioperative pain management. *Vet Clin N Am Small Anim Pract.* 2000;30:917–932.
165. Pascoe PJ, McDonell WN. The noxious effects of electroimmobilization in adult Holstein cows: A pilot study. *Can J Vet Res.* 1986;50:275–279.
166. Pertovaara A. Noradrenergic pain modulation. *Prog Neurobiol.* 2006;80:53–83.
167. Petherick JC, McCosker K, Mayer DG, Letchford P, McGowan M. Preliminary investigation of some physiological responses of *Bos indicus* heifers to surgical spaying. *Aust Vet J.* 2011;89:131–137.
168. Petherick JC, McCosker K, Mayer DG, Letchford P, McGowan M. Evaluation of the impacts of spaying by either the dropped ovary technique or ovariectomy via flank laparotomy on the welfare of *Bos*

indicus beef heifers and cows. *J Anim Sci.* 2013;91:382–394.
169. Pieler D, Peinhopf W, Becher AC, et al. Physiological and behavioral stress parameters in calves in response to partial scrotal resection, orchidectomy, and burdizzo castration. *J Dairy Sci.* 2013;96:6378–6389.
170. Repenning PE, Ahola JK, Callan RJ, et al. Impact of oral meloxicam administration before and after band castration on feedlot performance and behavioral response in weanling beef bulls. *J Anim Sci.* 2013;91:4965–4974.
171. Ringkamp M, Raja SN, Campbell JN, Meyer RA. Peripheral mechanisms of cutaneous nociception. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
172. Rizk A, Herdtweck S, Offinger J, Meyer H, Zaghloul A, Rehage J. The use of xylazine hydrochloride in an analgesic protocol for claw treatment of lame dairy cows in lateral recumbency on a surgical tipping table. *Vet J.* 2012;192:193–198.
173. Robbins JA, Weary DM, Schuppli CA, von Keyserlingk MAG. Stakeholder views on treating pain due to dehorning dairy calves. *Anim Welf.* 2015;24:399–406.
174. Roberts SL, Hughes HD, Burdick Sanchez NC, et al. Effect of surgical castration with or without oral meloxicam on the acute inflammatory response in yearling beef bulls. *J Anim Sci.* 2015;93:4123–4131.
175. Roofthooft DWE, Simons SHP, Anand KJS, Tibboel D, van Dijk M. Eight years later, are we still hurting newborn infants? *Neonatology.* 2014;105:218–226.
176. Rossi HL, Neubert JK. Effects of environmental enrichment on thermal sensitivity in an operant orofacial pain assay. *Behav Brain Res.* 2008;187:478–482.
177. Sandercock DA, Gibson IF, Rutherford KMD, et al. The impact of prenatal stress on basal nociception and evoked responses to tail-docking and inflammatory challenge in juvenile pigs. *Physiol Behav.* 2011;104:728–737.
178. Sandkühler J. Spinal cord plasticity and pain. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013.
179. Schneider JC, Harris NL, El Shami A, et al. A descriptive review of

neuropathic-like pain after burn injury. *J Burn Care Res.* 2006;27:524–528.

180. Schug SA. Opioids: Clinical Use. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia PA: Elsevier Saunders; 2013.
181. Schwacha MG, Nickel E, Daniel T. Burn injury–induced alterations in wound inflammation and healing are associated with suppressed hypoxia inducible factor-1α expression. *Mol Med.* 2008;14:628–633.
182. Schwartzkopf-Genswein KS, Stookey JM. The use of infrared thermography to assess inflammation associated with hot-iron and freeze branding in cattle. *Can J Anim Sci.* 1997;77:577–583.
183. Schwartzkopf-Genswein KS, Stookey JM, Crowe TG, Genswein BMA. Comparison of image analysis, exertion force and behavior measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding. *J Anim Sci.* 1998;76:972–979.
184. Schwartzkopf-Genswein KS, Stookey JM, de Passillé AM, Rushen J. Comparison of hot-iron and freeze branding on cortisol levels and pain sensitivity in beef cattle. *Can J Anim Sci.* 1997a;77:369–374.
185. Schwartzkopf-Genswein KS, Stookey JM, Welford R. Behavior of cattle during hot-iron and freeze branding and the effects of subsequent handling ease. *J Anim Sci.* 1997b;75:2064–2072.
186. Shaw-Edwards R. Surgical treatment of the eye in farm animals. *Vet Clin N Am Food Anim Pract.* 2010;26:459–476.
187. Sheta E, Ragab S, Farghali H, El-Sherif A. Successful practice of electroacupuncture analgesia in equine surgery. *J Acupunct Meridian Stud.* 2015;8:30–39.
188. Shimshony A, Chaudry MM. Slaughter of animals for human consumption. *Rev Sci Technol.* 2005;24:693–710.
189. Shir Y, Seltzer Z. Heat hyperalgesia following partial sciatic ligation in rats: Interacting nature and nurture. *Neuroreport*. 2001;12:809–813.
190. Sleigh J, Harvey M, Voss L, Denny B. Ketamine–More mechanisms of action than just NMDA blockade. *Trends Anaesth Critical Care*. 2014;4:76–81.
191. Smith G. Extralabel use of anesthetic and analgesic compounds in cattle. *Vet Clin N Am Food Anim Pract.* 2013;29:29–45.
192. Smith MA, Bryant PA, McClean JM. Social and environmental enrichment enhances sensitivity to the effects of kappa opioids: studies

on antinociception, diuresis and conditioned place preference. *Pharmacol Biochem Behav.* 2003;76:93–101.
193. Smith MA, Chisholm KA, Bryant PA, et al. Social and environmental influences on opioid sensitivity in rats: Importance of an opioid's relative efficacy at the mu-receptor. *Psychopharmacology (Berl).* 2005;181:27–37.
194. Sorge RE, Martin LJ, Isbester KA, et al. Olfactory exposure to males, including men, causes stress and related analgesia in rodents. *Nat Methods*. 2014;11:629–632.
195. Stafford K. Alleviating the pain caused by the castration of cattle. *Vet J.* 2007;173:245–247.
196. Stafford KJ, Mellor DJ, Todd SE, Bruce RA, Ward RN. Effects of local anaesthesia or local anaesthesia plus a non-steroidal anti-inflammatory drug on the acute cortisol response of calves to five different methods of castration. *Res Vet Sci.* 2002;73:61–70.
197. Stafford KJ, Mellor DJ, Todd SE, Ward RN, McMeekan CM. The effect of different combinations of lignocaine, ketoprofen, xylazine and tolazoline on the acute cortisol response to dehorning in calves. *N Z Vet J.* 2003;51:219–226.
198. Stafford KJ, Chambers JP, Mellor DJ. The alleviation of pain in cattle: A review. *CAB Rev Perspect Agric Vet Sci Nutr Nat Resourc* 2006; http://dx.doi.org/10.1079/PAVSNNR20061032.
199. Stein C, Lang LJ. Peripheral mechanisms of opioid analgesia. *Curr Opin Pharmacol.* 2009;9:3–8.
200. Stilwell G, de Carvalho RC, Lima MS, Broom DM. Effect of caustic paste disbudding, using local anaesthesia with and without analgesia, on behaviour and cortisol of calves. *Appl Anim Behav Sci.* 2009;116:35–44.
201. Stilwell G, Lima MS, Broom DM. Comparing plasma cortisol and behaviour of calves dehorned with caustic paste after non-steroidal-anti-inflammatory analgesia. *Livest Sci.* 2008a;119:63–69.
202. Stilwell G, Lima MS, Broom DM. Effects of nonsteroidal anti-inflammatory drugs on long-term pain in calves castrated by use of an external clamping technique following epidural anesthesia. *Am J Vet Res.* 2008b;69:744–750.
203. Stilwell G, Carvalho RC, Carolino N, Lima MS, Broom DM. Effect of hot-iron disbudding on behaviour and plasma cortisol of calves sedated

with xylazine. *Res Vet Sci.* 2010;88:188–193.
204. Stilwell G, Lima MS, Carvalho RC, Broom DM. Effects of hot-iron disbudding, using regional anaesthesia with and without carprofen, on cortisol and behaviour of calves. *Res Vet Sci.* 2012;92:338–341.
205. Stock ML, Baldridge SL, Griffin D, Coetzee JF. Bovine dehorning: Assessing pain and providing analgesic management. *Vet Clin N Am Food Anim Pract.* 2013;29:103–133.
206. Stock ML, Millman ST, Barth LA, et al. The effects of firocoxib on cautery disbudding pain and stress responses in preweaned dairy calves. *J Dairy Sci.* 2015;98:6058–6069.
207. Summer GJ, Puntillo KA, Miaskowski C, Green PG, Levine JD. Burn injury pain: The continuing challenge. *J Pain*. 2007;8:533–548.
208. Sutherland MA, Mellor DJ, Stafford KJ, Gregory NG, Bruce RA, Ward RN. Effect of local anaesthetic combined with wound cauterization on the cortisol response to dehorning in calves. *Aust Vet J.* 2002;80:165–167.
209. Sutherland MA, Ballou MA, Davis BL, Brooks TA. Effect of castration and dehorning singularly or combined on the behavior and physiology of Holstein calves. *J Anim Sci.* 2013;91:935–942.
210. Sylvester SP, Mellor DJ, Stafford KJ, Bruce RA, Ward RN. Acute cortisol responses of calves to scoop dehorning using local anaesthesia and/or cautery of the wound. *Aust Vet J.* 1998;76:118–122.
211. Sylvester SP, Stafford KJ, Mellor DJ, Bruce RA, Ward RN. Behavioural responses of calves to amputation dehorning with and without local anaesthesia. *Aust Vet J.* 2004;82:697–700.
212. Taddio A, Katz J, Ilersich AL, Koren G. Effect of neonatal circumcision on pain response during subsequent routine vaccination. *Lancet*. 1997;349:599–603.
213. Tapper KR, Goff JP, Leuschen BL, West JK, Millman ST. Novel techniques for anesthesia during disbudding of calves. *J Anim Sci.* 2011;89(E-Suppl.):413.
214. Theurer ME, White BJ, Coetzee JF, Edwards LN, Mosher RA, Cull CA. Assessment of behavioral changes associated with oral meloxicam administration at time of dehorning in calves using a remote triangulation device and accelerometers. *BMC Vet Res.* 2012;8:48.
215. Thuer S, Mellema S, Doherr MG, Wechsler B, Nuss K, Steiner A. Effect of local anaesthesia on short- and long-term pain induced by two

bloodless castration methods in calves. *Vet J.* 2007;173:333–342.
216. Ting ST, Earley B, Hughes JM, Crowe MA. Effect of ketoprofen, lidocaine local anesthesia, and combined xylazine and lidocaine caudal epidural anesthesia during castration of beef cattle on stress responses, immunity, growth, and behavior. *J Anim Sci.* 2003a;81:1281–1293.
217. Ting STL, Earley B, Crowe MA. Effect of repeated ketoprofen administration during surgical castration of bulls on cortisol, immunological function, feed intake, growth, and behavior. *J Anim Sci.* 2003b;81:1253–1264.
218. Ting STL, Earley B, Veissier I, Gupta S, Crowe MA. Effects of Burdizzo castration on CO_2 laser induced thermal nociception of Holstein-Friesian calves of different ages. *Appl Anim Behav Sci.* 2010;126:12–18.
219. Tsujita H, Plummer CE. Bovine ocular squamous cell carcinoma. *Vet Clin N Am Food Anim Pract.* 2010;26:511–529.
220. Tucker CB, Mintline EM, Banuelos J, et al. Effect of a cooling gel on pain sensitivity and healing of hot-iron cattle brands. *J Anim Sci.* 2014a;92:5666–5673.
221. Tucker CB, Mintline EM, Banuelos J, et al. Pain sensitivity and healing of hot-iron cattle brands. *J Anim Sci.* 2014b;92:5674–5682.
222. Turk DC, Audette J, Levy RM, Mackey SC, Stanos S. Assessment and treatment of psychosocial comorbidities in patients with neuropathic pain. *Mayo Clin Proc.* 2010;85:S42–S50.
223. Vadivelu N, Mitra S, Schermer E, Kodumudi V, Kaye AD, Urman RD. Preventive analgesia for postoperative pain control: a broader concept. *Local Reg Anesth.* 2014;7:17–22.
224. Valvis SM, Waithman J, Wood FM, Fear MW, Fear VS. The immune response to skin trauma is dependent on the etiology of injury in a mouse model of burn and excision. *J Investig Dermatol.* 2015;135:2119–2128.
225. Vega-Avelaira D, McKelvey R, Hathway G, Fitzgerald M. The emergence of adolescent onset pain hypersensitivity following neonatal nerve injury. *Mol Pain*. 2012;8:30.
226. Vickers KJ, Niel L, Kiehlbauch LM, Weary DM. Calf response to caustic paste and hot-iron dehorning using sedation with and without local anesthetic. *J Dairy Sci.* 2005;88:1454–1459.
227. Villemure C, Bushnell MC. Cognitive modulation of pain: How do

attention and emotion influence pain processing? *Pain*. 2002;95:195–199.
228. Viñuela-Fernández I, Weary DM, Flecknell P. Pain. In: Appleby MC, Mench JA, Olsson IAS, Hughes BO, eds. *Animal Welfare*. Wallingford, UK: CAB International; 2011.
229. Vo T, Rice AS, Dworkin RH. Non-steroidal anti-inflammatory drugs for neuropathic pain: how do we explain continued widespread use? *Pain*. 2009;143:169–171.
230. von Baeyer CL, Spagrud LJ. Systematic review of observational (behavioral) measures of pain for children and adolescents aged 3 to 18 years. *Pain*. 2007;127:140–150.
231. Walker KA, Mellish JE, Weary DM. Effects of hot-iron branding on heart rate, breathing rate and behaviour of anaesthetised Steller sea lions. *Vet Rec.* 2011;169:363.
232. Walker SM, Tochiki KK, Fitzgerald M. Hindpaw incision in early life increases the hyperalgesic response to repeat surgical injury: Critical period and dependence on initial afferent activity. *Pain*. 2009;147:99–106.
233. Warnock TM, Thrift TA, Irsik M, et al. Effect of castration technique on beef calf performance, feed efficiency, and inflammatory response. *J Anim Sci.* 2012;90:2345–2352.
234. Webster HB, Morin D, Jarrell V, et al. Effects of local anesthesia and flunixin meglumine on the acute cortisol response, behavior, and performance of young dairy calves undergoing surgical castration. *J Dairy Sci.* 2013;96:6285–6300.
235. Westlund K. To feed or not to feed: Counterconditioning in the veterinary clinic. *J Vet Behav Clin Appl Res.* 2015;10:433–437.
236. Whay HR, Huxley JN. Pain relief in cattle: A practitioners perspective. *Cattle Pract.* 2005;13:81–85.
237. Whitlock BK, Coffman EA, Coetzee JF, Daniel JA. Electroejaculation increased vocalization and plasma concentrations of cortisol and progesterone, but not substance P, in beef bulls. *Theriogenology*. 2012;78:737–746.
238. Wittek T, Tischer K, Gieseler T, Furll M, Constable PD. Effect of preoperative administration of erythromycin or flunixin meglumine on postoperative abomasal emptying rate in dairy cows undergoing surgical correction of left displacement of the abomasum. *J Am Vet Med*

Assoc. 2008;232:418–423.

239. Wood SL, Beyer BK, Cappon GD. Species comparison of postnatal CNS development: Functional measures. *Birth Defects Res Part B Dev Reprod Toxicol.* 2003;68:391–407.
240. Wright H, Li X, Fallon NB, et al. Heightened eating drive and visual food stimuli attenuate central nociceptive processing. *J Neurophysiol.* 2015;113:1323–1333.
241. Yalcin I, Barthas F, Barrot M. Emotional consequences of neuropathic pain: Insight from preclinical studies. *Neurosci Biobehav Rev.* 2014;47:154–164.
242. Youssef AM, Macefield VG, Henderson LA. Pain inhibits pain; human brainstem mechanisms. *Neuroimage*. 2016;124:54–62.
243. Zeilhofer HU, Brune K. Cyclooxygenase inhibitors: basic aspects. In: McMahon SB, Koltzenburg M, Tracey I, Turk DC, eds. *Wall and Melzack's Textbook of Pain*. Philadelphia, PA: Elsevier Saunders; 2013; 1184 pp.
244. Zenor BN, Weesner GD, Malven PV. Endocrine and other responses to acute administration of cannabinoid compounds to non-stressed male calves. *Life Sci.* 1999;65:125–133.
245. Zilberstein LF, Moens YP, Leterrier E. The effect of local anaesthesia on anaesthetic requirements for feline ovariectomy. *Vet J.* 2008;178:214–218.

8

Disease and injury

Beyond current thinking about top causes of cattle morbidity

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Abstract

This chapter focuses on the welfare implications of dystocia, diarrhea, mastitis, lameness, and respiratory disease, which are among the most common conditions in beef and dairy cattle. The magnitude of the associated welfare concerns may be elucidated by evaluating the prevalence, severity, and duration on a disease-by-disease basis. As reviewed here, recent trends in cattle morbidity and mortality rates, and considering the short- and long-term negative consequences that ill-health may have on a range of outcomes, from basic functioning to affective states, indicate that disease remains a major risk factor for poor welfare. In turn, mitigation may occur at three junctures—prevention, diagnosis, and treatment—with different barriers and opportunities at each stage. Overall, demands placed on cattle in modern production systems have the potential to at once increase the likelihood of disease, but simultaneously, offer opportunities to manage proactively in order to optimize health and welfare.

