Beef cattle transportation issues in the United States

D.U. Thomson, DVM, PhD; **J. Eisenbarth**, **J. Simroth**, MS; **D. Frese**, DVM, PhD; **T. Lee**, DVM, MS; **M. Stephens**, MS; **M. Spare**
Department of Diagnostic Medicine and Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506

Abstract

Transportation of cattle is one of the most common practices in the beef industry. This proceedings focuses on some specific opportunities for the beef industry pertaining to transportation. Whether transporting calves for veal production or cull cows for slaughter, fitness for transport must be evaluated by the producer. Cattle haulers need to focus on opportunities to provide a comfortable, safe ride between destinations. Finally, cattlemen and cattlewomen must be prepared to help cattle prepare and recover from transportation to improve cattle health and performance.

Key words: cattle, beef, transportation

Résumé

Le transport du bétail est l'une des pratiques les plus courantes dans l'industrie du bœuf. Ce compte-rendu met l'accent sur des opportunités particulières que l'industrie du bœuf pourrait envisager dans le domaine du transport. Que ce soit le transport de veaux dans le secteur de la production de veaux ou le transport de vaches réformées vers l'abattoir, l'aptitude au transport doit être évaluée par le producteur. Les transporteurs de bétail doivent cibler des opportunités pour rendre le transport entre les destinations le plus confortable et le plus sécuritaire possible. Finalement, les éleveurs de bovins doivent participer à la préparation et la récupération des animaux après transport afin d'améliorer la santé et la performance des bovins.

Bob Veal Transportation to the Packer

Bob veal calves are veal calves that are marketed up to 21 days old or less than 150 lb (68 kg). They make up about 15% of the veal calf market. Recently, there has been a push through the Veal Quality Assurance Program to certify 50% of all domestically produced veal markets as VQA certified.[75] They have also put an emphasis on educating producers on using best practices with bob veal.

In order to avoid non-ambulatory calves at the packing plant, producers and veterinarians should be intimately aware of the Veal Quality Assurance and Dairy Beef Quality Assurance guidelines. Many bob veal condemnations are due to icterus. There is a strong correlation between icterus in bob veal calves and lack of colostrum consumption.[35] For that reason, feeding adequate amounts of colostrum is critical for veal calves.[68] According to the Veal Quality Assurance

manual, 2 to 4 quarts of colostrum within 2 hours of birth and 3 times after, within 18 hours of life, are current best management practices.

Careful handling of calves will prevent stress and reduce the amount of downed calves at the packing plant. Bull calves to be used for bob veal should not be immunized. Calves should not be marketed and/or transported until after 3 days of age and only if they are fit for transport.[75] Stress to the calves occurs when they are taken from a comfortable environment and transported on a trailer to the packing plant. Proper transportation practices for bob veal calves is important to minimize condemnation, as stressful transportation can have an adverse effect on health and meat quality.[37] They should be kept dry and warm during transportation and not overexerted during loading and unloading. When transported at temperatures less than 48° F (8.8° C), calves should have dry bedding for nesting or other means of warmth. Care should be taken to avoid injury, as calves are uncoordinated and usually have not developed herding responses yet.[75]

On May 8th 2015, the US Department of Agriculture's Food Safety and Inspection Service published a proposed regulatory rule that would prohibit non-ambulatory veal calves from entering into the food supply. Current FSIS regulations allow downed calves to be slaughtered if they gain their ability to walk after being rested and warmed. The new proposal would require prompt, humane euthanasia of any downed calves without a rest period. According to FSIS, this proposal seeks to improve treatment of bob veal calves and thus, Human Methods of Slaughter Act compliance.[73]

The American Veal Association[1] (AVA) opposes this proposed rule, and believes that the new rule is "misleading and unnecessary" It is the position of the AVA that calves should be given time to rest and recuperate upon arriving at a packing plant, and that it is inhumane to not allow calves to rest upon arrival at the plant. The AVA contends that the proposed rule will cause condemnation of healthy animals and thus, a loss of meat that is safe for consumption.[1] No actual changes will be made until FSIS issues a final rule after reviewing comments from the public.[73]

Transportation from the Ranch to the Feedlot

Transporting cattle, especially young cattle, can dramatically increase plasma cortisol levels, indicating that cattle have experienced significant stress[16,23] which has profound negative effects on their immune system.[14] Transportation exposes cattle to a variety of physical stressors including

trailer vibrations, noise, exhaust fumes, wind, extreme temperatures, and deprivation of food, water, and rest. In the US, cattle are typically transported a minimum of 2 times in their lives – from the cow-calf/stocker operation to the feedlot and from the feedlot to slaughter. Feeder calves may also be transported from a cow-calf operation to a stocker operation, and yearlings may be transported to auctions or sale barns before arriving at a feedlot. Hence, ensuring that cattle are transported under optimal conditions and careful handling of cattle during loading and unloading will help reduce losses and improve animal welfare.

After unloading at the feedlot, cattle are generally placed in receiving pens and allowed to rest before processing them and moving them to a feeding pen. Cattle should have immediate access to fresh water and good quality hay.[72] At the receiving area in the feedlot, unloading ramps and receiving pens must be in good operating conditions and have non-slippery flooring. Observations in hundreds of facilities indicate that the number 1 facility problem is slippery floors that cause cattle to fall.[34] It is recommended that flooring in processing facilities and sorting pens, if made out of concrete, should be grooved to minimize falls and aid cattle in having a good grip while going through these facilities.

Preconditioning is a management technique developed to reduce economic losses associated with high morbidity and mortality related to acute respiratory disease in highly stressed weaned and transported beef calves.[58] Calves that are properly prepared while on the cow-calf operation prior to transportation to the feedlot tend to experience fewer health-related challenges.[72] Macartney et al[49] indicated that preconditioning calves has positive effects on their health status, which included reduced treatments for bovine respiratory disease (BRD) in the first 28 days after arrival to the feedlot. Bartlett et al[5] report that vaccinating and weaning calves 35 to 45 days prior to transport reduces mortality at the feedlot. Step et al[66] demonstrated that weaning calves 45 d before shipping to the feedlot dramatically reduced BRD morbidity by simply allowing calves to recover from the stress of weaning before transportation.

Mackenzie et al[50] found that both weaning and transport have an effect on calves' immune response, and the combination of early weaning and transport together have the greatest impact on immune responses. Schwartzkopf-Genswein et al[63] reported that preconditioning calves prior to transport resulted in lower cortisol concentrations pre- and post-loading, as well as higher percentages of time feeding and less time standing and milling in their pens immediately after transport compared to non-conditioned calves. The combined effect of conditioning and short-haul transport resulted in lower shrink, higher dry matter intake and average daily gain in the first month after transport. The latter is in accordance with Karren et al[45] and Shipper et al[65] who indicate that preconditioned calves have average daily gains up to 2 times greater than those observed in non-preconditioned calves.

A lack of appropriate water and feed intake prior to and/or during transport leads to dehydration and weight loss in cattle, usually referred to as shrink. Shrink can be defined as the amount of weight that cattle lose from the time they leave their origin to the time they arrive at their destination. Shrink provides a potential measure of transportation stress, and if used as a part of an overall program, it may be a useful tool for veterinarians to help predict the health outcomes in newly arrived calves.[79] Calves that have experienced long hauls have had more time in which to experience fecal, urine, and tissue loss that has been reported to be greatest within the first 5 to 11 hours in transport.[15]

Trips significantly shorter than 24 hours, when made without access to food and water, are capable of producing adverse effects. Warriss et al[77] transported cattle by road for up to 15 hours and demonstrated changes in their blood chemistry that suggested dehydration and disruption of their normal feeding pattern, taking 5 days post-transport for cattle's weight to return to pre-transport levels. Knowles et al[46] indicated that pre-transport body weight was regained by calves within 8 to 16 hours after transport, but their mean weights remained below a non-transported control group for up to 72 hours after transport. Knowles et al[47] also observed a significant weight loss (average of 7% of initial BW) among cattle transported for periods of 14 to 31 hours, even though cattle were allowed a stop for rest and drinking water after 14 hours. An increase in plasma total protein during the journeys was observed, suggesting dehydration. Knowles et al[46,48] also observed dehydration, as evidenced by changes in plasma total protein and albumin, and weight loss among calves transported 19 to 24 hours.

Transport presents several potentially stressful environmental factors for cattle, including extreme temperatures. Extreme heat and extreme cold can both be highly stressful, as can periods with wide swings between daytime and nighttime temperatures.[11] Goldhawk et al[28] reported that cattle loaded in the evening (1700 and 2100 h) during summer experienced more shrink than cattle loaded in the morning (0500 and 0700 h) (11.3 ± 0.5 vs 6.73 ± 0.34% of BW; $P < 0.01$).

The adverse effect of low temperatures during transport is considered an important predisposing factor for BRD.[40] Much greater fluctuations in body temperature have been documented in calves transported during winter than in those transported during summer, indicating that calves were less able to regulate their body temperature when transported during colder weather.[48] Knowles et al[46] also found that weight of calves transported during winter took longer to return to baseline levels after transport than those transported during summer. In addition to a greater and more prolonged reduction in body weight, body temperature was markedly reduced for at least 8 hours after transport, and high levels of plasma total protein and albumin provided evidence of dehydration. This is in accordance with Goldhawk et al[28] who reported that cattle transported during summer experienced more shrink than

cattle transported during winter (11.2 ± 0.5 vs 9.0 ± 0.5% of BW; *P* = 0.03).

Transportation from Feedyard to Packer

Cattle welfare is a high priority for the beef industry.[76] Recently, abnormalities in the mobility of cattle shortly after transportation to abattoirs has gained considerable media attention, with the greatest focus occurring in the fall of 2013.[74] These mobility issues consist of a series of clinical signs and serum biochemistry abnormalities that has become termed Fatigued Cattle Syndrome (FCS).[71] Cattle exhibiting FCS have various clinical signs including tachypnea with abdominal breathing, muscle tremors, stiff gait, and reluctance to move. Cattle with FCS also had elevated serum lactate and CK.[71] These clinical signs and serum biochemical abnormalities observed in affected cattle are similar to those observed in pigs with Fatigued Pig Syndrome (FPS), which was defined about a decade ago.[59] The FPS syndrome has been documented to be caused by multiple additive stressors, which includes animal handling, transportation, metabolic modifiers, environmental conditions, and pre-transportation sorting and preparation. Briefly, FPS is been characterized clinically by vocalization, blotchy skin, reluctance or inability to move, and muscle tremors.[59,61] Swine exhibiting from FPS have greater blood lactate, decreased blood pH, greater CK, and depleted muscle glycogen.[61] Greater serum lactate concentration has been identified as a consistent characteristic of FPS pigs that become reluctant to move or non-ambulatory.[2,59] Research has led to FPS mitigation strategies including management changes, such as improvements in handling, transportation and pre-transportation sorting and exercise.[9,26,59]

The stress of transporting finished cattle is a major consideration in FCS that needs further definition on the potential contribution it has on the incidence of FCS at the abattoir. Transportation and management of cattle to slaughter should take the prevailing environmental conditions into consideration as much as possible. Staging of shipment and arrival times to reduce the time in lairage, maximize efficiency at the plant, and reduce environmental stress on the cattle should be a top priority in managing the transportation, loading, and unloading of cattle. Transportation of cattle during summer months has been shown to increase transportation shrink and needs to be taken into consideration.[70] There is a need for research to be conducted on the management of cattle and design of facilities at the abattoir for further understanding of animal well-being at the packing plant. The beef industry needs to continually improve to ensure that animal well-being is being addressed at every phase of beef production from feedyard to the harvest floor. Investigation into these potential risk factors and mitigation strategies should be pursued to further define the management factors that can increase or decrease the risk for FCS.

Stocking density of cattle transported long distances also needs consideration. Increased stocking density greater that 550 kg/m^2 in trailers decreases the animals ability to stand in preferred orientations, most commonly perpendicular to direction of travel, and may increase incidence rates of loss of balance.[69] Additionally dressed weight has been shown to be reduced by high stocking densities. This reduction can only be partially accounted for by the increased rate of bruising in high-density loading.[19]

Transportation of Cull Cows to the Packer

Cull cows represent 35 to 45% of all cattle slaughtered for beef in the United States.[55] And while the welfare of these animals is generally recognized as "good" during the majority of their lives, it can become severely compromised as they reach their production potential and decline due to disease, anatomical/mechanical disorders, or simply old age.

Cows are considered as "cull" animals when they depart from the herd because of sale, slaughter, or death.[22] In turn, their departure from the farm requires that they be transported in some nature to their next destination, whether that be another farm, an auction barn, or a slaughter facility. Bascom and Young[6] reported that in dairy cows, reproduction, mastitis, decreased yield, udder conformation, and feet/leg problems were the most common reasons that animals were culled from herds. In beef cattle, reproductive failure, feet problems, vaginal and uterine prolapse, cancer eye, lump jaw, and udder conditions were the most common culling reasons reported.[36]

The reasons for culling have a direct effect on the welfare of the animal, and therefore should be considered by producers and veterinarians when culling decisions are made. It must be considered that while the animals are leaving the herd, there may be a long process between their removal from the herd to their final destination, likely a slaughter facility. The transportation process is one in which the welfare of these animals can be severely compromised, especially if they are already suffering from debilitating conditions. The stress of disease, poor conformation, or age, coupled with the stress of being transported for any time/distance, can result in further decline of the animal in to a non-ambulatory state, or even death before or upon arrival to the destination.

Recent research has shown that at slaughter facilities in the United States, up to 8.5% of incoming cull cows are reported to have at least 1 of 10 conditions present, including non-ambulatory state, severe lameness, cancer eye, wound, nervous disorder, malaise, uterine prolapse, pregnancy, udder condition, or poor body condition score.[21] This data indicates that the reasons (problems) for culling cows are not necessarily being dealt with at the farm, but are being passed along to the next facility, whether that be another farm, an auction barn, or a slaughter facility, creating animal welfare problems in multiple areas of the industry.

It is essential that the conditions that determine whether cull cows leave the farm be discussed by the producer and the veterinarian. Animals with conditions such as

those discussed here are not fit for transport to any facility other than a veterinary clinic for evaluation and correction or in cases such as cancer eye and non-ambulatory animals, euthanasia should be performed. If and only if these problems are addressed, corrected, and proper withdrawal times are observed for any drug administered, cull cows can be transported to an auction barn or slaughter facility. Veterinarians must be astute when evaluating these animals, and honest when giving their educated opinions on whether these animals are fit for transport.

With the recent increases in all cattle prices, producers have seen increased income from cull cows as well. It is very easy for one to look the other way, or pass the problem along when culling cows from the herd. As veterinarians, we are not able to police every move our clients make, but with good ethics and sound teaching skills, we can improve this area of the cattle industry and create sound animal welfare practices that consider both the producers' interests and those of the industry as a whole.

Carcass Bruising During Cattle Transport to Slaughter

A carcass bruise is an injury to tissue as a result of an impact from a blunt object and can occur to animals up to the point of exsanguination. Carcass bruising is a source of wastage to a beef carcass, and an indicator of suboptimal animal welfare. Bruising, if severe enough, may deem meat unsatisfactory for its original purpose, devaluing the carcass.

The 2011 National Beef Quality Audit (NBQA)-2011 evaluated 18,000 carcasses and observed 23.0% with bruising; 18.8% with 1 bruise, and 3.4% with 2 bruises, and 0.9% had 3 or more bruises. The location of the bruising occurred down the midline accounting for 50.1%, 21.3% occurred at the rib, 13.8% on the chuck, 7.3% on the round, and 7.5% was located on the flank/plate/brisket.

Bruise location and shape is often associated with the causative agents.[67] Examples of causative agents include handling, use of driving aids, facilities, and cohorts with horns. Barnett et al[4] and Jarvis et al[42] reported use of driving aids was significantly correlated with number of potentially traumatic events during unloading and pre-stunning phases at the abattoir. Driving aids are linked to a parallel red mark that is in a thin line and small mottled bruising. Small mottled bruising can be caused by the use of the end of a driving stick,[78] while bruises thought to be resulting from cohorts with horns are linked to circular shaped bruises.[64] Shaw et al[64] reported bruising trim losses to be almost doubled for horned cattle vs polled cattle (19.4 vs 12.1 lb or 8.8 vs 5.5 kg, respectively). Jarvis et al[43] found that cattle transported farther than 40 miles (64 km) to an abbatoir had significantly more bruising than cattle sourced closer. Further research in this area discovered other sources contributing to carcasses bruising; for example, space allowance on trailers. Cattle stocked at the recommended level of 172 ft² (1·16 m²)/animal, specified by Grandin,[30]

presented significantly less bruising at the abattoir than low and high stocking density groups.[19]

McCausland and Millar[52] suggested handling prior to slaughter has an effect on the prevalence of carcass bruising at time of slaughter. Stressful or inappropriate handling leads to an increase in difficulty of handling.[20] Barnett et al[4] observed cattle subjected to stressful handling procedures were more susceptible to carcass bruising. Grandin[30] observed cattle originating from feedlots with rough handling techniques resulted in increased bruising compared to feedlots with quiet handling techniques (15.5 verses 8.35 % respectively). Another source of bruising has been reported to be from the number of times animals are handled before their final destination, the abattoir. Eldridge et al[18] reported that cattle sold directly to the abattoir had smaller and few bruises than animals sold on a live weight basis. McNally and Warriss[54] observed animals sourced from markets had a bruising prevalence of 7.8%, sourced from a dealer 6.3%, and sourced directly from the farm 4.8%.

Carcass bruising is expensive, because a portion of bruised meat cannot be salvaged for human consumption.[39] McNally and Warriss[54] recorded in a survey that 6.5% of carcasses were bruised severely enough to warrant downgrading or rejection of bruised meat. The results from the NBQA-2011 audit (23.0% bruised) were improved from previous years; 1991, 1995, 2000, and 2005 had bruising rates of 39.2, 48.4, 46.7, and 35.2%, respectively, indicating animal handling and facilities have improved. This type of progress is beneficial for the beef industry, providing evidence that we are continually improving upon our practices and providing a humanly produced animal.

Beef Quality Assurance Master Cattle Transporter Certification and Program

Transportation of cattle in both beef and dairy industries has been demonstrated to play a vital role in the welfare of live animals and the quality of beef produced.[56] In fact, beef cattle typically are transported at least 1 to 5 or more times during their lifetime.[29] Each trip aboard a trailer presents a risk of serious injury or carcass devaluation at the least.[56] Past surveys of loading and unloading at feed yard and abattoir have revealed areas of concern, but have also shown marked improvement as the industry has held itself accountable for the quality of the finished product.[56] However, further improvement is needed.

Beef Quality Assurance, or BQA, is a national program that provides guidelines for beef cattle production with a goal of buttressing/supporting the confidence of consumers across the globe (BQA). Recognizing the important contribution of transportation to the success or failure of each production cycle, BQA has developed a program for transporters to aid the development of excellence among industry partners. Transportation Beef Quality Assurance, or TBQA, thoroughly explores the facets of transporting live animals, and allows

transporters to obtain certification through a 5-module program. The modules are available online and were developed from the checkoff-funded National BQA Guide for Cattle Transporters.[12]

Handling has been declared a major cause of stress in cattle during transport,[13] both on the ground and on the truck. Several factors can affect the level of stress on the cattle during transport and handling, including experience of handler, temperament and condition of cattle, and quality of handling facilities.[31] Therefore, the program begins with a basic description of cattle vision followed by a summary of their flight zone, and how a handler can engage the point of balance to inspire movement.[51] The next guideline addresses moving aids, and discourages the use of electric prods except as last resort. "Persuaders" are the tool encouraged by the checklist, including flags, paddles, and ribbons; however, the handler should understand to combine these with proper movement techniques and avoid using the moving aids as another striking object.

The next portion of the guide is dedicated to the actions of loading and unloading the truck. The checklists encourage planning ahead prior to loading cattle, knowing where and when the cattle are going, and keeping the truck clean between classes and species.[51] Also, the guidelines reaffirm application of good handling techniques to prevent injuries and accidents, because according to American Meat Institute Foundation, guidelines,[32,33] no more than 3% of livestock should slip during unloading. The full guide includes diagrams demonstrating optimal positioning during loading and unloading to encourage quiet, steady animal flow,[51] in order to limit cattle slippage during those situations.

The rest of the manual includes quick reference charts and checklists for traveling during extreme hot or cold weather, and for identifying "unfit" cattle. Loading worksheets and recommended loading distributions are available to help transporters double-check their own figuring and prevent costly animal injuries and even tragic accidents.[51] A section is also dedicated to emergency and/or biosecurity situations, repeating the necessity for a transporter to be prepared for everything. Upon completion of the program, a certified master transporter receives a copy of the manual for reference.

Most industry partners understand the impact that transportation has on the quality of the product, so the encouragement for transporters to participate in the program is widespread. According the "Beef for foodservice professionals" website, the program encourages transporters to step into their role as proponents of excellent animal husbandry.[7] Further, they write that the National Trucking Association urges its members to comply with the guidelines. Further utilization was described in an article featured by the Beef Cattle Institute, which revealed Cargill's transport employees have all completed the online training, becoming the first trucking fleet to do so.[38] With over 22,000 certificates presented for BQA training, and 287 Transportation Master Certificates achieved through the first half of 2015 alone, the program

continues to succeed in promoting excellence through the industry as a whole, and shows no signs of slowing down.

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Improving beef cattle welfare

Tiffany L. Lee, DVM; **Daniel U. Thomson**, DVM, PhD
Beef Cattle Institute, Kansas State University, Manhattan, KS 66506

Abstract

Animal welfare is at the epicenter of values-based and science-based reasoning. A question which must be posed is "Do scientific professionals consider animal welfare an established scientific field?" In many areas of animal production and research, the answer is a resounding yes. However, it must be established in all areas of science involving animals, and it must be maintained as a scientific field. To do so, we must be able to show that animal welfare can be measured and assessed using both subjective and objective measures. Animal welfare can be measured on a day-to-day basis by the producers and veterinarian who work directly with the animals, using outcome-based measures. When outcome-based measures are used, we can assess why certain management practices are put into place, and what impact those practices are making on production and welfare. According to the OIE (2008), the criteria for measurement of animal welfare include cattle behavior, morbidity rates, mortality rates, changes in weight and body condition, reproductive efficiency, physical appearance, handling responses, and complications due to routine procedure management. By using these and other outcome-based measures, animal welfare will become an established scientific field in which observations can be measured and recorded so that management changes and improvements can be implemented to maintain and improve welfare on production units.

Key words: cattle, beef, animal welfare

Résumé

Le bien-être animal est au centre du raisonnement fondé sur les valeurs et sur la science. Une question se doit d'être posée : Est-ce que les scientifiques professionnels considèrent le bien-être animal comme un domaine scientifique bien établi? Dans plusieurs domaines de recherche et de production animale, la réponse est certainement oui. Toutefois, le bien-être animal doit être reconnu dans tous les domaines scientifiques impliquant des animaux et il doit rester établi comme un domaine scientifique. Pour ce faire, nous nous devons de montrer que le bien-être animal peut être mesuré et évalué à l'aide de mesures toutes aussi bien subjectives qu'objectives. Le bien-être animal peut se mesurer au jour le jour par les producteurs et par le vétérinaire qui travaille directement avec les animaux en utilisant des mesures axées sur les résultats. En utilisant de telles mesures, il est possible d'évaluer pourquoi certaines formes de gestion sont mises en place et leur impact sur la production et le bien-être. Selon l'OMS (2008), les critères suivants sont disponibles pour mesurer le bien-être animal : le comportement du bétail, le taux de morbidité, le taux de mortalité, le changement de poids et de l'indice corporel, le succès de reproduction, l'apparence physique, les réactions à la manipulation et les complications causées par des procédures courantes de gestion. En utilisant ces mesures et d'autres mesures axées sur les résultats, le bien-être animal deviendra un domaine scientifique établi dans lequel les observations sont mesurées et enregistrées permettant ainsi des changements ou une amélioration de la gestion pour le maintien ou l'amélioration du bien-être dans les unités de production.

Introduction

More and more, scientific fields are becoming more like battlefields. It is a constant fight between science-based thinking and values-based reasoning.[1] And the field of animal welfare is at the epicenter of it all.

The first question we must ask ourselves as veterinarians and scientists is "Do we as professionals consider animal welfare to be an established scientific field?" Reason being that there are a number of people, some likely even in this group, who do not consider the welfare of animals to be a science, but rather a values-based issue. We have animal welfare specialists, and behaviorists, but do people *really* consider animal welfare a *science*? For example, many animal science departments around the country have only 1 or 2 classes which even address the issue of animal welfare, and in such classes, the issue could be lumped with other contemporary issues such as genetically modified organism (GMO) consumption and use of vaccines and antibiotics. And how many veterinary schools offer a course in animal welfare—we're supposed to be the welfare specialists!

Now, the great thing is that we're making progress. As veterinarians, we can now become board-certified in animal welfare. In addition, a number of universities are moving toward a more scientific take on animal welfare, and offering classes specific to the topic, and offering graduate programs focused on the subject. The number of meetings and conferences on the topic of animal welfare has skyrocketed in the last 10 to 15 years. Hundreds, possibly thousands, of studies, both observational and experimental, have been performed, and papers published showing ways to measure, assess, and improve animal welfare using management practices and other strategies. At the Beef Cattle Institute, many studies in which the sole objective was to measure or assess animal welfare or to gauge how well certain practices improve welfare have been performed. The topic is definitely being

discussed. However, we may still have a long way to go to get the skeptics of the scientific world to accept animal welfare as an established scientific field. We must keep going.[1] We must show the skeptics that we are able to measure animal welfare in a scientific manner and implement strategies for improvement, thereby making the field a legitimate science in the eyes of *everyone*, including academic professionals, students, and consumers.

The process has already been started for us. First and foremost, we must be able to show that animal welfare can be measured and assessed, using both subjective *and* objective measures. There are a number of assessments and audits currently used to evaluate animal welfare on beef production units, but we propose that animal welfare can also be measured on a day-to-day basis, by the producers and veterinarians who work directly with the animals, using outcome based measures. Outcome-based measures must be measureable and attainable, and are essential in the measurement and management of animal welfare in beef cattle. When we measure animal welfare on an outcome basis, we can assess why certain management practices are put into place, and what kind of impact those practices are having. They show producers and veterinarians the positive changes that occur due to management practices associated with good animal welfare.

According to the World Organization for Animal Health (OIE), the criteria for measurement of animal welfare include cattle behavior, morbidity rates, mortality rates, changes in weight and body condition, reproductive efficiency, physical appearance, handling responses, and complications due to routine procedure management.[2] Measures of these categories are tracked by both producers and veterinarians on a daily basis, as they are typically-measured animal health and production outcomes. By keeping track of specific outcome measures for each of these categories, recommendations can be made and management practices put in place to improve cattle welfare on beef production facilities.

Feeding and social behavior can be observed and recorded to implement management practices to improve animal welfare. Producers and veterinarians have a clear understanding of animals' behavior under various environmental conditions, and are therefore well-equipped to assess behavior with the use of outcome-based measures. In addition, cattle health is an important aspect of animal welfare. Morbidity and mortality rates serve as important direct outcome measures when assessing animal welfare.

Body condition is also a very good indicator of animal welfare in beef cattle. The use of a scoring system, while subjective, is the most practical method of assessing body condition, and can be used by a wide variety of assessors. Body condition has a huge impact on reproductive efficiency, which is also an important area in which to use outcome-based measures to determine animal welfare status. Poor reproductive efficiency, including anestrus or increased time between reproductive cycles, can be an indicator of disease or decreased nutritional status or problems with management programs, which can contribute to poor animal welfare. Body condition is also important when evaluating physical appearance of animals, along with hydration status, coat condition, and the presence of ectoparasites, all of which can be used as outcome-based measures in the assessment of animal welfare in cattle. Handling responses are also fantastic measures of animal welfare. Outcome-based measures that can show the status of animal welfare during handling include use of electric prods, the number of cattle slipping and falling in facilities, and even production-based measures such as feed intake and reproductive responses. Finally, outcome-based measures such as feed intake and pain responses can be used to assess animal welfare in regards to routine procedure management. Animal welfare is of utmost importance when evaluating the effects of painful procedures such as castration and dehorning, and outcome-based measures can provide evidence for the improvement of animal welfare during and after such practices.

By using these and other outcome-based measures discussed here, the concept of animal welfare becomes more than just a concept—it becomes an established scientific field in which observations can be measured and recorded in order to make management changes and improvements to constantly increase animal welfare. By using such measures, we as an industry are able to demonstrate that improvement of animal welfare can be assessed in a scientific manner, while also keeping in mind the values of both producers and consumers.

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People challenges and what can be done to overcome them

Matt Buyers
7645 Bison Bluff St., Loveland, CO 80538

Abstract

A targeted and practical overview of the tactics that can be employed to resolve common interpersonal challenges found in the livestock production industry is presented. A call to action for those seeking to help their clients improve their businesses.

Key words: livestock, personnel, leadership

Résumé

On présente ici un aperçu pratique et ciblé des tactiques qui peuvent être utilisées pour résoudre les problèmes interpersonnels courants dans l'industrie de la production du bétail. C'est un appel à l'action pour ceux qui cherchent à aider leurs clients à améliorer leurs entreprises.

Background

I want to start by giving you a little bit of background as to how I got to be here with you today. When I was originally asked to speak to this group, I was given the following guidance as to what my topic should be about:

- The leadership of this association thinks that veterinarians are not approaching the animal welfare topic as aggressively as they should be.
- This holds especially true on the dairy side.
- There are a lot of people watching abuse videos and hoping that one is never filmed on one of their dairies.
- It is known that the animal rights groups are staging some of these videos.
- The public is becoming wary, but is not in full belief yet.
- We would like to stir up the thought process that we can be more involved as veterinarians.
- We looked back at when Beef Quality Assurance (BQA) started and veterinarians were initially opposed to it.
- In that instance, it actually took the producers to influence the veterinarians to act differently.
- Change is hard.
- You can change it yourself or have it changed for you (examples exist in poultry and hogs).

I asked more specifically what I was supposed to do about this situation and I received the following guidance:

- We do not want to tell you what to talk about.
- We think that developing the leadership skills of veterinarians is good.
- Your topic does not have to be tied to animal welfare.
- Topics including accountability, "science vs the consumer vs public perception," and being proactive to make change as opposed to being told what to change would all be good to cover.
- There will be about 300 people in the group so it will be more like a lecture than anything.
- It is okay for you to use some guinea pigs.

Here is what I took away from all of this:

- Do whatever you want.