Keywords

Beef; culling; dairy; diagnosis; health; illness; mortality; prevention; treatment; welfare

8.1 Introduction

The dairy and beef industries have undergone impressive modernization during the last few decades, including advances in veterinary medicine, housing, nutrition, and increasing incorporation of technology in agriculture, as well as simultaneous increases in yield and production efficiency. Indeed, veterinarians and producers have traditionally focused on improving the health, basic functioning and productivity of the animals in their care (Fraser, 2008; von

Keyserlingk et al., 2009). This would imply that animal health is well accounted for in our modern production systems. However, I review evidence across a wide body of literature which suggests the opposite—that disease is a serious and even increasing concern, both generally, and specifically in terms of animal welfare. While it is clear that health is a key aspect of welfare, thorough evaluation of the widespread implications of disease for animals is complicated (Broom and Corke, 2002).

This chapter is divided into two primary sections. In the first, a paradigm by which the magnitude of the welfare concern posed by disease can be evaluated is reviewed. Recent research related to morbidity and mortality in cattle is provided as context for the discussion. In the second section, barriers and opportunities to mitigating the welfare implications of disease are examined at the three potential junctures for intervention—prevention, diagnosis, and treatment. Mortality is discussed in the first section as it relates to prevalence, which is a measure of disease burden, and severity, where death can indicate severe disease. Culling and mortality are also discussed in the second section, as related to diagnostic insights that can be gleaned from these data. Finally, mortality is included in the discussion of treatment, in terms of the implications of this outcome, including euthanasia, in diseased animals. When appropriate, examples from organic production systems are provided, given that this is of public interest, as reflected in the growth of this sector in recent years. Throughout the chapter, examples from five of the most prevalent diseases in dairy and beef cattle—dystocia, diarrhea, mastitis, lameness, and respiratory disease—are used to illustrate the various concepts.

8.2 Section A: Examining prevalence, severity, and duration to estimate the magnitude of welfare concern for the most common cattle diseases

In order to compare and contrast the impact of the welfare concerns posed by various diseases, it is helpful to consider the prevalence of the condition in the given population, severity, and duration of effect (Bruijnis et al., 2012).

8.2.1 Prevalence

Prevalence describes the proportion of a population that have or had a disease in a given period of time, where calculations may be based on morbidity or mortality. A related but distinct term is incidence, which describes the probability that a new case of disease will occur in a specified period of time (Smith, 2005). While welfare is a property of individual animals, prevalence is still an important consideration in evaluating the implications of various diseases. Specifically, considering disease prevalence offers an opportunity to comparatively evaluate the relative contribution of various conditions to ill-health in animal populations. In turn, this allows prioritization when determining which diseases should be addressed first because they are most problematic in a given population.

Importantly, the underlying causes of morbidity and mortality are changing. In the dairy population, it appears that the once-prevalent traumatic reticuloperitonitis and hypocalcemia may be less of a problem now with current management (McConnel et al., 2015). While dystocia and accidents have traditionally and still do contribute heavily to cow removals, there is an evolving set of health concerns that are likely related to modern production practices, including abomasal displacements, lameness, and multifactorial transition issues (McConnel et al., 2015).

In the following paragraphs, a review of the prevalence (or incidence, as reported) rates of common cattle diseases is provided to give a sense as to their welfare impact on a population level. However, generally speaking, caution must be used when interpreting findings which are based on producer-reported data. For example, in adult dairy cows, respiratory disease is estimated from producer records to cause 11% of deaths (USDA, 2009). In contrast, approximately one-third of culled animals have lung lesions at slaughter, which suggests that on-farm findings are likely an underestimate (Rezac et al., 2014a). This provides evidence that clinical disease, which is most likely to be noticed by producers, does not necessarily represent the actual disease burden.

In the USA, periodic systematic reports are published summarizing the current state of health issues in dairy and beef. According to these reports, in dairy animals, the top causes of death in descending order, are digestive (e.g., diarrhea) and respiratory disease in unweaned heifers, respiratory disease, lameness/injury, and digestive disease in weaned heifers, and lameness/injury, mastitis, and dystocia in cows (USDA, 2008c; USDA, 2010a). Specifically, clinical mastitis is reported as the most common infectious disease in USA dairy cattle, with a reported incidence of 17% (USDA, 2008c). The causes of young beef cattle mortality are similar to those in similarly aged dairy animals, where more than 50% of mortality in calves aged 3 weeks and older was caused by digestive or respiratory problems (USDA, 2010b). In the weaned beef population, respiratory disease is the top cause of mortality, responsible for almost 50% of feedlot cattle deaths (Vogel, 2015).

Clinical lameness is quite prevalent yet variable across dairy herds, ranging from 0 to 71% in North American surveys (see also Cook, 2017; Chapter 2: Assessment of cattle welfare:Common animal-based measures; von Keyserlingk et al., 2012; Solano et al., 2015), while worldwide, 20% of intensively managed dairy cows are estimated to be lame at any one time (Cook and Nordlund, 2009). In contrast to the dairy industry, where stakeholders identified lameness as one of the most pressing problems (Ventura et al., 2015), in feedlots, lameness appears to be an emerging and yet-unquantified problem, with personnel reporting that it is a relatively low-prevalence condition (Terrell et al., 2014).

Given that both the cow and calf can be negatively affected by dystocia, the welfare implications of each case are in effect doubled. Dystocia affects >35% of dairy calves (Lombard et al., 2007), but has a lower prevalence in beef cattle, with approximately 9% of calvings requiring assistance (USDA, 2010b; Waldner, 2014). The duality of dystocia's effect is demonstrated in the statistics for stillbirth incidence, which rise with increasing dystocia severity, ranging from 4% for mild to 60% for severe cases. One study found that three-quarters of calves requiring assistance during calving were stillborn (Lombard et al., 2007). From the perspective of the dairy cow, survival even late in lactation is decreased in those that birthed stillborn calves (Bicalho et al., 2007). Similarly, 17% of beef cows died of calving-related problems, which is the top cause of mortality in this group (USDA, 2010b).

The types of health challenges that organic and conventional dairy herds face are generally similar, with mastitis, lameness, and infertility the most prevalent conditions (Sutherland et al., 2013). However, some perceive organic production to result in reduced incidence of mastitis, lameness and other diseases, though results of various studies are contradictory (as reviewed by Sutherland et al., 2013; Barkema et al., 2015). Importantly, organic dairies differ from conventional dairies in key ways aside from which medical treatments are used, including cow parity distribution (greater), age at first calving (higher), milk yield (lower), herd size (smaller) housing systems used (typically non free-stall) and time on pasture (greater), feed ration (lower concentrate, pasture-based), and even farmer attitudes, compared to conventional farms (Sato et al., 2005; Richert et al., 2013; Sutherland et al., 2013). Any apparent differences in disease incidence between conventional and organic systems may have less to do with which medical interventions are or are not used and more to do with some of the other general differences related to the animals and their management (Ruegg, 2009). For example, although some report lower incidence of clinical mastitis on organic farms, once controlling for milk yield, there is no difference in mastitis incidence between organic and conventional dairy herds (Valle et al., 2007). Instead, the apparent difference in animal health (more mastitis in conventional) is likely secondary to differences in disease monitoring, higher recording of treatments in official health records in conventional and lower-intensity milk production and improved cow cleanliness in organic (Valle et al., 2007; as reviewed by Richert et al., 2013). Similarly, there is conflicting information as to whether lameness has a lower prevalence in organic systems (as reviewed by de Vries et al., 2011). Additionally, a higher average age at first calving and increased length of the summer grazing period may contribute to the apparent effect of organic systems on lowering incidence of this condition (as reviewed by Marley et al., 2010).

One only need to examine recent trends in cattle morbidity and mortality rates to understand that despite current efforts, disease is a major risk factor for poor welfare. As has been suggested for stillbirth rates, but is also true in a broader sense, when mortality rates are high there is a risk of normalization, causing under-estimation of the importance of disease as an animal welfare issue (Mee, 2013a). Morbidity rates are increasing across a variety of diseases, suggesting that prevention and treatment practices are either not effective or not being effectively implemented on the farm (USDA, 2008c). For example, dystocia rates are increasing in North America and Europe (Mee, 2008), as is clinical mastitis and respiratory disease incidence in the USA (USDA, 2008c). Similarly, mortality rates, which provide a much cruder measure of disease trends but are more commonly reported in the literature, are also on the rise across dairy and beef sectors (Table 8.1). Indeed, monitoring for herd mortality rate may provide a relatively sensitive, albeit not particularly specific, initial measure of facilities with likely welfare concerns that should be more closely inspected (Pannwitz, 2015). Beginning with the youngest in the population, rates of perinatal calf mortality are high and increasing (Berglund et al., 2003; Hansen et al., 2004; Del Río et al, 2007). In the USA, Norway, and Holland, death rates for dairy heifers during the first year of life are close to 8% (USDA, 2007; Gulliksen et al., 2009a; Santman-Berends et al., 2014), but reach 36% in the worst herds (Santman-Berends et al., 2014). In lactating dairy cows, mortality (both euthanasia and unassisted death) in USA herds is increasing, even though population age is declining (Hare et al., 2006; USDA, 2007b; Alvåsen et al., 2012; McConnel et al., 2015; Shahid et al., 2015). Likewise, in feedlots, mortality of beef cattle during the finishing phase is increasing (Engler et al., 2014; Vogel, 2015).

Table 8.1

Examples of increasing mortality trends in dairy and beef cattle in recent decades

Description	Start rate	End rate	Period	Reference
Stillbirth in Swedish Red Holstein calves	6%	10.3%	1992–2002	Berglund et al. (2003)
Mortality in Danish dairy cows (all breeds and age groups)	2%	3.5%	1990–1999	Thomsen et al. (2004)
Mortality in USA dairy cows (lactating)	2%	4.6%	1995–2005	Miller et al. (2008)
Mortality in beef cattle during finishing phase	1.34% (steers) 1.41% (heifers)	1.71% (steers) 1.84% (heifers)	2005–2014	Vogel (2015)

Culling records may also be used to glean information about overall disease prevalence as well as specific conditions underlying the reason for herd removal. Culling is a broad term referring to the departure of animals from a herd because of sale, slaughter for meat or salvage, or death, whether euthanasia or unassisted (Fetrow et al., 2006). Individual cow (e.g., health, pregnancy status, milk yield, parity), as well as herd (e.g., availability of replacement animals) and market (e.g., value of milk and beef) factors may be considered in culling decisions

(Beaudeau et al., 2000). There is evidence for a decrease in cows leaving the herd for economic reasons alone, while involuntary removals (e.g., secondary to incurable disease) are increasing (Weigel et al., 2003). Importantly, disease often occurs at a subclinical or clinical level that does not result in culling. Furthermore, as indicated above, reasons other than individual-animal health may underlie the reason for culling. For this reason, monitoring culling records may reveal only a small portion of a larger problem (Fetrow et al., 2006) and be a generally inaccurate method of evaluating disease status in the herd.

8.2.2 Severity

Disease severity can be considered from several perspectives, including the nature of associated clinical signs and eventual outcome, its effect on basic functioning as well as on affective state, and finally the likelihood of predisposition to further disorders. It is important to clarify at this juncture that disease, involving structural or biochemical malfunctioning of one or more body parts, does not always entail illness, the negative feelings associated with a disease. For example, a person with arteriosclerosis or hypertension may have no awareness of having a cardiovascular condition, with little or no negative effect on day-to-day functioning or sensations (Cassell, 1976). On the one hand, if a disease causes sudden death, with few or any perceptible changes in an animal's functioning or negative sensations or emotions, the severity from this perspective may be minimal. On the other hand, having a normal lifespan is a welfare criterion from some perspectives (Miele et al., 2011). In this case, a disease which hastens death may be considered more severe, even in the apparent absence of suffering, because it precludes the animal from having a normal lifespan.

Disease severity in the most straightforward sense encompasses the degree to which health is impaired from a clinical perspective. This ranges from mild signs or abnormalities, which may be imperceptible to outside observers or even the animal, to complete debilitation and finally, death. For example, mild mastitis may cause only slightly elevated somatic cell count with no other visible symptoms, while severe cases are accompanied by a swollen udder, large drops in milk production, fever, anorexia, and other indications of systemic impairment (Ruegg, 2012). Unfortunately, there are gaps in the literature related to the welfare implications of milder disease. Indeed, the degree of suffering experienced in mild disease and potential downstream effects are often not clear.

In contrast, death is one of the most commonly discussed disease endpoints in the literature, likely because it is absolute and therefore relatively easy to quantify. Mortality as an indicator of disease severity will be briefly reviewed. Generally speaking, in this context, the literature is much more comprehensive for dairy cattle as compared to beef. Respiratory disease and diarrhea are common causes of dairy-calf death (Gulliksen et al., 2009a; Torsein et al., 2011; Hötzel et al., 2014). Additionally, respiratory disease is the top disease concern in beef cattle, accounting for 40%–50% of all mortality in this population (Hilton, 2014), and increases the risk of death in dairy cows (McConnel et al., 2008). Clinical mastitis increases the risk of death in dairy cows (Hertl et al., 2011; McConnel et al., 2015). Locomotor disorders, including traumatic events or injuries resulting in lameness (McConnel et al., 2010), are a major, and possibly greatest proximate cause of mortality in dairy cows (Thomsen et al., 2012), accounting for 11%–28% of all deaths with an underlying reason recorded (Thomsen et al., 2004; as reviewed by de Vries et al., 2011). Finally, dystocia is a demonstrated mortality hazard for dairy cows (Bicalho et al., 2007; Alvåsen et al., 2014b) and calves (Berglund et al., 2003), with trauma from parturition one of the factors contributing to mortality (McConnel et al., 2010). However, death may occur only several weeks after the initial event. For example, dairy cows experiencing a calving abnormality, including dystocia, have greater odds of death or culling in the first month following compared to those calving normally (Vergara et al., 2014). Likewise, the odds of stillbirth rise with increasing dystocia (Lombard et al., 2007; Gulliksen et al., 2009a).

From a functional perspective, disease may be mild if an animal remains capable of day-to-day living with relatively little impairment. On the other hand, severe disease may render the animal incapable of even basic functioning. For example, a cow with moderate to severe lameness may show abnormalities in resting, walking, and feeding. In turn, lameness results in decreased milk production and poor reproductive performance (Cook and Nordlund, 2009) which, while not direct welfare indicators, illustrate the extent of this disease's negative effects on an animal's overall functioning.

Disease severity may also describe suffering associated with a condition, including pain, fear, and other negative feelings and emotions (affective state; Fraser, 2008). For example, dystocia may cause pain in calves secondary to parturient traumatic injuries (e.g., fractures, ruptured internal organs), and prolonged, forceful traction during extraction (as reviewed by Mee, 2013b; Murray and Leslie, 2013). Behavioral changes are one way to evaluate whether an animal with a particular disease is potentially experiencing pain, as in mastitis, lameness, and dystocia. Mastitis is associated with kicking and restlessness during milking (Medrano-Galarza et al., 2012; Fogsgaard et al., 2015a), though clearer in more severe cases as compared to milder ones (Leslie and Petersson-Wolfe, 2012). Mastitic cows also have low lying times (Yeiser et al., 2012; Fogsgaard et al., 2015a), in particular on the affected side of the udder (Siivonen et al., 2011), which may be because of a reluctance to put pressure on a painful area. Lame cows have increased lying compared to nonlame cows (Galindo and Broom, 2002) as well as asymmetric distribution of weight-bearing and gait changes (Rushen et al., 2007; Pastell et al., 2010), all likely pain-induced. An animal's response to treatment with an analgesic (e.g., nonsteroidal antiinflammatory drug; NSAID) or local anesthetic provides further evidence as to whether a disease is painful. For example, mastitis results in increased nociceptive sensitivity, which is normalized by NSAID treatment (Fitzpatrick et al., 2013). Likewise, lameness-induced changes in gait and weight-bearing are alleviated after lidocaine injection (Rushen et al., 2007).

Aside from pain, there are other negative sensations and emotions associated with disease. For example, respiratory disease is associated with breathlessness (Beausoleil and Mellor, 2015). Furthermore, sick animals may be generally unable to cope when kept in environments designed for healthy individuals. As a result, they experience fear, hunger, and exhaustion when they have to compete with healthy pen-mates for access to limited resources such as feed, water, and resting places (Millman, 2007). Additionally, while our understanding of fetal capacity to experience pain and other affective states is still limited, we may discover additional welfare implications of dystocia in terms of suffering not only of the dam, but also the fetus (as reviewed by Mee, 2013b; Murray and Leslie, 2013).

A final perspective to consider when evaluating disease severity is whether a condition predisposes to disorders beyond the inciting one. For example, lameness and dystocia both increase the likelihood of a dairy cow later experiencing metabolic conditions such as milk fever and ketosis, retained placenta, metritis, displaced abomasum, and pneumonia (Vergara et al., 2014). Similarly, heifer calves born to dams having severe dystocia have greater odds of stillbirth, respiratory and digestive disease, and overall mortality until at least 30 days of age (Lombard et al., 2007), in addition to bleeding, edema, impaired thermoregulation, and predisposition to failure of passive transfer (as reviewed by Mee, 2013b; Murray and Leslie, 2013).

8.2.3 Duration

Duration is the final component in evaluating the relative welfare impact of disease. Determining duration requires defining the start and end points—for example, is it measured as time from detection of clinical signs, knowing that animals were perhaps undetected for a period of time before that? And what is the end point—is it time until treatment or other intervention (e.g., euthanasia), when animal becomes subclinical, or until cure, if this is even a possibility for the disease in question? Indeed, both before diagnosis and after treatment, the ill-effects of a disease may impair welfare, such that the duration of a condition may be longer than the period in which clinical signs are obvious. For example, dairy cows with mastitis showed deviation of milk yield and decreased willingness to be milked by automated milking system from individual-cow baseline and from control animals as early as 3 weeks before mastitis treatment was initiated, and some failed to normalize for up to 8 weeks after cessation of antibiotics (Fogsgaard et al., 2015b). Behavioral changes of mastitis also persist at least 1 week after cessation of antibiotic treatment (Fogsgaard et al., 2015a). Indeed, for many diseases, it is very difficult to pinpoint an actual duration, especially because the sequellae of the initial disease may be another condition. For example, dystocia has numerous potential downstream effects on the calf, with surviving animals often experiencing compromised health in the long term (as reviewed by Murray and Leslie, 2013). Unfortunately, producers, who are most commonly on the "front lines" of diagnosis, may only notice disease when it is severe or in its terminal stages. For example, in 61% of all dairy cow cases submitted to necropsy, producers estimated that a disease had a short course (<2 weeks), but based on postmortem evaluation, this was the duration in only 23% of cases (Thomsen et al., 2012). This suggests that the actual duration of many common cattle diseases is actually longer than reported.

Finally, duration can also be considered from the perspective of repeat health events over the lifetime of an animal, since for some diseases, an individual is likely to be affected more than once. Dairy cows suffering from lameness in first lactation are more susceptible to lameness in subsequent lactations (Hirst et al., 2002), and those that experience dystocia more likely to experience it again at subsequent calving (Mee, 2008). Similarly, >20% of cows have ≥2 udder disorder events and 4% have >2 locomotion disorder events over their lifetime (Houe et al., 2011).

8.3 Section B: Prevention, diagnosis and treatment – barriers and opportunities

8.3.1 Prevention and predisposing factors to disease

As demonstrated in the previous section, common cattle diseases can have severe welfare consequences, ranging from prolonged suffering and susceptibility to further conditions in surviving animals to death. This highlights the importance of aiming to prevent disease when possible, rather than only addressing it from the diagnostic and treatment perspectives (McConnel et al., 2015). Prevention limits the need for subsequent intervention (as reviewed by Lorenz et al., 2011b), in addition to alleviating the welfare concerns associated with disease.

In this context, human attitudes and behavior have a large contributing role—from incorporating preventative practices on the one hand, to actively predisposing animals to developing disease on the other. Indeed, there is a clear relationship between producer behavior and attitudes (e.g., perception of disease causes, employee management strategies) and morbidity, for example, in bulk-tank somatic cell count, a proxy for mastitis (Schewe et al., 2015). Similarly, producer attitudes also explain and predict differences in mastitis incidence across facilities, and they underlie 47% of the variation in bulk tank somatic cell count and 30% of the variation in clinical mastitis incidence rate (Jansen et al., 2009). Producer management style is also a highly influential factor in observed variability in morbidity and mortality (Raboisson et al., 2011), whereas improving management quality is an important factor in lowering disease prevalence (Shahid et al., 2015). Unfortunately, even when best-practice recommendations are known, producers do not always incorporate them. The several examples that follow illustrate this, including the relationship between preventative practices and disease in calves and between management and dystocia.

Preventative practices relating to calf health include timely colostrum feeding to promote passive immunoglobulin transfer (McGuire et al., 1976; Bush and Staley, 1980; Besser and Gay, 1994; Lehenbauer, 2014), adequate provision of appropriately processed milk or milk replacer and navel disinfection (as reviewed by Gorden and Plummer, 2010). The importance of these preventative measures is well-established, with failure to do so, predisposing calves to infectious disease, especially gastrointestinal and respiratory (as reviewed by Khan et al., 2011). Despite this, studies indicate that producer behavior and choices are often motivated by practical convenience, short-term economic advantages, and tradition rather than best practice. For example, tradition was one of the main reasons identified for under-feeding dairy calves on small Brazilian farms (Hötzel et al., 2014), while in Canadian dairies, despite best-practice recommendations, almost 50% of herds use management practices that increase health risks of milk-fed calves, including restrictive milk provision and not taking precautions in feeding of waste milk (Vasseur et al., 2010). Similarly, 50% of Dutch producers indicated that they fail to take good care of dairy calves, including late colostrum delivery, because caring for milking cows is a higher priority (Santman-Berends et al., 2014). Finally, Canadian dairy producers do not disinfect calf navels in approximately 37% of herds, despite the resulting increased risk in respiratory and enteric disease (Vasseur et al., 2010). Surprisingly, even when a producer stands to benefit from healthy calves that will eventually become part of the milking herd, there is sometimes seemingly little effort to incorporate best practices.

Another example highlighting the role of human behavior in promoting cattle disease relates to dystocia. Generally speaking, it appears that calving management is often primarily focused on maintaining a healthy and fertile cow, with variable attention paid to the calf or more generally, the possibility of reducing dystocia risk. To reduce the risk, producers must take preventative steps necessary to reduce dystocia incidence, whether related to selection criteria (e.g., for lower body-weight calves), later age at first breeding, providing appropriate maternity facilities, and personnel training and incorporation of proper interventions at calving when necessary (Lombard et al., 2007; for reviews, see Lorenz et al., 2011b; Murray and Leslie, 2013; Mee et al., 2014). However, there is evidence of failure to incorporate practices such as adequate supervision of calving (Vasseur et al., 2010; as reviewed by Murray and Leslie, 2013 and Mee et al., 2014). This is apparent considering that an estimated 90% of calves that die in the perinatal period are alive at the start of calving, indicating that much of the loss is preventable (Mee, 2013b). Indeed, high stillbirth rates can be viewed as another indicator of deficits in herd husbandry and management (Nyman et al., 2011).

Unfortunately, some studies suggest that the widespread trend towards more intensified and consolidated production results in less time for individual-animal care, thus contributing to increased morbidity and mortality. For example, on larger farms, dairy producers are more distanced from routine cow health care, and this work is increasingly performed by a hired work force who, without routine monitoring and feedback, fail to consistently implement best management practices (Wenz and Giebel, 2012). A study of the Dutch dairy industry found that 40% of producers felt that intensification and consolidation underlie increased calf mortality rates (Santman-Berends et al., 2014), and similar results are apparent in Scandinavian data (Alvåsen et al., 2014c). This further underscores the need for a proactive approach in managing cattle health, especially if robust preventative care is threatened in modern production systems. On the other hand, there is evidence that larger herds are able to provide more specialized care than those with fewer animals; for example, small herd size is a risk factor for lameness in dairy cows (Chapinal et al., 2013, 2014). In organic systems, despite efforts to maintain animals in an environment that optimizes health without reliance on antimicrobials and other synthetic medications, disease is still impossible to entirely prevent (as reviewed by Marley et al., 2010). As has been demonstrated across various production systems, failure to properly incorporate preventative practices increases the risk of compromised health and therefore poor welfare. However, preventative management practices, when actively pursued, offer an opportunity for intervention at the most impactful level from a veterinary and welfare standpoint.

8.3.2 Diagnosis

Diagnosis of disease, particularly in its clinical stages, often relies on the detection of condition-specific signs (e.g., coughing, nasal discharge, and increased respiratory rate in pneumonia, or swollen, hard painful udder and watery milk with flakes and clots in mastitis; Radostits et al., 2007). In cases where sufficient circulating inflammatory mediators are generated as part of the immune response to the disease, animals also present with a constellation of nonspecific clinical signs known as the sickness response (Pecchi et al., 2009). The sickness response is comprised of physiological effects, including fever, and behavioral changes, whose components include anorexia, lethargy, social isolation, and less grooming (Hart, 1988; Dantzer, 2004). Therefore, caretaker monitoring of animals for both disease-specific and nonspecific clinical signs may provide the first indication that further diagnostic evaluation and treatment are warranted. The forthcoming discussion of diagnosis will focus on the need for standardization of case definitions and improved collection and recording of health-related data. Regarding the latter, the potential of necropsy-generated data and automated technology to improve disease detection capacity will be discussed.

In order to achieve more accurate and consistent health records and in turn, better inform disease management decisions, data must be consistently and uniformly recorded. This would in turn allow for an optimized approach to disease diagnosis and management (McConnel et al., 2010; Wenz and Giebel, 2012). One of the primary barriers to improved diagnosis of cattle disease is deficiencies in standardized data recording. This may relate to failing to record data altogether, inconsistencies in monitoring and detection, and variable case definitions. Without standardized and accurate recording, important measures of health management, including new disease episodes, relapse, recurrence, death, and culling, cannot be appropriately monitored (Wenz and Giebel, 2012).

In some cases, records are completely lacking. For example, approximately 17% of USA cow–calf producers who responded to a National Animal Health Monitoring Survey did not have any form of herd health records (USDA, 2008b) likely contributing to under-reporting of disease on these facilities. Many dairy record-keeping systems do not even consider calves as herd members until they are tagged; in turn stillbirths are not recorded (Pannwitz, 2015). The problem is circular, as in the absence of active dystocia monitoring, it cannot be recognized as priority by management when it falsely appears to be a low-magnitude issue (Lombard et al., 2007). As a class, organic farms may have incomplete case records relative to conventional operations because disease recordings are often coupled to recording of treatment. When treatments do not involve antimicrobials or other substances for which drug withdrawal times must be met in order to avoid residues, records may be less meticulous (Sato et al., 2005). Similarly, a higher number of clinical mastitis events are recorded in central databases in countries where veterinarians treat more intensively than where fewer interventions are used (Espetvedt et al., 2013b).

Even when health records do exist, when they are based on producer reporting, disease burdens may be significantly underestimated. Indeed, a producer's perception of disease and emphasis placed on actively managing the condition in question, coupled with the ability to accurately identify cases, directly affects detection rates and subsequent management. When producers do not consider a particular condition to be problematic or otherwise important, they are less likely to monitor for it, or seek veterinary involvement. Producers with a high mortality rate in calves indicated that they only asked a veterinarian for advice about milking cows (Santman-Berends et al., 2014), suggesting that lack of emphasis on managing calf health was a contributing factor to disease in this population. Those reporting that they did not perceive respiratory disease to occur on their farm or could not define it were 28 times more likely to record having no cases of pneumonia (Richert et al., 2013). In contrast, producers who perceive mastitis as important and proactively seek to detect it by routinely examining cows for clinical signs have an increase in reported rate of this disease (Richert et al., 2013). Similarly, Swedish dairy herds with a high case incidence of clinical mastitis more often contacted a veterinarian to initiate treatment as soon as milk appearance was altered. In contrast, low-incidence herds tended to wait until the general condition of the cow was abnormal before seeking veterinary input (Nyman et al., 2007). It follows that the herds with an apparently higher incidence may have actually been from producers with an increased awareness of early cases and aggressive in initiating treatment, versus actually having more mastitis. Organic farmers are less likely than conventional farmers to examine cows postpartum for retained placenta, abnormal body temperature, and decreased feed intake, which is expected to result in decreased apparent relative to actual incidence (Richert et al., 2013).

Accurate disease detection requires clear communication, good observation skills and uniform understanding of case definitions by farm personnel (Ruegg, 2012). Alternatively, differences in case definition and detection schemes contribute to inconsistent recording of disease events. For example, dystocia lacks a standardized case definition and scoring system (Mee, 2008). In mastitis, subtle clinical signs are often overlooked or disregarded by both personnel and automated detection systems, and veterinarians are rarely involved with diagnosis of mild to moderate cases, resulting in dramatic variability in reported clinical rates across studies (Ruegg, 2012). The same is true of respiratory disease (Guterbock, 2014). Unlike milk production, reproduction, and somatic cell count data, which have standardized methodology for data collection, recording and evaluation, health data are user-defined and hence inconsistent. This includes variable recording of affected body part, treatment type and duration, and suspected etiology in databases. Single diseases are often recorded using multiple different health event entries, even within operations (Wenz and Giebel, 2012).

One might assume that centralized cattle health databases promote objective recording. Unfortunately, however, even where such databases exist, the reporting and categorization of health events is still subjective. For example, in some Nordic countries, recording in the national database may only be required if a veterinarian is involved, with tracking infectious diseases the priority (R. Toaff-Rosenstein, personal communication). In this case, recorded incidence is dependent on the producer's threshold for contacting a veterinarian, as well as ability to detect the disease in the first place (Espetvedt et al., 2013a). Standardizing calf health data is particularly challenging, as national database recording in this population is even less rigorous. For example, 22% of calf diarrhea is underestimated and 53% of respiratory disease is underreported by producers and veterinarians. according to an evaluation of the Norwegian national health database (Gulliksen et al., 2009b).

Culling records are another source often used to glean information about disease diagnosis, based on those conditions that were reported to underlie the decision to remove animals from the herd. However, the association between health disorders and recorded reason for culling is often convoluted (Beaudeau et al., 2000). For example, the Dairy Herd Improvement Association, a national organization in the USA that facilitates health and production data management, has culling categories that include "sold for injury/other", "sold for udder problem", "sold for disease", and "sold for mastitis". These are potentially overlapping and very ambiguous groupings. In this regard, there is a need for improved coding systems such that culling outcomes are mutually exclusive (e.g., salvage, died, sale for milking). On the other hand, many databases require reporting a single disease or other reason for culling (Pinedo et al., 2010), an over-simplification which ignores the fact that many animals have multiple underlying reasons for being culled. As such, reporting only a single reason for culling may mask the reality of co-existing conditions, the documentation of which is important in understanding disease dynamics (Fetrow et al., 2006). Indeed, most health records observed in a USA study examining use of dairy software for recording health events associated with mastitis, metritis, and lameness lacked the consistency needed for accurately evaluating and informing herd-level health management decisions (Wenz and Giebel, 2012). Similarly, there is often failure to differentiate between euthanasia and unassisted death in studies and in dairy herd management systems (e.g., Miller et al., 2008; Alvåsen et al., 2014c; Shahid et al., 2015), and thus data interpretation is complicated from a welfare perspective (Pannwitz, 2015). For example, downer cows euthanized on dairies are recorded as having "died" (Fetrow et al., 2006). Danish laws now require reporting whether cow was euthanized or died unassisted, which is a step forward in promoting improved understanding of this issue (Thomsen and Sørensen, 2008). One potential underlying reason is because the records were intended for use by farm personnel, and in the absence of industry standards for health data recording practices, they contain many individual-user definitions. Finally, analyzing animal health dynamics from culling rates alone can be challenging, as economic considerations also factor heavily into these decisions (Dechow and Goodling, 2008).

In contrast to the above-discussed culling records, one of the most basic and important steps that can be used to accurately evaluate the underlying causes of morbidity and mortality is gathering information at necropsy, whether adults or stillborn calves (Mee, 2013b). It helps in defining cause and effect in an objective and accurate manner (McConnel et al., 2009; McConnel et al., 2010), rather than risking misdiagnosis from producer or veterinarian impressions alone. Indeed, disease recognition is suboptimal, with many cows dying without any treatment records or the producer knowing what went wrong (Thomsen et al., 2012), and producer-generated diagnoses are incorrect approximately 55% of the time (McConnel et al., 2009). For example, although respiratory disease is thought to affect primarily young-stock on dairies, lung lesion prevalence rates suggest that pneumonia is actually a leading cause of death in adults as well (Rezac et al., 2014b). There is also poor agreement between the causes of death as determined by necropsy, producer, and national cattle treatment recording database (as reported by whoever treated the cow—either veterinarian or producer). All three sources agreed in only 25% of cases, and necropsy and producer in 50% of cases for cows dying unassisted. In euthanized cows, all three sources agreed in 28% of cases, and necropsy and producer agreed in 64% of cases (Thomsen et al., 2012).

Ideally, necropsies should be performed when herd-level mortality is high or increasing, when no obvious cause of death can be identified, and to confirm tentative diagnoses (Thomsen et al., 2012). However, more than half of producers in one study reported lacking faith in diagnostic tests, considering them to have a poor cost–benefit ratio (Santman-Berends et al., 2014), and there is a common perception that necropsies are low-yield (as reviewed by Mee, 2013b). In turn, necropsies are rarely performed on USA dairies, with only 4% of dead cows receiving a postmortem examination (USDA, 2007a). This stands in stark contrast to poultry, swine, and beef facilities, where necropsy monitoring is routine (USDA, 2007b). Failure to utilize necropsy-generated data more widely in dairy production is somewhat ironic, as these animals face more intensive physiologic and management challenges not encountered by beef cattle in terms of their daily intensive handling (e.g., milking, reproductive examinations) and simultaneous pregnancy and high-yielding lactation. This results in potentially more complex and varied medical issues (McConnel et al., 2010) as compared to beef animals, such that necropsies would be particularly beneficial in this population. It is clear that the ability to better-address morbidity and mortality is hampered by lack of necropsy-derived information (McConnel et al., 2015). Furthermore, current on-farm record systems are not configured to efficiently or effectively capture necropsy findings in meaningful way, resulting in a profound lack of understanding of how and why animals die (McConnel et al., 2009).

8.3.2.1 Automated technology for disease diagnosis

As herd sizes grow, close observations of individual animals by personnel may become less feasible. Indeed, mortality increases at larger herd sizes (Raboisson et al., 2011; Alvåsen et al., 2012; Pannwitz, 2015; Shahid et al., 2015), likely because at-risk cows may not be identified in a timely manner. For example, while mastitis is typically detected at milking (e.g., observing abnormal milk and a swollen, painful udder), with less time available to focus on individual cows, there is a higher chance of missing mild to moderate cases (Leslie and Petersson-Wolfe, 2012).