So this worked out perfectly for me since my style is to do and say whatever I want anyway. Let this be disclaimer number 1. These are my thoughts and opinions only and not those of my employer.

Disclaimer 2 is this: I will consider it a victory if any of you leave this presentation angry, upset, mad, or with hurt feelings. It's not personal, that's just the effect I oftentimes have on others and I have found that if I can get people emotional, I can get them to take action.

My third disclaimer is that my approach to problem solving is pretty simple: 1) identify the problem, 2) identify possible solutions, 3) implement solutions, 4) measure results, 5) repeat as necessary. Why is this a disclaimer? Because in 90 minutes, the best I can do is work on items 1 and 2. Someone else will have to work on 3 through 5. Sorry.

My final disclaimer revolves around my qualifications to be here speaking in front of you today. The truth is that only my experience and my perspective qualify me. That's about all that I bring to the table. I'm not an academic nor am I an author, so if you feel the need to argue with me from an academic perspective, the odds are that either I will agree with your argument or I will disagree with it, thus making the argument pointless, so let's just forego the arguments altogether, shall we?

Now that we have all of that out of the way, here's the approach I took in getting started.

Method

I wanted to make my topic as relevant as I could, so I started by getting some feedback from a small sample of the membership. Twenty-two people completed a survey. They were asked the following questions:

1. What are the most significant people challenges or issues that you and/or your clients face today?
2. Considering your answers to question 1, tell me whether or not you think these challenges or issues will improve or worsen during the next 5 years. Why do you think what you think?
3. What are your most important PERSONAL leadership challenges?
4. What impact (if any) do these people challenges or issues and/or your PERSONAL leadership challenges have on your ability to ensure that the animals entrusted to your care are treated humanely?
5. In what year were you born?
6. If you were born in 1955 or earlier, answer this question: Do you have a succession plan? If so, have you or are you acting on it? What key steps must you take in the next 12 months?
7. What are your personal expectations for newly minted DVMs and technical work staff entering the workforce?

My hope was that the answers to these questions would lead me to developing relevant content for my remarks today. I discovered that items 3, 5, 6, and 7 were either not very relevant or not distinct, so I won't spend any time on those items. As for items 1, 2, and 4, item 1 generated the most interest and items 2 and 4 gave us a bit more insight into item 1. So as I present to you today, we will look at items 2 and 4 first and then we will dive into item 1 in greater depth. Look for any proposed solutions to be presented as "Helpful Tips" throughout the presentation today. I call these "Helpful Tips" for a reason. You are not obligated to follow any of them. They are meant to be helpful, but if you choose not to follow them, they will offer you no help.

Survey Item 2: The Forecast For The Future
- Fifteen respondents indicated that the problems and challenges identified (though not yet discussed) will either stay the same or get worse
- There were 7 hopeful people in the group who said things would improve and here is why they thought that (in summary):
  - As dairies realize the importance of employee training and as dairy size continues to grow, then the dairy will hire an employee that is in charge of employee training. This way the training will be completed. HR person – in charge of hiring employees and employee training and workmen's comp. This is becoming a full-time position and the dairy owner realizes this. Not everyone, but I see a trend in dairies having a full-time employee with this job description.
  - I believe they will improve as the industry and profession improve their training efforts and reduce the number of bad actors, which can be portrayed to the public.

- I think they will improve because we are working to diagnose our human resource problems and make an effort to resolve them.
- The primary reason I think they will improve is because I am being allowed to have more authority on hiring decisions and I have found that good people attract more good people - and I believe that since I have been able to have more impact on finding good people, there has been a steady attitude improvement.

Let me provide you with my interpretation of all of this in the form of a mission statement:

"Our ability to solve our people problems rests entirely on the shoulders of the human resources department."

Now, I have never personally seen this mission statement hanging on a wall anywhere, nor would I ever hope to. As a longtime corporate guy and former human resources professional, let me be clear when I tell you that if you are waiting on HR to fix something, you're backing up.

Helpful Tip #1: Leaders create culture and culture creates results

Find a great organization and you are likely to find a great human resources function, but you will also find great leaders. Do not confuse who created what. Great leaders run great organizations and they align the systems and processes within the organization to create great results. HR is part of this machine, but it is not the engine. The leader is the engine.

Helpful Tip #2: People are more likely to follow leaders than they are to follow policies

Do not abdicate leadership and don't let your clients do it either. Depend on HR for help, but not for leadership. Improvement will come from leadership. I promise.

Survey Item 4: The Impact People Have on Animal Care
When asked about the impact that the people challenges will have on animal care, survey respondents indicated as follows:
- Five respondents indicated that people challenges are neutral (no linkage to animal care)
- Nine respondents indicated that people challenges are somewhat negative from the standpoint that the challenges prevent them from making improvements in animal care
- Only 2 respondents indicated that the impact is negative
- One respondent indicated "not my job"
- The balance did not respond
- Here are some select comments to give you more insight into the issue:
  - If management is only focused on profit and the time clock, animal welfare will always come

second...when that is the mindset of the farm you can't change the culture of care...if the management isn't actually working with animals day to day, they don't see what can go wrong or right, nor do they remember the frustrations that came with working with 1,800 pound animals who never learned how to read a clock.

- Where do you draw the line between bad management decisions and mistreatment, and then when does mistreatment become abuse?
- It is more difficult on smaller farms to deal with animal welfare issues because the owner is the person who is often responsible for the welfare problem. If one sees a welfare issue from an employee the manager/owner can be approached. If I see an issue on a small farm I need to confront the person committing the problem (example - poor animal handling, lameness problems, etc.). It is sometimes difficult to convince an owner of the problem therefore fixing it can be difficult. Unfortunately, the worse the situation is, the harder it is to approach the owner and convince them to fix the problem.

How can one interpret this? People will do what is modeled over what is expected. They will choose to do what is expected or demanded only when there is legitimate accountability or enforcement involved. It is indeed possible to expect proper care for animals from people if and when the leadership of the organization models care. In some way, this is about inspecting what you expect.

**Helpful Tip #3: Remember the phrase "Tone At The Top"**

The top leader in the organization sets the tone by his or her actions. This is what I referred to as modeling. Very simply, this looks like, "let me show you." If you encounter an animal welfare issue, certainly talk to the offender, but be sure you are having the conversation to properly set the tone at the top as well.

Survey Item 1: The most significant people challenges or issues that we face today
There were several themes present in the responses. Here are the ones we are not going to discuss today:
- Price fluctuations
- Cash flow
- Immigration reform
Why am I ignoring these? Mostly because…
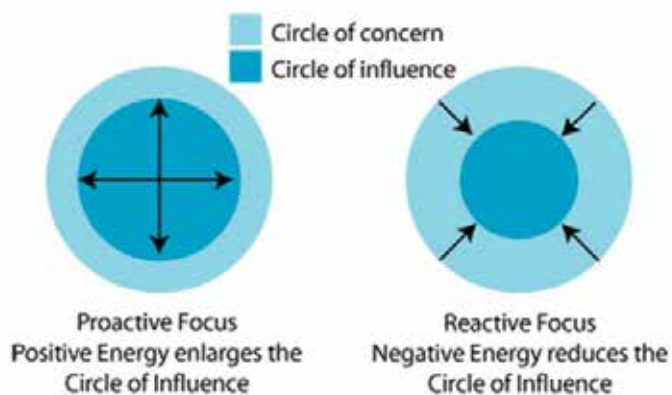
Source: Stephen R. Covey, *The 7 Habits of Highly Effective People*

We are going to spend our time talking about problems we can solve. I know for certain that we can't reform US immigration policy and I am reasonably confident that if we start talking about prices and cash flow, we will end up talking about economics and risk management and we just don't have time for that right now.

So, the key themes that we can do something about included:
- Finding and retaining quality people with some level of knowledge
- A topic that I now lovingly refer to as: "communication and language/cultural diversity" (I inserted the word "diversity" but the word I think was most frequently used in the responses was "barriers")
- Change
- Leadership, management, and accountability
- Maintaining touch with a society that is far removed from agriculture

So we are going to take these items 1 by 1 and see what we can do about them.

Finding and retaining quality people with some level of knowledge
Let's start by developing a baseline understanding of the underlying process involved in talent acquisition and retention. There are a few key items that are relevant to the process. We need to:
1. Have a clear understanding of the position we are trying to fill
2. Have a clear picture of the person we want to hire, which must include the required skills and abilities as well as the desired behavioral traits
3. Create a compelling reason why someone would choose to come work at our operation
4. Have a process by which we are going to onboard someone into our organization
5. Have a means to define, measure, and reward success
6. Have a mechanism for delivering and receiving routine and frequent feedback

These are just the guts of the process, but they are sufficient for our purposes today.

The position. In my days as a recruiter, it was quite common to get phone calls from an employer needing to find someone. Upon further investigation, I could quickly learn that there was no position description, no understanding of what it would take to have a person fit within the organization, and no understanding of what success would look like for the employee. I refer to this as the, "I'll know 'em when I see 'em" approach to hiring. For the record, the results are routinely disastrous.

At a minimum, we need to be able to clearly and concisely describe the position to a potential employee. They need to know what they can expect when they come to work at our operation. This would encompass everything from tasks, required training, work schedules, pay dates, benefits, and so on. We are trying to not only communicate what is expected, but we are also establishing the means by which we can measure their success once we get them hired. If you or your client do not have this type of a comprehensive written document, then failure is occurring.

Who are we looking for? This is a great question that needs an answer before you begin the search. When we go to hire someone, we often look for a direct replacement. Someone with the same experience and knowledge as the person we may be replacing. But let's keep it real for a moment. Are we looking for someone that actually exists or do we need to dial back our requirements? In other words, is the desired skillset even available in the workforce? How much training are we willing to give? Is it better to hire values and train competence or hire experience and hope that the employee does not stir up too much crap after they get onboard? These are a few of the questions we can ask to help ourselves or our clients get on the right track.

Many of you responded that it is a challenge to find knowledgeable and hardworking people to work with livestock. Are we looking for unicorns? Leprechauns? Fairies? I don't think so. We already know these people and we work with them on a daily basis. So they do exist, but are we doing what we must in order to attract them into our industry?

Helpful Tip #4: Develop Your POOLE

1. Purpose. If yours is to make money, that is great and as a capitalist myself, I applaud you. It's just not different and not compelling to me or to a lot of people. Figure out why you do what you do and communicate it. People care about this more than you think.
2. Organization. The company culture, the team, your processes, your approach, all the things that set you apart from your competitors. Define them and communicate them.
3. Opportunity. This is about the candidate. What do you have to offer them right now and into the future in terms of opportunity? Many people have an inherent desire to grow and develop. How can you communicate to a candidate that this opportunity exists for them?
4. Leader. This is your opportunity as the leader to talk about what you like, how you approach things, what makes you happy, mad, and so on. They need to know. Better to find out if there is a fit up front than to learn it later.
5. Everything else. This includes compensation, benefits, work schedule, and about everything else that can be of benefit for the candidate to know in order to choose you as an employer over another employer.

Most employers spend way too much time on item 5 and not nearly enough time on the other items. It is my view that if a leader will spend sufficient time understanding and explaining these areas, they will first learn where their shortcomings are and then they will learn how to create a compelling message that will attract top talent into their organization. If that is indeed the goal, then the good news is that we can do something about it using a very simple methodology, but just in case you are not convinced that this is necessary, let me show you some data that may help you change your mind:

http://www.google.com/publicdata/explore?ds=z1 ebjpgk2654c1_&ctype=l&strail=false&bcs=d&nselm=h& met_y=unemployment_rate&fdim_y=seasonality:U&scale_ y=lin&ind_y=false&rdim=country&idim=country:US&idi m=county:CN0812300000000:CN2006700000000:CN16 04700000000:CN4820500000000&ifdim=country&tsta rt=1362034800000&tend=1427608800000&ind=false

These are unemployment statistics for some cattle (beef and dairy) producing counties scattered throughout the Plains states. It's just a sample and no county was included or excluded for discriminatory purposes. I use this only as a means to illustrate why employers may need to differentiate themselves from their competition.

Just look at the unemployment rate in Hartley County, Texas. If you are trying to hire someone to work for you in that county, you can bet that the applicant pool will be quite thin. If by some miracle you are able to get a good applicant to walk through your door and you offer them the same everything as the guy next door, why will that applicant choose you over your neighbor? If he or she does, my bet is that they are a felon. More importantly, what must you do in order to attract that fantastic employee who is doing a great job at your competitor's place of business to come to work for you? Be different in order to be better.

In short, to hire the best employees, one must think about where they are first and what it would take to get them to work for you over someone else. A few things to think about:

- I'll say it again and maybe for the last time. KNOW YOUR PURPOSE.
- The leader matters. A lot. Think about it like this... what kind of person enjoys working for an a--hole? An a--hole does!
- Compensation, benefits, and work schedules matter. Remember, with low unemployment, people have choices. Figure out what you need to do to make them choose you or your client.
- There is a cost to having a poor performing person on the team. There is also a cost to having a vacancy on the team. Figure out the costs and use them to justify change in your organization or in your client's.

Here is a little story for you. I was working with a feed-lot operator who was looking for a cattle manager for their 80,000 head feedyard. The position had been vacant for 12 months. When I asked them what they wanted to pay to fill the spot, they told me, "No more than $65,000." I asked them a simple question, "If I could bring you an absolute superstar, would you consider paying them $85,000." Their response was predictable, "Absolutely not!"

I followed up by asking them what their fat cattle were worth. They didn't want to part with the exact figure, but for the sake of our discussion, we agreed to a value of a dead animal as $2,000. I asked the manager if he thought that a superstar cattle manager could save him 4 head of cattle per month just by being on top of things. He told me, "Well, he better." So with this in mind, we did some quick math... This person could save 48 cattle per year at an agreed-to cost of $2,000 per head, which works out to about $96,000 per year in savings, but we would not be willing to pay an additional $20,000 to get this value?

Helpful Tip #5: Do the math. Make the case. Pay the money.

Onboarding. There is probably not anything more critical during the beginning of an employee's employment than how they come on board. This is like a first date. You've had good ones and you've had bad ones. Most of you only needed 1 bad first date to get the picture... RUN! Each organization is going to have a different onboarding process. Of key importance are:
- Establishing the working relationship between employee, leader, and team
- Outlining expectations and means for giving and receiving performance feedback (more on this in a minute)
- Training to ensure that the way the employee will begin performing tasks is aligned with the way the company and leaders want to see tasks performed

All too often these items are taken for granted and this is a critical error. Assume nothing. Ensure everything.

Defining, measuring, and rewarding success. This one is fairly simple. If you have no expectations, they will most certainly be met. One of my favorite Stephen Covey quotes goes something like this, "Every organization is perfectly aligned to achieve the results it gets."

In order to be successful, one must first define what success will look like. In about a month from now, I will be competing in Iron Man 70.3 in Tempe, AZ. That's a 1.2-mile swim, a 56-mile bike ride, and a 13.1-mile run. I have been training for this race since April. My definition for success in this event is a 30-minute swim, 3 hours on the bike, 2 hours on the run, and 5 minutes in transitions. This adds up to a total time of 5 hours 35 minutes. I know what I want to achieve and I have a daily plan that I work from to achieve success. If I stick to my plan, success is predictable, though not necessarily easy.

On my refrigerator door is the training schedule laid out by day. I highlight sessions completed, make notes, track my activity using an assortment of apps on my iPhone, and so on. I am measuring my activity to ensure achievement of the goal. The point is this: the more I focus on executing my daily plan, the more likely I am to achieve my long-term goal. It should be no different in the work place. Success comes by:

Helpful Tip #6: Set goals, act on them, measure results, be accountable

- Knowing and taking measurement of the most important things that an employee or team needs to achieve within a given timeframe. This must be focused, so never more than 3 goals at a time and remember, these are the things that we must achieve in order to win. These are improvement-oriented and time-bound. Think of these goals as "improving from x to y by this date."
- Taking daily action on those things that will have the greatest impact on successful achievement of the goal. Frankly, these are bets you are going to take. You are trying to determine those 80/20 activities that you are going to work on that will help you achieve those top priorities. Completing these activities or tasks should have the greatest impact on achieving your important goals. That is the bet.
- Measuring achievement of both the actions and the larger goals so that a person knows if they are winning or losing at a glance. This is a scoreboard that is regularly and continuously updated.
- Establishing some mechanism to ensure accountability – very simply, did the employee do what they needed to do today? This must be done with routine frequency. Weekly is a minimum. If something is important, we study it and discuss it. If it's not, we ignore it. Do not ignore the need to achieve top priorities.

Feedback. As I outlined the necessary steps, I indicated that feedback goes both ways: from boss to employee and from employee to boss. This is critical. Why? Because it looks

a heckuva lot like a relationship, which is what is required for retention. Successful employees feel a part of the organization. They need to know where they stand and the environment needs to be safe, comfortable, and open.

Communication and Language/Cultural Diversity

Merriam-Webster defines barriers as follows: "A law, rule, or problem, etc. that makes something difficult or impossible."

Let me just point out that I think I understand this problem already. The problem is that we view this as a problem. A barrier. Cultural diversity and language differences are FACTS. They just are.

Helpful Tip #7: I don't care if you learn Spanish or if you teach your employees to read and write English or if you do both. I can promise you that leaving this type of a barrier in place is just ignorant.

My 2 best friends in this world are a 30-something South African and a 20-something Asian-Hawaiian. How much do you think we had in common in our first meeting? You know how I got to learn more about these 2 people? From talking to them and listening to them. The thing we did have in common was our language. We could communicate with one another. I will put it to you this way. If you can communicate with someone, you can learn about them. If you can learn about them, you can ask them questions and understand their background, biases, perspectives, and more. If you can do those things, the cultural barriers will vanish. 'Nuff said.

Change

As I went through the survey responses, I recognized that a number of you have been personality profiled. Although the profile was not named, it looked like maybe Insights or DISC had been something many of you may have been exposed to in the past. Why is this relevant? Because this next part is going to potentially upset some of you.

In more than 1 response, I read this, "Due to my innate hard-wiring, I am unable to conduct myself in such a way that will make things better with my clients." Okay, those may not have been the exact words that were used, but that was the message.

You know how you are hard-wired and you are using that hard-wiring as an excuse to not do the things that you need to be doing. Guess what? I am an introvert and yet I am right here in front of you all. Yes, this is sucking the energy from my body and in less than an hour I will be completely exhausted, but I am here. My hard-wiring never prevents me from doing what needs to be done. That is a choice that I can make any day and anytime.

Similarly, we want people we work with to change their behavior or hard-wiring even though we refuse to change the same things in ourselves? I don't get it.

Helpful Tip #8: If you recognize your own shortcomings, make corrections. If you recognize shortcomings in others, help them make corrections.

Resisting Change. For God's sake, who doesn't resist change? I suspect that everyone in this room resists change when it is being done to us. What makes your clients any different? If you want people to embrace change, there has to be a compelling reason to make the change. There are countless examples I could use that would demonstrate how this model works... the smoker who chooses to smoke every day up until they receive their lung cancer diagnosis, the obese person who does not eat right or exercise right up until they have a quadruple bypass, the dairy who mishandles cattle every day until someone shows up with a video camera and exposes their practices. This list could be exhaustive.

Helpful Tip #9: Think about change in this context and think about how you can create that "burning platform" for change with your clients. What are their emotional triggers and how can you trip them? What are yours and how can they be tripped?

We do what we do as people because we've always done it that way, right? Everything from our work schedules, to our pay practices, to our training regimens, and so on. We do what we do because we've always done it that way. But is it effective? Are we getting the results we are capable of getting? Note that I did not say, "Are we getting the results that we desire?" I think we are quite capable of lowering our expectations with little help, but what about raising the standard to excellence? What would that look like and what would we be willing to do in order to achieve it?

Leadership, Management, and Accountability

So what do you need to know about leadership, management, and accountability that can help you in your practices?

Let's start with the basics. At its essence, leadership is influence. That's pretty much it. How can I get someone to do what needs to be done but have it be his or her idea? Let's put this in the context of people. In an organization, either people matter or they don't. Really. You can't fake it. If your people don't matter to you, they probably already know. If your client's people don't matter to them, their people already know. In either of these situations, you are left with a couple of options:

1. Recognize the fact that people don't matter and adapt, (in other words, suck it up) OR
2. Change your own thinking (if you are the problem) or influence your client to think differently

If you are an analytical type who needs to see, touch, and feel the facts before making a decision, DO NOT assume that your client works the same way. Since many of you know how you are wired are you equally as aware of how your people or

clients are wired? Are you making the connections between what they need to know and what they actually know? This is influence in its simplest form.

I need to understand the motivation of the person I am trying to lead or influence. What makes them tick? What do I need to do in order to get them to see things differently? I know that many people don't see this as easy, but it is. The problem is that it requires us to learn. To converse, to ask questions, to understand. Most of the time our lips will not be moving when we do this and this is also hard.

Helpful Tip #10: If you want to lead or influence, listen first.

By listening, you will collect the data you need in order to understand how to influence your follower, client, owner, etc.

Since leadership is about people, management is about things and processes. The 4-step model given earlier about goals, actions, measurement, and accountability will get you where you want to be. I promise. I also promise that it doesn't work at all if you don't do it.

So the last aspect of this part of our discussion is accountability. This one is scary to a lot of people as was evidenced in the survey responses. "The Difficult Conversation" as it is often referred to is what people work hard to avoid. More on that in a minute, but let me first convince you as to why accountability is not scary. Because it is quite simply nothing more than asking why something did or did not get done. Nothing more. I have no plans to yell, berate, belittle, or otherwise demean the person I am helping to be accountable. I am only asking them questions to understand if any gaps in their performance exist and if they do how I can help them alleviate those gaps. I can do this with an owner, a CEO, a middle manager, and even my wife. I will be more successful if I stick to a certain playbook, which I will share right now.
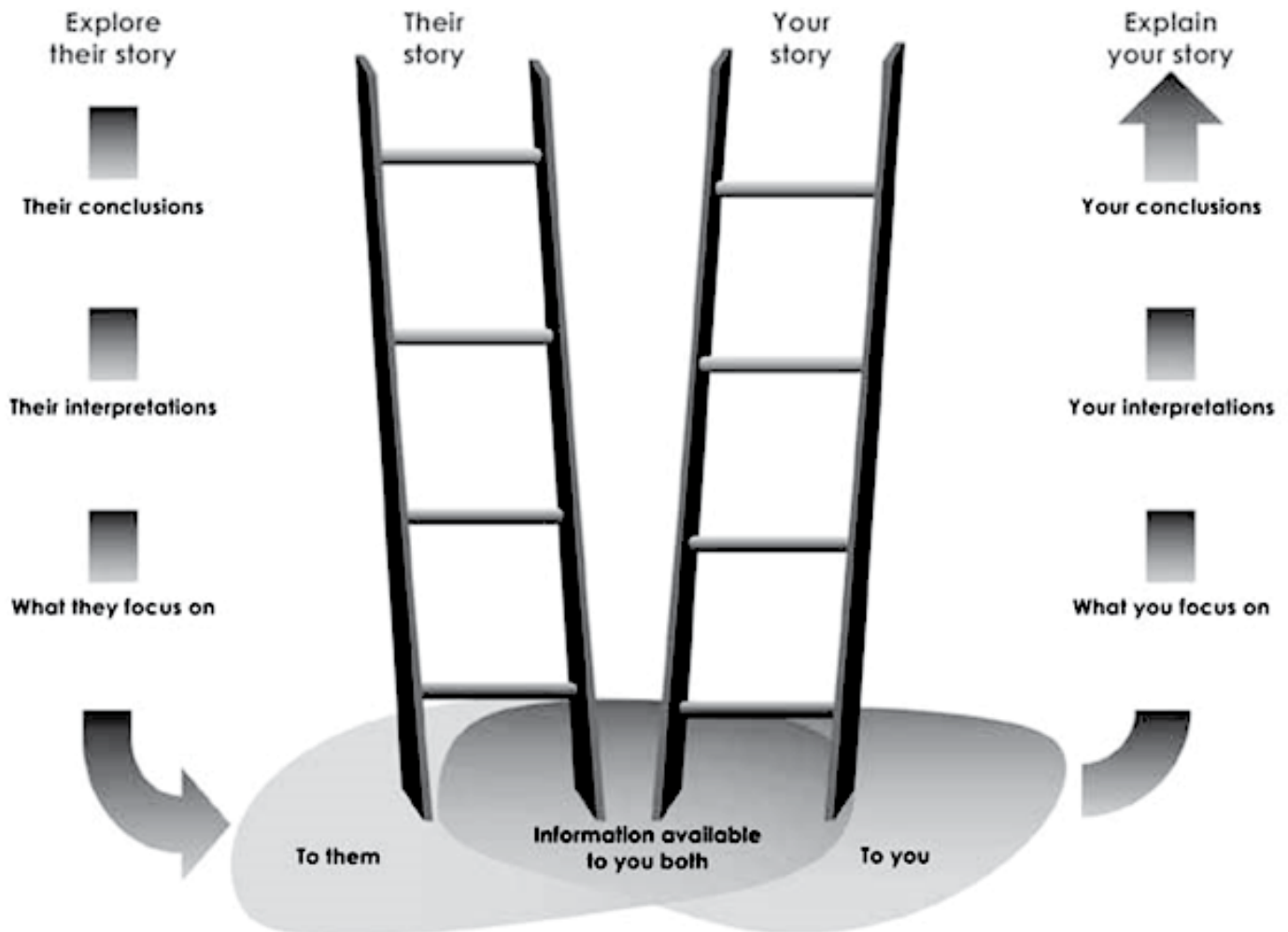
Adapted from Chris Argyris and Action Design. Argyris, C., Putnam, R., and Smith, D.M., *Action Science*. San Francisco, CA: Jossey-Bass, 1985.

Helpful Tip #11: Maintaining Touch with a Society that is far Removed from Agriculture

Here is 1 of the survey responses that sums this one up pretty well: "The biggest challenge as a whole for people in our industry is keeping in touch with a society that is constantly further removed from agriculture. We live in a country that is dominated by liberal media and headlines do not have to be justified by science. We are in a popularity contest and by definition rural America is outnumbered!"

Or...

http://fofarms.com/

https://www.youtube.com/watch?v=JJRy82i8e5Q)

So before we get into any kind of a debate about this outfit or before we start reading the negative comments posted on YouTube, let's just point out what they are doing: It's not nothing...

Is this for all of you or your clients? I don't know, but they are doing something, not nothing. Many of the survey responses indicated, "The consumer is demanding greater transparency." Well, Fair Oak Farms is transparent. They are not doing nothing. By the way, I went to their careers page and they don't have any vacancies in the production positions. Further, their tours are a revenue stream. People actually pay money to visit a dairy!

Conclusion

There are those out there who define insanity as doing the same thing over and over and expecting a different result. I am 1 of those people. I am a believer in change. As you consider the topics shared today, I would leave you with a few things to reflect upon:

- As you select your activities for continuing education each year, are they helping you to be a better veterinarian/leader/person?
- Are you engaging with the right stakeholder groups to push change?
- Are you pushing yourself to change enough?
- As an example, would something like involving yourself in the One Health Initiative be of value to you and the industry you work in?
- What about attending a workshop to further develop your leadership and influence skills?
- Maybe something that would help you learn how to apply the 4 Disciplines of Execution, or something that would help you improve your ability to hold others accountable?
- Would this make you an even more valuable resource to your clients?

As I come to a close, I am hopeful that 1 of you will leave here today with a sense of urgency to create change for your self, your clients, and within the industry. Sometimes it only takes 1.

The final thought that I would like to leave you with is this:

Helpful Tip #12: Your perception doesn't matter. Your client's perception doesn't matter. Everyone else's perception matters. That is our reality in production ag. Change or be changed. It comes whether you welcome it or not. You can wake up tomorrow and do the same things you did the day before and get the same results you've always gotten. Or you can wake up tomorrow, do differently, and achieve differently. The choice is yours.

Beef Session

Moderators: *Christine Navarre, Trent Fox*

Fetal programming: implications for beef cattle production

R.N. Funston, PhD; **A.F. Summers**
University of Nebraska, West Central Research and Extension Center, North Platte, NE 69101

Abstract

The beef cattle industry relies on the use of high-forage diets to develop replacement females, maintain the cow herd, and sustain stocker operations. Forage quantity and quality fluctuate with season and environmental conditions. Depending on class and physiological state of the animal, a forage diet may not always meet nutritional requirements, resulting in reduced average daily gain or body weight (BW) loss if supplemental nutrients are not provided. It is important to understand the consequences of such BW loss and the economics of providing supplementation to the beef production system. Periods of limited or insufficient nutrient availability can be followed by periods of compensatory BW gain once dietary conditions improve. This may have less impact on breeding animals, provided reproductive efficiency is not compromised, where actual BW is not as important as it is in animals destined for the feedlot. A rapidly evolving body of literature is also demonstrating that nutritional status of cows during pregnancy can affect subsequent offspring development and production characteristics later in life. The concept of fetal programming is that maternal stimuli during critical periods of fetal development have long-term implications for offspring. Depending on timing, magnitude, and duration of nutrient limitation or supplementation, it is possible that early measures in life, such as calf birth BW, may be unaffected, whereas measures later in life, such as weaning BW, carcass characteristics, and reproductive traits, may be influenced. This body of research provides compelling evidence of a fetal programming response to maternal nutrition in beef cattle. Future competitiveness of the US beef industry will continue to be dependent on the use of high-forage diets to meet the majority of nutrient requirements. Consequences of nutrient restriction or supplementation must be considered not only on individual animal performance, but also the developing fetus and its subsequent performance throughout life.