One potential opportunity to improve early disease detection is the use of automated means to collect health-related data. Instead of relying on infrequently collected data, which require dedicated and potentially costly personnel and increase the likelihood of parameter changes in the face of human presence or handling, animals can be automatically monitored real-time and with less stress. For example, although changes in locomotion (e.g., gait and posture) are the most commonly used and a direct way to monitor lameness, this evaluation may be too time consuming to repeat on a regular basis and only informs about the animal's status at that instant (Van Nuffel et al., 2015a). There are potential alternatives involving automated technology for lameness monitoring (Table 8.2).

Table 8.2

Examples of technology for automated disease detection

Method	Application	Reference
Infrared thermography	Lameness identification by detecting changes in blood flow non-invasively	Alsaaod (2015)
Force-plate measurements in 3 dimensions	Automated lameness detection based on changes in weight-bearing	Dunthorn et al. (2015)
Calving prediction and monitoring software	Early detection and intervention for dystocia	Reviewed by Lorenz et al. (2011b)
Automated monitoring of milk yield and electrical conductivity	Early mastitis detection	Lukas et al. (2009)
Automated monitoring of rumination time	Early warning system for animals at risk of transition diseases, including ketosis, mastitis, lameness, retained placenta, endometritis	Calamari et al. (2014)

Automated monitoring may also allow for earlier disease detection, potentially reducing animal suffering while improving the likelihood of treatment response. For example, automated methods can detect up to 10 days (mastitis) and up to 6 weeks (lameness) before diagnosis using standard physical evaluation methods, in addition to providing alerts to animals at risk of transition diseases (Table 8.2).

There are several practical issues that must be considered if automated technology is to be successfully incorporated for health management. They include the need for producer and veterinarian training, sufficient validation of products before they are marketed, and the need to integrate data derived from different technologies within the same facility (Barkema et al., 2015). While systems may show promise in research settings, as of 2015, there are no efficient automated lameness detection system yet available on the market (Van Nuffel et al., 2015b). In addition, there are potential barriers between automatically generated results and a producer's willingness to trust the data, especially if mildly affected animals are detected by the automated system but are not visibly sick according to personnel evaluation. In fact, most automated systems to-date (in research settings) are set to categorize mildly lame cows as "nonlame" (Van Nuffel et al., 2015b), reflecting a preference to intervene only once animals are obviously affected. A study of cow–calf operators found that new practices and technologies are more appealing for younger, better educated producers who depend on the operation as primary income source. This means that new protocols and technologies must be evaluated not only from a cost–benefit perspective, but also considering functionality, convenience, and willingness to adopt (Field, 2014).

8.3.3 Treatment

In the following section, some issues pertaining to treatment of disease will be discussed. Treatment is considered broadly, referring not only to medications or other veterinary care, but also addressing disease by removing an animal from the herd, whether by euthanasia or selling for slaughter or other purposes. For this reason, culling will also be covered in this section.

Generally, there appears to be a paradox in the treatment of commonly encountered cattle diseases. On the one hand, treatments such as antibiotics may be given on a symptomatic basis alone, resulting in animals receiving medications that at the very least may not cause harm, but offer no benefit. For example, mastitis is often diagnosed and treated symptomatically with antimicrobials, and without knowledge of the causative organism(s), even though many cases are culture-negative or may involve organisms such as yeast or mycoplasma that don't respond to this treatment (Oliveira and Ruegg, 2014). Similarly, diarrhea is one of the leading reasons that cattle receive antimicrobials, with at least 50% receiving empiric treatment, in both dairy and beef animals (USDA, 2008a, 2013). This is despite the fact that most cases of diarrhea in adult cattle, save Salmonella, are unlikely to respond to antimicrobial treatment. Similarly, routine use of antibiotics is not recommended in calves with diarrhea, save those with systemic involvement including depression, anorexia, and fever (as reviewed by Lorenz et al., 2011a; Smith, 2015). In contrast to potential over-reliance on antimicrobials in response to disease, some animals may be denied treatment when it would be beneficial to them. Indeed, from an animal welfare perspective, appropriate treatment should be given to animals in need, irrespective of individual cow or herd characteristics. However, a study of producer behavior around mastitis treatment indicated that cows with mild symptoms or those on the cull list would be less likely to be treated, in addition to accounting for other cow (e.g., milk yield, temperament, and reproductive history) and herd (e.g., overall somatic cell count) characteristics (Vaarst et al., 2002). Similarly, the apparent decrease in mortality in cows with higher milk yield may be secondary to preferential treatment of high-producing individuals (Shahid et al., 2015).

8.3.3.1 NSAID use in disease treatment

While there is more than one way to provide pain relief to diseased cattle, this discussion will highlight some of the issues by focusing on NSAIDs. NSAIDs have antiinflammatory, antipyretic, and analgesic properties (Lees et al., 2004), and offer an opportunity to improve clinical outcome in a variety of diseases. For example, neonatal calves with diarrhea (Todd et al., 2010; as reviewed by Lorenz et al., 2011a) and respiratory disease (Bednarek et al., 2013) and cows with mastitis (Banting et al., 2008; Bryan et al., 2009; as reviewed by Leslie and Petersson-Wolfe, 2012) were clinically improved compared to animals receiving standard treatments but without NSAIDs (Bednarek et al., 2013). Additionally, respiratory disease, mastitis, inflammatory limb lesions, trauma, and parturition all expected to result in pain, which NSAIDs may be used to address. For example, in an endotoxin model of mastitis, NSAID treatment reduced udder size and signs of pain upon palpation scored with a visual analog scale (Banting et al., 2008; as reviewed by Leslie and Petersson-Wolfe, 2012). Similarly, diarrhea can be accompanied by intestinal cramping and abdominal discomfort, with decreased signs of visceral pain when an NSAID is added to standard treatment compared to standard treatment alone (as reviewed by Constable, 2009). NSAIDs also modulate hyperalgesia associated with lameness (Whay et al., 2005), while lameness recovery rate secondary to claw horn lesions is maximized when NSAID treatment is added to therapeutic trimming and claw block in newly and mildly lame cows, though benefits are not seen when NSAID was used alone (Thomas et al., 2015). In the case of dystocia, results on the potential benefits of NSAID use are mixed, and more research is needed (Laven et al., 2012).

Even in countries such as the UK, in which a number of NSAIDs are licensed for use in cattle, many receive no or inadequate pain control (Barrett, 2004). Furthermore, for certain diseases, such as mastitis, most NSAID use is confined to severe cases of gram-negative disease. Cows with mild to moderate mastitis may also show improved clinical outcome (e.g., lower somatic cell count and likelihood of culling) after NSAID treatment, though more work remains to be done to evaluate use in these situations and the associated welfare implications (as reviewed by Leslie and Petersson-Wolfe, 2012). It is unfortunate that currently NSAID use for painful conditions is not widespread, as prevention of hyperalgesia in the acute phase of pain would be expected to have a beneficial effect extending beyond duration of the NSAID's action (Barrett, 2004). The effect of NSAID treatment timing (early vs late) on disease outcome has received little attention, but there is some evidence that in certain cases, early treatment may be beneficial. For example, NSAID treatment in the days immediately following parturition may offer benefits in terms of milk yield and reduced culling rates, potentially indicative of healthier cows secondary to reduction in postpartum inflammation (Carpenter et al., 2016). However, improved production and health are not consistently observed, even when NSAID treatment is given soon after parturition (Meier et al., 2014).

It is important to remember that NSAIDs are not a panacea in all cases. For example, NSAIDS have minimal to no effect on post-dystocia behavior, feed intake, and milk production (Newby et al., 2013) and no improvement in lying time in a mastitis model (as reviewed by Leslie and Petersson-Wolfe, 2012). Similarly, they do not always improve locomotion scores in lame dairy cows, although hyperalgesia is mitigated compared to baseline in these same animals (but not when compared to lame animals receiving conventional treatment alone; Whay et al., 2005). One reason may be that multiple doses are needed for effective pain relief (as reviewed by Leslie and Petersson-Wolfe, 2012), and practical or economic constraints may result in insufficient timing and frequency of dosing.

It is also prudent to carefully consider the role for NSAIDs in mitigating systemic signs of sickness, including anorexia, lethargy, hyperalgesia, and fever. These changes belong to the sickness response, an evolutionarily conserved immune reaction initiated by inflammatory mediators (Hart, 1988; Tizard, 2008). Generally speaking, this response is considered to contribute to an animal's ability to recover from infection, in that it promotes a more robust specific immune reaction (Dantzer, 2004). Therefore, one consideration in opposition to NSAID use for the purpose of normalizing clinical signs (and simultaneously dampening the sickness response) is that this may interfere with changes that are ultimately beneficial for recovery, especially if the underlying cause is not appropriately treated. The benefits of NSAID use have been broadly questioned for fever reduction in the face of mastitis (as reviewed by Leslie and Petersson-Wolfe, 2012) and after dystocia in the cow and calf (Laven et al., 2012). Some work in humans has also suggested that NSAID use early in severe pneumonia may mask initial symptoms and delay antimicrobial therapy, predisposing to worse outcomes (Messika et al., 2014). Ultimately, however, more research is needed in the diseases of greatest interest in cattle to determine in which cases limiting the sickness response by using NSAIDs is in fact beneficial, and specifically, when and how frequently NSAIDs should be used.

8.3.3.2 Treatment in organic systems

Consumer interest in organically produced products, including dairy and meat, continues to grow (USDA, 2016). One expectation of consumers of organic food products are higher animal welfare standards, in that regular pasture access is provided along with other features that promote expression of natural behavior. In theory, organic regulations encourage management that actively promotes health rather than supporting poor management. However, disease prevention and treatment, and therefore overall health and the concomitant potential to reduce suffering as a result of these conditions, may be limited when antimicrobials and other synthetic chemicals are prohibited (as reviewed by Sutherland et al., 2013). Not only do organic producers differ in the type of medications that they use, including use of alternative treatments (e.g., homeopathic) but they rely more on self-treatment (e.g., increased milking frequency for mastitic cows) in place of veterinary involvement (Valle et al., 2007). Importantly, national standards for organic production vary by country. In the USA, animals treated with antimicrobials permanently lose organic status, such that there is a strict prohibition on antimicrobial use (US-GPO, 2016), whereas EU organic standards (IFOAM-EU, 2016) allow for their use if they are the best way to restore health and prevent suffering. Indeed, organic producers in the USA face a confusing paradox regarding the provision of treatments to sick animals. They are required to provide appropriate medical treatment, including antimicrobials, to sick individuals, but on the other hand, those animals that receive this care are permanently disqualified from organic production. This creates a strong economic disincentive against provision of necessary treatments, potentially prolonging animal suffering (as reviewed by Sutherland et al., 2013; Barkema et al., 2015). For example, in Holland, prophylactic use of antimicrobials was forbidden in 2012 and overall use of these products fell by 56% between 2007 and 2012, including blanket use of antibiotic treatment at dry-off, in favor of selective dry-cow treatment for symptomatic animals. However, evidence indicates that this change resulted in an increase in clinical mastitis rate (as reviewed by Barkema et al., 2015). Another limitation of alternative therapies is that their efficacy is generally not appropriately tested (as reviewed by Sutherland et al., 2013). Alternatively, routine use of antibiotics is not a sustainable management approach, and can contribute to antimicrobial resistance (as reviewed by Marley et al., 2010). Currently, the impact of organic regulations on animal health is not well-documented (Ruegg, 2009).

Finally, organic producers also infrequently record and report treatments as compared to conventional producers (as reviewed by Richert et al., 2013; Sutherland et al., 2013), in particular because even in countries requiring veterinary oversight of antimicrobial administration, this is not required of organic products (Marley et al., 2010). This is a risk factor particular to organic systems, in that there is more likely a lack of veterinary input when animals are sick, and generally speaking, organic are less likely than conventional producers to have routinely scheduled veterinary visits (as reviewed by Richert et al., 2013) or otherwise involve veterinarians in treatment decisions (as reviewed by Ruegg, 2009).

8.3.3.3 Euthanasia, unassisted death and live removal as endpoints for diseased cattle

Euthanasia and selling of diseased cattle (generally to salvage or slaughter) are potential alternatives to medical intervention, and are therefore addressed in this section on treatment. Euthanasia offers an opportunity to prevent end-of-life suffering in animals with little chance of recovery and who are not fit for transport to slaughter (AVMA, 2013), in contrast to allowing animals to die a potentially protracted unassisted death. Indeed, there are vastly different welfare implications associated with the underlying type and timing of culling (Fetrow et al., 2006). Thus, while recent studies indicate that mortality has become the primary reported reason for culling on dairy farms, at approximately 20% of all culls (Pinedo et al., 2010; Shahid et al., 2015), without a deeper understanding of the details (i.e. euthanasia vs unassisted death) it is challenging to draw conclusions about animal welfare. The discussion will begin with euthanasia, followed by unassisted death, and finally selling of diseased cattle.

High euthanasia rates may be an indicator of negative welfare, if they are secondary to a high portion of seriously ill animals which are not fit for transport. Alternatively, they may indicate positive welfare, if there is a relatively low threshold for euthanasia such that sick animals are euthanized and not allowed to die unassisted (Thomsen et al., 2004). Indeed, in one study, producers reported a lower threshold for euthanasia compared to 5 years earlier (Thomsen and Sørensen, 2008). The odds of being euthanized as compared to having an unassisted death also increase in herds with a higher average milk yield. This suggests that better-managed herds may have stricter, clearer euthanasia policies and therefore higher rates for cows in which this is an appropriate intervention (Thomsen and Sorensen, 2009). Not only has overall mortality rate increased in Danish dairy cows, but the proportion of those dying that were euthanized has as well (Thomsen et al., 2004). One possible explanation for increasing on-farm mortality rates are regulations such as those passed in 2006 in the EU which permit only healthy animals to be sent to slaughter (Alvåsen et al., 2012), and a concomitant increase in on-farm euthanasia. A similar spike in on-farm mortality occurred in the USA and France likely because of governmental regulations prohibiting the transport and slaughter of non-ambulatory cattle (Miller et al., 2008; Shahid et al., 2015), and in France, a government subsidy for euthanasia of these animals (Raboisson et al., 2011). This indicates that increasing mortality risk may be driven in-part by higher likelihood of euthanasia for sick cows. Indeed, euthanasia may be an alternative to treatment, if labor and veterinary expenses are high, profits per cow are low, and increased scrutiny of fitness for transport result in producers being less likely to ship sick animals to slaughter. In contrast, a Danish study finding high rates of unassisted death of dairy cows suggested that higher beef prices may have resulted in decreased willingness for on-farm euthanasia (Thomsen and Sorensen, 2009), and with potentially severe welfare implications for sick animals. Unfortunately, euthanasia is not always widely practiced and veterinary oversight may be lacking. For example, nearly one-third of Wisconsin dairy producers indicated that they had not euthanized animals in the last 3 years, while for those cases in which euthanasia was contemplated, veterinarians were infrequently consulted (Hoe and Ruegg, 2006). This suggests a high potential for welfare compromise, both in terms of euthanasia being infrequent on certain farms and little veterinary involvement in determining the nature of the underlying disease and the most appropriate intervention.

Unassisted death, when it occurs, is a worrisome indicator that diseased cattle are not being treated, sold to slaughter, or euthanized in a timely manner. Based on recent studies, it is a widespread and serious concern. For example, 30% of culled Swedish (Alvåsen et al., 2014a) and 42% of culled Danish cows (Thomsen et al., 2004) died unassisted. Another Danish study found an even worse outcome, with 84% of cows that died on farms having unassisted deaths (Thomsen and Sorensen, 2009). Similarly, in one USA study, 76% of dying dairy cows died unassisted, and 33% were recumbent for >24 hours before death (McConnel et al., 2010). Additionally, the primary disposal code entered in USA dairy management systems is unassisted death, with a 7% annual rate for dairy cows, equivalent to 18%–21% of all culled animals (including those sold for slaughter, euthanized on-farm, and dying unassisted; Pinedo et al., 2010, 2014). Similarly, during first 100 days after calving on dairy farms, unassisted death is the top reason listed in databases for cows leaving the herd (Pinedo et al., 2014). On a related note, high rates of stillborn calves are also problematic, suggesting inadequate observation of calving pens for dystocia and failure to apply intervention strategies in these cases. For example, 25% of stillborn calves in the USA had an unassisted birth (Lombard et al., 2007). Cows that died on farms with stillbirth rates above the median of herds included in the study were more likely to die unassisted as opposed to being euthanized. This implies that generally sub-optimal management underlies both high stillbirth and unassisted death rates (Alvåsen et al., 2014a).

Finally, selling of cull cattle to auction or slaughter may occur at short-notice (e.g., teat injuries which prevent milking, calving-related accident) or their departure may be knowingly delayed, especially when the diseased individual is still reasonably productive (Beaudeau et al., 2000). For example, dystocia may result in culling only after 200 days in milk (Tenhagen et al., 2007), and cattle are infrequently removed from the herd for locomotor disorders, especially later in lactation (Rutherford et al., 2009). This suggests that the welfare considerations may be overlooked in favor of individual productivity (e.g., reproductive status, milk yield/quality) in determining when the animal will leave the farm (as reviewed by Beaudeau et al., 2000), and there is a risk that delayed selling may increase the risk of unassisted death. Indeed, there is a negative correlation between herd live culling rate (i.e. cow permanently leaves farm alive for auction or slaughter) and the disposal code "died" (Pinedo et al., 2010). For example, 3%–8% of New York dairy cows experiencing clinical mastitis died unassisted within the first 10 months of lactation (Hertl et al., 2011).

8.4 Conclusions

Common cattle diseases, as evaluated from the perspective of the prevalence-severity-duration paradigm, constitute a widespread, potentially severe and long-lasting welfare concern. Efforts to proactively limit the ill-effects of disease should ideally focus on preventing its occurrence altogether. Realistically, however, we are often limited to diagnosing and then formulating treatments for existing cases. As is clear from a review of recent literature, all three of these areas are in need of improvement, particularly as production practices continue to intensify. The human dimension is a fundamental component in mitigating the welfare impact of disease. Perhaps the first step is therefore recognizing the potential suffering of affected animals and formulating a compassionate approach to their care, including timely, on-farm euthanasia when necessary. In service of this goal, the accuracy and uniformity of health records are an area ripe for improvement, while automated technology is also a vastly underutilized tool which could greatly assist our ability to diagnose disease. Indeed, the demands placed on cattle in modern production systems have the potential to at once increase the likelihood of disease, but simultaneously, offer opportunities to proactively manage animals in an effort to optimize their health and welfare.

References

1. Alsaaod M, Schaefer AL, Büscher W, Steiner A. The role of infrared thermography as a non-invasive tool for the detection of lameness in cattle. *Sensors*. 2015;15:14513–14525.
2. Alvåsen K, Mork MJ, Sandgren CH, Thomsen PT, Emanuelson U. Herd-level risk factors associated with cow mortality in Swedish dairy herds. *J Dairy Sci.* 2012;95:4352–4362.
3. Alvåsen K, Thomsen PT, Sandgren CH, Mörk MJ, Emanuelson U. Risk factors for unassisted on-farm death in Swedish dairy cows. *Anim Welf.* 2014a;23:63–70.
4. Alvåsen K, Mork MJ, Dohoo IR, Sandgren CH, Thomsen PT, Emanuelson U. Risk factors associated with on-farm mortality in Swedish dairy cows. *Prev Vet Med.* 2014b;117:110–120.
5. Alvåsen K, Roth A, Mork MJ, Sandgren CH, Thomsen PT, Emanuelson U. Farm characteristics related to on-farm cow mortality in dairy herds: a questionnaire study. *Animal*. 2014c;8:1735–1742.
6. AVMA, 2013. American Veterinary Medical Association Guidelines for the Euthanasia of Animals: 2013 Edition. <http://www.avma.org/KB/Policies/Documents/euthanasia.pdf>.
7. Banting A, Banting S, Heinonen K, Mustonen K. Efficacy of oral and parenteral ketoprofen in lactating cows with endotoxin-induced acute mastitis. *Vet Rec.* 2008;163:506–509.
8. Barkema HW, von Keyserlingk MAG, Kastelic JP, et al. Invited review: Changes in the dairy industry affecting dairy cattle health and welfare. *J Dairy Sci.* 2015;98:7426–7445.
9. Barrett DC. Non-steroidal anti-inflammatory drugs in cattle - should we use them more? *Cattle Pract.* 2004;12:69–73.
10. Beaudeau F, Seegers H, Ducrocq V, Fourichon C, Bareille N. Effect of health disorders on culling in dairy cows: a review and a critical

discussion. *Ann Zootech.* 2000;49:293–311.
11. Beausoleil NJ, Mellor DJ. Introducing breathlessness as a significant animal welfare issue. *N Z Vet J.* 2015;63:44–51.
12. Bednarek D, Lutnicki K, Dudek K, et al. The effect of the combined use of a long-acting antibiotic with NSAID on the clinical status and cellular immune response in calves affected with bovine respiratory disease. *Cattle Pract.* 2013;21:91–97.
13. Berglund B, Steinbock L, Elvander M. Causes of stillbirth and time of death in Swedish Holstein calves examined post mortem. *Acta Vet Scand.* 2003;44:111–120 http://dx.doi.org/10.1186/1751-0147-44-111.
14. Besser TE, Gay CC. The importance of colostrum to the health of the neonatal calf. *Vet Clin North Am Food Anim Pract.* 1994;10:107–117.
15. Bicalho RC, Galvão KN, Cheong SH, Gilbert RO, Warnick LD, Guard CL. Effect of stillbirths on dam survival and reproduction performance in Holstein dairy cows. *J Dairy Sci.* 2007;90:2797–2803.
16. Broom D, Corke M. Effects of disease on farm animal welfare. *Acta Vet Brno*. 2002;71:133–136.
17. Bruijnis MRN, Beerda B, Hogeveen H, Stassen EN. Assessing the welfare impact of foot disorders in dairy cattle by a modeling approach. *Animal*. 2012;6:962–970.
18. Bryan MA, McDougall S, Tiddy RM. Incorporating the non-steroidal anti-inflammatory drug meloxicam into the treatment of clinical mastitis reduced SCC and the risk of culling. *Cattle Pract.* 2009;17:173–183.
19. Bush LJ, Staley TE. Absorption of colostral immunoglobulins in newborn calves. *J Dairy Sci.* 1980;63:672–680.
20. Calamari L, Soriani N, Panella G, Petrera F, Minuti A, Trevisi E. Rumination time around calving: an early signal to detect cows at greater risk of disease. *J Dairy Sci.* 2014;97:3635–3647.
21. Carpenter AJ, Ylioja CM, Vargas CF, et al. Hot topic: Early postpartum treatment of commercial dairy cows with nonsteroidal antiinflammatory drugs increases whole-lactation milk yield. *J Dairy Sci.* 2016;99:672–679.
22. Cassell EJ. Illness and disease. *Hastings Cent Rep.* 1976;6:27–37.
23. Chapinal N, Barrientos AK, von Keyserlingk MAG, Galo E, Weary DM. Herd-level risk factors for lameness in freestall farms in the northeastern United States and California. *J Dairy Sci.* 2013;96:318–328.

24. Chapinal N, Liang Y, Weary DM, Wang Y, von Keyserlingk MAG. Risk factors for lameness and hock injuries in Holstein herds in China. *J Dairy Sci.* 2014;97:4309–4316.
25. Constable PD. Treatment of calf diarrhea: antimicrobial and ancillary treatments (Special Issue: Bovine neonatology). *Vet Clin North Am Food Anim Pract.* 2009;25:101–120.
26. Cook NB, Nordlund KV. The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. *Vet J.* 2009;179:360–369.
27. Cook NB. Assessment of cattle welfare: common animal-based measures. In: Tucker CB, ed. *Advances in Cattle Welfare*. Wallingford, United Kingdom: CABI; 2017.
28. Dantzer R. Cytokine-induced sickness behaviour: a neuroimmune response to activation of innate immunity. *Eur J Pharmacol.* 2004;500:399–411.
29. de Vries M, Bokkers EA, Dijkstra T, van Schaik G, de Boer IJ. Invited review: associations between variables of routine herd data and dairy cattle welfare indicators. *J Dairy Sci.* 2011;94:3213–3228.
30. Dechow CD, Goodling RC. Mortality, culling by sixty days in milk, and production profiles in high- and low-survival Pennsylvania herds. *J Dairy Sci.* 2008;91:4630–4639.
31. Del Río NS, Stewart S, Rapnicki P, Chang YM, Fricke PM. An observational analysis of twin births, calf sex ratio, and calf mortality in Holstein dairy cattle. *J Dairy Sci.* 2007;90:1255–1264.
32. Dunthorn J, Dyer RM, Neerchal NK, et al. Predictive models of lameness in dairy cows achieve high sensitivity and specificity with force measurements in three dimensions. *J Dairy Res.* 2015;82:391–399.
33. Engler M, Defoor P, King C, Gleghorn J. The impact of bovine respiratory disease: the current feedlot experience. *Anim Health Res Rev.* 2014;15:126–129.
34. Espetvedt M, Lind A-K, Wolff C, Rintakoski S, Virtala A-M, Lindberg A. Nordic dairy farmers’ threshold for contacting a veterinarian and consequences for disease recording: Mild clinical mastitis as an example. *Prev Vet Med.* 2013a;108:114–124.
35. Espetvedt MN, Rintakoski S, Wolff C, Lind AK, Lindberg A, Virtala AMK. Nordic veterinarians' threshold for medical treatment of dairy

cows, influence on disease recording and medicine use: Mild clinical mastitis as an example. *Prev Vet Med.* 2013b;112:76–89.
36. Fetrow J, Nordlund KV, Norman HD. Culling: nomenclature, definitions, and recommendations. *J Dairy Sci.* 2006;89:1896–1905.
37. Field TG. Factors that influence producer decisions to implement management strategies. *Anim Health Res Rev.* 2014;15:189–192.
38. Fitzpatrick CE, Chapinal N, Petersson-Wolfe CS, et al. The effect of meloxicam on pain sensitivity, rumination time, and clinical signs in dairy cows with endotoxin-induced clinical mastitis. *J Dairy Sci.* 2013;96:2847–2856.
39. Fogsgaard KK, Bennedsgaard TW, Herskin MS. Behavioral changes in freestall-housed dairy cows with naturally occurring clinical mastitis. *J Dairy Sci.* 2015a;98:1730–1738.
40. Fogsgaard KK, Lovendahl P, Bennedsgaard TW, Ostergaard S. Changes in milk yield, lactate dehydrogenase, milking frequency, and interquarter yield ratio persist for up to 8 weeks after antibiotic treatment of mastitis. *J Dairy Sci.* 2015b;98:7686–7698.
41. Fraser D. Understanding animal welfare. *Acta Vet Scand.* 2008;50:1–7 http://dx.doi.org/10.1186/1751-0147-50-S1-S1.
42. Galindo F, Broom DM. The effects of lameness on social and individual behavior of dairy cows. *J Appl Anim Welf Sci.* 2002;5:193–201.
43. Gorden PJ, Plummer P. Control, management, and prevention of bovine respiratory disease in dairy calves and cows. *Vet Clin N Am Food Anim Pract.* 2010;26:243–259.
44. Gulliksen SM, Lie KI, Loken T, Osteras O. Calf mortality in Norwegian dairy herds. *J Dairy Sci.* 2009a;92:2782–2795.
45. Gulliksen SM, Lie KI, Osteras O. Calf health monitoring in Norwegian dairy herds. *J Dairy Sci.* 2009b;92:1660–1669.
46. Guterbock WM. The impact of BRD: the current dairy experience. *Anim Health Res Rev.* 2014;15:130–134.
47. Hansen M, Misztal I, Lund MS, Pedersen J, Christensen LG. Undesired phenotypic and genetic trend for stillbirth in Danish Holsteins. *J Dairy Sci.* 2004;87:1477–1486.
48. Hare E, Norman HD, Wright JR. Survival rates and productive herd life of dairy cattle in the United States. *J Dairy Sci.* 2006;89:3713–3720.
49. Hart BL. Biological basis of the behavior of sick animals. *Neurosci Biobehav Rev.* 1988;12:123–137.

50. Hertl JA, Schukken YH, Bar D, et al. The effect of recurrent episodes of clinical mastitis caused by gram-positive and gram-negative bacteria and other organisms on mortality and culling in Holstein dairy cows. *J Dairy Sci*. 2011;94:4863–4877.
51. Hilton WM. BRD in 2014: where have we been, where are we now, and where do we want to go? *Anim Health Res Rev*. 2014;15:120–122.
52. Hirst WM, Murray RD, Ward WR, French NP. A mixed-effects time-to-event analysis of the relationship between first-lactation lameness and subsequent lameness in dairy cows in the UK. *Prev Vet Med*. 2002;54:191–201.
53. Hoe FG, Ruegg PL. Opinions and practices of Wisconsin dairy producers about biosecurity and animal well-being. *J Dairy Sci*. 2006;89:2297–2308.
54. Hötzel MJ, Longo C, Balcão LF, Cardoso CS, Costa JHC. A survey of management practices that influence performance and welfare of dairy calves reared in southern Brazil. *PLoS One*. 2014;9:e114995 http://dx.doi.org/10.1371/journal.pone.0114995.
55. Houe H, Sandøe P, Thomsen PT. Welfare assessments based on lifetime health and production data in Danish dairy cows. *J Appl Anim Welf Sci*. 2011;14:255–264.
56. IFOAM-EU, 2016. List of EU Organic Regulations. <http://www.ifoam-eu.org/en/organic-regulations/list-eu-organic-regulations> (accessed 10.08.16.).
57. Jansen J, van den Borne BHP, Renes RJ, van Schaik G, Lam TJGM, Leeuwis C. Explaining mastitis incidence in Dutch dairy farming: The influence of farmers' attitudes and behaviour. *Prev Vet Med*. 2009;92:210–223.
58. Khan MA, Weary DM, von Keyserlingk MAG. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. *J Dairy Sci*. 2011;94:1071–1081.
59. Laven R, Chambers P, Stafford K. Using non-steroidal anti-inflammatory drugs around calving: Maximizing comfort, productivity and fertility. *Vet J*. 2012;192:8–12.
60. Lees P, Landoni MF, Giraudel J, Toutain PL. Pharmacodynamics and pharmacokinetics of nonsteroidal anti-inflammatory drugs in species of veterinary interest. *J Vet Pharmacol Ther*. 2004;27:479–490.
61. Lehenbauer TW. Control of BRD in large dairy calf populations. *Anim*

Health Res Rev. 2014;15:184–185.
62. Leslie KE, Petersson-Wolfe CS. Assessment and management of pain in dairy cows with clinical mastits. *Vet Clin N Am Food Anim Pract.* 2012;28:289–305.
63. Lombard JE, Garry FB, Tomlinson SM, Garber LP. Impacts of dystocia on health and survival of dairy calves. *J Dairy Sci.* 2007;90:1751–1760.
64. Lorenz I, Fagan J, More SJ. Calf health from birth to weaning II Management of diarrhoea in pre-weaned calves. *Ir Vet J.* 2011a;64:64–69.
65. Lorenz I, Mee JF, Earley B, More SJ. Calf health from birth to weaning I General aspects of disease prevention. *Ir Vet J.* 2011b;64:1–8.
66. Lukas JM, Reneau JK, Wallace R, Hawkins D, Munoz-Zanzi C. A novel method of analyzing daily milk production and electrical conductivity to predict disease onset. *J Dairy Sci.* 2009;92:5964–5976.
67. Marley CL, Weller RF, Neale M, Main DCJ, Roderick S, Keatinge R. Aligning health and welfare principles and practice in organic dairy systems: A review. *Animal*. 2010;4:259–271.
68. McConnel CS, Lombard JE, Wagner BA, Garry FB. Evaluation of factors associated with increased dairy cow mortality on United States dairy operations. *J Dairy Sci.* 2008;91:1423–1432.
69. McConnel CS, Garry FB, Lombard JE, Kidd JA, Hill AE, Gould DH. A necropsy-based descriptive study of dairy cow deaths on a Colorado dairy. *J Dairy Sci.* 2009;92:1954–1962.
70. McConnel CS, Garry FB, Hill AE, Lombard JE, Gould DH. Conceptual modeling of postmortem evaluation findings to describe dairy cow deaths. *J Dairy Sci.* 2010;93:373–386.
71. McConnel C, Lombard J, Wagner B, Kopral C, Garry F. Herd factors associated with dairy cow mortality. *Animal*. 2015;9:1397–1403.
72. McGuire TC, Pfeiffer NE, Weikel JM, Bartsch RC. Failure of colostral immunoglobulin transfer in calves dying from infectious disease. *J Am Vet Med Assoc.* 1976;169:713–718.
73. Medrano-Galarza C, Gibbons J, Wagner S, de Passillé AM, Rushen J. Behavioral changes in dairy cows with mastitis. *J Dairy Sci.* 2012;95:6994–7002.
74. Mee J. Explaining unexplained bovine stillbirth: How to deal with 'farm blindness'. *Vet J.* 2013a;197:120–121.
75. Mee JF. Prevalence and risk factors for dystocia in dairy cattle: a review.

Vet J. 2008;176:93–101.
76. Mee JF. Why do so many calves die on modern dairy farms and what can we do about calf welfare in the future? *Animals*. 2013b;3:1036–1057.
77. Mee JF, Sánchez-Miguel C, Doherty M. Influence of modifiable risk factors on the incidence of stillbirth/perinatal mortality in dairy cattle. *Vet J*. 2014;199:19–23.
78. Meier S, Priest NV, Burke CR, et al. Treatment with a nonsteroidal antiinflammatory drug after calving did not improve milk production, health, or reproduction parameters in pasture-grazed dairy cows. *J Dairy Sci*. 2014;97:2932–2943.
79. Messika J, Sztrymf B, Bertrand F, et al. Risks of nonsteroidal antiinflammatory drugs in undiagnosed intensive care unit pneumococcal pneumonia: Younger and more severely affected patients. *J Crit Care*. 2014;29:733–738.
80. Miele M, Veissier I, Evans A, Botreau R. Animal welfare: Establishing a dialogue between science and society. *Anim Welf*. 2011;20:103.
81. Miller RH, Kuhn MT, Norman HD, Wright JR. Death losses for lactating cows in herds enrolled in dairy herd improvement test plans. *J Dairy Sci*. 2008;91:3710–3715.
82. Millman ST. Sickness behaviour and its relevance to animal welfare assessment at the group level. *Anim Welf*. 2007;16:123–125.
83. Murray CF, Leslie KE. Newborn calf vitality: Risk factors, characteristics, assessment, resulting outcomes and strategies for improvement. *Vet J*. 2013;198:322–328.
84. Newby NC, Pearl DL, LeBlanc SJ, Leslie KE, von Keyserlingk MAG, Duffield TF. Effects of meloxicam on milk production, behavior, and feed intake in dairy cows following assisted calving. *J Dairy Sci*. 2013;96:3682–3688.
85. Nyman AK, Ekman T, Emanuelson U, et al. Risk factors associated with the incidence of veterinary-treated clinical mastitis in Swedish dairy herds with a high milk yield and a low prevalence of subclinical mastitis. *Prev Vet Med*. 2007;78:142–160.
86. Nyman A-K, Lindberg A, Sandgren CH. Can pre-collected register data be used to identify dairy herds with good cattle welfare? *Acta Vet Scand*. 2011;53:1–6 Available from: http://doi.org/10.1186/1751-0147-53-S1-S8.