Key words: cattle, beef, fetal programming

Résumé

L'industrie de l'élevage bovin se fie aux diètes de fourrage pour le développement des génisses de remplacement et le maintien du troupeau de vaches et pour soutenir le parc d'élevage. La quantité et la qualité du fourrage changent avec la saison et les conditions environnementales. Selon la classe et l'état physiologique de l'animal, il est possible qu'une diète de fourrage ne réponde pas bien aux besoins nutritifs, ce qui peut entraîner une réduction du gain de poids quotidien ou du poids si des éléments nutritifs complémentaires ne sont pas disponibles. Il est important pour l'industrie de l'élevage bovin de bien comprendre les conséquences de telles pertes de poids et la rentabilité associée à l'utilisation d'éléments nutritifs complémentaires. Des périodes de disponibilité réduite ou insuffisante d'éléments nutritifs peuvent être suivies de périodes de gain de poids compensatoires lorsque les conditions d'alimentation s'améliorent. Ceci peut avoir moins d'impact sur les animaux en reproduction, en autant que la reproduction ne soit pas affectée, car contrairement aux animaux destinés à l'engraissement le poids est en fait est moins important. Un nombre d'études grandissant démontre aussi que le statut nutritionnel de la vache en gestation peut affecter le développement du veau et son profil de production plus tard dans la vie. Selon le concept de la programmation fœtale, les stimuli maternels durant les périodes critiques du développement fœtal ont des implications à long terme pour le jeune. Selon le moment, l'amplitude et la durée de la limitation ou de la supplémentation alimentaire, il est possible que des mesures prises tôt dans la vie, comme le poids du veau à la naissance, ne soient pas affectées alors que des mesures prises plus tardivement, comme le poids au sevrage, les caractéristiques de la carcasse et de la reproduction, le soient. Cet ensemble de travaux supporte bien l'idée que la nutrition maternelle chez les bovins de boucherie a un impact par le biais de la programmation fœtale. La compétitivité future de l'industrie américaine du bœuf restera liée à l'utilisation de diètes de fourrage pour répondre à la plupart des besoins nutritifs. Les conséquences de la restriction ou de la supplémentation alimentaire doivent être prises en compte non seulement pour la vache gestante elle-même mais aussi pour le fœtus en développement et sa performance à vie.

Introduction

The concept of fetal programming, also known as developmental programming, was first hypothesized using human epidemiological data in which environmental stimulus in utero resulted in altered long-term development, growth, and disease susceptibility in children from undernourished mothers during the Dutch famine.[1] Recently, literature regarding fetal programming effects in domesticated livestock has been reviewed.[8,9]

Many factors influence livestock nutrient requirements including breed, season, and physiological function.[31] Fetal programming responses can result from a negative nutrient environment, which can be caused by 1) breeding of young dams who compete for nutrients with rapidly growing fetal systems; 2) increased incidences of multiple fetuses or large litters; 3) selection for increased milk production, which competes for nutrients with increased energy demand from fetal and placental growth; or 4) breeding of livestock during high environmental temperatures and pregnancy occurring during periods of poor pasture conditions.[40,54] Studies have reported instances of compromised maternal nutrition during gestation resulting in increased neonatal mortality, intestinal and respiratory dysfunction, metabolic disorders, decreased postnatal growth rates, and reduced meat quality.[54] Proper management of cow nutrition during gestation can improve progeny performance and health.

Placental Development

The bovine placenta attaches along the uterine wall at locations known as caruncles. These knob-like structures along the uterine luminal surface serve as attachment sites for the chorionic villi of the fetal placenta known as cotyledons. The caruncle-cotyledonary unit, also known as a placentome, serves as the primary functional area of physiological exchange between mother and fetus.[9] Establishment of functional uteroplacental and fetal circulation is one of the earliest events during embryonic and placental development[32,35] allowing for transportation of all respiratory gas, nutrient, and waste exchanges between the maternal and fetal systems.[37,38] The efficiency of transport is related to uteroplacental blood flow,[37] and although placental growth slows during the last half of gestation, blood flow to the placenta increases 3- to 4-fold from mid to late gestation to support the exponential rate of fetal growth.[7,27,36,37,42]

Due to the importance of placental development on fetal nutrient transfer, studies have been conducted to determine how maternal nutrition can influence placental development, or placental programming. Zhu et al[56] reported nutrient restriction of beef cows from day 30 to 125 of gestation resulted in reduced ($P < 0.05$) caruncular and cotyledonary weights from nutrient-restricted cows compared to control, unrestricted cows, and fetal weights from nutrient-restricted

cows tended ($P = 0.12$) to be reduced compared to control cows. Following realimentation during day 125 to 250 of gestation, caruncular and cotyledonary weights were still reduced for nutrient-restricted cows; however, fetal weight was not different. Vonnahme et al,[53] using the same cows, reported increased placental angiogenesis as well as angiogenic factor mRNA abundance in the caruncular and cotyledonary tissues at the end of the nutrient restriction period. It was hypothesized the lack of significant fetal weight differences in regard to maternal nutrient restriction may have resulted from the increase in cotyledonary arteriolar density allowing for adequate nutrient transfer.[53,56]

To measure capillary vascularity of the cotyledon, 4 measurements are collected: capillary area density (**CAD**), a flow-related measure; capillary number density (**CND**), an angiogenesis-related measure; capillary surface density (**CSD**), a nutrient-exchange measure; and area per capillary (**APC**), a capillary density per cross section of muscle area. Vonnahme et al[53] reported no difference in these 4 measures from day 30 to day 125 of gestation; however, from day 125 to 250, there were significant differences in CAD, CND, and CSD when comparing control and nutrient-restricted cows, suggesting capillary area, numbers, and surface densities had been hindered upon realimentation. Nutrient restriction from day 30 to 125 of gestation in cows did not alter the vasculature of the bovine placenta; however, placental function must have been compromised due to reduced fetal weights.

Fetal Organ Development

Robinson et al[41] reported 75% of ruminant fetal growth occurs during the last 2 months of gestation. Due to the minimal nutrient requirement during early gestation, inadequate nutrition during this time was thought to have little significance. However, during the early phase of fetal development critical events for normal conceptus development occur, including differentiation, vascularization, fetal organogenesis, and as previously mentioned, placental development.[9]

Fetal organ formation occurs simultaneously to placental development, with limb development occurring as early as day 25 of gestation. Following limb development is a sequential development of other organs including the pancreas, liver, adrenal glands, lungs, thyroid, spleen, brain, thymus, and kidneys.[19] Testicle development begins by day 45 in male calves, and ovarian development begins in female calves by day 50 to 60. Another important event in female gonadal development occurs approximately day 80 of gestation, when oocyte nests break down to form primordial follicles.[30] These follicles represent the oocyte supply available to a female after puberty known as the ovarian reserve, which can influence her reproductive lifespan.[18] A review by Caton et al[3] lists fetal programming examples in livestock models of individual organs including heart,[17] lung,[13] pancreas,[22,23] kidney,[12] placenta,[39] perirenal fat,[25,26] and small intestine.[14]

Fetal Muscle Development

The fetal stage is also crucial for skeletal muscle development because muscle fiber numbers do not increase after birth.[47,55] Skeletal muscle is a lower priority in nutrient partitioning compared with the brain, heart, or other organ systems,[2,4] making it particularly vulnerable to nutrient deficiency. Thus, a decrease in nutrient availability to the dam during gestation can result in a reduced number of muscle fibers through fetal programming, reducing muscle mass and impacting animal performance. Both muscle fiber number and intramuscular adipocytes, which provide the sites for intramuscular fat accumulation or marbling formation, are influenced during fetal development.[6,50]

Figure 1 depicts the effects of maternal nutrition on fetal skeletal muscle formation and control points in which maternal nutrition has been shown to impact fetal muscle development. Although primary muscle fibers of the bovine fetus begin forming within the first 2 months of gestation,[43] very limited numbers of muscle fibers are formed at this stage; thus, maternal nutrition has little influence on primary muscle formation during this early time frame.[6] During the second to eighth month of gestation, the majority of muscle fibers form; therefore, reduction of muscle fiber formation during this stage through any source of stimuli (e.g., maternal nutrition) has long-lasting, irreversible consequences to the offspring.[6] The prospect of nutritional management's altering marbling may be greatest for the fetal stage, due to its importance in adipocyte formation, followed by the neonatal stage, early weaning stage (i.e., 150 to 250 days of age), and finally, weaning and older stages.[6]

Larson et al[21] reported increased progeny birth weights from protein-supplemented dams, suggesting a potential alteration in fetal muscle growth. Greenwood et al[15] reported steers from cows nutritionally restricted during gestation had reduced body weight and carcass weight at 30 months of age compared to steers from adequately fed cows. Both Larson et al[21] and Greenwood et al[15] reported a retail yield on a carcass weight basis was greater in steers from nutrient-restricted cows, indicating an increased propensity for carcass fatness was not a consequence of nutritional restriction in utero.
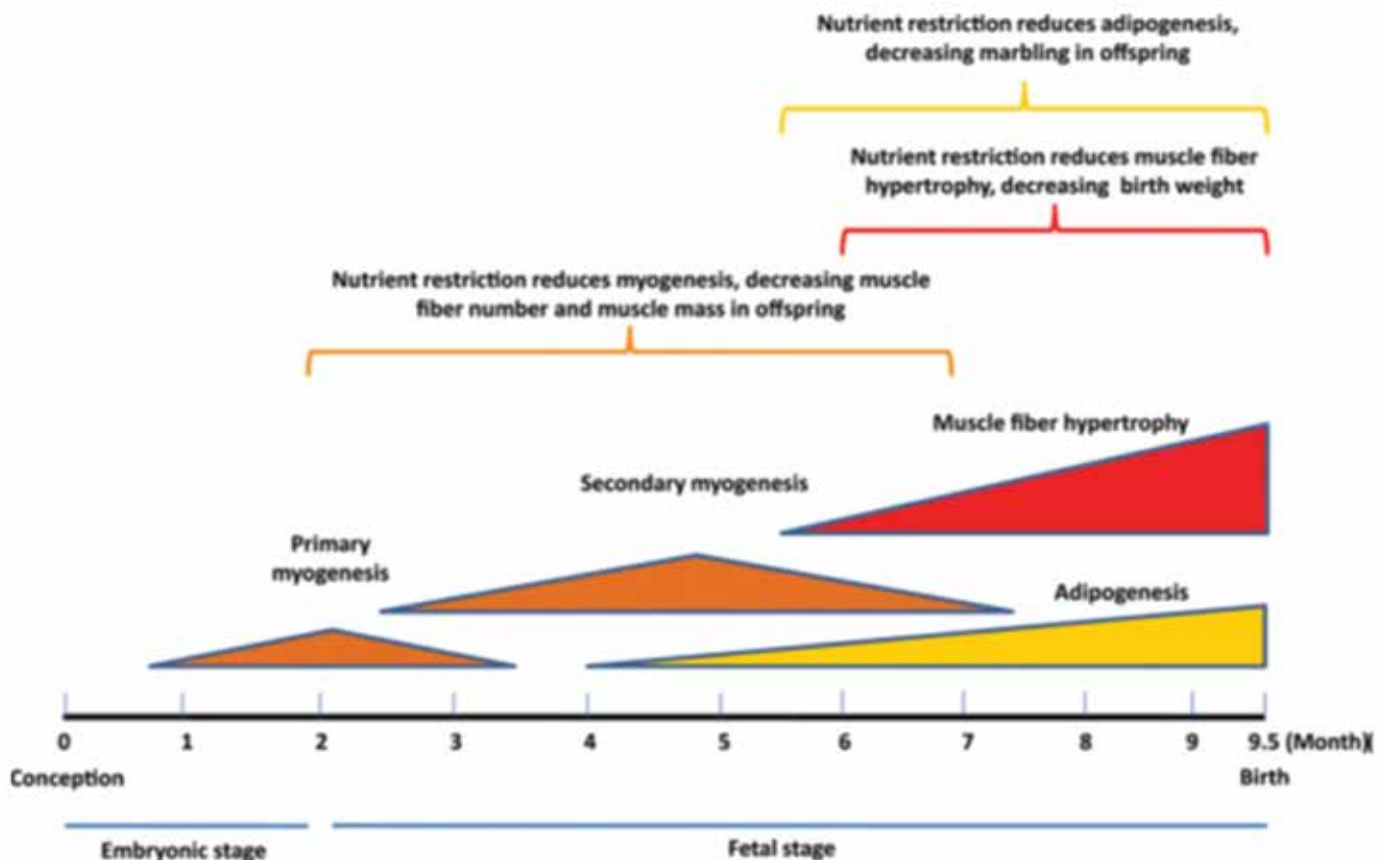

Figure 1. Effects of maternal nutrition on bovine fetal skeletal muscle development. Dates are estimated mainly based on data from studies in sheep, rodents, and humans and represent progression through the various developmental stages. Nutrient restriction during mid-gestation reduces muscle fiber numbers, whereas restriction during late gestation reduces both muscle fiber sizes and the formation of intramuscular adipocytes. From Du M, Tong J, Zhao J, Underwood KR, Zhu M, Ford SP, Nathanielsz PW. Fetal programming of skeletal muscle development in ruminant animals. J Anim Sci 2010; 88(E. Suppl.):E51-E60.

Although fetal adipocyte development begins early in gestation, the majority of fetal adipose tissue is not deposited until the final few weeks of gestation.[48] Adipose tissue growth occurs through preadipocyte proliferation, impacting formation of new mature adipocytes (hyperplasia); and increased size and lipid storage capacity of mature adipocytes (hypertrophy). By feeding ewes 150% of National Research Council (NRC) nutrient requirements, Tong et al[49,50] reported increased adipogenesis in fetal skeletal muscle. In a review on fetal programming of skeletal muscle, Du et al[6] reported when University of Wyoming scientists fed beef cattle 1 of 3 diets (100%, 70% of NRC nutrient requirements,[31] or 70% of NRC nutrient requirements plus supplementation of ruminal bypass protein from day 60 to 180 of gestation), steer progeny from dams fed 70% nutrient requirements plus supplement had numerical decreases in marbling scores when compared to steers from dams fed 100% of requirements. Underwood et al[51] also reported increased tenderness in steers from dams grazed on improved pasture compared to steers from dams grazed on native range during mid-gestation.

Heifer Progeny Performance

Data regarding the effect of late-gestation protein supplementation on heifer progeny performance are reported in Table 1. Martin et al[24] conducted a study with cows grazing dormant Sandhills range during late gestation. One group received a 42% CP (DM basis) cube offered 3 times weekly at the equivalent of 1.0 lb (0.45 kg)/day while another group re-

Table 1. Effect of maternal protein supplementation on heifer progeny performance.

| | Dietary treatment | | | |
| | Martin et al[24] | | Funston et al[10] | |
Item	NS	SUP	NS	SUP
Weaning BW, lb	456	467	492[a]	511[b]
Adj. 205-d wt, lb	481[a]	498[b]	470	478
DMI, lb/d	14.39	14.88	20.89	20.50
ADG, lb/d	0.90	0.88	1.86[x]	1.74[y]
Residual feed intake	-0.12	0.07	0.08	-0.04
Age at puberty, d	334	339	365[x]	352[y]
Pregnant, %	80[a]	93[b]	83	90

[1]NS = dams did not receive protein supplement while grazing dormant Sandhills range during the last third of gestation; SUP = dams were supplemented 3 times per week with the equivalent of 1.0 lb (0.45 kg)/d of 42% CP cube (DM basis) while grazing dormant Sandhills range during the last third of gestation.
[2]NS = dams did not receive protein supplement while grazing dormant Sandhills range or corn residue during the last third of gestation; SUP = dams were supplemented 3 times per week with the equivalent of 1.0 lb (0.45 kg)/d of 28% CP cube (DM basis) while grazing dormant Sandhills range or corn residue during the last third of gestation.
[a,b]Means within a study with different superscripts differ ($P \leq 0.05$).
[x,y]Means within a study with different superscripts differ ($P \leq 0.10$).

ceived no supplement. Calf birth weight between heifer progeny from supplemented and non-supplemented dams was not different; however, heifer progeny from supplemented cows had increased adjusted 205-day weaning weights, prebreeding weight, weight at pregnancy diagnosis, and improved pregnancy rates compared to heifers from non-supplemented dams. Martin et al[24] also reported after a subset of these heifers were placed in a Calan gate individual feeding system, dry matter intake (DMI), average daily gain (ADG), and residual feed intake between heifer progeny from supplemented and non-supplemented dams was not different.

Funston et al,[10] using the same cow herd, offered a distillers based supplement (28% CP, DM basis) 3 times weekly at the equivalent of 1.0 lb (0.45 kg)/day, or no supplement during late gestation as cows grazed either dormant Sandhills range or corn crop residue. Calf weaning weight was greater ($P = 0.04$) for heifers from protein-supplemented dams, whereas Martin et al[24] reported a trend ($P = 0.12$) for increased weaning weight for heifers from protein-supplemented dams. Funston et al[10] also reported a decreased age at puberty for heifers from protein-supplemented cows and a trend ($P = 0.13$) for higher pregnancy rates when compared to heifers from non-supplemented dams, possibly related to decreased age at puberty. Similarly, Corah et al[5] reported heifers born to primiparous heifers fed 100% of their dietary energy requirement during the last 90 days of gestation were pubertal 19 days earlier than heifers born to primiparous heifers fed 65% of their dietary energy requirement.

Funston et al[10] reported no differences in heifer weight at prebreeding and no differences in calf birth weight, calf production, or second calf rebreeding when comparing heifer progeny from supplemented and non-supplemented cows. Gunn et al[16] reported a decrease in the proportion of singleton, and an increase in the proportion of multiple births over 3 parities in progeny born to ewes offered a protein supplement while grazing native pastures during the last 100 days of gestation compared to progeny from non-supplemented ewes. Late-gestation supplementation did not alter the proportion of barren ewe progeny.[16] Martin et al[24] reported a 28% increase in the proportion of heifers calving in the first 21 days of the calving season from protein-supplemented dams compared to heifers from non-supplemented dams. Pryce et al[33] reported no difference in progeny heifer reproductive performance when considering dairy cow maternal nutritional status, determined by body condition score (BCS), DMI, and milk yield of fat and protein.

Steer Progeny Performance

As previously mentioned, studies have reported improved muscle development in steers from adequately fed dams when compared to progeny from nutrient-restricted dams. Underwood et al[51] reported increased weight gains, final weight, and hot carcass weight in steers from cows grazing improved pasture from day 120 to 180 of gestation

when compared to progeny from cows grazing native range during that same time (Table 2). Steers from cows grazing improved pasture had increased back fat and tended to have improved marbling scores compared to steers from cows grazing native range.

To determine the effect dietary energy source had on progeny calf performance, Radunz[34] offered cows 1 of 3 diets during gestation beginning on approximately day 209 of gestation: hay (fiber), corn (starch), or distillers grains with solubles (fiber plus fat). Corn and distillers grains diets were limit-fed to ensure isocaloric intake among treatments. Results indicated reduced birth weights for calves from dams fed grass hay when compared to calves from the other 2 groups (Table 2), with an increase ($P \leq 0.05$) in calf body weight reported through weaning when comparing calves from corn-fed dams to hay-fed dams. Feedlot performance among treatments was not different; however, calves from hay-fed dams required 8 and 10 more days on feed to reach a similar fat thickness when compared to calves from distillers and corn-fed dams, respectively.

Stalker et al[45,46] reported steer progeny from dams supplemented the equivalent of 1.0 lb (0.45 kg)/day (42% CP, DM basis) cube during late gestation had no difference in calf birth weight when compared to steers from non-supplemented dams. Conversely, Larson et al[21] using the same cow herd, reported an increase in calf birth weight when comparing calves born to dams supplemented the equivalent of 1.0 lb (0.45 kg)/day (28% CP, DM basis) cube during late gestation to calves from non-supplemented dams. In the study reported by Stalker et al,[45] cows were utilized in a switchback design, whereas cows utilized by Larson et al[21] remained on the same treatment over the 3-year study.

Protein supplementation during late gestation increased weaning weight, ADG to weaning, and proportion of calves weaned when comparing calves from supplemented to non-supplemented dams grazing dormant winter range[21,45,46]

(Table 3). Stalker et al[45] reported no differences in steer progeny feedlot performance and carcass characteristics when comparing progeny from supplemented and non-supplemented dams. However, Larson et al[21] reported increased ADG, HCW, and marbling scores in steers from supplemented dams. Furthermore, a greater proportion of steers from supplemented dams graded USDA Choice and USDA Choice or greater when compared to steers from non-supplemented dams. Non-supplemented cows in Larson et al[21] may have been under greater nutritional stress than Stalker et al[45] as average weaning date was approximately 1 month later and possibly had greater impact on fetal development.

Influence of Maternal Nutrition on Progeny Health

Several reports have linked maternal nutrition during gestation to calf health, including Corah et al,[5] indicating increased morbidity and mortality rates in calves born to primiparous heifers receiving 65% of their dietary energy requirement over the last 90 days of gestation compared to calves from primiparous heifers receiving 100% of their energy requirement. One factor contributing to increased morbidity and mortality is decreased birth weight. Calves born to nutrient-restricted dams were 4.5 lb (2.04 kg) lighter at birth compared to calves from dams receiving adequate nutrition (Corah et al).[5] Similarly, Moule[28] reported as birth weight increased from 4.5 to 9 lb (2.04 kg to 4.08 kg), mortality decreased dramatically in lambs.

Mulliniks et al[29] and Larson et al[21] indicated reduced proportions of steers treated in the feedlot from cows supplemented with protein compared to calves from nonsupplemented dams. Stalker et al[45] reported increased proportions of live calves weaned to dams offered supplement during late gestation; however, there was no difference in the number of treated calves prior to weaning or in the feedlot. Furthermore, Larson et al[21] reported no difference in the number of steer calves treated for respiratory disease prior to weaning.

Table 2. Effect of maternal nutrition on steer progeny performance.

| | Dietary treatment | | | | |
| | Underwood et al[1] | | Radunz[2] | | |
Item	NR	IP	Hay	Corn	DDGS
Birth BW, lb	85	81	86[a]	95[b]	91[b]
Weaning BW, lb	534[a]	564[b]	580[a]	607[b]	591[a,b]
ADG, lb/d	3.28[a]	3.65[b]	3.37	3.46	3.41
HCW, lb	726[a]	768[b]	688	688	675
12th rib fat, in	0.49[a]	0.65[b]	0.48	0.50	0.51
Marbling score[3]	420	455	549[a]	506[b]	536[ab]

[1]NR = dams grazed native range from day 120 to 180 of gestation; IP = dams grazed improved pasture from day 120 to 180 of gestation.
[2]Hay = dams offered a diet of grass hay beginning on day 209 of gestation; Corn = dams offered limit-fed diet of corn beginning on day 209 of gestation; DDGS = cows offered a limit-fed diet of distillers grains with solubles beginning on day 209 of gestation.
[3]Where 400 = Small[0].
[a,b]Means within a study with different superscripts differ ($P \leq 0.05$).

Similarly, Funston et al[10] reported no differences in illness in cohort heifers.

Snowder et al[44] reported disease incidence is more likely after 5 days on feed and remains high through the first 80 days in the feedlot. Furthermore, steers were more likely to become sick compared to heifers in the feedlot. Post-weaning stress is a factor influencing calf health. As mentioned earlier, Funston et al[10] did not report any differences in heifer calf health. These heifers, unlike their steer cohorts, remained at the ranch post-weaning and were maintained on a forage based diet, likely reducing the amount of stress placed on the animal when compared to their steer cohorts who were transported to the feedlot 2 weeks post-weaning and adapted to a concentrate-based diet.

Conclusion

Management of maternal diet beginning during early gestation will ensure proper placental programming resulting in adequate nutrient transfer to the fetus. Maternal nutrition later in gestation has been reported to influence fetal organ development, muscle development, postnatal calf performance, carcass characteristics, and reproduction. Although the mechanisms by which placental and fetal programming occur are not clear, managing resources to ensure proper cow nutrient intake during critical points of gestation can improve calf performance and health.

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Table 3. Effect of maternal protein supplementation on steer progeny performance.

| Item | Dietary treatment | | | | | |
| | Stalker et al[1] | | Stalker et al[1] | | Larson et al[2] | |
	NS	SUP	NS	SUP	NS	SUP
Weaning BW, lb	463[a]	489[b]	463[a]	476[b]	514[a]	529[b]
DMI, lb/d	24.6[a]	26.6[b]	18.7	18.8	19.8[x]	20.3[y]
ADG, lb/d	3.53	3.70	3.46	3.44	3.66	3.75
Feed:gain	6.97	7.19	5.41	5.46	5.37	5.38
HCW, lb	765[a]	805[b]	800	814	805[a]	822[b]
Choice, %	-	-	85	96	71	85
Marbling score[3]	449	461	467	479	445[a]	492[b]

[1]NS = dams did not receive protein supplement while grazing dormant Sandhills range during the last third of gestation; SUP = dams were supplemented 3 times per week with the equivalent of 1.0 lb (0.45 kg)/d of 42% CP cube (DM basis) while grazing dormant Sandhills range during the last third of gestation.

[2]NS = dams did not receive protein supplement while grazing dormant Sandhills range or corn residue during the last third of gestation; SUP = dams were supplemented 3 times per week with the equivalent of 1.0 lb (0.45 kg)/d of a 28% CP cube (DM basis) while grazing dormant Sandhills range or corn residue during the last third of gestation.

[3]Where 400 = Small^0.

[a,b]Means within a study with different superscripts differ ($P \leq 0.05$).

[x,y]Means within a study with different superscripts differ ($P \leq 0.10$).

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Genetic testing in beef practice

Jason B. Osterstock, DVM, PhD
Zoetis, 333 Portage St., Kalamazoo, MI 49007

Abstract

Genomic technologies are emerging as an important tool in beef genetic improvement strategies. Genetic tests are used extensively by many progressive seedstock breeders to increase accuracy of selection and accelerate genetic progress. Increasing use of these technologies in the seedstock sector have also led to development of applications for commercial cattle. There are several keys to technical evaluation of genomic technologies. The first is the accuracy of the prediction which can be expressed as a genetic correlation or an increase in accuracy of EPDs when incorporated into genetic evaluation. The second is the association between the prediction and the observed phenotype. In the case of the genomically enhanced EPD, this is implicit in the reported accuracy. For commercial applications, this should include some external validation of the predictions in a population independent of that used for the development of the test. Provided these validation criteria are met, the application of the technology is very straightforward and effectively the same as historical practices. The principal differences are that the selection decisions can be made earlier in life with greater accuracy, including for traits that are not expressed phenotypically until much later in life. This accelerates genetic progress by minimizing selection mistakes and allowing producers to identify and exploit superior genetics much sooner than with traditional approaches.

Key words: cattle, beef, genomics, EPD

Résumé

Les technologies de la génomique deviennent des outils de plus en plus importants dans le contexte des stratégies d'amélioration de la génétique des bovins de boucherie. Les tests génétiques sont utilisés par plusieurs producteurs de géniteurs avant-gardistes afin d'augmenter la précision de la sélection et d'accélérer le progrès génétique. L'utilisation accrue de ces technologies dans la filière des géniteurs a aussi permis le développement d'applications pour les bovins mis en marché. Il y a plusieurs éléments clés dans l'évaluation technique des technologies de la génomique. Le premier est la précision de la prédiction qui peut s'exprimer par la corrélation génétique ou par l'augmentation du degré de précision des écarts prévus de la descendance (EPD) lorsqu'incorporés dans l'évaluation génétique. Le second est l'association entre le phénotype prédit et observé. Dans le cas des EPD rehaussés génomiquement, ceci découle de la précision rapportée. Pour les applications commerciales, il est important d'avoir une validation externe des prédictions dans une population indépendante de celle utilisée pour le développement du test. En autant que ces critères de validation soient rencontrés, l'application de cette technologie est directe et ressemble en fait aux pratiques antérieures. La principale différence réside dans le fait que les décisions de sélection peuvent se faire plus tôt dans la vie et avec plus de précision incluant les caractéristiques qui ne s'expriment phénotypiquement que plus tard la vie. Ceci accélère le progrès génétique en minimisant les erreurs de sélection et en permettant aux producteurs d'identifier et d'exploiter des génétiques de plus haut niveau plus tôt qu'avec des approches traditionnelles.

Introduction

The use of genetic testing in beef production has made significant advancements in the last 5 years. This has included expanded scope of traits that can be predicted from genomic data, increased accuracy of the resulting predictions, and greater appreciation of the benefits associated with use of the technology. Adoption of genetic testing has increased accordingly with the greatest growth observed in the seedstock sector as a complement to existing genetic evaluation systems, although an increasing number of applications for commercial cattle are also becoming available.

The significance of these developments to beef practitioners will vary considerably depending upon their role. In some instances, they may be very involved, providing assistance in analysis and interpretation of results for their customers, perhaps very consultative in their contribution. In other instances, they may serve principally as a trusted advisor that can help producers evaluate the decision of whether to apply the technology in their herds. Unfortunately, the technology moves very quickly, requiring a good foundation of basic knowledge about genomic technologies that can readily be adapted as new applications emerge.

Drivers of Genetic Progress

Genetic progress, whether in seedstock or commercial production, is influenced by the same principles. The simplest approach is to examine the classical genetic progress formula:

$$\Delta G = \frac{(r \cdot i \cdot \sigma)}{GI}$$

Where ΔG is the increase in average genetic merit; r is the accuracy of the prediction of genetic merit; i is the selection intensity; σ is the genetic variation of the trait under selec-

tion; and *GI* is the generation interval defined as the average age of parents.

Genomic technologies can influence *ΔG* in 2 primary ways. The first and most important is the increase in accuracy of the genetic predictions. As accuracy increases, genetic progress increases. The second is by reducing generation interval. In some instances, the availability of higher accuracy data from genomic technologies may allow superior animals to be used as breeding animals more aggressively earlier in life, as may be the case for bulls used for artificial insemination or identifying donor females at an earlier age. Decreasing the average age of parents also increases the rate of genetic progress.

Defining Accuracy

Without a doubt, the most challenging aspect of becoming comfortable with evaluating genomic technologies is understanding how to assess accuracy of the predictions of genetic merit. Some of this is related to the terminology applied. Some is just wrapping one's head around the statistical elements involved in estimating accuracy. Regardless of the root of the confusion, there are some common metrics used to describe accuracy, and some practical context which can be used to better understand what it means.

The accuracy of a prediction of genetic merit is an assessment of how well that prediction reflects an animal's true, but unknown, genetic merit for a given trait. The most common statistic used in quantitative genetics to describe accuracy is the genetic correlation. This is a parameter estimated in genetic analyses that describes the correlation between a predictor and an estimate of genetic potential, also referred to as a breeding value. This correlation varies between 0 and 1 with 1 representing a perfect prediction. Generally, higher accuracy is achieved as more information contributes to the prediction, and for more highly heritable traits.

The genetic correlation may be reported in a variety of ways. In genetic evaluation of seedstock as performed for a variety of breed associations, this correlation is used to compute Beef Improvement Federation (BIF) accuracy.[2] The BIF accuracy is then reported for each calculated expected progeny difference (EPD). The BIF accuracy, although also ranging from 0 to 1, is always numerically lower than the genetic correlation. This correlation can also be used to calculate reliability or estimate the percent of genetic variation explained. Importantly, all of these metrics – genetic correlations, accuracy, reliability, and percent genetic variance – are all representing the same statistical property of the prediction.

The effect of increased accuracy is a more dependable comparison of the relative genetic merit of selection candidates. As a result, any given selection decision will be more effective and the average genetic merit of selected animals will be greater than if a less-accurate prediction were used. Genomic data simply serves as an additional source of information that can be added to other available data, thus increasing the accuracy of genetic predictions.

Criteria for Selection

There are a large number of genetic predictions that can be used to inform selection decisions. Seedstock genetic evaluations often support predictions for 10 to 15 different traits. These typically include growth traits, carcass traits, calving ease, and reproductive traits. The available information can be used to support a variety of selection priorities. However, the sheer number of traits available can make selection decisions quite difficult to process.

Seedstock producers are generally well versed in selection strategies, and often breed for several different types of animals to meet the needs of their commercial cow-calf customers. For example, it is common to simultaneously breed for cattle with high calving ease and moderate growth potential, and a second line with greater growth and carcass merit. The benefit for the commercial cattlemen is that the seedstock breeder has, in this instance, created 2 general categories of cattle (specifically bulls for use as herd sires), thus simplifying selection decisions.

Another commonly applied approach to simplifying selection is the use of selection indexes. These represent a strategy to provide a single, consensus estimate of genetic merit across a broad range of traits. Indexes are intended to provide comprehensive selection across a range of traits, preventing risky single-trait selection. Selection indexes are developed by defining a production outcome (e.g., calves sold at weaning or premium carcass quality) and then describing the relative contribution of each trait to the economic value of that production outcome. Based on the variation within and among traits, the heritability of the traits, and the economic value of each trait, an optimal combination of relative emphasis can be defined for each trait included in the index. This process removes subjectivity from development of the index and ensures that the ultimate outcome will favorably impact profitability.

Types of Selection Decisions

The emergence of genomic technologies has not altered how genetic improvement is achieved. There are effectively only 3 selection decisions that any producer can make. The first is choosing which animals will be retained / enter the herd. This applies to both replacement females and herd sires. The second selection decision is defining how to assign matings to address individual weaknesses and complement existing strengths. The final selection decision is how many progeny each animal will produce. Elite animals are assigned to produce many progeny, as may be the case with AI sires and donor females.

To execute any of these selection decisions, the breeder/producer needs to be able to rank animals from best to

worst based on their selection criteria. This requires a genetic prediction for economically relevant traits with sufficient accuracy to make the right selection decisions – and avoid mistakes. Genomic technologies, by virtue of their contribution to accuracy, help to ensure that animals are ranked more dependably against their true differences in genetic merit.

The Science Behind Genomics

Genomic technologies provide a mechanism to provide information that complements available pedigree, performance, and progeny data to more accurately inform selection decisions. Given that DNA can be analyzed in every animal very early in life, genetic tests also have the potential to support selection decisions in young animals for a host of traits, including those traits that are difficult to measure or are not expressed until much later in life.

Genetic tests can be designed to support these objectives in 2 ways. The first approach is to develop genetic tests that describe genetic variation in genomic reasons with known associations to phenotypic outcomes. These generally interrogate quantitative trait loci (QTL), regions of the genome linked to quantitative traits like weight, height, or milk production. The challenge with this approach, often referred to as the candidate gene approach, is that the vast majority of economically relevant traits are polygenic, influenced by many regions of the genome. In addition, since the majority of the genetic markers used to query QTL are not causative mutations, but instead markers in close proximity within the genome to unknown causative mutations, the associations may be tenuous and may not apply to animals outside the reference population. Markers that are close to a gene tend to be inherited with that gene, but mutations do occur and identified markers may be segregating differently relative to the causative mutation in different populations of cattle. For this reason, external validation of genomic predictions designed using the candidate gene approach is critically important.

A second and increasingly common approach is to utilize genetic markers that are not selected on the basis of their association with a specific outcome, but based on their ability to describe genetic variation in general. As such, these genetic tests typically include thousands of markers that span the entire genome. This approach seeks to principally evaluate lineage or genomic relatedness and, in so doing, allow inferences to be made regarding an individual animal's genetic merit based on prior knowledge of the genetic potential of other animals possessing similar genomic patterns. This approach is used extensively in seedstock animals to derive genomic information that can be integrated into existing genetic evaluations.

The genome-wide approach typically produces more comprehensive and accurate genomic predictions. However, they require genotypes for a far greater number of genetic markers and therefore are generally more expensive to obtain. A significant recent innovation that is helping to overcome this challenge is imputation. With a sufficient number of higher-density genotypes on the right animals, it is possible to begin to recognize common patterns within the genotypes. Imputation leverages the knowledge of the patterns that are common in the reference population to predict higher-density genotypes from a strategically selected subset of markers. In well documented populations (e.g., Angus, Nelore), the predicted genotypes will correctly match the true genotype in greater than 95% of the markers.[1,3] This degree of imputation accuracy is sufficient to inform predictions with very nearly the same accuracy using a more cost-effective genotyping platform.

Conclusions

Genomic technologies have the potential to provide valuable support to cattle producers' genetic improvement strategies. For veterinarians, there is minimally a responsibility to understand how the technology is applied so as to provide relevant guidance to their clients. The technology is complex, in large part because it is intended to describe the inherently complex. However, there are some key concepts that can be readily understood. Given the value of the technology and the impact it is having in the industry today, it is likely that it will continue to emerge and gain greater adoption throughout the industry. Beef producers, particularly commercial cattlemen, will continue to need sound guidance from their veterinary advisors as they integrate genetic testing and genomic data into their operations.

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Pre-weaning bovine respiratory disease in the cow-calf herd

David R. Smith, DVM, PhD, Dipl. ACVPM (Epidemiology)
Department of Pathobiology and Population Medicine, Mississippi State University, College of Veterinary Medicine, Mississippi State, MS 39762; Phone: 662-325-1344; E-mail: david.smith@msstate.edu

Abstract

Bovine respiratory disease (BRD) in beef calves prior to weaning is a problem for 1 in 5 cow-calf farms. Pre-weaning BRD is a costly problem for the cattle industry and a detriment to animal well-being. This is a perplexing health problem because ranch calves typically live in conditions of little stress and relative isolation, risk factors commonly associated with BRD in weaned calves. Some factors that appear to be related to BRD risk in pre-weaned calves are waning maternal immunity, loss of herd immunity in herds with short calving periods, activities that result in increased animal density, calf gender, and age of the dam. Collectively, these factors are related to the calf's ability to resist infection and to opportunities for pathogen exposure. Activities such as commingling and weaning may have less impact on calf health if they are completed prior to or after calves are 3 to 5 months of age, thereby avoiding the period of greatest susceptibility. Vaccination programs intended to induce adequate immunity in calves prior to 90 days of age have shown some efficacy, but require further study.

Key words: cattle, beef, cow-calf, BRD

Résumé

Le complexe respiratoire bovin (CRB) chez les veaux de boucherie avant sevrage est un problème dans près de 20% des exploitations vaches-veaux. Le CRB en pré-sevrage coûte cher à l'industrie du bœuf et nuit au bien-être des animaux. Ce problème de santé laisse perplexe car les veaux dans les ranchs sont quand même assez isolés et soumis à peu de stress, deux facteurs de risque associés au CRB chez les veaux sevrés. Les facteurs suivants semblent être reliés au risque de problèmes respiratoires chez les veaux pré-sevrés : l'immunité maternelle décroissante, la perte de l'immunité de troupeau dans les troupeaux avec courtes périodes de vêlage, les activités qui augmentent la densité animale, le genre du veau et l'âge de la mère. Ensemble, ces facteurs influencent la résistance à l'infection du veau et les chances d'exposition aux agents pathogènes. L'agrégation des veaux et le sevrage peuvent avoir moins d'impact sur la santé du veau s'ils sont complétés lorsque les veaux ont moins de 3 à 5 mois d'âge, ce qui permet d'éviter la période de plus grande susceptibilité. Les programmes de vaccination dont le but est de rehausser l'immunité chez les veaux âgés de moins de 90 jours se sont avérés assez efficaces mais nécessitent plus de travaux.

Introduction

In some cow-calf herds pneumonia (bovine respiratory disease or BRD) is a leading cause of sickness and death of calves, especially after the first few weeks of life.[13] This is perplexing because ranch calves typically live in conditions of little stress and relative isolation. Surveys of beef cattle producers[15] and veterinarians[16] from the northern plains region and southeastern US indicate that pre-weaning BRD is a problem for approximately 1 out of 5 cattle producers. Pre-weaning BRD may affect up to 10% of US beef calves,[4] resulting in death of 0.6% to 1.4% of all calves.[2,11,12] Calves affected with pre-weaning BRD may weigh 17 to 37 lb (7.7 to 16.8 kg) less at weaning, compared to calves not affected.[11,14]

The Cost of Pre-Weaning BRD

A risk analysis of the cost of pre-weaning BRD is currently underway,[a] but "back of the envelope" calculations considering death loss, morbidity, and treatment costs indicate that BRD in pre-weaned calves might currently cost the US cattle industry $290 million annually.[a] If so, that is approximately $10 for every beef cow in the country, or $50/cow in affected herds.

Epidemiology of Pre-Weaning BRD

As with all infectious diseases, the occurrence of BRD is affected by factors of host immunity, presence of specific pathogens, and opportunity for transmission of pathogens between or within herds. It may be useful to think of the various factors that contribute to risk for respiratory disease as component causes. Each factor that contributes to the development of disease is a "component cause". Disease is observed when component causes add up to complete a sufficient cause.[9] Without completing a sufficient cause, there is no expression of disease. Component causes explain why we might recover *Mannheimia haemolytica* from a deep nasopharyngeal swab of a calf without respiratory disease (other component causes being absent), or why a rancher might observe greater rates of BRD with changes in the weather, and another rancher observes BRD following

a pasture move (different component causes completing the sufficient cause). Each outbreak of respiratory disease is the result of the completion of a sufficient cause, which might have also included components of viral and bacterial pathogens, a certain state of immunity, or other component causes of respiratory disease in cattle that we fail to understand. Removing 1 or more component cause prevents the expression of disease. Manageable component causes are called "key determinants".

Agents

Although the bacterial pathogens of pneumonia are commonly found in the upper respiratory tract of cattle, the inciting damage is often due to viral infections that may not be present in all cattle herds all of the time. Commonly recognized viral BRD pathogens are bovine herpes virus 1, bovine viral diarrhea virus, and bovine respiratory syncytial virus, but many others, including bovine coronavirus,[5,6] are likely to be involved.

Pathogen Transmission

In confinement systems, the opportunity for pathogen transmission is high because of animal density. But, even in extensive pasture-based systems typical of cow-calf production, opportunities for pathogen transmission may be high because cattle congregate closely around water sources, feedbunks, in shade, and when bothered by flies. Some management practices, such as pasture moves and gathering for sorting, result in high animal density and greater opportunity for pathogen transmission.

Age-Associated Immunity

Passively acquired maternal immunity is important for protecting calves against respiratory pathogens. However, maternal antibodies wane with time. Approximately every 16 to 20 days after ingestion, the amount of maternal antibodies left in the blood stream is halved, so that by 96 to 120 days of age, a calf retains less than 2% of the antibodies it absorbed from colostrum. The immune system is functional but unprimed at birth, and prior to 5 to 8 months of age the immune response of calves is weak, slow, and easy to overcome.[1] Therefore, even in the absence of additional stressors, calves 3 to 5 months of age may be particularly susceptible to pneumonia.

Herd Immunity

Herd immunity is the protection afforded to susceptible individuals because the majority of the individuals in the population are immune. In herds with a narrow calving window, calves are similar in age and herd immunity is lost in a short span of time as calves approach 90 to 120 days

of age. Vaccines to improve immunity against respiratory pathogens have been important for reducing the incidence of BRD in feedlot calves. However, the optimum vaccination protocol to prevent BRD in calves < 5 months of age remains an important subject of investigation. Weaning, commingling groups, and exposure to severe weather can be powerful stressors that further reduce a calf's ability to resist disease.

Other Factors Affecting Risk for Pre-Weaning BRD

Health records representing over 5,000 calves from 20 cattle-management groups within 4 beef cattle ranches were analyzed to test the effect of calf gender and age of the dam.[b] We concluded that the sex of calves affects their risk for BRD (bulls > steers > heifers), and calves born to dams younger than 4 years of age had greater risk for BRD. The male sex of other species has been associated with greater risk for pneumonia.[3,17] The age of the dam may be a correlate of colostrum absorption. Colostrum ingestion may be delayed for calves born to a young dam because of dystocia or poor mothering skills. Also, the young dam's colostrum may not contain as many antibodies, in quantity and range of protection, as older dams.[7,8,10]

Prevention of Pre-Weaning BRD

Management and environment-related risk factors for pre-weaning BRD have been the subject of research.[2,4,15,16] Management practices prior to weaning, such as gathering and sorting for artificial insemination, provide opportunity for pathogen introduction and transmission. Activities such as gathering, commingling, sorting, and weaning that increase stress and opportunities for pathogen transmission may have less impact on health if they are completed prior to or after calves are 3 to 5 months of age.[b] Anecdotal evidence indicates that vaccination programs intended to induce adequate acquired immunity in calves prior to 90 days of age have shown some efficacy, but require further study.

Endnotes

[a]Smith DR et al, unpublished
[b]Smith DR et al, unpublished

Acknowledgements

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Designing effective calf vaccination programs

Christopher C.L. Chase, DVM, MS, PhD, Diplomate ACVM
Department of Veterinary and Biomedical Sciences, South Dakota State University, PO Box 2175, Brookings, SD 57007

Abstract

Vaccination is an important component for the pre-vention and control of bovine bacterial and viral diseases. Modified-live vaccines (MLV) have been used because of the good antibody response, longer duration of immunity, fewer doses needed per animal, and lower cost. The selec-tive pressure from an animal's immune response may lead to new viruses that persist and cause problems in the herd. An interesting vaccine will be the live *Pasteurella multicida* and *Mannheimia hemolytica* vaccines. Non-adjuvanted MLV vaccines also fail to booster well vaccinated animals as active vaccine-induced immunity neutralizes vaccine virus pre-venting the MLV from replicating and preventing a booster immune response. Improved adjuvants have increased the scope and duration of inactivated virus immunity. Inacti-vated vaccines generate cell-mediated response and can enhance the immune response in well-vaccinated animals. This whole process from vaccination to achieving mature immune response takes at least 3 weeks. This fully developed mature primary response can then be boosted to get a true anamnestic secondary response. There is no "single vaccina-tion program" that will work on most farms or ranches. Each vaccine program needs to be designed based on the actual threats and needs of the farm, and not based on a company's or neighbors suggested program.

Key words: cattle, calf, vaccination, immunity

Résumé

La vaccination est un élément important pour la préven-tion et le contrôle des maladies bactériennes et virales bo-vine. Modification-vaccins vivants (MLV) ont été utilisés en raison de la bonne réponse anticorps, plus longue durée de l'immunité, un moins grand nombre de doses nécessaires par animal, et à moindre coût. La pression sélective de la réponse immunitaire d'un animal peut conduire à de nouveaux virus qui persistent et causer des problèmes dans le troupeau. Un intéressant le vaccin sera le live Pasteurella hemolytica multicida et Mannheimia vaccins. Sans adjuvant MLV vac-cins échouent également à bien d'appoint animaux vaccinés que l'immunité induite par le vaccin actif neutralise le virus du vaccin empêchant la réplication du MLV et prévenir un booster de la réponse immunitaire. Adjuvants améliorés ont accru la portée et la durée de l'immunité de virus inactivés. Les vaccins inactivés générer réponse à médiation cellulaire et peuvent accroître la réponse immunitaire dans bien des animaux vaccinés. Tout ce processus de la vaccination pour atteindre réponse immunitaire mature prend au moins 3 semaines. Cette réponse primaire mature pleinement développé peut ensuite être stimulé pour obtenir une vraie réponse secondaire anamnestique. Il n'y a pas de "programme de vaccination unique " qui fonctionne sur la plupart des exploitations agricoles ou des ranchs. Chaque programme de vaccins doit être conçus sur la base des menaces réelles et des besoins de la ferme, et non pas fondées sur une entreprise ou voisins programme suggéré.

Bovine Vaccine Principles

Vaccination is an important component for the pre-vention and control of bovine bacterial and viral diseases. Intranasal vaccines have the advantages of inducing mucosal immunity, stimulating good immunity in young animals, and are not being affected by maternal antibody.[10,20] Maternal antibody interference to bovine viral diarrhea virus (BVDV) or infectious bovine rhinotracheitis (IBR) are less of a prob-lem than it is for bovine respiratory syncytial virus (BRSV),[8] but animals should receive their first parenteral dose at 1 to 3 months of age with subsequent boosters depending on the type of vaccine (inactivated vs modified live (MLV)) and re-vaccination 30 days prior to breeding.[3] Adjuvanted MLV vaccines can overcome maternal interference.[22,23] Another approach to assess the impact of maternal interference is to collect serum samples from 10 to 20% of the calves (at 3 to 4 months of age), and measure BVDV, IBR and/or BRSV anti-body titers to determine if maternal antibody titers are high. If they are high, then retesting could be done 1 to 2 months later to determine if antibody levels are low enough to allow a good vaccine response. Vaccines should contain both CP BVDV 1 and 2. Even though there is some cross protection between Type I and Type II, the best protection comes from CP vaccines containing both Type I and II. NCP BVDV vaccines provide excellent cross protection with just a single type[1,12] as does the Singer CP BVDV strain.[5]

Vaccine Types

Modified live vaccines are used because of the good antibody response, longer duration of immunity, fewer doses needed/animal, and lower cost. These vaccines are administered intramuscular, intranasally or subcutaneously. MLV vaccines have drawbacks because they can contain ad-ventitious agents and the MLV BVDV and IBR vaccines are immunosuppressive. Although the return to virulence in MLV viruses has been minimal, mutations will occur and there is some risk of new strains arising. The selective pressure from

an animal's immune response may lead to new phenotypes. MLV vaccines also fail to booster well vaccinated animals as active vaccine induced immunity neutralizes vaccine virus, thereby preventing the MLV from replicating and preventing a booster immune response.[7,17] One of the more interesting developments has been the development of intranasal live-bacterial vaccine containing *Mannheimia hemolytica* and *Pasteurella multicida*.[6]

Inactivated vaccines contain chemically or physically treated bacteria, toxins and/or viruses so there is no danger of replication of the pathogen in the vaccinated animal or adventitious agents that maybe present in a MLV. Improved adjuvants have increased the scope and duration of inactivated virus immunity. They have several disadvantages including cost and more doses required/animal. Inactivated vaccines generate cell-mediated responses.[18,19] Hypersensitivity reactions (allergic) also occur more often with inactivated vaccines. Interestingly there is ample evidence that inactivated vaccines can effectively boost MLV vaccines.[9,13,17]

Timing of Vaccination

Vaccination at the Time of Arrival (and/or Weaning)

Vaccination programs are a routine practice in beef and dairy operations to protect cattle against bovine respiratory diseases (BRD). Numerous commercial vaccines for the prevention of BRD have been available since the 1950s. Current vaccine protocols recommend that calves be vaccinated prior to weaning or commingling to provide protection against BRD. Unfortunately, many calves are not vaccinated prior to weaning or commingling into backgrounding lots, feedlots or pasture operations. These animals are at increased risk of viral infection and are predisposed to secondary bacterial pneumonia.[16] However, the highly-stressed calf presents a unique problem—the vaccines may sometimes actually predispose the calves to more severe disease while on other occasions providing protection.

The time from vaccination to onset of protection can play an important role in subsequent health management of newly arrived cattle, in particular protection against BRD viral agents such as bovine herpesvirus 1 (BHV-1; IBR) BRSV, and BVDV. Commercially available MLV vaccines administered to non-vaccinated, low-stress calves at weaning or at arrival to feedyards will provide increased weight gain and protection to animals as early as 48 hours prior to an IBR exposure,[4] at 5 to 7 days prior to a BVDV[2] exposure, and 8 days prior to BRSV exposure. This protection is due to the innate immune response, which is activated within hours after exposure to MLV vaccines or infectious virus.

Frequency of Vaccination

No more than 1 to 2 doses of MLV or 2 to 3 doses of inactivated vaccine should be administered to young calves less than 4 months of age to develop good herd immunity against respiratory diseases.

Interval between Doses of Vaccine

In all animals there is expansion in the populations of responding T- and B-cells following vaccination[14] (Figure 1). However, to have a complete and mature immune response, this T- and B-cell expansion must not only stop but also an active process of cell death (apoptosis) must also occur. This "waning process" allows "culling" T- or B-cells that may be poor responders or even cause autoimmunity to be removed by apoptosis (Figure 1). This whole process from vaccination to achieving mature immune response homeostasis takes at least 3 weeks. This fully developed mature primary response can then be boosted to get a true anamnestic secondary response. In many cases, cattle vaccine primary and booster doses are administered at 2-week intervals. In young calves, this is done to provide an opportunity to make sure that the calves develop a primary response in the face of maternal immunity. The adjuvants that are used with most commercial vaccines provide superior immune development over older generation adjuvants like alum. Therefore, in most instances, if primary vaccination occurs after 3 weeks of age, booster vaccination beyond 3 weeks and even longer will be efficacious. The dogma that revaccination must occur within 2 weeks of the primary vaccination is not true, and the anamnestic response will be better if we wait longer

The Special Case of Young Calves and their Immune Response

Active Immunity in the Calf

While all the essential immune components are present in the neonate at birth, they do not seem fairly functional until at least 2 to 4 weeks of age. The developing and newborn calf is subject to a number of immunomodulatory effects. The
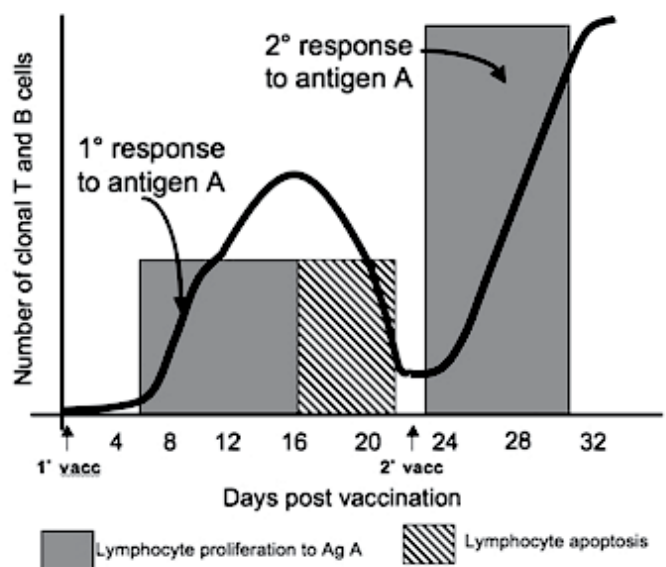

Figure 1. Interval between vaccinations.

placenta produces hormones and cytokines, such as IL-4 and Il-10, that affect both the fetus and the dam and suppress immunity. In addition, the cow produces estrogen and cortisol prior to parturition that all also have immunosuppressive effects. Finally the calf, as part of the parturition process produces high levels of cortisol that remain elevated for the first week of life. The cumulative effect of these hormones is to suppress the immune system and to direct the immune response away from the long-term memory response to the short-term antibody immune.[3]

Innate Immunity

The humoral components of the innate system are suppressed. Complement activity at birth in the newborn calf is about 50% of the cows and quickly decreases to <20% of the cows activity at 1 day of age. They gradually increase and by 1 month of age are back to 50%. Interferon production by leukocytes is lower. The cellular component is also affected. Neutrophils numbers in the newborn calf are 4X higher than 3-week-old calves.[11,21] The neonatal neutrophils and macrophages have reduced phagocytic ability that increases following the ingestion of colostrum. By 1 week of age, neutrophils are functional and able to mount an effective response. Neutrophil function gradually improves to adult levels by 5 months of age. The number of dendritic cells is lower and their ability to present antigen to the acquired immune system is also decreased.[11,21] Natural killer cells are also low at 1 week of age (3% of total lymphocytes) and increases to 10% by 6 to 8 weeks of age.[11,21]

Acquired Immunity

The neonatal calf is born without any antibody and is totally dependent on colostral intake for immunoglobulins. The number of B cells is greatly reduced in the neonate at 4% of the total lymphocytes at a week of age, and increase gradually to 20% of total lymphocytes at 6 to 8 weeks of age (normal is 20 to 30%).[11,21] This low number of B cells coupled with the immune suppression induced by the calves endogenous corticosteroids, maternal, and placenta hormones results in a lack of an antibody response until at least 3 weeks of age against parenterally administered viral and bacterial antigens.[15] Activation of T-lymphocytes is slightly less depressed at birth and remains constant through 28 days after birth. The take home message of active immune response in young calves is that cell mediated responses to vaccines can be induced very early, however animals must be 3 to 4 weeks of age before vaccines will induce robust antibody responses that will develop in 10 to 14 days following vaccination. The management of the calf's immune response requires understanding of the immaturity and development of the calf immune system. Vaccine timing needs to be managed to take advantage of the biology of the immune system and not haphazardly.

Calf Vaccination Programs

There is no "single vaccination program" that will work on most farms or ranches (Table 1). Each vaccine program needs to be designed and based on the actual threats and needs of the farm, and not based on a company's or neighbors suggested program. The generic disease syndromes (respiratory, reproductive or enteric) included in this sample vaccination program are provided as examples, and vaccines for specific diseases should be those that are either present (and/or have been a problem in the past) and/or a new disease that is a real threat to the farm. Any calf disease control program begins with a good vaccination program in the cow prior to calving, particularly for calf diarrheal diseases. Colostrum is essential for beef calf immune development and protection.

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Table 1. Vaccination programs for calf immunity.

Beef
Heifers (prebreeding) need to receive at least 1 dose of MLV prior to addition to the breeding herd
                              Respiratory and Reproductive Diseases
      MLV-2 doses
            >6 months of age and repeated 2 months before breeding
      Inactivated-2 doses
            5 weeks and 2 weeks before breeding
      Enteric Diseases
      MLV-2 doses
            5 weeks and 2 weeks before calving
      Inactivated-2 doses
            10-12 weeks and 4 weeks before calving
Cow Herd
      Respiratory and Reproductive Diseases
      Inactivated
            3-4 weeks before breeding is ideal
      MLV
            3-4 weeks prior to breeding is ideal. Do not vaccinate pregnant cows - no efficacy demonstrated for preventing PI in subsequent pregnancy. Problems with IBR abortion in animals poorly vaccinated
      Enteric Diseases
      MLV-1 doses
            2-4 weeks before calving
      Inactivated-1 dose
            4-6 weeks before calving
Calves (<4 months)
      MLV - viral and bacterial respiratory (*M. hemolytica* and *P. multicida*) vaccines
            Calves on vaccinated cows - MLV intranasal vaccines (depends on maternal antibody levels. MANY MLV IM or SC **NOT EFFECTIVE - ** ONLY adjuvanted MLV IM or SC)
      Inactivated Respiratory - well adjuvanted, not affected by maternal antibody
      Bacterial respiratory *M. hemolytica*, *P. multicida*, *H. somni* - (live or bacterins, subunit vaccines intranasal)
      Clostridials
      Leptospirosis???
Calves (>4 months)
      2-3 weeks prior weaning
            MLV respiratory virals - 1 dose
            Inactivated respiratory virals - 2 doses
            Bacterial respiratory *M. hemolytica*, *P. multicida*, *H. somni* - (live or bacterins, subunit vaccines)
            Clostridials
      At weaning (worse time to give vaccines)
            MLV respiratory - immunosuppressive
            Inactivated respiratory virals - 2 doses - least stressful
      2-3 weeks post weaning
            MLV - 1 dose
            Inactivated virals - 2 doses
            Bacterials *M. hemolytica*, *P. multicida*, *H. somni* - (live or bacterins, subunit vaccines)
            Clostridials
      Brucellosis
      Leptospirosis

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Rectal temperature and bovine respiratory disease outcome

Miles Theurer, DVM, PhD
Center for Outcomes Research and Education, Kansas State University, Mosier Hall J 118, 1800 Denison Avenue, Manhattan, KS 66506

Abstract

Rectal temperature is a common component of health-monitoring protocols to diagnose bovine respiratory disease. Information about the effectiveness of using rectal temperature as a diagnostic method and as a prognostic indicator for case outcome is provided. There are several factors that affect rectal temperature including environmental condition, time of day, and timing relative to disease progression. Rectal temperature of feedlot calves at first treatment of bovine respiratory disease has limited value as a prognostic indicator of case outcome; however, the use of rectal temperature does provide some form of objective monitoring for use in production practice.

Key words: rectal temperature, bovine respiratory disease, environment

Résumé

La température rectale représente une composante courante des protocoles de surveillance de la santé pour dépister les maladies respiratoires bovines. On évalue ici l'efficacité de l'utilisation de la température rectale en tant qu'outil diagnostic et indicateur pronostique pour le résultat clinique. Il y a plusieurs facteurs qui influencent la température rectale incluant les conditions environnementales, le temps de la journée et le moment dans l'évolution de la maladie. La température rectale des veaux en parc d'engraissement lors du premier traitement pour les maladies respiratoires bovines a une valeur limitée en tant qu'indicateur pronostique du résultat clinique. Toutefois, l'utilisation de la température rectale représente quand même une certaine forme de surveillance objective pour l'utilisation courante.

Introduction

Bovine respiratory disease (BRD) continues to be the most economically significant disease affecting the feedlot industry. Bovine respiratory disease is routinely diagnosed based upon visual observations evaluating for clinical signs of depression, lack of rumen fill, nasal discharge, and anorexia.[10] Rectal temperature is routinely collected on approximately 60% of morbid calves, and may influence the selection of an antimicrobial used to treat a morbid calf.[16] A rectal temperature is a relatively easy diagnostic tool to perform in practice, but there are a variety of factors that may affect the outcome. The objective of these proceedings are to summarize some of the recent published research studies evaluating the use of the rectal temperature and also BRD outcomes.

Effects of Weather Parameters on Rectal Temperature During Periods of Extreme Heat

Heat stress in cattle has been estimated to cause loses of $282 million/year in beef cattle due to decreased performance and increased risk of death.[11] Clinical signs of heat stress in cattle are similar to visual observations used to diagnose BRD, including increased respiratory rate and effort, decreased activity, and increased body temperature.[4,8] These similar physical observations make it difficult to distinguish between animals affected with heat stress and those animals that have BRD.