87. Oliveira L, Ruegg PL. Treatments of clinical mastitis occurring in cows on 51 large dairy herds in Wisconsin. *J Dairy Sci.* 2014;97:5426–5436.
88. Pannwitz G. Standardized analysis of German cattle mortality using national register data. *Prev Vet Med.* 2015;118:260–270.
89. Pastell M, Hänninen L, de Passillé AM, Rushen J. Measures of weight distribution of dairy cows to detect lameness and the presence of hoof lesions. *J Dairy Sci.* 2010;93:954–960.
90. Pecchi E, Dallaporta M, Jean A, Thirion S, Troadec J-D. Prostaglandins and sickness behavior: Old story, new insights. *Physiol Behav.* 2009;97:279–292.
91. Pinedo PJ, De Vries A, Webb DW. Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. *J Dairy Sci.* 2010;93:2250–2261.
92. Pinedo PJ, Daniels A, Shumaker J, De Vries A. Dynamics of culling for Jersey, Holstein, and Jersey × Holstein crossbred cows in large multibreed dairy herds. *J Dairy Sci.* 2014;97:2886–2895.
93. Raboisson D, Cahuzac E, Sans P, Allaire G. Herd-level and contextual factors influencing dairy cow mortality in France in 2005 and 2006. *J Dairy Sci.* 2011;94:1790–1803.
94. Radostits OM, Gay CC, Hinchcliff KW, Constable PD. *Veterinary Medicine—A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats* 10th ed. Pennsylvania, USA: Saunders; 2007.
95. Rezac DJ, Thomson DU, Bartle SJ, Osterstock JB, Prouty FL, Reinhardt CD. Prevalence, severity, and relationships of lung lesions, liver abnormalities, and rumen health scores measured at slaughter in beef cattle. *J Anim Sci.* 2014a;92:2595–2602.
96. Rezac DJ, Thomson DU, Siemens MG, Prouty FL, Reinhardt CD, Bartle SJ. A survey of gross pathologic conditions in cull cows at slaughter in the Great Lakes region of the United States. *J Dairy Sci.* 2014b;97:4227–4235.
97. Richert RM, Cicconi KM, Gamroth MJ, Schukken YH, Stiglbauer KE, Ruegg PL. Risk factors for clinical mastitis, ketosis, and pneumonia in dairy cattle on organic and small conventional farms in the United States. *J Dairy Sci.* 2013;96:4269–4285.
98. Ruegg PL. Management of mastitis on organic and conventional dairy farms. *J Anim Sci.* 2009;87:43–55.
99. Ruegg PL. New perspectives in udder health management. *Vet Clin*

North Am Food Anim Pract. 2012;28:149–163.
100. Rushen J, Pombourcq E, Passillé AMD. Validation of two measures of lameness in dairy cows. *App Anim Behav Sci.* 2007;106:173–177.
101. Rutherford KMD, Langford FM, Jack MC, Sherwood L, Lawrence AB, Haskell MJ. Lameness prevalence and risk factors in organic and non-organic dairy herds in the United Kingdom. *Vet J.* 2009;180:95–105.
102. Santman-Berends IMGA, Buddiger M, Smolenaars AJG, et al. A multidisciplinary approach to determine factors associated with calf rearing practices and calf mortality in dairy herds. *Prev Vet Med.* 2014;117:375–387.
103. Sato K, Bartlett PC, Erskine RJ, Kaneene JB. A comparison of production and management between Wisconsin organic and conventional dairy herds. *Livest Prod Sci.* 2005;93:105–115.
104. Schewe RL, Kayitsinga J, Contreras GA, et al. Herd management and social variables associated with bulk tank somatic cell count in dairy herds in the eastern United States. *J Dairy Sci.* 2015;98:7650–7665.
105. Shahid MQ, Reneau JK, Chester-Jones H, Chebel RC, Endres MI. Cow- and herd-level risk factors for on-farm mortality in Midwest US dairy herds. *J Dairy Sci.* 2015;98:4401–4413.
106. Siivonen J, Taponen S, Hovinen M, et al. Impact of acute clinical mastitis on cow behaviour. *Appl Anim Behav Sci.* 2011;132:101–106.
107. Smith G. Antimicrobial decision making for enteric diseases of cattle. *Vet Clin North Am Food Anim Pract.* 2015;31:47–60.
108. Smith RD. *Veterinary Clinical Epidemiology* third ed. Urbana, IL: Taylor & Francis; 2005.
109. Solano L, Barkema HW, Pajor EA, et al. Prevalence of lameness and associated risk factors in Canadian Holstein-Friesian cows housed in freestall barns. *J Dairy Sci.* 2015;98:6978–6991.
110. Sutherland MA, Webster J, Sutherland I. Animal health and welfare issues facing organic production systems. *Animals*. 2013;3:1021–1035.
111. Tenhagen B-A, Helmbold A, Heuwieser W. Effect of various degrees of dystocia in dairy cattle on calf viability, milk production, fertility and culling. *J Vet Med A.* 2007;54:98–102.
112. Terrell SP, Thomson DU, Reinhardt CD, Apley MD, Larson CK, Stackhouse-Lawson KR. Perception of lameness management, education, and effects on animal welfare of feedlot cattle by consulting nutritionists, veterinarians, and feedlot managers. *Bov Pract.*

2014;48:53–60.
113. Thomas HJ, Miguel-Pacheco GG, Bollard NJ, et al. Evaluation of treatments for claw horn lesions in dairy cows in a randomized controlled trial. *J Dairy Sci.* 2015;98:4477–4486.
114. Thomsen PT, Kjeldsen AM, Sørensen JT, Houe H. Mortality (including euthanasia) among Danish dairy cows (1990–2001). *Prev Vet Med.* 2004;62:19–33.
115. Thomsen PT, Sørensen JT. Euthanasia of Danish dairy cows evaluated in two questionnaire surveys. *Acta Vet Scand.* 2008;50 33–33. Available from: http://doi.org/10.1186/1751-0147-50-33.
116. Thomsen PT, Sørensen JT. Factors affecting the risk of euthanasia for cows in Danish dairy herds. *Vet Rec.* 2009;165:43–45.
117. Thomsen PT, Dahl-Pedersen K, Jensen HE. Necropsy as a means to gain additional information about causes of dairy cow deaths. *J Dairy Sci.* 2012;95:5798–5803.
118. Tizard I. Sickness behavior, its mechanisms and significance. *Anim Health Res Rev.* 2008;9:87–99.
119. Todd CG, Millman ST, McKnight DR, Duffield TF, Leslie KE. Nonsteroidal anti-inflammatory drug therapy for neonatal calf diarrhea complex: Effects on calf performance. *J Anim Sci.* 2010;88:2019–2028.
120. Torsein M, Lindberg A, Sandgren CH, Waller KP, Tornquist M, Svensson C. Risk factors for calf mortality in large Swedish dairy herds. *Prev Vet Med.* 2011;99:136–147.
121. USDA, 2007a. Dairy 2007, Part I: Reference of Dairy Cattle Health and Management Practices in the United States. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.). CEAH, Fort Collins, CO.
122. USDA, 2007b. Dairy 2007 Part II: Changes in the U.S. Dairy Cattle Industry, 1991–2007. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.). CEAH, Fort Collins, CO.
123. USDA, 2008a. Antibiotic Use on U.S. Dairy Operations, 2002 and 2007. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.). Centers for Epidemiology and Animal Health.
124. USDA, 2008b. Beef 2007–08, Part III: Changes in the U.S. Beef Cow-Calf Industry, 1993–2008. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.) CEAH, Fort Collins, CO.
125. USDA, 2008c. Dairy 2007 Part III: Reference of the dairy cattle health and management practices in the United States, 2007. In: USDA-

APHIS: VS-CEAH-NAHMS (Ed.), Fort Collins, CO.
126. USDA, 2009. Dairy 2007, Part V: Changes in Dairy Cattle Health and Management Practices in the United States, 1996–2007. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.), Fort Collins, CO.
127. USDA, 2010a. Dairy 2007, Heifer Calf Health and Management Practices on U.S. Dairy Operations. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.). USDA, Fort Collins, CO.
128. USDA, 2010b. Beef 2007-08 Part V: Reference of beef cow-calf management practices in the United States, 2007-08. In: USDA-APHIS: VS-CEAH-NAHMS (Ed.), Fort Collins, CO.
129. USDA, 2013. Feedlot 2011 Part IV: Health and Health Management on U.S. Feedlots with a Capacity of 1,000 or More. In: USDA-APHIS:VS-CEAH-NAHMS (Ed.), Fort Collins, CO.
130. USDA, 2016. Organic market overview. <http://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview.aspx> (accessed 01.08.16.).
131. US-GPO, 2016. Electronic Code of Federal Regulations. <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=3f34f4c22f9aa8e6d9864cc2683cea02&tpl=/ecfrbrowse/Titl
(accessed 10.08.16.).
132. Vaarst M, Paarup-Laursen B, Houe H, Fossing C, Andersen HJ. Farmers' choice of medical treatment of mastitis in Danish dairy herds based on qualitative research interviews. *J Dairy Sci.* 2002;85:992–1001.
133. Valle PS, Lien G, Flaten O, Koesling M, Ebbesvik M. Herd health and health management in organic versus conventional dairy herds in Norway. *Livest Sci.* 2007;112:123–132.
134. Van Nuffel A, Zwertvaegher I, Pluym L, et al. Lameness detection in dairy cows: Part 1 How to distinguish between non-lame and lame cows based on differences in locomotion or behavior. *Animals*. 2015a;5:838–860.
135. Van Nuffel A, Zwertvaegher I, Van Weyenberg S, et al. Lameness detection in dairy cows: Part 2 Use of sensors to automatically register changes in locomotion or behavior. *Animals*. 2015b;5:861–885.
136. Vasseur E, Borderas F, Cue RI, et al. A survey of dairy calf management practices in Canada that affect animal welfare. *J Dairy Sci.*

2010;93:1307–1316.
137. Ventura BA, Keyserlingk MAGV, Weary DM. Animal welfare concerns and values of stakeholders within the dairy industry. *J Agric Environ Ethics*. 2015;28:109–126.
138. Vergara CF, Döpfer D, Cook NB, et al. Risk factors for postpartum problems in dairy cows: Explanatory and predictive modeling. *J Dairy Sci*. 2014;97:4127–4140.
139. Vogel GJ, Bokenkroger CD, Rutten-Ramos SC, Bargen JL. A retrospective evaluation of animal mortality in US feedlots: rate, timing, and cause of death. *Bovine Pract.* 2015;49:113–123.
140. von Keyserlingk MAG, Rushen J, de Passillé AM, Weary DM. Invited review: The welfare of dairy cattle—Key concepts and the role of science. *J Dairy Sci.* 2009;92:4101–4111.
141. von Keyserlingk MAG, Barrientos A, Ito K, Galo E, Weary DM. Benchmarking cow comfort on North American freestall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows. *J Dairy Sci.* 2012;95:7399–7408.
142. Waldner CL. Cow attributes, herd management and environmental factors associated with the risk of calf death at or within 1 h of birth and the risk of dystocia in cow–calf herds in Western Canada. *Livest Sci.* 2014;163:126–139.
143. Weigel KA, Palmer RW, Caraviello DZ. Investigation of factors affecting voluntary and involuntary culling in expanding dairy herds in Wisconsin using survival analysis. *J Dairy Sci.* 2003;86:1482–1486.
144. Wenz JR, Giebel SK. Retrospective evaluation of health event data recording on 50 dairies using Dairy Comp 305. *J Dairy Sci.* 2012;95:4699–4706.
145. Whay HR, Webster AJF, Waterman-Pearson AE. Role of ketoprofen in the modulation of hyperalgesia associated with lameness in dairy cattle. *Vet Rec.* 2005;157:729–733.
146. Yeiser EE, Leslie KE, McGilliard ML, Petersson-Wolfe CS. The effects of experimentally induced *Escherichia coli* mastitis and flunixin meglumine administration on activity measures, feed intake, and milk parameters. *J Dairy Sci.* 2012;95:4939–4949.

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9

Metabolic challenge

How does it affect welfare?

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Abstract

Intensively managed and grazing cattle, whether they be beef or dairy, often face metabolic challenges. Broadly, metabolic challenge can be characterized by two situations: where metabolic outputs exceed inputs and where metabolic inputs exceed outputs. Metabolic challenge can result in changes that include clinical and subclinical disease and other, adaptive changes in physiology and behavior. Metabolic diseases are complex, and often multifactorial, and diagnosis is not always simple. In this chapter the major contributing factors to metabolic challenge, namely high levels of growth and production, nutrition, climate and exogenous production promotants for growth and lactation) and their impact on welfare will be presented. Interestingly, although implied, there is little mention of the nonhealth related welfare implications in the literature published on metabolic challenge.

Keywords

Metabolic challenge; cattle; welfare

9.1 Introduction

The biological systems of a bovine are complex, multifactorial, and dynamic (Leblanc, 2010). Animals attempt to maintain a degree of homeostasis across a wide range of biological functions but this is often challenged by internal and external factors. Broadly, metabolic challenge can be characterized by two situations: where metabolic outputs exceed inputs and where metabolic inputs exceed outputs. As a result of either situation, the animal's processing system may be compromised (McDonald et al., 2011) and lead to a metabolic disease. However, disease is not the only outcome of metabolic challenge. Cattle often adapt to the challenges, e.g., reducing feed intake when challenged by hot weather.

This spectrum, from homeostatic adaptation to pathology, broadens the welfare implications of metabolic challenge. Clinical expression of acidosis, lameness, mastitis, and ketosis are relatively easily defined, as is their impact on bovine welfare. However, there may be subtle, undetected metabolic changes that occur well before any overt outcomes are seen. For example, unregulated inflammatory responses, subclinical acidosis, and subclinical ketosis are often not detected. Numerous papers have discussed metabolic challenges in cattle, but few have highlighted the associated welfare concerns beyond health.

Metabolic challenges may result from: genetic selection for increased production (e.g., selection of high-producing dairy cows), nutrition, climate, and exogenous production promotants (growth and lactation). Furthermore the aforementioned factors do not act in isolation. Many are multifactorial and further complicated by the difficulty associated with diagnosis of the health-related problems. In this chapter, how these major metabolic challenges influence the welfare of cattle will be discussed. There will not been an in-depth outline of the etiology of the various metabolic challenges as these have been thoroughly reviewed and are available in peer-reviewed journals, and text books.

9.2 Metabolic challenges

9.2.1 The high-performance animal: increased metabolic output over generations

Significant changes in the level of production (growth and milk) primarily due to genetic selection, but also due to improved nutrition and management (Clapper et al., 2009), and the use of growth-promotant technology (Elam and Preston, 2004), has occurred over the last 50 years. The change in those animals due to selection for increased performance is perhaps the biggest metabolic challenge facing the animals. For example, in 1950 the average milk production from US dairy cows was 2361 kg/cow per year (Blayney, 2002). By 2016 this had increased to 10,318 kg/cow per year (USDA, 2017). The growth rate of beef cattle finished in feedlots within the US was approximately 1.0 kg/day in the 1950s and 1.6 kg/day in the early 2000s (Elam and Preston, 2004). During the same period, the age at slaughter dropped from 24–36 months of age to 16–20 months of age. Management decisions between 1970 and 2015 saw a 100-kg increase in carcass weight of steers (304 kg cf. 409 kg) (USDA, 2016a). These changes present challenges for managers and for the animals themselves. Animals are typically managed so that they are close to their genetic potential for growth and/or milk production.

9.2.2 Nutritional challenges

Nutritional challenges are metabolic challenges resulting from nutrient over or under supply. There are complex interactions between nutritional disorders and the cascade effects this has on metabolic systems.

9.2.2.1 Acidosis

Mortality is relatively rare in feedlots, less than 0.5% (Galyean and Rivera, 2003). However, digestive disorders account for 25%–33% of deaths in feedlot cattle (Galyean and Rivera, 2003), this is somewhat of a concern given that digestive orders are largely management induced (NB: not purposely). Similarly, Smith (1998) presented feedlot data from five studies showing that digestive disorders accounted for approximately 24% (range 3%–42.4%) of total diagnosed morbidity. Specifically, acidosis and acidosis-induced disorders are the most common metabolic disorders associated with nutrition in intensively housed beef and dairy cattle. As numerous reviews on the symptoms and etiology of ruminal acidosis have been published (e.g., Owens et al., 1998) only a brief overview will be provided here.