Since rectal temperature is a common component of diagnosis of BRD, a research study was conducted to determine the relationship between weather parameters and rectal temperatures during extreme summer conditions.[12] The study protocol included processing 500 lb (227 kg) heifers every 2 hours for 24 hour periods on 3 non-consecutive days during the summer and collect rectal temperature from each heifer. Ambient temperature, relative humidity, wind speed, and barometric pressure were continuously monitored from a remote weather station placed at the research station. A temperature-humidity index (THI) was calculated for observation.[5,15] A positive relationship was determined for ambient temperature and THI with rectal temperature. However, quantification of the effects of environmental conditions on rectal temperatures have not been performed before.

A diurnal pattern in rectal temperature was detected, which is in agreement with other published literature.[3,6] The diurnal pattern of rectal temperature may have an effect on case definition for BRD, depending on the time of the day when rectal temperatures are collected on calves. Waiting to process calves until later in the day may result in more calves being above the common rectal temperature cutoffs used to diagnose BRD in the field of 103.0°F (39.4°C), 103.5°F (39.7°C), or 104.0°F (40°C) due to normal body temperature rather than an elevated body temperature from being infected with BRD. Knowledge of the diurnal pattern of rectal temperature may need to be considered when using rectal temperature cutoffs in protocols for BRD diagnosis and/or therapeutic treatment regimens.

Changes in Rectal Temperature Relative to Disease Challenge

Challenge models are useful for initial evaluation of therapeutic treatments or diagnostics as the exact timing, dose, and method of administration if the onset of disease is known. Challenge models are able to evaluate how some physiological parameters may change over time in calves challenged with the pathogen of interest and control calves that were not challenged. *Mannheimia haemolytica* is the most common bacterial pathogen associated with BRD.[9]

A research study was developed evaluating the effects of induced pneumonia caused by *M. haemolytica* during high ambient temperatures on body temperature.[13] Ten beef heifers were endoscopically challenged with *M. haemolytica* and 8 beef heifers were assigned as non-inoculated control calves. Calves were monitored every 2 hours for 24 hours after challenge, and then twice daily for 9 days after challenge. At each monitoring time point, the rectal temperature was collected from each heifer. A treatment-by-time interaction ($P < 0.05$) was identified for rectal temperature during the initial 24 hour monitoring period, and also the daily monitoring period. During the initial 24 hour monitoring period, calves in the *M. haemolytica* treatment group had greater ($P < 0.01$) average rectal temperature 6 hours after challenge up to 24 hours after challenge compared to control calves. However, during the daily monitoring period of the trial, calves in the *M. haemolytica* treatment group only had a greater average rectal temperature on days 0 and 1 relative to the challenge compared to control calves. On days 2 through 8, no differences were detected between treatment groups. In other *M. haemolytica* challenge studies, rectal temperatures returned to normal 1 to 3 days after challenge, which has been attributed to endotoxin release or other pyrogenic effects from *M. haemolytica*.[1,7,13,17]

The use of rectal temperature may be only beneficial to detect animals during the acute pathological phase of BRD, as up to 3 days after challenge no difference in rectal temperature between control and challenged animals has been detected. During the initial 24-hour monitoring period, all 10 calves in the *M. haemolytica* treatment group had rectal temperatures greater than 103.0°F (39.4°C), but 5 of the 8 control calves had rectal temperatures that exceeded this cutoff as well. Refinement of where these body temperature cutoffs are established may need to be considered.

Use of Rectal Temperature to Predict Probability of Finishing the Production Cycle Normally

A retrospective data analysis was performed on feedlot production records to evaluate the relationship between rectal temperature at first pull for BRD and the probability of not finishing the production cycle normally.[14] Individual animal data from 19 United States feedlots were collected from 2000 to 2009. Case definition of BRD was determined by feedlot personnel and rectal temperature was collected as initial treatment for BRD. A binary variable was created to identify calves that died or were realized prior to harvest of their cohorts. Associations of rectal temperature, number of days in the feedlot at first pull for BRD, arrival weight, quarter of year at feedlot arrival, sex, and all 2-way interactions with rectal temperature were evaluated. A receiver-operating characteristic curve was also created from the final model to evaluate the overall accuracy of the model.

A total of 344,982 calves identified with having BRD were included in the analyses; 7.97% of these did not finish the production cycle normally. The mean and median rectal temperature of calves diagnosed with BRD was 104°F (40°C). As rectal temperature increased, the probability that a calf would not finish the production cycle normally increased; but the relationship was not linear and was influenced by quarter of year at feedlot arrival, sex, and number of days in the feedlot when pulled for BRD. The final statistical model was only able to accurately classify whether or not a calf would be classified as did-not-finish was low, as the model was only accurate 64.6% of the time. The model used in the analysis included information that feedlot managers routinely have available at treatment of BRD.

Other classification algorithms have been created to more accurately predict outcomes of feedlot cattle identified with BRD which agreed with the overall poor accuracy of identifying calves that did not finish the production cycle normally.[2] However, Amrine et al were able to improve these accuracies of some of these models utilizing different sampling methods and matching the algorithms with appropriate datasets.[2] In the retrospective study, we were not able to identify a specific rectal temperature that could be used as a threshold on which BRD treatment decisions can be made. Rectal temperature of feedlot calves at first treatment of BRD has limited value as a prognostic indicator of case outcome.

Conclusions

There are several factors that affect rectal temperature, including environmental condition, time of day, and timing relative to disease progression; however, the use of rectal temperature does provide some form of objective measure for use in production practices, and is less subject to human error than many other measures. Interpretation of rectal temperature results needs to be considered along with other clinical signs the animal displays. Multiple factors can affect BRD outcome including arrival weight, sex, known previous health status, and time of the year. Other modalities may be available to more accurately determine the health status of a calf which may influence our ability to make improvements of BRD diagnosis.

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Bovine thoracic ultrasonography: a potential tool for the management of bovine respiratory disease

Ryan D. Rademacher, DVM
Feedlot Health Management Services Ltd., PO Box 140, Okotoks, AB T1S 2A2, Canada

Abstract

Bovine respiratory disease (BRD) continues to be the major animal health concern facing the North American cattle feeding industry. Despite improvements in technologies and the development of new antimicrobials, morbidity and mortality rates have remained flat or even increased. Thoracic ultrasonography (TUS) is a technology that has shown promise as a chute-side diagnostic tool for BRD. Degree of lung consolidation, as determined by TUS, has been negatively correlated to clinical outcome in cattle pulled for signs attributable to BRD and not treated with antimicrobials (negative controls). Thoracic ultrasonography is relatively simple to perform, and many of the available ultrasound machines and probes used for bovine reproductive ultrasonography can also be used to examine the lungs and pleura. While the procedures and techniques for large-scale use in a production setting remain to be validated, practitioners may currently be able to use the technology to add accuracy and value to their recommendations for case management of individual animals.

Key words: bovine, cattle, ultrasound, BRD

Résumé

Le complexe respiratoire bovin (CRB) demeure la préoccupation la plus importante au niveau de la santé animale dans le secteur du bétail pour l'alimentation en Amérique du Nord. En dépit des percées technologiques et du développement de nouveaux agents antimicrobiens, les taux de morbidité et de mortalité restent inchangés ou ont même augmenté. L'échographie thoracique est une technologie prometteuse qui pourrait servir d'outil de diagnostic du CRB à même l'enclos. Le degré de consolidation dans le poumon, tel que déterminé par l'échographie thoracique, montre une relation négative avec le résultat clinique chez les bovins retirés en raison de signes attribuables au CRB et non traités avec des agents antimicrobiens (témoins négatifs). L'échographie thoracique est relativement simple à utiliser et plusieurs des échographes et des sondes échographiques utilisés pour l'échographie du système reproducteur chez les bovins peuvent être utilisés pour l'examen des poumons et de la plèvre. Bien que les procédures et techniques pour l'utilisation à grande échelle en milieu de production restent à valider, les praticiens peuvent dès maintenant utiliser cette technologie pour augmenter la précision et ajouter de la valeur à leurs recommandations pour la gestion des cas individuels.

Introduction

In recent decades, multiple new antimicrobial treatment options have become available for use in feedlot cattle. Unfortunately, even in the face of these new antimicrobials, death loss for feedlots has remained similar or even increased during the same time period.[16] According to the National Animal Health Monitoring System (NAHMS) survey data from 1994, 1999, and 2011, death loss for all feedlots greater than 1000-head capacity that were surveyed was 1.1%, 1.3%, and 1.6% respectively.[16] Bovine respiratory disease (BRD) remains the primary health concern for the North American cattle feeding industry.

Commonly used criteria for determining disease in feedlot cattle can be summarized with systems such as DART (Depression, Appetite, Respiration, and Temperature); although peer-reviewed references for DART are lacking.[10] While these descriptions attempt to apply objective criteria to disease detection, good pen-riding is a combination of art and science. Multiple studies have evaluated the presence of lung lesions at slaughter and correlated these back to feedlot performance and previous treatment data. Animals with lung lesions present at slaughter range from 42 to 87%, and the presence of lesions in treated and untreated animals range from 40 to 97% and 37 to 83%, respectively.[4,7,9,13,14,15,17] These findings indicate that many animals with BRD or subclinical BRD may be missed by conventional means of disease detection and that a subset of animals treated for BRD may be misclassified and not require treatment. Lung lesions present at slaughter have been associated with poorer average daily gain (ADG) during the feeding period,[4,15,17] and the severity of lesions have been correlated to the degree of impact on ADG.[13]

While working towards systems that reduce the impact of BRD on beef production it is important to consider antimicrobial stewardship. Some current indications for antimicrobial use will face increased public scrutiny and government regulation in the coming years. However, it is our responsibility as practitioners to go above and beyond these measures to ensure that antimicrobials are used in a prudent and responsible manner. Some regulation may be unavoidable; however, industry initiative on this topic and the further development of new or existing technologies that may improve identification of animals truly in need of antimicrobial therapy may help in the fight to keep these valuable

tools available for practitioners and producers.

In this day and age, with decreasing technology costs and increasing value of cattle, new technologies that may aid in the diagnosis and classification of BRD deserve increased attention. One technology that shows promise as a means of determining the degree of lung pathology is the use of thoracic ultrasonography (TUS). Thoracic ultrasonography has been proven to be well correlated with lung pathology present at necropsy[8,11] and has high specificity as a tool for diagnosing BRD in dairy calves.[6] In addition, following some basic training, TUS is a procedure that can be performed accurately by individuals with no prior background with ultrasound interpretation.[5] Therefore, it is a logical and practical option to evaluate as an augment to clinical impression score for the classification of BRD in the feedlot. By using such technologies to more accurately and specifically diagnose BRD and better classify the severity of disease in affected individuals, there may be opportunity to differentially treat animals, thus producing better outcomes and reducing total antimicrobial use.

Thoracic Ultrasonography

Thoracic ultrasonography is a relatively simple procedure to perform chute-side. Equipment needed includes an ultrasound machine, probe, and conducting agent. The most useful probe is a linear array in the range of 5 to 8 MHz; however, curvilinear or convex probes may also be used. The benefits of a linear array are: 1) it allows for good contact between the probe and skin due to the relatively flat nature of the hide within the intercostal spaces, 2) this is a commonly used probe for transrectal ultrasound and is commonly found in practices; or even in feedlots where ultrasound is used to determine pregnancy status of heifers on arrival. For a conducting agent, 70% isopropyl alcohol is an economical choice and allows for appropriate image quality. No clipping of the hair is necessary unless there is significant tag that requires removal. The lungs and pleura are examined by positioning the probe longitudinally within the intercostal spaces and scanning a region that approximates the auscultable lung field, focusing on the cranioventral regions near the heart. In feedlot cattle, the front limb precludes evaluation of the right cranial lung lobe, which is most often affected by BRD.

Many good resources are available on lung ultrasonography,[2,3,8,11] and an in-depth explanation falls beyond the scope of this paper. In brief, normal aerated lung will reflect all sound waves creating a hyperechoic line at the pleural surface. The visceral pleura can be seen sliding across the parietal pleura during inspiration and expiration. The lung parenchyma is not examined in normal lung and a reverberation artifact is often seen deep to the pleural surface. When lung becomes consolidated, the visceral pleura loses its sharp definition and heterogenous echotexture is present in lung parenchyma as sound waves pass through areas of fluid-filled alveoli (hypoechoic) and are reflected by air filled bronchi

(hyperechoic). In severely consolidated lung, the entire parenchyma is fluid filled and takes on a more homogenous hypoechoic echotexture (also termed hepatization of lung due to the similar appearance as normal liver). Other possible ultrasonographic lesions of varying significance include pleural effusion, pleural irregularities, abscesses, and comet tails.

Feedlot Applications

There is minimal research published on the use of TUS in a feedlot setting. The first study in a feedlot setting was performed by Abutarbush and colleagues in 2006-2007[1] to evaluate utility of TUS at first diagnosis for BRD using a case:control design. These researchers scanned 3 intercostal spaces on the right side of the animal at time of first treatment for BRD and determined that there was no correlation between TUS and subsequent animal health outcomes.[1] They did, however, postulate that TUS may be of some value in certain populations, such as those suffering from a longer course of disease (e.g. animals in the chronic pens).[1]

A second case:control study performed in 2012 to evaluate TUS findings during the natural progression of BRD showed a strong negative correlation between degree of consolidation and subsequent clinical outcome (defined as death prior to the end of the 15-day trial period).[12] In this study, case animals were not treated with antimicrobials as an objective of the study was to follow natural progression of BRD, and the entire lung field was scanned for lesions on both sides of the animal.[12] When evaluating the agreement between consolidation diagnosis in the right and left lungs, the kappa agreement was moderate (0.50; 95% confidence interval from fair to good (0.25 to 0.74)), suggesting that at least a region of both lungs must be scanned for accurate assessment.[12] Additionally, this study[12] used a 5 to 8 MHz linear array whereas the previous study[1] utilized a 3.5 MHz sector probe. These above mentioned differences in study design may have contributed to the conflicting findings between the 2 studies. It was also determined that 9 sites (4 right and 5 left hemithorax) had an odds ratio significantly greater than 1 ($P<0.05$) for predicting negative outcome when consolidation was present at time of enrollment.[12] The locations outlined by these sites primarily encompass a region caudal to the heart at, or ventral to, the level of the shoulder joint, highlighting a more targeted area for future work evaluating the use of TUS in a feedlot setting.

While there is still much to be done in evaluating this technology for large scale use in the feedlot, practitioners should be aware of this tool and consider TUS as an aid in the diagnosis and management of individual cases. When asked to evaluate or make management decisions on an individual animal, TUS can add to the value of recommendations provided. Many practitioners already have equipment suitable for performing TUS, as many ultrasound machines

and probes routinely used for reproductive work will also provide diagnostic images of the lungs in the bovine.

Conclusions

Thoracic ultrasonography may prove a valuable tool for diagnosing and further classifying severity of BRD in feedlot cattle. A strong negative correlation exists between degree of lung consolidation present at time of initial pull and subsequent outcome in calves not treated with antimicrobials (negative controls). While TUS may not be practical for all applications on the feedlot, there is the potential that this tool may be valuable in certain scenarios. By merging the art of good pen-checking with the science of improved technologies, producers and practitioners can achieve new levels of disease detection, diagnosis, and management. Further research on this topic is warranted, and the goal of future work should be to identify applications of TUS that provide an economic advantage to the producer.

Practitioners should be aware of this technology and may be able to incorporate it as an additional tool for diagnosis and management of individual cases.

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Eating behavior in the feedlot: a tool to assist in detection of bovine respiratory disease

D. Scott MacGregor,[1] DVM; **David Sjeklocha,**[2] DVM; **Rob Holland,**[3] DVM
[1]Feedlot Health Management Services-USA, 506 East Cave Court, Boise, ID 83702
[2]Cattle Empire, LLC, 1174 Empire Circle, Satanta, KS 67870
[3]Zoetis Animal Health, Lexington, KY
Corresponding author: Dr. Scott MacGregor; email: dscottmacgregor@gmail.com

Abstract

Historically, bovine respiratory disease (BRD) has caused major challenges in the North American feedlot industry. Commonly, BRD is the leading cause of morbidity and mortality in feedyards. Current BRD detection practices involve visual appraisal of clinical signs, such as depression, nasal discharge, altered locomotion, lack of fill, and cough. A novel high-frequency active integrated electronics system (AIES) was utilized to collect and record eating behavior of newly received, southeastern, auction-market derived calves. Two studies evaluated the health performance of calves managed by a traditional health system (cowboy assessment) versus a technology system. Results demonstrated the AIES decreased total percentage of respiratory pulls from 38.3 to 19.6 ($P = 0.0001$), while BRD mortalities were numerically lower for the technology treatment group, but not significantly different from the traditional system.

Key words: cattle, feedlot, BRD, detection

Résumé

Le complexe respiratoire bovin (CRB) constitue depuis longtemps un défi à l'industrie Nord-Américaine des parcs d'engraissement. Le CRB est très souvent la cause principale de morbidité et de mortalité dans les parcs d'engraissement. Les méthodes actuelles de détection du CRB s'appuient sur l'examen visuel de signes cliniques, tels la dépression, l'écoulement nasal, les changements de locomotion, le manque d'appétit et la toux. Un nouveau système actif à haute fréquence à composantes électroniques intégrées a été utilisé pour la cueillette et l'enregistrement du comportement alimentaire de veaux d'encan du sud-est nouvellement arrivés. Deux études ont évalué la performance de santé des veaux avec le système de surveillance traditionnelle de la santé par les employés du parc et avec le nouveau système de surveillance électronique. Les résultats ont montré que l'utilisation du nouveau système électronique a permis une réduction du pourcentage d'animaux retirés pour causes respiratoires de 38.3 à 19.6 ($P = 0.0001$). Par ailleurs, la mortalité associée au CRB était plus basse avec le système électronique qu'avec l'approche traditionnelle bien que la différence n'était pas statistiquement significative.

Introduction

Current feedyard metrics measure case fatality rates, therapy response, and days to fatal disease onset. However, as veterinarians, we are constantly trying to balance current metrics while incorporating judicious antimicrobial use and animal welfare, along with balancing economic sustainability. Health systems that would allow more accurate identification of calves with health abnormalities could potentially improve our metrics while allowing us to address challenges around judicious use, animal welfare, and sustainability. There is a poor correlation between visual appraisal of feeder calves and actual BRD infection[1]. Numerous studies have examined associations between cattle eating behavior and clinical infectious disease.[2,3,4] Sowell et al demonstrated healthy steers spend more time over a 24-hour period at the bunk, and also have more eating bouts than sick cattle. In addition, Quimby et al found unhealthy animals were detected 4.5 days prior to standard detection by feedyard personnel. While each of these systems may have merit, the commercial applicability has been limited due to defining the value that each system offers the industry.[5]

The objective of the studies was to evaluate the health performance of calves managed by traditional health system (cowboy assessment) versus technology system.

Materials and Methods

Two 60-day studies were conducted at a large commercial feedyard in southwest Kansas. In Study 1, 484 southeastern, auction-market derived calves were purchased and arrived weighing 448 lb (203 kg). In Study 2, 976 southeastern, auction-market derived calves were purchased and arrived weighing 478 lb (216.8 kg). Calves were processed on arrival using standard feedyard operating protocols (SOP). Calves were vaccinated against infectious bovine rhinotrachetis virus, bovine viral diarrhea virus type 1 and 2, parainfluenza virus, and bovine respiratory syncytial virus and *Mannheimia haemolytica*.[a] Calves were treated for internal and external parasites with ivermectin[b] (1 mL/110 lb (50 kg) bodyweight (BW) subcutaneously). All study calves received a lot/pen/individual identification ear tag and were tested for persistent infection with bovine viral diarrhea virus. All calves received tulathromycin[c] at 1.2 mL/100 lb (45.4 kg) BW

subcutaneously upon arrival with a 10-day post-metaphylaxis moratorium. Calves were booster vaccinated against infectious bovine rhinotrachetis virus, bovine viral diarrhea virus type 1 and 2, parainfluenza virus, and bovine respiratory syncytial virus vaccine[d] approximately [something missing here?] after arrival.

Study 1 consisted of approximately 80 head/pen and 3 replicates. The first study contained 3 treatments: 1) traditional health system (cowboy assessment); 2) technology system and traditional system; and 3) technology system alone. The traditional and technology system hybrid was a combination of the traditional health system evaluation in conjunction with the technology system evaluation. Study 2 had approximately 95 head/pen and 5 replicates, with 2 treatments per replicate: 1) traditional health system (cowboy assessment) and 2) technology system. The active integrated electronic system (AIES) was utilized in the calves assigned to the technology treatment group. Randomization was accomplished by using a 5×5 gate sort of animals until the paired replicates were full.

A linear antennae, spanning the entire length of the feed bunk, was placed in all feed bunks. This recognized individual animal identification and recorded frequency and duration of visits to the bunk. Every 24 hours data was sent to a centralized off-site location for analysis. Previously modeled algorithms determined if calves had an abnormal eating behavior and should trigger an alert. Alerts were sent daily to the feedyard identifying calves with abnormal eating behavior patterns that were to be evaluated.

All study calves received the same therapy regimen. Calves deemed as 'sick' the first time were treated with ceftiofur[e] (1.5 mL/100 lb (45.4 kg) BW, at the base of the ear) and vitamin C[f] (4 mL/100 lb (45.4 kg) BW, subcutaneously). A 5-day post-treatment interval (PTI) was used. Calves treated a second time received florfenicol (6 mL/100 lb (45.4 kg) BW, subcutaneously) and vitamin C[f] was given (4 mL/100 lb (45.4 kg) BW, subcutaneously). A 4-day PTI was observed following treatment with florfenicol. The third treatment was danofloxacin[g] (2 mL/100 lb (45.4 kg) BW, subcutaneously) and vitamin C[f] (4 mL/100 lb (45.4 kg) BW, subcutaneously); a 6-day PTI was utilized for danofloxacin.[g]

Treatment success was defined as a calf that was pulled for BRD, treated, and subsequently did not get treated again. Necropsies were performed by feedyard staff under the guidance of the on-staff veterinarian. Study 1 and Study 2 were combined for statistical analysis. It was apparent, via numerical comparison, that the traditional and technology system hybrid treatment group in Study 1 was not advantageous compared to the other 2 treatment groups. Therefore, no statistical comparisons between the traditional system or the technology system and the traditional and technology system hybrid were completed. A mixed linear model was used for analysis of all dependent variables. For the analyses, the model included a fixed treatment effect and random effects of phase, block within phase and error. The error term was used to test the effect of treatment.

Results and Discussion

The respiratory morbidity rate was significantly ($P = 0.0001$) lower in the technology system than in the traditional system. The traditional system resulted in 38.3% morbidity rate and the technology system had 19.6% morbidity rate. It is important to note that while the technology system resulted in fewer animals being treated, it did not negatively affect the mortality rate. In fact, the BRD mortality rate was numerically lower in the technology system compared to the traditional system (3.9% vs 5.1%, respectively).

Medication and processing costs were reduced when using the technology system as compared to the traditional system ($39.99 vs $33.74; $P = 0.04$). This resulted in a $6.25 savings/head treated. In addition to the advantage in medi-

Table 1. Health performance of calves managed in either a traditional or a technology system: 60-day study.

	Traditional system	Technology system	*P*-value
Number head	730	730	
Effective head count[*]	697	699	
Initial pulls,[†] %	38.2	19.6	0.0001
Second pulls,[†] %	44.4	23.1	0.0001
Third pulls,[†] %	54.4	36.7	0.0001
Fourth pulls,[†] %	6.5	0	0.0001
Medication and processing charges, $/hd	39.99	33.74	0.04
Bovine respiratory deads, %	5.1	3.9	
Treatment success rate,[‡] %	67.6	81.5	0.05

[*]Effective headcount = number of head enrolled − (number of BVD-PI head removed + number of head diagnosed with pneumonia during the 10-day post-metaphylaxis interval).

[†]Least Squares Means

[‡]Treatment success = a calf that was pulled for BRD, treated, and subsequently did not get treated again

cation and processing costs, the calves on the technology system also responded better to treatment therapy ($P = 0.05$). Cattle on the technology system had a treatment success rate of 81.5% vs only a 67.6% treatment success rate in the traditional system.

Conclusions

Today, feedyards have to manage challenges around labor resources, time management, and judicious antimicrobial usage, along with maintaining high health and growth performance of the cattle. The feeding industry continues to evaluate technologies that have potential to allow for more efficient daily operations, while maintaining economic sustainability.

This technology system demonstrated a statistically significant ($P = 0.0001$) reduction in the number of times a calf had to pass through the chute, with a numerical advantage in overall BRD mortality. In addition, those calves identified by the technology system and subsequently treated had a higher percentage treatment success rate ($P = 0.05$). These studies suggest this technology to be an asset in the identification of cattle with health abnormalities leading to potential economic value by reducing treatment rates and improving treatment success.

Endnotes

[a]Pyramid® 5 + Presponse® SQ, Boehringer Ingelheim, St. Joseph, MO

[b]Noromectin®, Norbrook Laboratories, LTD, Corby, Northamptonshire, Ireland
[c]Draxxin®, Zoetis, Florham Park, NJ
[d]Titanium 5®, Elanco Animal Health, Greenfield, IN
[e]Excede®, Zoetis, Florham Park, NJ
[f]Vitamin C, Vedco Inc, St Joseph, MO
[g]Nuflor Gold™, Merck, Kenilworth, NJ
[h]Advocin™, Zoetis, Florham Park, NJ

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Monitoring systems for identifying bovine respiratory disease

Brad White, DVM, MS
Department of Clinical Sciences, Kansas State University, Manhattan, KS 66502

Abstract

Accurate diagnosis of bovine respiratory disease (BRD) is a critical component of applying appropriate therapy at the optimal time. Visual observation is the conventional manner for BRD diagnosis; however, this method has been shown to have relatively low diagnostic accuracy. Identifying diseased calves visually is a challenging prospect as observers often have limited time, and the clinical signs of BRD are subjective and variable among cases. Several tools have been evaluated to augment the BRD diagnostic accuracy including evaluation of rectal temperature, specific pathogen diagnostics, evaluation of the inflammatory profile, and determination of changes in behavior. New methods have been employed remotely monitoring cattle behavior and utilizing these data to determine changes in wellness status. Remote behavioral monitoring has shown promise for early, accurate BRD diagnosis, but the decision to use this technology should be based on the expected benefits compared to costs of employing the system.

Key words: cattle, feedlot, pen riding, BRD

Resumé

Le diagnostic fiable du complexe respiratoire bovin (CRB) est une composante essentielle du traitement appropriée au moment opportun. L'observation visuelle est la méthode utilisée traditionnellement pour poser un diagnostic. Toutefois, on reconnait que cette méthode n'a pas une valeur diagnostique très élevée. L'identification visuelle des veaux atteints représente un défi pour les observateurs en raison de la limite de temps et parce que les signes cliniques associés au CRB sont subjectifs et variables selon les cas. Plusieurs outils ont été évalués afin d'augmenter la fiabilité du diagnostic du CRB incluant l'évaluation de la température rectale, le diagnostic d'agents pathogènes particuliers, l'évaluation du profil d'inflammation et la détermination de changements comportementaux. De nouvelles méthodes de surveillance de veaux à distance ont été développées et leurs données sont utilisées pour déterminer les changements dans l'état de santé. La surveillance à distance du comportement semble prometteuse pour poser un diagnostic fiable et précoce du CRB. La décision d'utiliser cette technologie devrait toutefois se baser sur les bénéfices attendus versus les coûts d'utilisation du système.

Introduction

Bovine respiratory disease (BRD) is a major disease syndrome for post-weaned calves. Despite advances in preventatives and therapeutics, the overall level of morbidity in US feedyards has been relatively unchanged in recent years from 14.4% in 1999 to 16.2% in 2011.[10] During this same period the cost of BRD treatment has increased from an average of $12.59 per head to $23.60.[10] The detrimental impact of BRD encompasses more than just the cost of therapy, but also includes adverse health outcomes and decreased performance associated with this disease syndrome. In a study comparing economic and performance outcomes associated with the number of BRD treatments, cattle that were never treated had a $72 advantage over cattle that were treated 3 or more times.[2] Feedyards are affected by BRD, and while it is unlikely to eliminate the disease, minimizing the deleterious impacts of this syndrome are important.

One of the key components of applying effective therapy is accurate, timely, and consistent identification of cases. The objective of this review is to describe BRD diagnostic procedures including conventional modalities, the value of adjunct information to improve diagnostic accuracy, and potential new methods to identify BRD cases.

Conventional Diagnosis

The most common method for identification of BRD cases is visual observation based on clinical signs. Clinical signs associated with BRD are subjective and include depression, anorexia, nasal discharge, and labored breathing. Feedyards observe calves once or twice daily depending on the expected risk status of the animals. While visual observation is the most common BRD identification method, several reports have identified a relatively high number of calves with lung lesions present at slaughter that were never identified as BRD or treated during the feeding phase.[5,14] This finding coincides with other estimates that have described relatively low sensitivity (61.8%) and specificity (62.8%) associated with visual observation for diagnosis of BRD.[13]

There is no gold standard for diagnosis of BRD in live animals, but research has evaluated the association of clinical signs with pulmonary lesions soon after diagnosis in a small population.[1] In this study, multiple observers classified calves as diseased or healthy and a comparison of the results to pulmonary lesions revealed a broad range in estimated

sensitivity and specificity among observers. Additionally, there was a low level of agreement (kappa = 0.16) among observers. Identifying a clear case definition and ensuring that observers are evaluating similar signs can help with agreement, but further work may need to be done to increase the overall accuracy of observations.

The accuracy of BRD diagnosis could be improved by adding multiple tests in parallel (increased sensitivity) or multiple serial evaluations (increased specificity). Changing the sensitivity or specificity of a diagnostic test often does not result in equivalent differences in gained value due to differential costs of false positive and false negative diagnosis. Improving the diagnostic characteristics of BRD detection in feedlots was evaluated with a stochastic economic model, and the results illustrated that improvements in diagnostic specificity had a greater influence on expected profitability than improvements in diagnostic sensitivity.[7] While other factors had greater influence on overall cattle profitability than BRD diagnostic characteristics, this work illustrates the importance of BRD confirmation as part of an accurate diagnostic plan.