Acidosis (rumen pH 5–5.2) occurs when there are large increases of lactic acid in the rumen, which results from diets that are high in ruminally available carbohydrates, or forages that are low in effective fiber (Nocek, 1997). Acute acidosis leads to impaired physiological function and in some instances cattle may die (Nocek, 1997). As rumen pH decreases, there is a change in microbial profile of the rumen. Eventually lactobacilli fill the void left by the demise of other species and rumen pH falls further. The net results of this are: ruminal motility, stasis, ruminitis, laminitis, and hyperkeratosis (Bull et al., 1965; Nocek, 1997). Leading on from this condition, cattle may develop liver abscesses, develop systemic inflammation and localized inflammation of the tissues of the papillae of the rumen, become dehydrated, have decreased cardiac output, have decreased peripheral perfusion, have decreased renal blood flow, go into shock, and then death is likely (Nocek, 1997; Owens et al., 1998; Danscher et al., 2015). Death from acidosis is painful. Anecdotally, cattle may kick at their belly, and show signs of discomfort and stress.

One-third of dairy cows may be affected by metabolic or infectious disease in early lactation (Leblanc, 2010). In dairy cows sub-acute ruminal acidosis (SARA: rumen pH 5.2–5.6) is prevalent in intensive dairies, and is also an issue in some grazing situations (O'Grady et al., 2008). Surveys have reported that the incidence of SARA within herds ranges from 11% to 26% (Oetzel et al., 1999; Danscher et al., 2015). However Enemark (2009) reported that in one-third of the dairy herds observed in a US field study, 40% of all cows were found to have SARA. The overall incidence of acidosis in beef feedlots is not really known. Liver abscesses associated with ingestion of high-starch diets have been reported to be in the range of 12% and 32% (Nagaraja and Lechtenberg, 2007), but in some cases may be as high as 56% (Fox et al., 2009). Furthermore, little is known about the severity of these disorders and how they impact on welfare, for example, it is not really known whether conditions such as SARA are painful to cattle. SARA is known to contribute to a number of disorders that are likely to impact cow welfare e.g. rumen mucosal damage, diarrhoea, inflammation, reduced feed intake, liver and lung abscesses, and laminitis (Nocek, 1997; Stone, 2004; Plaizier et al., 2009). Because of the difficulty in detecting SARA many cases probably go undetected (Danscher et al., 2015; Loor et al., 2016) thus it is difficult to clearly articulate the welfare challenge that affected cattle will face.

Laminitis is one of the physiological implications of acidosis and SARA and results in severe lameness. Lameness is one of the most serious welfare and production concerns in the dairy industry worldwide (Sordillo and Raphael, 2013), in part because of the pain experienced. The prevalence of lameness in dairy herds has been reported to be between 15% and 25% of cows examined, with the majority of cases being attributed to laminitis (Stone, 2004). However, there is some disagreement in the literature. Others have reported that in many cases lameness thought to be due to laminitis may be misdiagnosed (Thoefner et al., 2004).

9.2.2.2 Negative energy balance

High-yielding dairy cows and in particular overconditioned cows often have suppressed immune systems and are susceptible to metabolic diseases during the early postpartum period (Kessel et al., 2008; Sordillo and Raphael, 2013), due in part to inadequate nutrient intake (von Keyserlingk and Weary, 2010). If the metabolic pathways fail to adapt to the transition from pregnancy to lactation there is risk of digestive, metabolic, and other disorders such as displaced abomasum, ketosis, and mastitis (Hachenberg et al., 2007). This is further complicated by interactions with cattle genetics. For example, high-producing dairy cows have been selected for high milk yield, but there appears to be a biological limit on feed intake which causes a disconnect between the genetic disposition for milk production and the ability to consume enough nutrients to meet the metabolic demand, especially during the transition phase. Negative energy balance (NEB) occurs when nutrient intake lags behind the nutrient levels required to meet increasing milk production and maintenance needs of the cow (Bell, 1995), especially during the transition from late pregnancy to early lactation (Sordillo and Raphael, 2013). When faced with an energy shortfall, dairy cows need to mobilize adipose tissue to compensate for the deficit of glucose that occurs during the peripartum period (Hachenberg et al., 2007). The reduction in blood glucose results in lower insulin levels, which triggers lipid mobilization (Sordillo and Raphael, 2013), and leads to insulin resistance. The resultant insulin resistance in association with reduced nutrient intake increases the risk of subclinical or clinical ketosis (Vickers et al., 2013). Fat mobilization occurs through a process called lipogenesis. Lipid mobilization provides the cow with the energy needed to promote increased milk production. During lipolysis there is an increase in the blood concentration of nonesterified fatty acids (NEFAs). NEFAs can be used as an energy source and they also initiate negative feedback loops to regulate the amount of lipolysis (Sordillo and Raphael, 2013). However, excessive lipid mobilization and subsequent accumulation of high concentrations of free fatty acids in the blood may lead to metabolic disorders such as ketosis and fatty liver disease (van Knegsel, 2005; Leblanc, 2010; Sordillo and Raphael, 2013).

There is widespread agreement that cattle welfare is compromised once clinical disease is diagnosed. Much less is known about how the affective states are affected by NEB. It is unclear whether animals experience hunger, for example, during this process.

9.2.2.3 Ketosis (acetonemia)

Cows are predisposed to ketosis and other disorders as a result of having a negative energy balance, which leads to lipid mobilization (see above). If lipid mobilization is intense and prolonged glycogen reserves in the liver may be depleted, compromising gluconeogenesis, leading to hypoglycemia and thus the cow has a high risk of developing ketosis (Drackley, 1999). Ketosis may be defined as a relative or absolute loss of carbohydrate in the liver leading to a breakdown of fat (Hungerford, 1975). This results in the production of ketone bodies (acetone, acetoacetic acid and B-hydroxybutyric acid), which are only really a problem if they accumulate in the body. If cows are subjected to long-term elevation in ketone bodies, blood acidosis (ketoacidosis) may also occur. Ketosis is a metabolic disease which is the end result of stressors impacting on high-production cows (Hungerford, 1975). Ketosis may present as clinical or subclinical, and may be a direct result of metabolic imbalance or be induced by other disorders such as metritis or mastitis (Hungerford, 1975; Duffield, 2000). Overt symptoms of clinical ketosis include acetone odor on the breath of the cow, loss of appetite, weight loss, lethargy, reduced milk production, hard dry feces, cold legs and ears, reduction in body temperature, and occasionally nervous signs and blindness (Hungerford, 1975; Duffield, 2000; Champness, 2007). A number of studies have shown that the incidence of subclinical ketosis has a worldwide prevalence of 8.9%–34% for cows in the first 2 months of lactation, whereas the reported incidence of clinical ketosis during lactation varies from 2% to 15% (see Duffield, 2000). However in a very early study Emery et al. (1964) reported subclinical ketosis in up to 50% of the cows in high-producing herds and that 20%–30% of these cows developed clinical ketosis. One in 20 affected cows dies. Cows may stagger and go down to a “sitting” position, often with a “kink” in their necks, and finally lie flat on their side before circulatory collapse, coma, and death (Champness, 2007). Again, the health implications of ketosis are clear, but the other, more subtle or subclinical changes may go unrecognized. Understanding what the cow experiences during this illness, in terms of how she feels, is unknown.

9.3 Macro mineral metabolism

Both deficiencies and excesses in macro minerals have welfare implications for cattle. DeGaris and Lean (2008) stated that the transition dairy cow should be able to adapt to provide minimal risk of metabolic disorders associated with macro-minerals (i.e. absolute or conditioned Ca, P or Mg; and deficiencies or excesses in K and Na). Unfortunately this does not always occur. Absolute and conditioned can be thought of as primary and secondary causes of a metabolic problem. For example, the primary cause of P deficiency may be an absolute deficiency of P in the diet, and a secondary or conditioned cause is when a deficiency in P is due to another factor such as excess Ca intake (Constable et al., 2017).

9.3.1 Hypocalcemia (milk fever)

Milk fever is an afebrile hypocalcemic disease of cattle usually associated with parturition and initiation of lactation (Littledike et al., 1981). Milk fever is caused by the removal of large amounts of calcium from blood (50 g/day) to ensure rapid synthesis of milk (DeGaris and Lean, 2008; Thirunavukkarasu et al., 2010). Other factors such as cows being over fat, and being a high-production cow are risk factors for hypocalcemia. Clinical hypocalcemia and subclinical hypocalcemia are risk factors for: mastitis, ketosis, retained placenta, displaced abomasum, and uterine prolapse (DeGaris and Lean, 2008). Field studies undertaken in North America, Europe, and Australia have reported that the incidence of milk fever ranges from 0% to 10% (DeGaris and Lean, 2008). However, Lean et al. (2006) reported that the mean incidence from a meta-data analysis study was 21% (range 0%–83%). As with previous disorders, there appears to be a disparity between diagnosis and actual incidence of the disease. Again this is partly due to the disorders being acute or sub-acute, and because they often occur with other disorders so it is sometimes difficult to separate them out. For example, milk fever and ketosis often occur at the same time (Hungerford, 1975).

9.3.2 Hypomagnesemia (grass tetany)

Grass tetany is a problem of grazing cattle in the temperate regions of the world (Littledike et al., 1981). It is a complex disorder and is often associated with other metabolic problems (Hungerford, 1975). Although the primary cause of grass tetany is a deficiency of Mg in the blood due to low concentrations of Mg in forage material, other factors which reduce Mg availability also play a role (Littledike et al., 1981). Hypomagnesemia often presents as sudden death without premonitory signs (Arnold and Lehmkuhler, 2014). As with many metabolic disorders the welfare indications associated with hypomagnesemia are intense pain. For example, Hungerford (1975) describes symptoms of peracute grass tetany associated with lactation to include recumbent cattle that thrashed uncontrollably, with a heartbeat audible at up to 2 m away.

9.4 Climate challenges

Climatic, and in particular heat stress, may impose a number of metabolic challenges, via disruptions to feed intake, the immune system, and changes in a number of metabolic pathways including energy, protein, and water metabolism. These changes lead to reduced growth rate, production (e.g., growth rate, milk yield), and impaired reproduction (O'Brien et al. 2010; Gaughan et al. 2010), which on their own are not necessarily welfare issue, unless heat stress is prolonged. To further compound this, heat mitigation such as shades is not a common practice in US beef feedlots, for example. The use of shades and water application (in some conditions) has been shown to reduce the impact of heat load on cattle (Mitlöhner et al. 2002; Kendall et al. 2007; Gaughan et al. 2010; Sullivan et al., 2011). For dairy, cooling of lactation cows using shade and/or sprinklers is common, but not universal. For example, over 82% of all US dairy operations provide some form of shade or shelter from sun, 75.7% use fans and 25% use sprinkles/misters for lactating cows (USDA, 2016b). However, cooling of dry cows and heifers may be insufficient with only 10.7% provided with access to sprinklers/misters, 49.7% with access to fans, and 72.5% with access to shelter (USDA, 2016b). On face value, heat stress appears to invoke challenges that are similar to some of the nutritional disorders outlined above, e.g., reduced feed intake, NEB, and so on. However, Baumgard and Rhoads (2013) suggested that heat stressed animals use novel homeorhetic strategies to direct metabolic and fuel selection priorities independent of nutrient intake or energy balance. These authors went on to state that "the heat stress response markedly alters post absorptive carbohydrate, lipid, and protein metabolism independently of reduced feed intake through coordinated changes in fuel supply and utilization by multiple tissues".

Heat-stressed dairy cows are often hypoglycemic with a 5%–10% decrease in blood glucose. It has been postulated that this is a consequence of increased basal glucose that is stimulated by plasma insulin (Baumgard et al., 2011; Wheelock et al., 2010). Despite displaying a similar glucose response when subjected to an adrenaline challenge, heat-stressed cows subjected to glucose tolerance testing presented a higher glucose clearance rate than pair-fed counterparts housed under thermoneutral conditions. This indicates that heat stress triggers a "conventional" stress response rather than a change in sensitivity of the glucose–insulin-like growth factor (IGF)-I axis to adrenaline per se (Baumgard et al., 2011).

Increased levels of circulating NEFA are expected in animals experiencing reduced feed intake. Interestingly, heat-stressed cows, which voluntarily reduce their feed intake, do not appear to mobilize NEFA (Wheelock et al., 2010; Baumgard et al., 2011). When subjected to an adrenaline challenge, the heat-stressed cows had a 50% lower NEFA response than pair-fed animals which were housed under thermoneutral conditions (Baumgard et al., 2011). With the apparent deficiencies in NEFA mobilization, Wheelock et al. (2010) suggested that glucose is the favored fuel during heat stress, with increased insulin driving increased glucose consumption, and suggested that the suppression of lipid mobilization in the heat-stressed animals is an adaptive response since cold-stressed animals have both increased glucose and NEFA. Baumgard et al. (2007) postulated that the reason for this metabolic adaptation was that a higher heat cost was associated with accessing ATP from NEFAs relative to glucose.

The welfare implications associated with changes in metabolism of dairy cows during heat stress are largely associated with loss of body condition. However, as seen previously, cattle faced with an NEB are susceptible to a number of metabolic disorders. There is a need to better understand the effects of heat stress on metabolic function in cattle.

9.5 Growth-promoting technologies

Hormonal growth promotants act by directly influencing the metabolism of the animal and by modifying the microbial flora of the gastrointestinal tract (Zinn, 1985; Hunter and Vercoe, 1987; Blackman, 1990). Metabolic actions involve the laying down of more protein and fat, more efficient use of protein, and a reduction in the relative proportion of carcass fat (Blackman, 1990). Generally, improvements in performance of 10%–15% are expected. Beta agonists, on the other hand, are repartitioning agents which modify fat and protein metabolism in the animal (Blackman, 1990), resulting in improved weight gains (8–10 kg), improved average daily gain (0.15 g/day), and an improvement in feed efficiency (0.02 gain (kg) per feed intake (kg)) (Beermann, 2002; Scramlin et al., 2010; Brandt et al., 2016). However, there is some evidence that the use of hormonal growth promotants and beta agonists, in particular, may have negative welfare implications for cattle in certain circumstances (Gaughan et al., 2005; Vance, 2013; Centner et al., 2014). These will be discussed in more detail below.

9.5.1 Beta agonists

Zilpaterol hydrochloride and ractopamine are β-adrenergic agonists that are feed to beef cattle (and pigs) at specific dosing regimens to improve weight gain, feed efficiency, and reduce carcass fat (Centner et al., 2014). These compounds work by activation protein synthesis and decreasing protein degradation (Mersmann, 1998). Ractopamine was approved for use in 2000 and zilpaterol was approved in 2006. However, an increased incidence of lameness and mortality associated with the use of β-agonists (specifically zilpaterol) has been reported (Strydom, 2016). A study by Loneragan et al. (2014) determined that cumulative risk and incidence rate of death was 75%–90% greater in animals administered the β-agonists compared to contemporaneous controls. In addition, 40%–50% of feedlot cattle deaths could be associated with the administration of β-agonists (Loneragan et al., 2014). Furthermore lameness at slaughter facilities has also been associated with the use of β-agonists (Thomson et al., 2015). However there is debate as to whether this a direct effect or an effect induced by poor handling of cattle and other factors (Grandin, 2013; Thomson et al., 2015). There are also reports of a negative interaction between zilpaterol and hormonal growth implants. Stackhouse-Lawson et al. (2015) reported that Angus crossbred steers with hormonal growth implants and fed zilpaterol demonstrated more agonistic behavior compared with controls (no implants and no zilpaterol). Because of the perceived welfare implications, zilpaterol was removed from the US market in 2013, but is still being used in a number of countries.

9.5.2 Recombinant bovine somatotropin (rBST)

Recombinant bovine somatotropin (rBST) is a synthetically derived bovine growth hormone (Dohoo et al., 2003) that is administered via injection to dairy cows to increase milk production and improve efficiency of production (Bauman, 2014). Cows are injected 2 months after having their calf and then every 14 days for the next 8 months (FDA, 2017). A number of possible adverse health effects were identified prior to the approval of rBST in 1993. These included an increased risk of adverse reproductive effects, clinical mastitis, foot and leg problems, injection-site reactions, and udder edema (Dohoo et al., 2003). Dohoo et al. (2003) undertook a meta-analysis of 53 papers and reports dealing with the effects of rBST in dairy cows. They reported that there was a 25% increase in the risk of clinical mastitis when cows were being supplemented with rBST, a 40% increased risk of cows failing to conceive, and approximately 55% increase in the risk of lameness. In contrast to the negative health effects there was one study where there was a significant reduction in ketosis and parturient paresis after rBST treatment.

9.5.3 Hormonal growth promotants (HGP)

Hormonal growth promotants (HGPs) are small dissolvable hormonal implants which are placed under the skin in the ear of cattle to improve growth and efficiency. Depending on the productions system, basically how long cattle are in feedlots, cattle will be implanted once or twice. Cattle maintained in rangelands may also be implanted. The majority of the implants have estrogenic, androgenic, or a combination of estrogenic and androgenic activities (Kreikemeier and Mader, 2004). Broadly, estrogenic implants work by increasing thyroid gland activity and stimulate feed intake (Trenkle, 1997) while androgenic compounds decreases maintenance energy requirements (Hunter and Vercoe, 1987). The androgenic compounds work better when combined with estrogenic compounds. A very basic mode of action is that estrogenic compounds increase the number of muscle cells and the androgenic compounds increase the size of the cells. When combined there are more cells and larger cells (Hunter and Davis, 2010).

There are possible metabolic challenges associated with HGP use and heat stress in feedlot cattle (Kreikemeier and Mader 2004; Gaughan et al., 2005). On hot days, the rectal temperatures of cattle implanted with HGPs were 0.62°C higher compared to before implanting. Across all environmental conditions (thermoneutral, hot and cold) rectal temperatures were 0.5°C greater for cattle implanted with an oestrogen based implant (E) compared with those implanted with trenbolone acetate (TBA) or a combination of TBA+E than for TBA or ET cattle (Gaughan et al., 2005). Very little work has been done in this area in regards to metabolic challenges. However, other challenges may occur that could impact on cattle welfare. For example, there is mixed evidence about the likelihood that HGP will increase aggressive interactions among animals (reviewed by Tucker et al., 2015): some implants do, while others have no effect on this response.

Little is known about how cattle experience the increase in growth rate associated with either HGP or β-adrenergic agonists or the higher milk production associated with rBST. More stretching has been anecdotally reported associated with zilpaterol, and steers fed this compound perform more lateral lying (stretched on their side) that controls (Stackhouse-Lawson et al., 2015). Although several studies have examined how cattle respond to increased udder fill, all of this work has been during dry-off or the end of lactation (reviewed by Zobel et al., 2015), not in response to high levels of production alone.

In addition to the welfare implications of higher growth rates or milk production, the mode of delivery may affect welfare. Although beta agonists are fed to cattle, both HGP and rBST are delivered via injection. Although there has been no work evaluating the welfare effects of injections in adult cattle, it is well established as painful in humans (e.g., Taddio et al., 2016). A number of factors may affect the pain experienced including the number of injections given, as well as the properties of the material injected, the speed of the process, needle size and sharpness, the skill of the operator, and the type of restraint used. The location of the injection, as well as the method may also affect the pain experienced. For example, the label for Elanco's Posilac (rBST) recommends subcutaneous injection in the neck, behind the shoulder or in the tailhead depression every 14 days after the 10th week of lactation, possibly resulting in approximately 15 injections before dryoff. The cumulative welfare implications of these types of injections are poorly understood.

9.6 Future trends

Leblanc (2010) stated that prediction and early detection of health problems is an important goal. As the need for individual animal management becomes more and more a focus of animal welfare groups, consumers, and farmers, there will be a concurrent requirement for rapid reliable methodologies to identify susceptible animals. These may be in the form of behavioral changes, changes in feed intake, or the use of metabolic markers to detect problems early and implement preventative strategies. More work is required to further elucidate the effects of growth-promoting technologies on the welfare of cattle.

9.7 Conclusions

Metabolic challenge is multifactorial. Metabolic inputs can increase the overall load by causing disruption to how the animal functions (e.g., acidosis, hypocalcemia, hypomagnesaemia). Metabolic outputs are increased by rapid growth and high milk production, often as a result of genetic selection for optimal performance. Both of these outputs can also be increased further by exogenous production promotants and insufficient provision of heat abatement in the housing system. How animals fares in terms of metabolic challenge, particularly metabolic disease, is intimately connected to how these inputs and outputs are managed by their care givers. The other, nonhealth-related welfare implications of this metabolic balance have received much less attention. Areas ripe for attention include understanding more about the causes and protective factors for morbidity and mortality associated with metabolic challenge, as well as how the affective state of the animals is affected by indirect, nonhealth-related aspects of metabolic load.

References

1. Arnold M, Lehmkuhler J. *Hypomagnesemic Tetany or "Grass Tetany"* Lexington: Agricultural and natural Resources Publication, Cooperative Extension Services, University of Kentucky, College of Agriculture, Food and Environment; 2014.
2. Baumgard LH, Rhoads RP. Effects of heat stress on postabsorptive metabolism and energetics. *Ann Rev Anim Biosci*. 2013;1:311–337.
3. Bauman, D.E., 2014. Facts about recombinant bovine somatotropin (rbST). <www.ansci.cals.cornell.edu/sites/ansci.cals.cornell.edu/files/shared/doc (accessed 01.07.17).
4. Baumgard, L.H., Wheelock, J.B., O'Brien, M., Shwartz, G., Zimbelman, R.B., Sanders, S.R., VanBaale, M.J., Collier, R.J., Rhoads, M.L., Rhoads R.P., 2007. The differential effects of heat stress vs. underfeeding on production and post-absorptive nutrient partitioning. In: 22nd Annual Southwest Nutrition & Management Conference February 22–23, Tempe, Arizona, USA.
5. Baumgard LH, Wheelock JB, Sanders SR, et al. Postabsorptive carbohydrate adaptations to heat stress and monensin supplementation in lactating Holstein cows. *J Dairy Sci.* 2011;94:5620–5633.
6. Bell AW. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. *J Anim Sci.* 1995;73:2804–2819.
7. Beermann DH. Beta-adrenergic receptor agonist modulation of skeletal muscle growth. *J Anim Sci.* 2002;80:E18–E23.
8. Blackman NL. Invited review the role for hormonal growth promotants and other chemical growth regulators in animal production. *Proc Austral Soc Anim Prod.* 1990;18:28–36.
9. Blayney D. *'The changing landscape of U.S milk production. USDA Statistical Bulletin No SB-978* Washington, DC: US Department of Agriculture Economic Research Service; 2002.

10. Brandt Jr RT, Corbin MJ, Quinn MJ. Comparison of the β-agonists Actogain 45 and Optaflexx on finishing steer performance and carcass characteristics. *Prof Anim Sci.* 2016;32:201–204.
11. Bull LS, Bush LJ, Friend JD, Harris B, Jones EW. Incidence of ruminal parakeratosis in calves fed different rations and its relation to volatile fatty acid absorption. *J Dairy Sci.* 1965;48:1459–1466.
12. Capper JL, Cady RA, Bauman DE. The environmental impact of dairy production: 1944 compared with 2007. *J Anim Sci.* 2009;87:2160–2167.
13. Centner TJ, Alvey JC, Stelzleni AM. Beta agonists in livestock feed: Status, health concerns, and international trade. *J Anim Sci.* 2014;92:4234–4240.
14. Champness, D., 2007. Milk fever (hypocalcaemia) in cows: Note number: AG0067. <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/animal-diseases/beef-and-dairy-cows/milk-fever-hypocalcaemia-in-cows> (accessed 16.03.17).
15. Constable PD, Hinchcliffe KW, Done SH, Grünberg W. *Veterinary Medicine.. A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs and Goats*. Vol. 1 11th ed. St. Louis, Missouri, USA: Elsevier; 2017; 2065 pp.
16. Danscher AM, Li S, Andersen PH, Khafipour E, Kristensen NB, Plaizier JC. Indicators of induced subacute ruminal acidosis (SARA) in Danish Holstein cows. *Acta Vet Scand.* 2015;57:39–52 Available from: https://doi.org/10.1186/s13028-015-0128-9.
17. DeGaris PJ, Lean IJ. Milk fever in dairy cows: A review of pathophysiology and control principles. *Vet J.* 2008;176:58–69.
18. Dohoo IR, DesCôteaux L, Leslie K, et al. A meta-analysis review of the effects of recombinant bovine somatotropin 2 Effects on animal health, reproductive performance, and culling. *Can J Vet Res.* 2003;67:252–264.
19. Drackley JK. Biology of dairy cows during the transition period: the final frontier. *J Dairy Sci.* 1999;82:2259–2273.
20. Duffield T. Subclinical ketosis in lactating dairy cattle. *Vet Clin N Am Food Anim Pract.* 2000;16:231–253.
21. Elam, T.E., Preston, R.L., 2004. Fifty years of pharmaceutical technology and its impact on the beef we provide to consumers. <http://www.merck-animal-health-usa.com/binaries/50_Years_of_Technology_and_impact_on_beef_produ

113484.pdf>.
22. Emery RS, Burg N, Brown LD, Blank GN. Detection, occurrence, and prophylactic treatment of borderline ketosis with propylene glycol feeding. *J Dairy Sci.* 1964;47:1074–1079.
23. Enemark JMD. The monitoring, prevention and treatment of sub-acute ruminal acidosis (SARA): a review. *Vet J.* 2009;176:32–43.
24. FDA (US Food & Drug Administration), 2017. Bovine somatotropin (BST) fact sheet. <www.fda.gov/animalveterinary/safetyhealth/productsafetyinformation/u (accessed 04.07.17).
25. Fox JT, Thomson DU, Lindberg NN, Barling K. A comparison of two vaccines to reduce liver abscesses in natural fed cattle. *Bovine Pract*. 2009;43:168–174.
26. Galyean ML, Rivera JD. Nutritionally related disorders affecting feedlot cattle. *Can J Anim Sci.* 2003;83:13–20.
27. Gaughan JB, Kreikemeier WM, Mader TL. Hormonal growth-promotant effects on grain-fed cattle maintained under different environments. *Int J Biometeorol.* 2005;49:396–402.
28. Gaughan JB, Bonner S, Loxton I, Mader TL, Lisle A, Lawrence R. Effect of shade on body temperature and performance of feedlot steers. *J Anim Sci.* 2010;88:4056–4067.
29. Grandin, T., 2013. Temple Grandin explains animal welfare problems with beta-agonists. Beef, September 9 2013. <http://beefmagazine.com/processors/temple-grandin-explains-animal-welfare-problems-beta-agonists> (accessed 22.03.17).
30. Hachenberg S, Weinkauf C, Hiss S, Sauerwein H. Evaluation of classification modes potentially suitable to identify metabolic stress in healthy dairy cows during the peripartal period. *J Anim Sci.* 2007;85:1923–1932.
31. Hungerford TG. *Diseases of Livestock* 8th ed. Sydney, Australia: McGraw-Hill Book Company; 1975; 1318 pp.
32. Hunter RA, Davis BL. *Using Hormone Growth Promotants to Improve Beef Production* Nth Sydney NSW: Meat and Livestock Australia (MLA); 2010.
33. Hunter RA, Vercoe JE. Reduction of energy requirements of steers on low-quality-roughage diets using trenbolone acetate. *Br J Nutr.* 1987;58:477–483.

34. Kendall PE, Verkerk GA, Webster JR, Tucker CB. Sprinklers and shade cool cows and reduce insect-avoidance behaviour in pasture-based dairy systems. *J Dairy Sci.* 2007;90:3671–3680.
35. Kessel S, Stroehl M, Meyer HHD, et al. Individual variability in physiological adaptation to metabolic stress during early lactation in dairy cows kept under equal conditions. *J Anim Sci.* 2008;86:2903–2912.
36. Kreikemeier WM, Mader TL. Effects of growth-promoting agents and season on yearling feedlot heifer performance. *J Anim Sci.* 2004;82:2481–2488.
37. Leblanc S. Monitoring metabolic health of dairy cattle in the transition period. *J Reprod Dev.* 2010;56 S29–S25.
38. Lean IJ, DeGaris PJ, McNeil DM, Block E. Hypocalcemia in dairy cows: Meta analysis and dietary cation anion difference theory revisited. *J Dairy Sci.* 2006;89:669–684.
39. Littledike ET, Young JW, Beitz DC. Common metabolic diseases of cattle: Ketosis, milk fever, grass tetany, and downer cow complex. *J Dairy Sci.* 1981;64:1465–1482.
40. Loneragan GH, Thomson DU, Scott HM. Increased mortality in groups of cattle administered the b-adrenergic agonists ractopamine hydrochloride and zilpaterol hydrochloride. *PLoS ONE.* 2014;9:e91177 http://dx.doi.org/10.1371/journal.pone.0091177.
41. Loor JJ, Elolimy AA, McCann JC. Dietary impacts on rumen microbiota in beef and dairy production. *Anim Front.* 2016;6:22–29.
42. McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA, Wilkinson RG. *Animal Nutrition* seventh ed. London, UK: Prentice Hall; 2011; 697 pp.
43. Mersmann HJ. Overview of the effects of beta-adrenergic receptor agonists on animal growth including mechanisms of action. *J Anim Sci.* 1998;76:160–172.
44. Mitlöhner FM, Galyean ML, McGlone JJ. Shade effects on performance, carcass traits, physiology, and behaviour of heat-stressed feedlot heifers. *J Anim Sci.* 2002;80:2043–2050.
45. Nagaraja TG, Lechtenberg KF. Acidosis in feedlot cattle. *Vet Clin Food Anim.* 2007;23:333–350.
46. Nocek JE. Bovine acidosis: Implications on laminitis. *J Dairy Sci.* 1997;80:1005–1028.

47. O'Brien MD, Rhoads RP, Sanders SR, Duff GC, Baumgard LH. Metabolic adaptations to heat stress in growing cattle. *Domest Anim Endocrinol.* 2010;38:86–94.
48. Oetzel GR, Nordlund KV, Garrett EF. Effect of ruminal pH and stage of lactation on ruminal lactate concentration in dairy cows. *J Dairy Sci.* 1999;82:38.
49. O'Grady L, Doherty ML, Mulligan FJ. Subacute ruminal acidosis (SARA) in grazing Irish dairy cows. *Vet J.* 2008;176:44–49.
50. Owens FN, Secrist DS, Hill WJ, Gill DR. Acidosis in cattle: A review. *J Anim Sci.* 1998;76:275–286.
51. Plaizier JC, Krause DO, Gozho GN, McBride BW. Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences. *Vet J.* 2009;176:21–31.
52. Scramlin SM, Platter WJ, Gomez RA, Choat WT, McKeith FK, Killefer J. Comparative effects of ractopamine hydrochloride and zilpaterol hydrochloride on growth performance, carcass traits, and longissimus tenderness of finishing steers. *J Anim Sci.* 2010;88:1823–1829.
53. Smith RA. Impact of disease on feedlot performance: a review. *J Anim Sci.* 1998;76:272–274.
54. Sordillo LM, Raphael W. Significance of metabolic stress, lipid mobilization, and inflammation on transition cow disorders. *Vet Clin Food Anim Pract.* 2013;29:267–278.
55. Stackhouse-Lawson KR, Tucker CB, Calvo-Lorenzo MS, Mitlöhner FM. Effects of growth promoting technology on feedlot cattle behaviour in the 21 days before slaughter. *Appl Anim Behav Sci.* 2015;162:1–8.
56. Stone WC. Nutritional approaches to minimize subacute ruminal acidosis and laminitis in dairy cattle. *J Dairy Sci.* 2004;87:E13–E26.
57. Strydom PE. Performance-enhancing technologies of beef production. *Anim Front.* 2016;6:22–30.
58. Sullivan ML, Cawdell-Smith J, Mader TL, Gaughan JB. Effects of shade area on performance and welfare of short fed feedlot cattle. *J Anim Sci.* 2011;89:2911–2925.
59. Taddio A, Wong H, Welkovics B, et al. A randomized trial of the effect of vaccine injection speed on acute pain in infants. *Vaccine.* 2016;34:4672–4677.
60. Thirunavukkarasu M, Kathiravan G, Kalaikannan A, Jebarani W. Quantifying economic losses due to milk fever in dairy farms. *Agric*

Econ Res Rev. 2010;23:77–81.
61. Thoefner MB, Pollitt CC, van Eps AW, et al. Acute bovine laminitis: A new Induction model using alimentary oligofructose overload. *J Dairy Sci.* 2004;87:2932–2940.
62. Thomson DU, Loneragan GH, Henningson JN, Ensley S, Bawa B. Description of a novel fatigue syndrome of finished feedlot cattle following transportation. *J Am Vet Med Assoc.* 2015;247:66–72.
63. Trenkle, A., 1997. Mechanisms of action of estrogens and androgens on performance of cattle: Hormonal basis. In: Proceedings Symposium on the Impact of Implants on Performance and Carcass Value of Beef Cattle. Oklahoma Agric. Exp. Stn. Publ. No. P-957. Stillwater, Oklahoma, USA pp. 15–22.
64. Tucker CB, Coetzee JF, Stookey JM, Thomson DU, Grandin T, Schwartzkopf-Genswein KS. Beef cattle welfare in the USA: identification of priorities for future research. *Anim Health Res Rev.* 2015;16:107–124.
65. USDA, 2016a. Overview of the United States cattle industry. <http://usda.mannlib.cornell.edu/usda/current/USCatSup/USCatSup-06-24-2016.pdf> (accessed 12.07.17).
66. USDA. *Dairy 2014–Dairy Cattle Management Practices in the United States 2014* CO: In: USDA-APHIS: VS-CEAH-NAHMS (Ed.). USDA, Fort Collins; 2016b.
67. USDA, 2017. Charts and Maps, Milk: Production per cow by year, US. <https://www.nass.usda.gov/Charts_and_Maps/Milk_Production_and_M (accessed 12.07.17).
68. Vance, A., 2013. Tyson stops buying cattle fed popular beta-agonist. Feedstuffs, August 8, 2013.
69. van Knegsel ATM, van deb Brand H, Dijkstra J, Tamminga S, Bas Kemp B. Review: Effect of dietary energy source on energy balance, production, metabolic disorders and reproduction in lactating dairy cattle. *Reprod Nutr Dev.* 2005;45:665–688.
70. Vickers LA, Weary DM, Veira DM, von Keyserlingk MAG. Feeding a higher forage diet prepartum decreases incidences of subclinical ketosis in transition dairy cows. *J Anim Sci.* 2013;91:886–894.
71. von Keyserlingk MAG, Weary DM. Invited review: feeding behaviour of dairy cattle: measures and applications. *Can J Anim Sci.* 2010;90:303–309.

72. Wheelock JB, Rhoads RP, VanBaale MJ, Sanders SR, Baumgard LH. Effects of heat stress on energetic metabolism in lactating Holstein cows. *J Dairy Sci.* 2010;93:644–655.
73. Zinn RA. *Growth implants in growing-finishing steers: dosage level and implant frequency*. *California Feeders Day Report* El Centro, California: University of California; 1985;4–10.
74. Zobel G, Weary DM, Leslie KE, von Keyserlingk MAG. Invited review: cessation of lactation: effects on animal welfare. *J Dairy Sci.* 2015;98:8263–8277.

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