Value of Adjunct Information for BRD Diagnosis

One way to improve the accuracy of BRD diagnosis is collecting additional information after initial identification of diseased cattle based on clinical signs. Several methods are available to augment the diagnostic process including using rectal temperature, diagnostics for specific pathogens, combining available production information, evaluation of the inflammatory profile, or determining objective measures of behavioral changes.[16] The evaluation of rectal temperature at the time of diagnosis is commonly included in many diagnostic protocols and discussed in detail elsewhere so will not be addressed in this review.[8]

Evaluation of the animal's inflammatory or infectious disease response could be helpful for confirming BRD diagnosis; however, in calves challenged with BRD pathogens, the complete blood count and serum biochemistry profiles do not provide the level of discrimination to separate true cases from healthy cattle.[3,4] Specific inflammatory proteins or biomarkers (e.g. haptoglobin) may be useful as a confirmatory diagnostic technique as these variables have been shown to distinguish true cases from healthy controls.[9] One challenge of biophysical profiling at the time of treatment to determine BRD status is the ability to collect samples and evaluate the results chuteside in a real time fashion.

Visual observation for BRD often focuses on identifying behavioral changes in cattle indicative of changes in wellness status. Several tools are available that can accurately monitor calf behavior, both activity and feeding information, and this technology has been evaluated for identification of BRD. Research projects have illustrated differences in behavior associated with BRD status.[9,12,15] Multiple tools are available to augment visual observation for BRD diagnosis, and research

should be evaluated to determine which additional tests are most appropriate and economically efficient in each situation.

Potential New Methods of BRD Detection

Automated behavioral monitoring combined with diagnostic algorithms has illustrated promise for improving the accuracy and timing of BRD diagnosis. Aspects of feeding behavior have been shown to be associated with BRD status,[6] and recent technological changes have allowed further progression of this work.[15] In a direct comparison of a system that evaluated calf movement, feeding behavior, and social network, the system agreed with a trained observer 85% of the time, but identified cases an average of 18 hours before the observer.[11] This research indicates that remote monitoring of cattle behavior can be a valuable asset for early, accurate identification of BRD. Further research should be performed to evaluate the efficacy of employing behavioral monitoring to accurately identify BRD cases.

Conclusions

Bovine respiratory disease is a major disease in feedlots and accurate, timely diagnosis can lead to the appropriate application of therapy to diseased animals. Visual observation is the most common method for diagnosis, and several tools exist to augment the accuracy of this technique. Evaluating which additional diagnostic tests should be employed in each situation is dependent on the additional diagnostic costs compared to the potential benefits of improved diagnostic accuracy.

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Feed additives: a nutritionist's perspective on their purpose and application

Tony C. Bryant, PAS, PhD
JBS Five Rivers Cattle Feeding, Greeley, CO 80634

Abstract

Numerous feed additives are utilized in feedlot diets for various purposes including growth, efficiency, carcass merit, and for prevention and treatment of disease. This article is to review the most common feed additives utilized in feedlot cattle in North America as well as their indications and restrictions. The Veterinary Feed Directive will require veterinarians to understand these principles for feed-grade antibiotics for purposes of writing prescriptions in coordination with colleague nutritionists.

Key words: cattle, feedlot, feed additives

Résumé

De nombreux additifs alimentaires sont utilisés dans les diètes de parcs d'engraissement pour diverses raisons, dont la croissance, l'efficacité, la carcasse du mérite, et pour la prévention et le traitement de la maladie. Cet article est d'examiner les plus communs d'additifs alimentaires utilisés dans un parc d'engraissement des bovins en Amérique du Nord ainsi que leurs indications et restrictions. La directive vétérinaire pour les aliments exigera des vétérinaires de comprendre ces principes pour antibiotiques fourrager pour fins de rédaction de prescriptions en coordination avec collègue nutritionnistes.

Feed Additive Definitions

Medicated feed additives are categorized by FDA.[6] Category-I drugs are those that require no withdrawal period at the lowest use level in each of the species for which they are approved. Category-II drugs require a withdrawal period at the lowest use level for at least 1 species they are approved for or are regulated at a "no-residue" or "zero-tolerance" basis. FDA also defines 3 types of medicated products. A Type-A medicated article is a product of standardized potency which is destined for production of a Type-B or Type-C medicated feed. A Type-A medicated feed is typically the feed article that comes directly from the drug manufacturer and is the most concentrated form of a product that can be used by feedlots. If a Type-A drug is used at a feedyard, it would be fed from a microingredient machine which batches with high accuracy and precision. In order to use a Type-A, Category-II drug, a feed manufacturing facility must have an approved and active Medicated Feedmill License (MFML); these include

feed additives such as amprolium, tilmicosin, and zilpaterol. A Type-B feed is also intended for the production of other Type-B and -C feeds, but it also has a substantial quantity of other nutrients such as vitamins and minerals which dilute the Type-A article. A Type-C medicated feed is produced by substantial dilution of the Type-A or -B medicated articles and may be offered as a complete feed to the animals. We would typically consider the diet that we manufacture at the feedlot and deliver directly to a pen of cattle the Type-C feed.

The maximum concentration of active ingredient allowed into the Type-B of Category-I and -II drugs is 200 and 100 times the continuous use level, respectively.[6] For example, the maximum level of ractopamine, a Category-I drug, in a Type-C feed is 24.6 g/ton (90% DM basis). Consequently, the maximum level allowed in the Type-B is 2.46 g/lb. Similarly, the maximum level of zilpaterol, a Category-II drug, in a Type-C feed is 6.8 g/ton (90% DM basis); consequently, the maximum level allowed in the Type-B is 680 g/ton or 0.34 g/lb. It is also important to note that use levels can be defined in terms of concentration (e.g. mg/kg or g/ton) and/or dosage (mg/day or mg/lb of body weight per day). In many cases, a drug will have use levels in terms of both concentration and dosage. This can become challenging to meet both dosage and concentration requirements on some drugs, such as tylosin and tilmicosin. It is also important to know that most label requirement concentrations are expressed on a 90% DM basis; however, most diets are formulated on a 100% DM basis. Consequently, care must be taken to ensure that units are on the same basis. For example, ractopamine can be fed up to 24.6 g/ton (90% DM basis) in cattle; this is equivalent to 27.3 g/ton on a 100% DM basis. Moreover, feed tags for mixed feeds, supplements (e.g. Type-B) are expressed on an as-is basis.

It is also important to note the language on the feed additive labels. For example, some labels state to feed the product "continuously as the sole ration". This means that the feed additive is to be fed in every feeding the animals get during the described labeled period. Also note that drugs can only be fed in combinations with other drugs if it listed as an approved product.[6] This also means that if 2 drugs are not approved to be together in the same diet, they cannot be in the same feed bunk together on the same day even if they were batched separately. For example, monensin and chlortetracycline cannot be in the same feed bunk together on the same day.

In the last few years FDA has released 3 guidance documents pertaining to the use of feed-grade antibiotics. FDA Guidance 152 categorized antibiotics into categories

on the basis of their use to treat enteric food-borne pathogens and their importance in treating human disease. These categories are 1) critically important, 2) highly important, and 3) important. Of the common feed additives used in the US cattle, macrolides (tylosin and tilmicosin) were listed as critically important. Tetracyclines (chlortetracycline and oxytetracycline) and streptogramins (virginiamycin) were listed as highly important; these are also feed additives. Feed additives not listed as medically important include ionophores, anti-coccidials, bambermycin, and bacitracin. FDA Guidance 209 defined judicious use of antibiotics and included steps to limit their use to only those uses needed to assure animal health, and not for purposes of growth and efficiency. FDA Guidance 213 lays out the plans and timeline for establishment of VFDs for medically important antibiotics such as tylosin, chlortetracycline, oxytetracycline, virginiamycin, and tilmicosin (tilmicosin is already under VFD).

Ionophores, Anti-Coccidials, and Other Non-Medically Important Feed Antibiotics

Ionophores

Ionophores are non-medically important antibiotics which are not used in human medicine and are commonly used in traditional grazing and feedyard nutritional programs. The name ionophore is derived from "-phore", meaning to carry or bear, and "ion", meaning a positively- or negatively-charged atom. Therefore, ionophores facilitate the carrying and exchange of ions across cellular membranes in human and bacterial cells. As a result, this exchange alters the osmotic balance of cells. The rumen in cattle is comprised of millions of bacteria which are responsible the fermentation of feed, specifically carbohydrates from grain and forage, into byproducts including short chain fatty acids, commonly referred to volatile fatty acids (VFA), as well as methane, carbon dioxide, and heat. The primary VFAs produced in the rumen are acetate, propionate, and butyrate, and they are then utilized by the body to convert to energy primarily in the form of glucose and long-chain fatty acids. Of the VFAs, propionate is the most efficient in terms of retaining more energy in the rumen (i.e. less lost as carbon dioxide and methane) as well as due to its entry point in the tricarboxylic acid cycle, which results in less loss as carbon dioxide. Consequently, propionate is the preferred VFA to be produced. Ionophores favor the production of propionate by shifting the bacterial population in the rumen. Gram-negative and gram-positive bacteria exist in the rumen. Gram-positive bacteria have a simple membrane structure whereas gram-negative bacteria have a complex outer membrane. This complex outer membrane in gram-negative bacteria prevent ionophores from acting in the inner membrane; however, ionophores can act on the simple outer membrane of gram-positive bacteria. Although there are slightly different modes of actions of various ionophores, they primarily work by attaching to the membrane of gram-positive bacteria and creating a channel to move sodium and hydrogen ions into the cell. In an effort to maintain osmotic equilibrium, the cells pump potassium and hydrogen out.[3] As a result, the pH in the cell drops and osmotic pressure increases, which causes a futile cycling of ions across the membrane, depletion of ATP, and cellular rupture, all of which result in cellular death and decreased proliferation of some gram-positive bacteria as well as protozoa, the latter of which are involved in coccidiosis. Consequently, gram-negative bacteria become a larger proportion of the bacterial population in the rumen. This shift in population results in bacteria which produce more propionate, resulting in improved efficiency of feed utilization and improved cattle performance. Due to their mode of action in affecting cellular ion exchange and osmosis, care must be used to prevent mixing mistakes which can cause damage to cardiac muscle, especially in horses.

In the US, 3 ionophores are approved; monensin (Rumensin®), lasalocid (Bovatec®), and laidlomycin (Cattlyst®). For up-to-date information, please review current FDA label indications and combination clearances.[6] Monensin-Type A is currently formulated to have 90.7 g/lb (i.e. 20%). For cattle fed in confinement, monensin has an indication for improved feed efficiency to be fed at a concentration of 5 to 40 g/ton (90% DM basis) and at a dosage of 50 to 480 mg/animal daily. Monensin also has an approval for prevention and control of coccidiosis at a concentration of 10 to 40 g/ton (90% DM basis) to provide 0.14 to 0.42 mg/lb of bodyweight (BW) up to a dosage of 480 mg/animal daily. Monensin has cross-clearances with other feed additives such as tylosin, melengestrol acetate, decoquinate, ractopamine, zilpaterol, and tilmicosin in cattle (refer to FDA clearances for more information).

Lasalocid-Type A is manufactured in various concentrations. Although lasalocid has primarily been used for cattle in grazing situations, lasalocid has an indication for improved feed efficiency for cattle fed in confinement and is to be fed at a concentration of 10 to 30 g/ton (90% DM basis) and at a dosage of 100 to 360 mg/animal daily. Lasalocid is also approved for control of coccidiosis for cattle up to 800 lb at a concentration of 30 to 181.8 g/ton (90% DM basis) to provide 1 mg/2.2 lb of bodyweight (BW) up to a dosage of 360 mg/animal daily. Lasalocid has cross-clearances with other feed additives such as chlortetracycline, oxytetracycline, melengestrol acetate, and tylosin in cattle (refer to FDA clearances for more information).

Laidlomycin-Type A is currently formulated to have 50 g/lb (i.e. 11%). Laidlomycin is indicated for improved feed efficiency to be fed at a concentration of 5 to 10 g/ton (90% DM basis) and at a dosage of 30 to 150 mg/animal daily. Unlike the other 2 approved ionophores, laidlomycin does not have an approval for control of coccidiosis. Laidlomycin has a cross-clearance with chlortetracycline in cattle (refer to FDA clearances for more information).

Non-Medically Important Feed Antibiotics Used for Growth

Although not an ionophore, bambermycin (trade name GAINPRO®; flavophospholipol) is not used in human medicine and is classified as non-medically important. Bambermycin

is a glycolipid antibiotic that inhibits peptidoglycan synthesis and cell walls in bacteria.[2] Bambermycin-Type A is currently formulated to have 10 g/lb (i.e. 2.2%). For cattle fed in confinement, bambermycin is indicated for improved feed efficiency and rate of weight gain and is to be fed at a concentration of 1 to 4 g/ton (90% DM basis) and at a dosage of 10 to 20 mg/animal daily. Although approved for prevention of coccidiosis in chickens, bambermycin is not approved for such use in cattle. Bambermycin has no cross-clearances with other feed additives in cattle (refer to FDA clearances for more information).

Non-Ionophore Anti-Coccidials

Parasitic protozoa such as *Eimeria bovis* and *Eimeria zuernii* can cause morbidity and mortality in cattle. These protozoa are called coccidian and can be ingested via consumption of infected water, feed, or fecal material or via direct contact with infected animals, so it is a very contagious disease. Once ingested, sporozoites are released from sporocysts by digestive enzymes in the small intestine and then asexually reproduce creating merozoites which then undergo cell division and then sexual reproduction in the large intestine to form oocysts.[7] These oocysts and resulting ruptured intestinal cells are then passed in the feces, and the oocysts can be sporulated which can then start a vicious cycle of infecting cattle. Amprolium (trade name Corid® and Amprol® 25%), is an anti-coccidial compound that is a thiamine analog. It blocks the thiamine receptor in coccidia, which then blocks thiamine uptake and its role as a cofactor in carbohydrate metabolism needed for the rapid division and reproduction of coccidia. Amprolium-Type A is currently formulated to have 113.4 g/lb (i.e. 25%). Amprolium is indicated for prevention and treatment of coccidiosis, and is to be fed at a concentration of 113.5 to 11,340 g/ton (90% DM basis) and at a dosage of 5 mg/kg of BW daily for 21 days for prevention or 10 mg/kg of BW daily for 5 days for treatment. Additionally, a 24-hour withdrawal is required when using this product. Amprolium has no cross-clearances with other feed additives in cattle (refer to FDA clearances for more information).

Decoquinate (trade name Deccox®) is also an anti-coccidial compound that is a quinolone derivative. Decoquinate inhibits sporozoite development by inhibiting DNA gyrase and, hence DNA synthesis.[7] Decoquinate-Type A is currently formulated to have 27.2 g/lb (i.e. 6%). Decoquinate is indicated for prevention of coccidiosis, and is to be fed at a concentration of 12.9 to 535.7 g/ton (90% DM basis) and at a dosage of 22.7 mg/100 lb of BW daily for at least 28 days. Decoquinate has cross-clearances with chlortetracycline, monensin, and tylosin in cattle (refer to FDA clearances for more information).

Liver Abscess Antibiotics

Tylosin (trade name Tylan® and Tylovet®) is a macrolide antibiotic which binds to the 50S ribosomal subunit of bacteria and inhibits linking of amino acids and elongation in protein synthesis.[5] For similar reasons as ionophores, tylosin has greater effectiveness against the less complex membrane structure of gram-positive bacteria. Macrolides are considered ***critically important*** in FDA Guidance 152 due to their importance in human medicine, and tylosin is commonly fed to cattle. Tylosin-Type A is currently formulated to have 40 or 100 g/lb (i.e. 8.8 or 22.0%). Tylosin is also indicated for reduction of liver abscess incidence caused by *Fusobacterium necrophorum* and *Truperella pyogenes* (previously known as *Arcanobacterium* or *Actinomyces pyogenes*), and is to be fed at a concentration of 8 to 10 g/ton (90% DM basis) and at a dosage of 60 to 90 mg/animal daily. Tylosin has cross-clearances with other feed additives such as monensin, lasalocid, melengestrol acetate, decoquinate, ractopamine, and zilpaterol in cattle (refer to FDA clearances for more information).

Virginiamycin (trade name V-Max®) is a streptogramin antibiotic which consists of mixtures of 2 separate structurally distinct compounds, type A and B. Similar to tylosin, streptogramin-A binds to the 50S ribosomal subunit of bacteria preventing elongation of protein. This binding allows for greater binding affinity of streptogramin-B, which then can cause more amino acids to be released during elongation of the protein.[5] Streptogramins are considered ***highly important*** in FDA Guidance 152 due to their importance in human medicine; however, virginiamycin is not commonly fed to cattle. Virginiamycin-Type A is currently formulated to have 50 or 227 g/lb (i.e. 11 or 50%). Virginiamycin is indicated for reduction of liver abscesses and is to be fed at a concentration of 13.5 to 16 g/ton (90% DM basis) and at a dosage of 85 to 240 mg/animal daily. Virginiamycin has no cross-clearances with other feed additives in cattle (refer to FDA clearances for more information).

Bacitracin methylene disalicylate (trade name BMD® and Pennitracin MD®) is a polypeptide antibiotic which mainly affects gram-positive bacteria by decreasing the synthesis of bacterial walls and also increasing the permeability of bacterial cell walls, which leads to cell death.[8] Bacitracins are ***not*** considered medically important in FDA Guidance 152, and are not commonly fed to cattle. Bacitracin methylene disalicylate-Type A is currently formulated to have 30, 50, 60, or 75 g/lb (ie 6.6, 11.0, 13.2, or 16.2%). Bacitracin methylene disalicylate has an indication for reduction in number of liver condemnations due to abscesses and is to be fed at a dosage of 70 mg/animal daily throughout the feeding period or at 250 mg/animal daily for 5 consecutive days followed by discontinued use for the next 25 days and then repeating this cycle throughout the feeding period. Bacitracin methylene disalicylate has no cross-clearances with other feed additives in cattle (refer to FDA clearances for more information).

Tetracyclines such as oxytetracycline (trade name Terramycin® and Pennox®) and chlortetracycline (trade name Aureomycin® and Pennchlor®) are in their own class and primarily act to inhibit protein synthesis in bacterial cells by binding to receptors on their 30S ribosomal subunit, result-

ing in prevention of protein chain elongation.[4] Tetracyclines are considered **_highly important_** in FDA Guidance 152 due to their importance in human medicine, and tetracyclines are commonly fed to cattle. Tetracyclines, both oxy-and chlortetracyclines, are manufactured at numerous concentrations in Type-A formulations. In addition to other indications described in the subsequent section, tetracyclines do have an indication for reduction of liver condemnation due to liver abscesses and is to be fed at 70 mg/animal daily for chlortetracycline or 75 mg/animal daily for oxytetracycline. Chlortetracycline has some cross-clearances with other feed additives such as sulfamethazine, decoquinate, laidlomycin, and lasalocid in cattle (refer to FDA clearances for more information). Oxytetracycline has a cross-clearance with lasalocid in cattle (refer to FDA clearances for more information).

Bovine Respiratory Disease Feed Antibiotics

Tetracyclines (oxytetracycline and chlortetracycline) and a macrolide (tilmicosin) are also approved for respiratory ailments in cattle. Chlortetracycline has indications for control of bacterial pneumonia associated with bovine respiratory disease (BRD) at a target dosage of 350 mg/animal daily. Chlortetracycline is also indicated for treatment of bacterial enteritis caused by _Escherichia coli_ and bacterial pneumonia caused by _Pasteurella multocida_ organisms at a target dosage of 10.0 mg/lb BW daily for not more than 5 consecutive days. Similar to chlortetracycline, oxytetracycline has indications for treatment of bacterial enteritis caused by _Escherichia coli_ and bacterial pneumonia caused by _Pasteurella multocida_ organisms at a target dosage of 10.0 mg/lb of body weight daily for 7 to 14 consecutive days.

Tilmicosin is indicated for control of BRD associated with _Mannheimia haemolytica_, _Pasteurella multocida_, and _Histophilus somni_ in situations where active BRD has been diagnosed in at least 10% of the animals in a group. Additionally, tilmicosin cannot be used concurrently or subsequent to administration of an injectable macrolide or within 3 days of administration of a non-macrolide; it can only be fed within the first 45 days of the production period. When utilized under these criteria, tilmicosin must be fed at a dosage 12.5 mg/kg of BW daily with a dietary concentration of 568 to 757 g/ton (100% DM basis) for a 14-day period and as the sole ration. A 28-day withdrawal must also be adhered to following this use of feed grade tilmicosin. Tilmicosin Type A is currently formulated to have a concentration of 90.7 g/lb (ie 20%).

Estrus Suppression

Melengestrol acetate is a steroidal progestin fed to suppress the expression of estrus in heifers. Melengestrol acetate has a structure that is very similar to progesterone, blocking ovulation and estrus while follicular growth and estrogen production are not inhibited. Melengestrol acetate moder-ates the release of luteinizing hormone from the pituitary gland which maintains the follicular development without formation of corpus luteum. Consequently, endogenous estrogen levels are maintained, and growth rate is enhanced.[2] Melengestrol acetate Type A is marketed under the trade names of MGA® and HeifermaX®. MGA is currently formulated to have a concentration of 200 and 500 mg/lb while HeifermaX is formulated to have concentration of 500 mg/lb. Melengestrol acetate is indicated for increased weight gain, improved feed efficiency, and suppression of estrus (heat) and is to be fed at a dosage of 0.25 to 0.50 mg/animal daily. Melengestrol acetate has cross-clearances with other feed additives such as monensin, tylosin, lasalocid, decoquinate, ractopamine, and zilpaterol in cattle (refer to FDA clearances for more information).

Beta-Adrenergic Agonists

Beta-adrenergic agonists have been approved for use in beef cattle in the US for almost a decade. Beta-adrenergic agonists are analogs of the catecholamine hormones epinephrine and norepinephrine. The 2 beta-agonist hormones that are currently FDA-approved in North America for use in finishing beef cattle are ractopamine hydrochloride (Optaflexx, Elanco Animal Health, Greenfield, IN; Actogain, Zoetis, Kalamazoo, MI) and zilpaterol hydrochloride (Zilmax; Merck Animal Health; Summit, NJ). Ractopamine was approved by FDA in 2003 and marketing began in 2004. Zilpaterol was approved in 2006 and then received combination approval with monensin and tylosin in 2008. Actogain, a generic ractopamine, was approved in 2013. Both beta-agonists are to be fed continuously until harvest; however, ractopamine must be fed as the sole ration unless utilizing the top-dress clearance. Ractopamine is to be fed the final 28 to 42 days of the feeding period and does not have a withdrawal period. Additionally, ractopamine can be fed either on a dosage or concentration basis up to 27.3 g/ton (100% dry matter basis) in combination with monensin and tylosin. Depending on intake this equates to a maximum of approximately 300 mg/animal daily. Ractopamine can also be fed in a top-dress form up to a maximum of 400 mg/animal daily. Zilpaterol can be fed for the final 20 to 40 days of the feeding period immediately prior to harvest, and then must be withdrawn for at least 3 days to ensure tissues meet the FDA residue clearance requirements. Currently, zilpaterol can be fed on a concentration basis at 7.56 g/ton (100% dry matter basis) or on a dosage basis targeting between 60 and 90 mg/animal daily; the latter is a component feeding claim. These beta-agonists can be incorporated into finishing diets either in the concentrated Type-A form (Optaflexx & Actogain = 45.4 g ractopamine/lb; Zilmax = 21.77 g zilpaterol/lb) or in a diluted Type-B supplement which is typically manufactured by a third-party mill. The manufacturer that uses the Type-A zilpaterol product to prepare a Type-B zilpaterol supplement or a Type-C zilpaterol complete feed must be a licensed feed

mill. In contrast, a feedmill license is not required to feed a Type-B supplement containing ractopamine or zilpaterol or to feed Type-A ractopamine. Feedyards with a licensed feed-mill license that use Type-A ingredients have microingredient machines to add these ingredients to the diet.

Conclusions

It is important to understand the purpose, indications, and restrictions for use of feed additives. Review the feed additive labels, the Feed Additive Compendium, and your nutritionist colleague when making recommendations to ensure these feed additives are being utilized properly.

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Comparing group pens to individual pens for inside feeding of dairy calves—top 10 considerations

T. L. Ollivett, DVM, PhD, DACVIM; **S. M. McGuirk**, DVM, MS, PhD, DACVIM
University of Wisconsin-Madison School of Veterinary Medicine, Madison, WI 53706

Abstract

Feeding and housing calves in groups is becoming increasingly popular in North America. This has been driven by the desire for increased labor efficiency and improved quality of life for caregivers during inclement winter weather. Raising calves in this manner requires a high level of commitment and management. This review will discuss the top 10 factors important for veterinarians advising clients about adopting indoor, group feeding.

Key words: bovine, dairy, calves, housing

Résumé

Nourrir et loger les veaux dans des groupes est de plus en plus populaires en Amérique du Nord. Cela a été motivée par le désir d'accroître l'efficacité du travail et amélioration de la qualité de vie des aidants dans de mauvaises conditions météorologiques hivernales. Qui élève des veaux de cette manière requiert un niveau élevé d'engagement et de la gestion. Cette revue discute de la top 10 facteurs importants pour les vétérinaires à conseiller les clients au sujet de l'adoption d'intérieur, alimentation en groupe.

Introduction

Approximately 63% of commercial heifer raisers in the eastern portion of the US house pre-weaned calves indoors.[22] Although individual, outdoor housing remains the gold standard for raising healthy calves, the desire for greater flexibility, efficiency, and quality of life for caregivers has driven the recent shift towards indoor, group housing and feeding.

Using automatic calf feeders (ACF) and indoor, group housing requires excellent animal husbandry and environmental management. Failure of passive transfer, poor ventilation, inconsistent nutrition, direct contact between calves, unsanitary environments, and stressful procedures contribute to poor growth and high rates of disease in these facilities. We must take into account several other factors that are unique to group feeding:
- Group size
- Age at introduction to the ACF
- Delivery of nutrition prior to introduction to the ACF
- Cleaning, calibration, and quality control of equipment
- Volume and nutritional density of feeding from the ACF
- Nutritional consistency prior to and while on the ACF
- Cross sucking
- Weaning strategy
- Screening for disease and growth
- Monitoring and oversight

Group Size

When using ACF, the size of the group is often dictated by the company selling or installing the equipment, with 25 to 30 calves/feeding station often recommended. Unfortunately, calves grow better and have lower risk for pneumonia when group size is less than 12 to 18 calves.[20] Reduced access to the nipple as a result of too many calves is also associated with a greater number of competitive interactions, decreased feeding time, and decreased milk intake.[24]

Large groups inevitably have a wider age range between the oldest and the youngest calf, exposing the susceptible younger calves to a greater risk of disease. Although it is difficult to establish in smaller operations, 1 week is the ideal age range within a pen. Crowded and/or highly populous pens also impede our ability to detect sick calves. Continuous introduction of calves is a constant source of social stress and at least 1 study has shown that calves have higher growth rates when moved in socially stable groups.[7] The ideal group size is most likely less than 10 animals.[20]

Age at Introduction to the ACF

Young calves are less competitive and require more guidance to the feeder compared to calves that are older at introduction.[11] These calves also spend less time at the feeder during the 12 days after introduction and consume significantly less milk.[11] Early introductions will require once or twice daily assistance to the feeder. Clinical experience has shown poor performance in calves moved to the group within the first 2 days of life, particularly during cold weather. It is preferred to group calves after 10 to 14 days of age, once these animals are past their risk period for scours.

Delivery of Nutrition Prior to Introduction to the ACF

The method of feeding, volume, and nutritional density of the milk or milk replacer should be as consistent as

possible with the system used within the group. Calves will undergo some degree of stress when transitioning from 2 to 3 large meals per day to several small meals. Studies have shown that offering fewer, larger meals (4 meals/day vs 8 meals/day) reduces competition for the feeder and may be more beneficial in large, highly competitive groups.[10]

Cleaning Equipment

Whether using ACF, cleanliness is of utmost importance as multiple calves nursing on a single nipple enhances the buildup of pathogens. Producers have control over the brand and volume of cleaning agent, frequency of cleanings, hose type, frequency of hose replacement, and mixer and hose drainage. Cleaning can be manually or automatically initiated and involves a pre-clean rinse, wash cycle with detergent, and lastly a water rinse. Cleaning agents should function at 104 to 122°F (40 to 50°C) and may either be alkaline (to remove fat deposits) or acidic (to remove mineral deposits). Chlorine bleach may be used at slightly lower temperatures (75 to 100°F) (23.9 to 37.8°C) but should be mixed with other cleaning agents.[6] Ideally, the whole circuit (feeding hoses included) is cleaned daily and the mixer and associated heat exchanger (HE) is cleaned twice/day. Increasing the frequency of mixer/HE cleanings keeps bacteria levels lower. In a recent Virginia Tech study[6] only 40% of facilities were cleaning appropriately. Feeder hoses should be replaced every 1 to 2 weeks, whereas mixer hoses are replaced less often. Nipple ends will deteriorate more quickly, increasing the risk for aspiration pneumonia secondary to flooding of the pharynx by excessive milk. Samples taken directly from the nipple, mixer, and hoses can be checked for excessive bacterial counts. Total bacterial counts < 10,000 cfu/mL and 0 cfu/mL fecal coliforms are recommended and achievable.[6,14]

Volume and Nutritional Density of Milk from the Automatic Calf Feeder

Automated feeding systems have an advantage over many hand-feeding systems in being able to customize feeding strategies to efficiently deliver more milk or milk replacer to calves in multiple feedings throughout the day. Feeding larger volumes of milk or milk replacer does not require automated calf feeders, but it does favor their use as most automatic calf feeders (ACF) are programmed to deliver a minimum of 20% of body weight as milk or milk replacer, delivered in frequent, small meals spread throughout the day. Consumption of more milk improves pre-weaning average daily gain, which is positively correlated with milk production.[2,18] Calves offered milk ad libitum typically drink 7 to 12 times/day, a frequency that is very similar to calves nursing a cow.[4] Calves fed larger volumes of milk or milk replacer have improved digestion and feed efficiency when the frequency of feeding is increased.[23] Increasing the number of milk or milk replacer meals may also lower risk for the development of abomasal ulcers.[1]

The nutrition of preweaned calves fed by ACF is dependent on a number of variables, including volume consumed, nutrient density, milk type and components, group housing dynamics, group size, number and type of feeding stations, and individual calf factors such as calf vigor, immune status, age at introduction to the ACF and adaptation to group housing. With a 10 L or greater milk allowance, competition at the feeder is rarely a problem and the number of unrewarded visits is low until the group size exceeds 24 calves.[10] Computerized ACFs usually deliver milk portions that range between 0.5 and 3 L, with a time lag between meals of 30 to 240 minutes.[19] Increasing meal size and lowering number of visits may lower competition for access to the feeder.[10] Advancing technologies in ACFs offer precision feeding, phase feeding through combination feeders, calf-rail feeders to feed individually housed calves, water meters, feed bunks to measure texturized feed and forage consumption in real time and body scales at the feeding station.[19]

Most ACFs can deliver either whole milk or calf milk replacer. The volume fed and the type of milk product used, in part, determine expectations for average daily gain (ADG) (Table 1). Even with the best paper ration, the ACF must deliver the expected ration and the calves consume it for expectations of 1.6 to 2.3 lb (0.73 to 1.04 kg) ADG and performance to be reached.

An important advantage of using an automated feeding system to feed preweaned calves is reduced time for feeding. Estimated at 10 minutes/calf/day for 2 times daily manual milk replacer feeding, it is estimated that 1 minute/calf/day is the labor requirement for feeding calves using an ACF system.[12] Time savings is gained from feeding in an ACF system should be redirected towards regular, frequent monitoring – machine settings, feed delivery, feeding consistency, cleaning, and monitoring of milk/milk replacer and calves.

Nutritional Consistency Prior to and While on the ACF

Regardless of whether the ACF delivers whole milk or milk replacer, an increased milk allowance has a positive effect on calf health and future milk production, provided that the diet is consistent and that digestive tract function is optimal. Digestive tract function of the preweaned calf can be affected by many things, including meal volume, osmolality of the liquid diet, total solids of the liquid diet, caloric content, protein and fat content, pH, abomasal and intestinal motility, water availability, microbial flora, inflammation, and infection. Inconsistencies in timing of meals, temperature of the liquid, presence of feed additives, total solids of the milk product delivered at the nipple, nipple height, or mineral and vitamin content can have a significant impact on calf health and performance, even in ACF systems. ACF equipment performance and cleanliness must be monitored on a regular basis. When milk replacer is fed in ACFs, there should be less

than a 1 to 2% difference between the expected (gm/L) milk concentration, the concentration of the milk replacer in the mixer, and the concentration of the milk replacer delivered through the nipple. Mixer and circuit cleaning frequency, feeding and mixer hose replacement, and nipple height may affect this. Whole milk total solids should also be consistent throughout the ACF system.

Prior to being introduced to the ACF, milk or milk replacer consistency is similarly important and accomplished by preparing milk replacer meals using weight rather than volume measurements, having the appropriate temperature of water at the time of milk replacer mixing, having water weight or volume consistent from 1 feeding to the next, keeping the milk replacer solution agitated through the entire delivery process, and having clean mixing, delivery, and feeding equipment.

Monitoring nutritional consistency between calves, between feedings and between parts of the ACF system is accomplished by monitoring calf weights, calf health parameters, and taking Brix readings. For whole milk, it has been estimated that the Brix reading can be converted to estimated total solids percentage by using a calculated standard curve equation derived from spectrophotometric results: $y = 0.9984x + 2.077$.[16] For milk replacer solutions, the Brix reading must be related to the total solids percentage by making a standard curve equation using a known set of milk replacer concentrations between 8 and 18%. Every milk replacer yields a unique standard curve equation. Once the relationship between the Brix reading and the milk replacer concentration total solids has been established, reliable trending can be performed using frequent Brix reading testing. Samples (milk or milk replacer) for Brix readings can be stored up to 7 days at room temperature, refrigerated or frozen.[8] Total solids percentage greater than 18% and less than 12% should be avoided and more than a 1 to 2% change between feedings may create a risk for ulcers, bloat, abomasitis, abomasal tympany, intermittent appetite, abnormal manure, or clostridial problems.

Table 1. NRC comparisons of whole milk and milk replacer diets for a 100 lb Holstein calf, consuming 0.5 lb of an 18% CP calf starter at 65°F.

Whole milk	5 L/day	10 L/day
Energy allowable ADG	1.63 lb/day	3.52 lb/day
ADP allowable gain	1.35 lb/day	2.75 lb/day
Growth limiting nutrient	Protein	Protein
Crude protein balance	-34 gm /day	-90 gm/day
20:20 milk replacer	**5 L/day**	**10 L/day**
Energy allowable ADG	1.51 lb/day	3.33 lb/day
ADP allowable gain	1.12 lb/day	2.30 lb/day
Growth limiting nutrient	Protein	Protein
Crude protein balance	-48 gm/day	-122 gm/day

Where ADG=average daily gain; ADP=apparently digested protein

Bacterial counts can be used to assess milk and milk replacer quality of the calf diet, especially in ACF systems where variability in mixer and circuit cleaning frequency and effectiveness may be noted, where feeding hose, mixer hose or nipple sanitation and replacement frequency may not be ideal, or the presence of biofilms may prevent adequate sanitation. Feed contamination can be a source of pathogen or toxin exposure for calves.

Cross Sucking

Non-nutritive sucking directed to the body parts of another calf, a problem referred to as cross sucking, commonly occurs amongst group-housed calves fed from ACFs. Non-nutritive sucking directed towards parts of the calf pen and intersucking, when calves suck the udder of another calf, are also frequently observed in this environment. Because these behaviors can lead to unwanted consequences like hair loss, inflammation, teat or udder injury, mastitis, decreased milk production or persistence into adulthood, preventive measures are warranted. Effective control measures include feeding more milk, prolonging meal duration to a minimum of 10 to 15 minutes by reducing milk flow, using nipples with a smaller orifice (4 mm vs 6 mm), having protected feeding stalls or reducing group size. Some reduce cross sucking by feeding water through a teat or nipple. Providing access to high energy, high quality solid feed at all times and implementation of a programmed, gradual weaning process will also reduce cross sucking behaviors.

Weaning Strategy

When larger amounts of milk are fed to calves, less starter is consumed pre-weaning and, unless a gradual milk step-down procedure is implemented, post weaning growth depression and increased cross sucking may be observed.[9,17] Automated feeding systems that provide calves the opportunity to make multiple rewarded feeding visits during the day offer the flexibility to deliver a gradual step-down, programmed weaning process. ACF systems can be used to implement a number of automatically controlled weaning steps, increasing the duration of weaning. In ACF systems, delayed weaning is common, thus reducing the drop in energy intake, number of unrewarded visits to the feeder, and other unwanted weaning behaviors.[5] In a recent producer survey of ACF systems in the midwest, 73% of producers reported that calves were consuming 3 to 5 lb (1.36 to 2.27 kg) of starter at the average weaning age for heifers of 7 weeks.[3]

Screening for Disease and Growth

Most automated calf feeding systems are introduced into group housing settings. While it has been reported that disease and mortality rates amongst calves raised in small groups can mimic those reported when calves are raised in

individual pens,[13] increased morbidity is common in pre-weaned calf group housing. Raised in groups, calf contact, shared nipples, cross sucking, communal bedding, and shared aerosol are among the risk factors that can increase exposure to the organisms that cause diarrhea and respiratory disease, especially in calf group sizes greater than 6 to 9.[20] Of particular concern are group-housed calves with failure of passive transfer (FPT) because they shed more organisms in bodily secretions (urine, feces, saliva, nasal and ocular discharge), thus augmenting environmental exposure to potential pathogens amongst commingled calves. In larger groups and in calf pens that are continuously occupied, both the number and survival of environmental organisms increase, conditions that almost always increase calf morbidity and mortality.

With a recognized risk of increased disease morbidity in calves fed by ACFs in group housing, disease detection is a critical part of management. Early recognition of diarrhea, respiratory disease, umbilical and joint problems, and effective treatment will curtail but not eliminate horizontal transmission amongst commingled peer calves, but disease detection can be very challenging. While many dairies rely on ACF computerized data output for disease detection by establishing preset alarms, the sensitivity of finding a change in milk intake (reduced intake, reduced visits, slow drinking) or an increased number of unrewarded visits has been questioned.[21] Undoubtedly technologic advancements will result in improved methods that can be used for disease detection and enhanced automated output data that will improve disease detection sensitivity. Until that time, it is suggested that a regular in-pen health screening process be implemented at least twice weekly.[15] In-pen health screening tools (Calf Health Scorer and Group Pen Respiratory Scorer iTunes store apps) are designed to look at all calves in a pen, not just the selective calves found as outliers by the ACF computer. In addition to the twice-weekly in-pen health screening, a trained individual should be assigned the daily chore of performing a complete exam on any individual calves identified by the ACF computer as being abnormal. A complete exam includes rectal temperature, appearance of eyes, ears, nose, manure, navel and joints (Calf Health Scorer app). Treatment protocols for respiratory disease, scours, umbilical and joint infections are established by a veterinarian with a valid VCPR, and given to individuals trained to effectively implement the plan. Efficacy is dynamic and requires regular monitoring by management and the veterinarian for consistency, compliance, and record-keeping. Most autofeeders allow for targeted provision of medication to sick calves through a medicator, but parenteral treatments and diagnostic testing require protocols, training, and equipment for stress-free handling and restraint of calves.

Monitoring and Oversight

Group housing and feeding calves can reduce the labor needed for feeding calves and more easily allows for feeding a higher plane of nutrition. However, the labor saved on feeding must be redistributed to monitoring several of the factors previously mentioned. Regardless of when calves are introduced to the ACF, follow-up should be implemented to ensure that consumption is appropriate and that calves are not losing weight. Software can track consumption, visits (rewarded and non-rewarded), drinking speed, break-offs, and alarms are built in to help identify calves with low consumption or slow drinking speeds. Calves not consuming their allotment may be indicative of poor transition, disease, or over-crowding. Milk and/or replacer quality should be regularly checked.

Conclusion

In conclusion, while it is possible to raise calves using indoor, group-feeding strategies, special care must be taken to consider the aforementioned factors. Incorporating proactive oversight will ensure that these young calves develop into high quality dairy cattle.

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Recombinant bovine somatotropin: overview and results from a recent meta-analysis of effects on health and welfare of dairy cows

Dale E. Bauman,[1] PhD; **Normand R. St-Pierre**,[2] PhD; **George A. Milliken**,[3] PhD; **Robert J. Collier**,[4] PhD; **Joseph S. Hogan**,[2] PhD; **Jan K. Shearer**,[5] DVM; **K. Larry Smith**,[2] PhD; **William W. Thatcher**,[6] PhD

[1]Department of Animal Science, College of Agriculture and Life Sciences, Cornell University, Ithaca, NY 14853

[2]Department of Animal Science, College of Food Agricultural and Environmental Sciences, The Ohio State University, Columbus, OH 43210

[3]Department of Statistics, College of Arts and Sciences, Kansas State University, Manhattan, KS 66506

[4]School of Animal and Comparative Biomedical Sciences, College of Agriculture and Life Sciences, The University of Arizona, Tucson, AZ 85721

[5]Department of Veterinary Diagnostic and Production Animal Medicine, College of Veterinary Medicine, Iowa State University, Ames, IA 50011

[6]Department of Animal Sciences, College of Agricultural and Life Sciences, University of Florida, Gainesville, FL 32611

Corresponding author: Dr. Bauman, deb6@cornell.edu

Abstract

Historically, the dairy industry has made remarkable gains in productivity and a gallon of milk can be produced today with less feed resource inputs and a markedly reduced carbon footprint. Recombinant bovine somatotropin is a production-enhancing technology and 20 years commercial use of POSILAC® (rbST-Zn) provided the backdrop for an updated meta-analysis of effects on cow health and welfare. Our meta-analysis used data from peer reviewed publications or regulatory reports in which the commercial formulation of rbST-Zn was used was according to label specifications.[29] Twenty six studies were identified which had usable data (13,784 cows). Results indicated milk yield was increased by about 9 lb/d whereas milk fat, protein, and lactose content were unaltered. For health and welfare variables, treatment with rbST-Zn had little or no effect on udder health, reproduction, lameness, body condition or culling. Overall, these results and 20 years of US commercial experience demonstrate that management practices used by US dairy producers are adequate for the effective use of rbST-Zn to increase milk yield and productivity with no unmanageable adverse effects on cow health or welfare.

Key words: dairy, health, lactation, productivity, rbST, somatotropin, welfare.

Résumé

Historiquement, l'industrie laitière a fait des gains remarquables dans la productivité et un gallon de lait peut être produite aujourd'hui avec moins d'intrants provenant des ressources d'alimentation et d'une empreinte carbone réduite de façon marquée. La somatotropine bovine recombinante est une technologie d'amélioration de la production et 20 ans de l'utilisation commerciale de POSILAC® (STBR-Zn) ont fourni le contexte pour une mise à jour de méta-analyse des effets sur la santé de la vache et du bien-être social. Notre méta-analyse a utilisé des données provenant de publications révisées par des pairs ou des rapports réglementaires dans lesquels la formulation commerciale de la Stbr-Zn a été utilisé conformément aux instructions figurant sur l'étiquette.29 Vingt-six études ont été identifiés qui avaient des données utilisables (13,784 vaches). Les résultats indiquent le rendement en lait a augmenté d'environ 9 lb/D. considérant que les matières grasses du lait, de protéines et de lactose contenu n'étaient pas altérés. Pour Santé et Bien-être social variables, le traitement par la Stbr-Zn avaient peu ou pas d'effet sur la santé du pis, la reproduction, la boiterie, la condition physique ou l'abattage. Dans l'ensemble, ces résultats et 20 années d'expérience commerciale aux États-Unis démontrent que les pratiques de gestion utilisés par les producteurs laitiers américains sont adéquats pour l'utilisation efficace de la Stbr-Zn à augmenter le rendement laitier et la productivité sans ingérable des effets nocifs sur la santé de la vache ou du bien-être social.

Introduction

Increases in productivity have been the engine of growth for U.S. agriculture. For the dairy cow, productivity can be defined as "milk output per unit of resource input", and it represents a key component of sustainability. The dairy industry has made remarkable gains in productivity; over the last 70 years milk yield per cow has more than quadrupled and associated with this the carbon footprint in production of a gallon of milk has been reduced by more than two-thirds.[6] As milk production increases, total nutrient requirement also

increases but productive efficiency is improved because the fixed cost (maintenance) is diluted out over more units of milk production. Dilution of maintenance is usually thought of in terms of feed resources, but benefits also apply more broadly to all cow-related fixed costs of producing milk including renewable and non-renewable resources as well as the costs for facilities and labor.

The impressive gains in productivity reflect a better understanding of the biology of the dairy cow. Thus, the dairy industry has utilized AI and genetic selection to increase the production potential of dairy cows and at the same time implemented management practices and technologies which provide an opportunity for cows to achieve their high milk potential. One production–enhancing technology that allows the dairy industry to produce milk more efficiently is recombinant bovine somatotropin.

Recombinant Bovine Somatotropin

The bovine somatotropin (bST) story began in the 1930's when it was first demonstrated that injection of a crude pituitary extract caused a transient increase in milk production in low producing cows.[1] Over the next 50 years, these results were verified and bST was identified as the galactopoetic factor in pituitary extracts. In the late 1970's and early 80's, studies utilized highly purified bST and demonstrated the bioenergetics of the gains in efficiency and the effectiveness of bST in high producing cows.[2] Additional information about the historical aspects of bST and details as to its mechanism of action are available elsewhere.[3,15]

The 1980's also ushered in a new era in science with the introduction of biotechnology and the use of recombinant DNA techniques. The potential application in the dairy industry was obvious and recombinant bovine somatotropin (rbST) was among the first proteins produced through the use of "biotechnology". As the first recombinant protein with potential use in production animals, several companies were involved in developing methods to produce rbST and production studies involved a number of different formulations carried out mainly at land-grant universities. Evaluation was extensive and rbST received an unprecedented scrutiny. In the US this included the traditional evaluation by FDA as well as public hearings, science evaluations and legislative reviews.[2,3] After a thorough review of well-controlled studies, FDA concluded that rbST could be used safely and effectively by the US dairy industry. The commercial formulation of rbST approved by FDA is recombinant sometribove-zinc (rbST-Zn), a formulation given every two weeks. Commercially marketed under the trade name POSILAC®, sales of rbST-Zn began on February 1984. To date an estimated 35 million US dairy cows have received the commercial formulation of rbST-Zn[29] and results have confirmed that cows treated with rbST produce a litter of milk with less feed resources and a reduced carbon footprint.[7]

Updated Meta-Analysis of rbST-Zn effects on Animal Health and Welfare

Not everyone agreed with the FDA conclusions on use of rbST. Health Canada requested that the Canadian Veterinary Medical Association (CVMA) evaluate if "rbST used in accordance with label directions will increase milk production without resulting in serious health problems which cannot be adequately controlled by current management practices".[12] CVMA formed a task force and addressed this mandate by conducting a meta-analysis of results from rbST studies. The CVMA Report,[12] subsequently published in the Canadian Journal of Veterinary Research, concluded that use of rbST would increase yields of milk and milk components, but would also adversely impact cow health and welfare, especially udder health, lameness, body condition, reproduction and lifespan.[13,14] Other less rigorous evaluations also predicted catastrophic health and welfare problems for rbST treated cows.[5,24]

Since the CVMA Report,[12] there have been several large scale rbST investigations relating to various aspects of cow health and welfare, e.g.[4,9,22,26,27] Results from these investigations and over 20 years of commercial experience on US dairy farms appear at odds with the conclusions reached by the CVMA.[13,14] Thus, an updated evaluation of the impact of rbST on the efficacy and the health and welfare of dairy cows would be of value.

Objective and Approach

To provide an updated evaluation of the efficiency and safety of rbST we formed an expert panel. It consisted of a data manager and project coordinator, a professional statistician, and six domain experts and results of were recently published.[29] Briefly, our evaluation involved a set of meta-analyses using data that had been published in peer-reviewed scientific journals or regulatory agency reports. Our criterion was that the commercially approved rbST-Zn formulation was used according to label; data from studies involving off-label use of rbST-Zn or studies that used unapproved formulations or doses of rbST were excluded.

Studies for the analysis were identified by an extensive literature search using PubMed (US National Library of Medicine, US National Institute of Health, Bethesda, MD), Agricola (National Agriculture Library, US Department of Agriculture, Beltsville, MD), Web of Science (Thomson Reuters Science, New York, NY), and CAB Direct (CAB International, Wallingford, UK). We identified a total of 26 studies that met the criteria and data from these formed our meta-analysis database. The sequence followed in identifying studies that met the criteria and specific details of the methodology for the meta-analysis are given in St-Pierre et al.[29]

Results and Discussion

Seven variables were analyzed to characterize the milk and milk composition responses to rbST-Zn milk yield, percent milk fat, percent milk true protein, percent lactose, 3.5% fat-corrected milk yield, fat yield and protein yield. Except for the percentage of lactose in milk, responses across studies were heterogeneous ($P < 0.10$), indicating that unidentified factors associated with individual studies affect the magnitude of the response. Meta-analysis results indicated that yield of milk and milk components were all increased by rbST-Zn (Table 1). Treatment with rbST-Zn increased milk yield (+8.8 lb/d) and 3.5% fat corrected milk (+8.9 lb/d) by about 15% over control cows (Table 1). However, milk composition for fat ($P = 0.088$), protein ($P = 0.067$), and lactose ($P = 0.264$) were not affected by rbST-Zn (Table 1). Thus, yield of these components increased in parallel to milk production with daily yields of fat ($P < 0.001$) and protein ($P < 0.001$) being increased by an average of 13.3% and 15.9%, respectively.

Milk yield results from our meta-analysis are in agreement with other summaries that indicate rbST-Zn treatment results in an increase in milk which is typically 8 to 12 lb/d.[3,7,25] Likewise, reviews have consistently observed that the yield of milk components increases to the same extent as milk yield and as a consequence rbST-Zn treatment has no effect on milk composition.[2,21,25]

Milk somatic cell count (SCC) is an indicator of inflammation in the mammary gland, and milk SCC will increase in response to both sub-clinical and clinical mastitis.[20] Therefore, our evaluation of udder health included SCC as well as the incidence of clinical mastitis. Tests for heterogeneity indicated significance for both milk log SCC ($P < 0.001$) and mastitis incidence rate ($P < 0.035$); thus, unidentified factors associated with individual studies affect the observed values. In the case of SCC, the control group averaged nearly 100,000 SCC/mL, and there was no effect of rbST-Zn supplementation ($P = 0.540$; Table 1). Likewise, mastitis incidence rate was not different between the control and rbST-supplemented groups ($P < 0.122$; Table 2). Across all studies, rbST-Zn treated cows were significantly more likely to development clinical mastitis in only 4 of the 14 studies evaluated. Only one study[23] conducted cultures and used intramammary infection status to ensure a balance in treatment group assignment. That study involved 4 herds (total cows = 555) and results indicated

Table 1. Estimates of responses to rbST and associated statistics from the meta-analyses of continuous traits.[a]

Variables	Number of studies	Mean of control cows	Response estimate	Standard error of estimate	P value	95% Lower CL[e]	95% Upper CL
Milk production & composition							
Milk yield (lb/d)	15	60.0	8.82	0.891	<0.001	7.08	10.56
Fat (%)	13	3.64	-0.073	0.043	0.088	-0.156	0.011
Protein (%)	13	3.15	0.025	0.013	0.067	-0.001	0.051
Lactose (%)	11	4.82	0.023	0.021	0.264	-0.017	0.063
3.5% FCM (lb/d)	13	64.4	8.91	0.904	<0.001	7.143	10.67
Fat yield (lb/d)	13	2.38	0.317	0.046	<0.001	0.229	0.408
Protein yield (lb/d)	13	1.90	0.302	0.397	<0.001	0.227	0.381
Reproduction (all parities)							
Days open	5	104.2	-0.21	4.18	0.960	-8.39	7.98
Services per conception	4	1.66	-0.25	0.162	0.121	-0.57	0.07
Udder health							
Log$_{10}$ somatic cell count	9	4.99[f]	-0.034	0.055	0.540	-0.141	0.074
Lameness and lesions[b]							
Clinical lameness	7	0.38	0.13	1.14	0.991	-2.18	2.21
Lameness lesions	3	1.12	0.32	29.2	0.991	-55.4	56.0
Traumatic lesions	5	0.11	0.093	7.59	0.991	-15.5	15.7
Body condition							
Body condition score[c]	15	3.31	-0.064	0.031	0.037	-0.124	-0.004
Culling							
Culling density[d]	6	4.64	0.603	0.633	0.341	-0.637	1.018

[a]From St. Pierre et al (2014).
[b]Expressed as incidence rate per 1,000 cow-days at risk.
[c]Body condition score is expressed on a 1 to 5 scale, with 5 being severely over-conditioned.
[d]Culling density is expressed as incidence rate per 10,000 cow-days at risk.
[e]CL = confidence limit.
[f]Log$_{10}$ somatic cell count of 4.99 = 97,734 somatic cells/mL milk.

there were no significant differences in number of cows that developed clinical mastitis or number of days that milk was discarded because of mastitis.[23]

Udder health results from our meta-analysis were consistent with the recent systematic review of the effects of rbST-Zn on mastitis incidence and SCC conducted by JEFCA.[21] Their review of clinical and epidemiological studies found no effect of rbST-Zn on mastitis incidence. In the case of sub-clinical mastitis, they reported that the "vast majority of studies reported no effect of rbST-Zn treatment on SCC values, although a few studies reported small transient increases".[23] Our results were also consistent with the conclusions of the public hearing conducted by the FDA Veterinary Medicine Advisory Committee.[18] Environmental and management factors are major causes of mastitis and they impact both SCC and mastitis incidence.[20] In addition, genetic studies have demonstrated a small positive relationship between mastitis risk and milk production. However, high producing herds are better managed so that effects of increased milk production are minimized or negated.[20]

Dairy cows need to maintain adequate body condition over the lactation cycle. Thus, it was of interest whether rbST-treated cows would become thin and emaciated due to the use of body reserves to support the increased milk production. Data for body condition score (BCS) were available for 15 studies, and the test for heterogeneity of responses among studies approached significance (P = 0.104). The BCS data used in the meta-analysis consisted of the BCS obtained during and after rbST-Zn treatment. Mean BCS was significantly lower in cows treated with rbST-Zn as compared to control cows (P = 0.037) with the difference being –0.064 ± 0.031 points (mean ± SE; Table 1). As reviewed in St-Pierre et al.[29] published studies indicate that 1 point of BCS represents about 110 lb (50 kg) body weight. Thus, the difference in BCS for the rbST-treated cows observed in our meta-analysis represents about 7 lb (3.2 kg) body weight. While significant,

this difference would not be visually apparent and is about equivalent to the change in body weight associated with a typical feeding or drinking episode for a dairy cow. Thus, our meta-analysis indicates that treatment with rbST-Zn has little or no effect on body condition in spite of the increase in milk yield. The explanation for this comes from the review by Chillard[8] who demonstration that across studies cows treated with rbST-Zn increased voluntary intake in an amount energetically comparable to the rbST-induced increases in milk yield.

Lameness is the most visible animal welfare issue for the US dairy industry. The altered locomotion or mobility that occurs with clinical lameness represents a range of foot and leg disorders that can result from disease, management, or environmental factors.[28] Results of our meta-analysis for clinical lameness demonstrated that treatment with rbST-Zn had no effect (P = 0.999; Table 1). Wherever possible, data for foot lesions were also separated into two categories - lameness lesions and traumatic lesions. Lameness lesions are lesions that directly cause clinical lameness (e.g. laminitis, sole ulcers or digital dermatitis) whereas traumatic lesions are lesions that rarely cause or result in lameness (e.g. mechanically induced skin lesions).[28] We observed that incidence rates for either lameness lesions or traumatic lesions did not differ between control cows and cows that received rbST-Zn (P = 0.991; Table 1).

Reproductive variables were of special interest in our evaluation. Results from the meta-analysis indicated a significant 5.4% improvement in pregnancy proportion in the rbST-supplemented cows for the first two breeding cycles after the voluntary wait period (P < 0.007; Table 2). When compared over the full length of the trial, the pregnancy proportion was reduced 5.5% for the group receiving rbST-Zn (P < 0.048; Table 2), a reduction that was likely due to reduced estrous behavior. The fact that rbST-treated cows were more likely to become pregnant during the first two

Table 2. Estimates of responses to rbST expressed as odds ratios and associated statistics from the meta-analyses of non-continuous traits.[a]

Variables	Rate of Control Cows	Estimates of Odds Ratio	P Value	95% Lower CL[d]	95% Upper CL
Reproduction, all parities					
Pregnancy rate in LRP[b]	0.291	1.281	0.007	1.072	1.530
Pregnancy rate in ERP[c]	0.761	0.753	0.048	0.568	0.997
Fetal losses rate	0.115	1.065	0.650	0.812	1.397
Twinning rate	0.065	1.107	0.679	0.685	1.787
Cystic ovaries rate	0.065	1.171	0.425	0.795	1.725
Udder health					
Mastitis incidence rate	0.174	1.249	0.122	0.942	1.655

[a]From St. Pierre et al.[29]

[b]Limited response period (first and second AI inseminations).

[c]Extended response period (full duration of the trial).

[d]CL = confidence limit.

breeding cycles, the period when cows are generally enrolled in a timed-AI protocol, suggests that rbST-Zn did not impair, and might even have a positive effect on the reproductive performance of dairy cows during this period.

There was no effect of rbST-Zn on days to pregnancy, inseminations per conception, fetal losses, or twinning incidence (Tables 1 and 2). Similarly, the incidence rate of cystic ovaries did not differ between controls and rbST-treated cows (P = 0.425; Table 2). The lack of effect on ovulation failure and cystic ovaries in dairy cows is consistent with the results from De La Sota et al.[11] in which rbST-treated cows had ovaries with healthy estrogen-active follicles.

Culling was also examined and meta-analysis results indicated that culling density did not differ between controls and cows treated with rbST-Zn (P = 0.341). These findings corroborate those of a large longitudinal field study conducted over 4 years on 340 commercial dairy herds in the Northeastern US; those results demonstrated that rbST-Zn use had no effect on stayability or herd-life.[4] Culling rate is often incorrectly assumed to reflect the quality of the production and management system. The optimal culling rate increases when there is a relative abundance of replacements and the cost of a replacement cow is similar to the slaughter value of the cow being replaced.[29]

Meta-analysis Summary

Overall, results of our updated meta-analysis indicated that administration of the commercially available rbST formulation to lactating dairy cows according to FDA-approved label directions resulted in an increase in yields of milk and milk components with no unmanageable adverse effects on milk SCC, incidence of mastitis, reproduction, body condition, lameness, or culling (.St-Pierre et al., 2014). These findings are contrary to the earlier meta-analysis conducted by the CVMA (Dohoo et al., 2003a; 2003b). The bases for conclusion differences have been extensively discussed.[29] In particular our updated meta-analysis included studies conducted subsequent to the CVMA Report (1998), and several of these were large scale studies conducted on commercial dairy farms. Further, we included only studies that used the commercial formulation of rbST-Zn according to "label directions", whereas the CVMA Report combined rbST studies that varied in formulation, dose, administration route, and period of use. In addition, we identified several errors in CVMA's data base that would affect results.[29] Suffice to say conclusions from our updated meta-analysis were consistent with FDA evaluations, the minimal reports of adverse drug experiences,[17] numerous scientific reviews,[3,10,16,19,21,25] and large-scale studies conducted on commercial dairy operations.[4,9,22,23,26,27]

Conclusions

The dairy industries advances in management practices and the application of new technologies has resulted in im-

pressive gains in productivity. Recombinant bovine somatotropin is a production-enhancing technology that allows cows to produce a gallon of milk using fewer nutrients and a lower carbon footprint. Our meta-analysis indicated that administration of the commercially available rbST-Zn formulation according to FDA-approved label directions increased yields of milk and milk components with no unmanageable adverse effects cow health or welfare. Collectively these results and 20 years of commercial experience involving rbST-Zn treatment of over 35 million US dairy cows provide definitive evidence that management practices used by US dairy producers are adequate for the safe and effective use of rbST-Zn.

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Salmonella Dublin: what you can do to help your herds

Paul D. Virkler, DVM

Cornell University, College of Veterinary Medicine, 240 Farrier Road, Ithaca, NY 14853, pdv3@cornell.edu

Abstract

Salmonella Dublin (SD) is a serotype of *Salmonella* that is host-adapted to cattle and can lead to persistent carrier infections. It can cause serious disease outbreaks with high morbidity and mortality in youngstock, and abortions or morbidity and mortality in older cattle. There are also food safety concerns related to SD, a zoonotic pathogen that can cause serious human illness or death. A high morbidity and mortality outbreak has been associated with people consuming unpasteurized milk, and it is identified as one of the top three *Salmonella* serotypes found in beef products, notably ground beef. It also has the potential to infect and cause serious illness in cattle care workers exposed to infectious secretions of SD infected cattle. Veterinarians need to be fully educated on the clinical disease presentations of SD as well as the current diagnostic tests to identify and manage this disease. Strategies to keep SD out of individual herds need to be discussed and implemented. For those herds where it is already present, a plan to control the transmission of SD needs to be in place as well as a monitoring strategy to ensure its success.

Key words: cattle, dairy, *Salmonella* Dublin

Résumé

Salmonella Dublin (SD) est un sérotype de Salmonella qui est l'hôte adapté à bétail et peut conduire à des infections porteur persistant. Elle peut causer de graves flambées de maladies à forte morbidité et mortalité dans youngstock, et d'avortements ou de la morbidité et de la mortalité chez le bétail adulte. Il y a également des préoccupations en matière de sécurité alimentaire liés au DD, un pathogène zoonotiques qui peuvent causer des maladies humaines graves ou la mort. Un taux élevé de morbidité et de mortalité flambée a été associée avec de personnes qui consomment du lait non pasteurisé, et elle est identifiée comme l'un des trois principaux sérotypes de Salmonella trouvée dans les produits à base de viande bovine, notamment le boeuf haché. Il a également la possibilité d'infecter et de provoquer de graves maladies chez les bovins care Travailleurs exposés aux maladies infectieuses les sécrétions du DD des bovins infectés. Les vétérinaires doivent être pleinement renseignés sur la maladie clinique des présentations du DD ainsi que les tests diagnostiques actuels afin d'identifier et de gérer cette maladie. Des stratégies pour garder SD hors de troupeaux individuels doivent être discutées et mises en oeuvre. Pour les troupeaux où il est déjà présent, un plan visant à contrôler la transmission du DD doit être en place ainsi qu'une stratégie de suivi afin d'assurer son succès.

Introduction

Salmonella enterica ssp. *enterica* Dublin (SD) is a *Salmonella* serotype that is host adapted to cattle and has been known for years to cause serious disease in cattle.[1] It is also a serious human pathogen that has been associated with a significant disease outbreak in humans who have consumed raw milk containing SD.[2] In recent years it has become one of the top three *Salmonella* serotypes isolated from ground beef as reported by USDA FSIS.[14] Since approximately 2006 all of the SD that the Animal Health Diagnostic Center (AHDC) has isolated are resistant to the majority of antibiotics that can be legally used.[3] This means that prevention of SD versus the treatment of individual animals needs to be the focus of large animal veterinarians. In a study from the Netherlands it was determined that in over 50% of SD outbreaks the disease became persistent in a herd.[15] Furthermore, a modeling paper from Denmark estimates that in 60% of the situations there is within herd spread with the introduction of one SD infected springing heifer.[9]

Recent data from the 2014 NAHMS dairy study estimates 8% of dairy operations had *Salmonella* Dublin antibodies present in bulk-tank milk.[5] There looks to be a large difference, though, by region as the West region (CA, CO, ID, TX, WA) had 52.1% of bulk tanks SD antibody positive versus the East region [IA, IN, KY, MI, MN, MO, NY, OH, PA, VT, VA, WI] which had 2.8% of bulk tanks SD antibody positive.[5] A study done specifically in New York State (NYS) on greater than 95% of bulk tanks showed less than 1% of bulk tanks were SD antibody positive.[13] In a collaboration between the New York State Cattle Health Assurance Program (NYSCHAP) and the Animal Health Diagnostic Center (AHDC) at Cornell University, College of Veterinary Medicine, a significant education effort for large animal veterinarians focused on SD was undertaken over the last several years. This was initiated in part due to the increase in the number of SD cases that the AHDC was receiving in which the veterinarian did not have SD on the differential list. The following information is part of that education effort to ensure that veterinarians have the tools necessary to assist their herds in dealing with SD.

Clinical Presentation

The most common clinical presentation in the Northeast has been respiratory disease in calves ranging in age from one week to eight months.[6] The other common signs noted

in these calves with septicemia are high fevers and depression although sometimes practitioners have reported that a farm just finds dead calves. There also may be animals which present with one or more of the following signs: hot and swollen joints, bloody or watery diarrhea, and neurologic signs. Mortality rates on farms that the AHDC has worked with can be quite variable but in the worst scenarios have been over 90% in a group of affected calves. Some of the variability in mortality appears to be related to level of management of the facility with those farms that have the poorest hygiene, nutrition, and ventilation having the highest mortality rates. Practitioners have also reported that some of the calves that recover from SD are unthrifty, have scruffy hair coats, and grow poorly.

Since other types of *Salmonella* that present primarily as enteric disease have been much more common on Northeast dairies it has been a mindset change for practitioners to include SD on their differential list for respiratory cases. Educational outreach efforts have focused on providing practitioners with the necessary background information on SD so that it is not missed if it appears on their client's herds.

On necropsy the most common findings reported by practitioners to the AHDC have been heavy, wet lungs with diffuse changes throughout the entire lung field, a swollen liver with rounded edges and maybe a mottled appearance, and intestines with signs of inflammation.[6] Many practitioners also note fibrin throughout the peritoneal and pleural cavity.

In adult cattle, clinical disease has been much less common in cases reported to the AHDC but there have been cases of enteritis and abortions that were proven to be SD. In one study from Great Britain[4] abortion was the predominant clinical sign in adult cattle diagnosed with SD.

Diagnostics

Agent Tests

On a live sick animal the most reliable diagnostic test that the AHDC has found is blood culture. The blood sample needs to be collected aseptically and inoculated immediately into specialized blood culture media. Contact your diagnostic laboratory to obtain the appropriate media. For a basic protocol on blood culture technique see the following web link: https://ahdc.vet.cornell.edu/docs/Blood_Culture_Technique.pdf

Other diagnostic specimens on live, sick animals that are appropriate to submit for bacterial culture are feces, transtracheal wash fluid, and potentially nasal swabs.[6] For cattle that have aborted, the AHDC has cultured SD from vaginal swabs submitted in Amies transport media. The AHDC has found that the specific type of enrichment media used for SD versus other enteric *Salmonella* has a large influence on the recovery rate.[a] There have been notable cases where fecal culture was negative for SD but either blood culture was positive for SD ante mortem or tissue culture was positive for SD post mortem. Since the AHDC does not currently of-

fer a SD specific PCR the author does not have information concerning the performance of this test although other US diagnostic labs do offer this option.

On post mortem specimens, SD can be quite reliably cultured from organs such as lung, spleen, lymph nodes, and intestines. The AHDC recommends a full set of fixed tissues as well for histopathology to further confirm the diagnosis. On an aborted fetus it is recommended to submit a standard set of fresh and fixed tissues to allow a full complete workup. Consult your diagnostic laboratory for specific directions or see the following web link for directions: https://ahdc.vet.cornell.edu/docs/Ruminant_Abortion_Kit_Complete_Paperwork.pdf.

Antibody Test

Since 2012, the AHDC has offered a commercial ELISA* which detects the presence of antibodies specifically to SD although there is a small possibility of cross reaction with *Salmonella* Typhimurium. The framework of this test was originally developed and tested in connection with the Danish Veterinary Institute and it has been shown to be useful in their national SD control program.[7] This ELISA is an antibody test that can be used on serum or milk from individual animals or a bulk tank milk sample. For the individual animal the estimation of sensitivity and specificity varies based on age and cut-off used but is estimated to be between 45-74% and 89-100%, respectively.[7] Although the results of this ELISA could be interpreted on the individual animal level, the strength of this test really is when it is interpreted at the herd level. In other words, although the results of individual animals are obtained with this test, it is more useful to consider the results of all the animals in the group tested and make herd level decisions rather than individual animal decisions. If repeated testing of individual animals over a longer period of time, for example four months to one year, are performed then there may be some individual animal decisions that would have more value.

For bulk tank milk samples it is recommended that repeated sampling be performed over time. A study from Denmark estimated that if four bulk tank samples were collected over a 5-12 month period and analyzed with the SD ELISA, the sensitivity would be 95% and the specificity would be 96% assuming a 15% national prevalence.[18] The current recommendation of the AHDC is to perform four bulk tank samples over the course of a year.

Determining Your Herd's SD Status

The first recommendation for your clients should be to determine the SD status of their herd which will then set the stage for the next step. If there are animals with clinical disease similar to what is outlined above then using the agent tests such as bacterial culture on the samples suggested above is the best strategy. If there has been previous undiagnosed disease that is suspicious for SD and individual animals have

recovered then the use of serology could be considered on these animals and their cohorts. One important point in the selection of animals to test is that the time to the maximal antibody titer for SD has been estimated in calves to be between six to eleven weeks.[7] If there has been no evidence of clinical disease that is suspicious for SD then most herds that the AHDC has worked with have either chosen to use the ELISA antibody test on repeated bulk tank milk samples or on a cohort of heifers between four to six months of age. Table 1 below outlines the sensitivity of various testing methods to determine the status of your client's herds.[7]

Keep SD out of Your Herd

If a herd is determined to be at low risk for having SD then the farm should institute strict written biosecurity protocols specifically aimed at keeping it out. In several Danish studies, the largest risk factors for a herd to change from a test negative SD herd to a test positive herd was the number of other SD positive herds in the area, the number of purchased animals from a SD test positive herd, and herd size.[8,11] If the farm is not purchasing any animals or bringing heifers home from a heifer raiser that has commingled animals from other farms then the risk of bringing in SD is lower. There are still other areas to consider, though, and one of the primary areas to target is to not allow vehicles (such as rendering trucks, livestock trucks, etc) or visitors with manure contaminated tires or boots access to cattle or feed areas. See the following link for a more detailed discussion of other areas to consider: https://ahdc.vet.cornell.edu/Sects/NYSCHAP/docs/SalmonellaCCPs.pdf.

If the farm is purchasing animals or bringing springing heifers home that have been commingled with other animals then there is a need to have some awareness if SD could be brought into the home herd. The ideal situation would be to have confirmation of the SD status of the herd of origin of pur-chased animals or of the herds that heifers are commingled with. This could be achieved in the manner outlined above for determining the herd status. This may not be practical in some situations and therefore individual springing heifers may need to be tested with the SD ELISA to detect antibody positive animals. As outlined above, the goal with this type of testing would not necessarily be to interpret individual animal results but rather to get an assessment of the cohort of animals. This would provide stronger evidence that this group of animals potentially all were exposed to SD and there-fore need to be handled differently as they move through the calving pens. It should be stated that a single antibody test at only one time point does not allow a distinction between an animal that was previously exposed and cleared the SD infection and a potential SD carrier animal that could shed in the future. It should also be stated that there is a small percentage of carrier animals that do not have positive anti-body titers.[7] With the above assumptions in mind, there have been individual herds in the Northeast that have chosen to test purchased animals so that they have a better notion of the risk of bringing SD into their herd. A few have chosen to more closely monitor any SD positive animals and retest them at some time point later to determine if their antibody level remains elevated.

Isolation of any introduced cattle whether purchased or returning from off the farm is recommended to allow for the detection of any clinical illness prior to commingling with other cattle. This isolation is recommended for many different pathogens and should be performed although it should be noted that specifically for SD, a carrier animal may not show clinical illness and can shed SD well beyond the normal two to three week quarantine period.

For heifer raising facilities trying to keep SD out can be challenging especially if there are many source farms. It is the author's opinion, though, that a heifer raiser and their veterinarian should have a written SD plan in place with

Table 1. Adapted from Table 3.18 Herd sensitivity (HSe) for different herd testing procedures.

Herd testing procedure	HSe
Bulk-tank milk LPS ELISA at cut-off OD=0.4	38%
Culture of dung-pits	45%
Drinking water cultures	5%
Bulk-tank milk filter cultures	7%
Fecal culture of animals with current or earlier signs of salmonellosis	38%
Serology of all young stock	100%
Serology of all young stock between 4 to 6 months	91%
Serology of animals with current or previous signs of salmonellosis	80%
Combination of bulk-tank milk ELISA and serology of animals with current or previous signs of salmonellosis	91%
Combination of bulk-tank milk ELISA and serology of all young stock between 4 to 6 months of age	99%
Combination of bulk-tank milk ELISA in 4 samples collected over 5 to 12 months	95%

Veling J, Barkema HW, van der Schans J, van Zijderveld F, Verhoeff J. Herd-level diagnosis for *Salmonella enterica* subsp *enterica* Serovar Dublin infection in bovine dairy herds. *Prev Vet Med* 2002; 53:31-34. Warnick LD, Nielsen LR, Nielsen J, Greiner M. Simulation model estimates of test accuracy and predictive value for the Danish *Salmonella* surveillance program in dairy herds. *Prev Vet Med* 77:284-303, 2006.

each source farm. On the simplest level this could solely state that the risks of bringing heifers home infected with SD from the heifer raiser have been discussed with all parties. In the Northeast, a fairly frequent mode of introduction of SD to newly infected farms has been from heifers raised at a commingled heifer facility. In my opinion, this is not necessarily a fault of the management at the heifer raiser but most likely a result of one of the source farms introducing SD to the heifer raising facility. If the heifer raiser does not have an SD plan in place, though, and is not aware that it existed in their facility then it has been the experience of the AHDC that the source farms start to solely blame the heifer raiser.

Ideally as part of a heifer raiser's SD plan they would know the SD status of all the source farms and continue to monitor this over time such as by repeated antibody tests on bulk tank milk samples. The AHDC has also worked with heifer raisers that have implemented a monitoring strategy which involved performing antibody testing on a small percentage of incoming calves or heifers from each source farm. See the following web link to a NYSCHAP document that outlines in more details strategies for heifer raisers to deal with SD: https://ahdc.vet.cornell.edu/Sects/NYSCHAP/docs/Calf_HeiferRaiserSDRecommendations_12_2012.pdf.

Control in an SD-Positive Herd

For those herds that have definitively identified SD in their animals a detailed risk assessment needs to be performed. The NYSCHAP modified a risk assessment developed by the Danish group[10] and it is available at the following web link: https://ahdc.vet.cornell.edu/Sects/NYSCHAP/modules/salmonella/salmonellasection2.cfm

Click on link labeled "NYS Modified Risk Scores" which brings up a Microsoft Excel® sheet that can be completed in each category based on the history, farm visit, and walk through. It is the author's experience that there are numerous benefits to the herd veterinarian taking the time to walk through each part of the facility and make sure that all the questions of the risk assessment are answered accurately. Completing this document gives the veterinarian the opportunity to explore the small details that may have been overlooked but are crucial to making progress and at the same time reinforces to the farm which critical areas they need to manage on a daily basis. Having all the data in the spreadsheet allows for a comprehensive analysis and a graphic summary of the highest risk practices.

Solutions to correct the deficiencies noted in the risk assessment as well as systems to monitor success should be included in a herd specific written SD control plan. One of the most important areas to focus on is to close the infection routes that expose newborn and young calves to SD.[10] As is the case with other numerous other pathogens shed by adult animals, if calves are not exposed to SD from adult carrier animals then a population of animals that are free of SD develops. Over time this SD free population becomes a larger and

larger percentage of the herd. This is still dependent as well on making sure there are no other routes of infection such as from older heifers which may be shedding, from manure contaminated feed that is offered to younger heifers, or from contaminated fomites. One large Danish study[12] showed good calving area management as one of the primary factors that prevented the exposure of calves to SD.

As with any good control program, having some way to document success and to monitor this over time is critical. For SD, one obvious way that farms monitor success is with the lack of morbidity and mortality that is associated with SD. This may not be a sensitive enough monitoring tool, though, for some herds that are experiencing low levels of the disease. This is another area where the use of the antibody ELISA test has proven valuable to both the Danish group[10] and herds that the AHDC has worked with. Testing cohorts of heifers in the 3-6 month age range with the ELISA test for the presence of SD antibodies allows farms to have reasonably timely feedback to gauge the success of their calf control measures. If all calves are negative for SD antibodies then it reinforces to the farm the success that they have been able to achieve and helps to motivate them to continue. If there are calves that are positive for SD antibodies then it points out that there are breaks in the protocol and that management needs to review, revise, and retrain employees on the protocols.

The use of the SD ELISA as a monitoring tool was demonstrated in a small study[17] performed in NYS. The dairy herd in this study was able to effectively prevent new calves from being exposed to SD when all of their calving pen management protocols were in place and followed by employees even when SD positive cows were being calved out. This was documented by performing the SD ELISA on all calves at 3-6 months of age and on all lactating cows four times per year. The situation changed, though, when this herd went through a large expansion which overwhelmed the system and caused a break in the calving pen protocols as documented by quarterly risk assessments by the herd veterinarians. Graph 1 illustrates the percent of SD positive calves over a nine month period. Note the change in the percent positive for SD in July 2014 which correlated to the start of the expansion.

Conclusion

Large animal veterinarians need to be concerned with SD not only because of the cattle illness caused by this pathogen but also due to its zoonotic potential, food safety risk, and multi-drug resistance. Herd veterinarians can play a large role in helping their herds to have a plan in place to keep SD out or control new infections in an endemically infected herd.

Endnotes

[a]McDonough PL. Personal communication, 2012
[b]PrioCHECK® Salmonella Ab bovine Dublin. Prionics AG, Switzerland

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New developments in digital dermatitis control

Nigel B. Cook
University of Wisconsin-Madison, School of Veterinary Medicine, Madison, WI 53706

Abstract

Recent work has provided a greater understanding of the etiopathogenesis of digital dermatitis (DD) infection within cattle populations. With enhanced lesion scoring and an understanding of the transitioning between lesion stages, coupled with improved data-gathering systems, we now understand the significance of the chronic stages of the disease in herd-infection dynamics. Herd control of DD must begin during the heifer-rearing period. Breeding resistant animals and use of in-feed organic trace mineral supplements are coupled with active surveillance for early acute stages of the disease. Combined with strategic foot bathing and hoof-trimming, when fully implemented on a farm, these strategies can reduce the incidence of the disease and provide a sustainable solution to this troublesome problem.

Key words: cattle, digital dermatitis, footbath

Résumé

Des travaux récents ont permis une meilleure compréhension de l'etiopathogenesis de dermatite numérique (DD), l'infection au sein de la population de bovins. Avec lésion amélioré la notation et une compréhension de la transition entre les stades de la lésion, conjuguée à l'amélioration des systèmes de collecte de données, nous comprennent maintenant l'importance du stade de la maladie chronique dans le troupeau dynamique de l'infection. Troupeau de DD de contrôle doit commencer au cours de la période d'élevage des génisses. Reproduction, l'utilisation d'animaux résistants dans les aliments Suppléments minéraux traces organiques, associée à une surveillance active pour le début des stades aigus de la maladie en combinaison avec footbathing stratégique et le sabot-fraisage, lorsqu'il sera entièrement mis en oeuvre à la ferme, peut réduire l'incidence de la maladie et fournir une solution durable à ce problème ennuyeux.

Introduction

Digital Dermatitis (DD) is the most common infectious cause of lameness in dairy cattle worldwide and it has proven a challenging disease to control. Despite our efforts, DD has continued to spread globally since it was first recognized in 1974, to the point where it is difficult to find a country with a developed dairy industry without the disease. Within herds, lesions commonly affect 20% of the cows at any one time.[30] Given the ubiquity of the condition, it is likely that DD deserves the title of being the most infectious disease present on modern dairy operations. Indeed, the condition is not confined to the dairy industry. Beef producers express growing concern over the prevalence of DD in their operations also.

Typical strategies to control DD in a herd involve topical treatment of cows at routine hoof-trimming or identified lame with a DD lesion, and routine use of a foot bath using an antimicrobial agent at regular intervals. When implemented aggressively, this strategy has been somewhat successful, but it has proven costly, both financially to the producer and environmentally, as farms have been challenged to safely dispose of chemicals such as copper sulfate, which carry environmental contamination concerns.

Our claw health team led by Dr. Dörte Döpfer developed a 5-year plan to investigate the etiopathogenesis of DD in dairy herds. The work focused on a prospective longitudinal study of DD in youngstock and led to some revelations that provide us with new tools and ideas to combat the disease. In this article, I will summarize the main findings of these studies and other recent work by others in the field.

Etiology

DD is a multifactorial disease with a strong bacterial component.[29,32] Various *Treponema* spp have been identified as the bacteria essential for development of active DD lesions – *T. denticola, maltophilum, medium, putidum, phagedenis* and *paraluiscuniculi* being the most commonly found in the US.[40] These spirochetal bacteria are strict anaerobes and are difficult to handle in the laboratory. However, using refined PCR techniques, they have been found to be common in the rumen and feces of cattle. While other bacteria such as *Candidatus Amoebophilus asiaticus* may be involved in the disease,[40] we believe that for DD to occur, treponemes are essential for 3 main reasons. Firstly, *Treponema* spp are found ubiquitously in DD lesions.[2,13,15,22] Secondly, an initial attempt to reproduce the disease from a pure culture using an isolate of *Treponema vincentii* was able to replicate an early DD lesion,[15] confirmed at the histological (immuno-histochemistry, hematoxylin–eosin and Steiner silver stains) and molecular level (polymerase chain reaction). Third, in contrast to what was found in DD lesions, T*reponema* spp were never found in control samples of healthy skin, and significant immune responses were not observed in animals without clinical signs of the disease.[5,15,23,27]

For infection to occur, the microenvironment must be such that it allows for contamination of the skin with the bacterial inoculum, and the surface layer of the epidermis must be macerated with constant exposure to moisture.[15] It is proposed DD results from penetration of the 3 defense

layers of the epidermis. Moisture erodes the inter-cellular cement between the surface epidermal skin squames, allowing the bacteria to penetrate through the zone 1 skin barrier. Continued penetration into the deeper layers of the epidermis is facilitated by a breakdown in the connections between the epidermal cell columns in zone 2, with destruction of the gap junctions and disruption of intercellular communication. Finally, the massive tissue destruction and loss of zone 1 and 2 barriers allows for the penetration of *Treponema* into the dermis due to damage to the integrity of the basement membrane (Döpfer and Mülling, personal communication).

Hydropic maceration of the skin is commonplace in confinement-housed dairy systems, as the cow is kept in intimate contact with her manure 24/7, significantly contributing to the spread of this disease in conjunction with the intensification of the dairy industry around the world.

Lesion Stages and Treatment

The industry has been focused on the treatment of DD without consideration of the stage of the disease for several decades. Attempts to treat chronic stages of DD – often referred to as hairy heel warts—prove futile, and do not improve our ability to control DD in a herd. There are a number of reasons for this apparent treatment failure.

First, cows afflicted with DD are generally singled out to receive individual treatment based on the presence of lameness. Frankena et al,[14] however, reported that only 26.3% and 39.5% of the animals with slight or severe DD lesions, respectively, showed an identifiable lameness. Therefore, the true prevalence of DD on farms is likely underestimated and only the most severely affected animals receive treatment. Second, *Treponema* spp organisms are known to migrate into deep layers of the skin shortly after infection. Gomez et al[15] reported invasion of the dermis by *Treponema* spp organisms within a period of 7 days after experimental infection. Even in these early cases, bacterial clearance in deep layers of the skin after topical treatment was incomplete.[10] Third, *Treponema* spp organisms share with other spirochetal bacteria such as *Borrelia* spp the ability to evolve to cystic forms (so-called "round bodies") under stress and the impact of antimicrobials, chemicals, and extreme pH values.[4,33] In this regard, Döpfer et al[11] described changes in the morphology of 3 *Treponema* spp in vitro, showing the presence of spiral and cystic forms, suggesting encystation as 1 of the reasons why persistent infections could lead to recurrent lesions. Fourth, dyskeratotic skin is a common finding in chronic DD lesions[9,29,34] in the form of scaly, mass-like, and filamentous proliferations. Progressive hyperkeratosis and proliferation on the skin of untreated lesions could prevent penetration of antimicrobials into deeper (epi-) dermal layers and therefore lead to an incomplete elimination of treponemes and subsequent recurrence of DD.

For accurate assessment of DD, the lesion must be classified. DD transitions through 4 lesion stages using the so-called "M-stage" classification system.[9] M1 lesions are small, less than 20 mm, and may spontaneously resolve or expand into acute M2 lesions – the typical painful strawberry type lesion, >20 mm, on the plantar aspect of the interdigital space. If left untreated, M2 lesions expand and may become proliferative with long projections or pili developing due to uncontrolled skin proliferation, eventually becoming chronic M4 lesions with little hope for cure with topical therapy. However, if treated effectively, M2 lesions will pass through an M3 scab stage before resolving. M4 lesions may frequently recrudesce, developing small M1 lesions within the chronic lesion—we refer to these as M4.1 lesions. These lesions may transition back to M2 stages, causing pain and lameness.

The goal of control is to treat and cure the M2 lesions as soon as they occur. This cannot be done with a program that identifies lesions in lame cows and cows at routine trims. We have to treat the lesion when the cows are not yet lame, and this requires frequent organized surveillance. We recommend once-a-week checks either in the parlor or along the lockups in the pen, so that fresh M2 lesions can be identified and the cows topically treated with powdered or liquid oxytetracycline, with or without a light wrap. Good cure rates can be achieved with this approach. Any strategy relying on curing M4 lesions will likely ultimately fail due to very high relapse rates.[1] Following implementation of this early detection approach in a heifer pen over a 2-year period in the absence of footbath use, we saw a reduction in total M2 lesions over time, but also a striking reduction in the proportion of M2 lesions with proliferation—suggesting that this type of presentation in both M2 and M4 lesions is a measure of the timeline of infection and representative of the degree of tissue destruction that has occurred prior to identification.

The role of the footbath should not be to treat the cows with lesions, but to hold the chronic M4 affected cows in check, so that they do not recrudesce and revert back to new M2 lesions. In combination with an organized surveillance
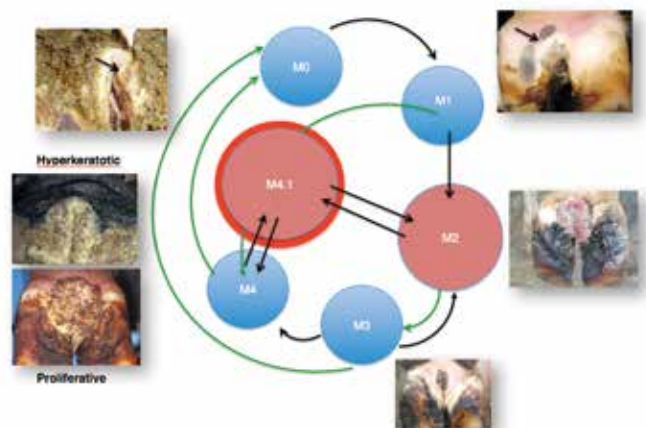

Figure 1. The M-Stage Classification for Digital Dermatitis Lesions (from Döpfer et al, 1997; Berry et al, 2012)

and treatment plan, we can reduce the frequency of footbathing and utilize products that have fewer safety concerns than formalin, and are less troublesome in the environment than copper sulfate. Without a plan to identify early M2 lesions, herds become too reliant on the frequent use of footbaths, and often times, chemical costs can rival the cost of all other pharmaceuticals for the dairy.

Timing of Infection

Within the dairy industry, we have recently turned our focus toward DD infection in the heifer population. It is not uncommon to find 20-30% of heifers after breeding age affected by DD in many rearing facilities, likely as a result of the same poor leg hygiene risk factors that have exacerbated the problem in mature cows. Laven and Logue (2007) and Holzhauer et al. (2012) have demonstrated the importance of the pre-partum period in affecting DD occurrence during the following lactation.

For his PhD study, Dr. Arturo Gomez followed 640 pregnant heifers housed in freestalls on one dairy facility through first calving to the end of their first lactation. During the rearing period, we identified heifers that did not suffer DD at any time (Type I), heifers that suffered only one case of DD (Type II) and heifers that suffered more than one case of DD (Type III). All cases were treated topically as soon as they were identified as described. The incidence rates of DD in heifers during their first lactation were remarkable when compared to their infection history pre-partum. The first lactation incidence of DD was 3%, 37% and 44% for Type I, II and III heifers respectively. This astonishing result suggests that control of DD at the herd level must start with the heifer or it is doomed to failure. We have submitted samples from each group of heifers for genomic testing and determined that the heritability for being a Type III heifer is 0.41-0.56, suggesting a significant genetic component to this complex disease (Döpfer, personal communication). In the future, genomic bull selection may help us to control DD with the

Figure 2. Implementation of active M2 surveillance in a heifer pen and impact on M2 incidence and prevalence of proliferation over a 2-year period.

breeding of less susceptible animals. However, in the meantime, we must look elsewhere for solutions to this problem.

Consequences of Infection

We had the opportunity to investigate the short and long-term impact of DD infection in our longitudinal study.

Locally, DD infection causes changes to the conformation of the foot that may increase the likelihood of prolonged infection. Previously, Laven (2007) described a significant negative relationship between DD and both heel height and toe length. We had the ideal opportunity to prospectively examine conformation changes around the time of DD lesion development in heifers. DD lesions were associated with an increase in heel height, an increase in the depth of the interdigital space, a worsening of manure contamination in the interdigital space and a significant increase in the amount of heel horn erosion (HHE) that accompanied the infection. Indeed, for the most part, layered heel erosion appeared to be a consequence of DD infection and an obvious marker for a DD infection problem in the herd (Gomez et al., 2015). Holzhauer et al. (2006) used a cross-sectional study to estimate a DD attributable risk of 32.2% for ID/HHE and 9% for interdigital hyperplasia (corns), suggesting that these diseases could be causally associated with DD.

Proliferation of M2 lesions was also a marker of significance. The odds ratio for becoming a Type III animal was 2.1 when proliferation was present at the first M2 lesion, further emphasizing the need to treat lesions early on, while changes to tissue architecture are limited. Interestingly, following prompt effective treatment, most of the changes in the structure of the claw observed after DD lesion development were reversed upon cure.

Animals identified with M2 stages of DD had a significant immune response to *Treponema* spp as measured by a 45% increase in specific serum IgG levels (Gomez et al., 2014). After treatment, a gradual decrease of these anti-*Treponema* antibodies was observed in animals that did not relapse with the disease. However, a sustained response was observed in animals diagnosed with repeated cases of the disease. In contrast, there was a null reaction of the immune system to early and intermittent (M1, M4.1) cases of the disease, particularly in heifers chronically affected by repeated episodes of active M2 lesions. This finding has important epidemiological implications - chronic DD lesions can harbor large numbers of *Treponema* spp that under favorable conditions develop into clinically active M2 stages, therefore representing reservoirs of infection. However, the systemic reaction from such chronically affected individuals seems delayed or non-existent, likely limiting the animals' ability to cure the infection.

The economic consequences of infection have been previously examined. Relun et al. (2013) reported an average milk production loss of approximately 1.2 lb (0.55 kg) per day in primiparous cows and 1.43 lb (0.65 kg) per day
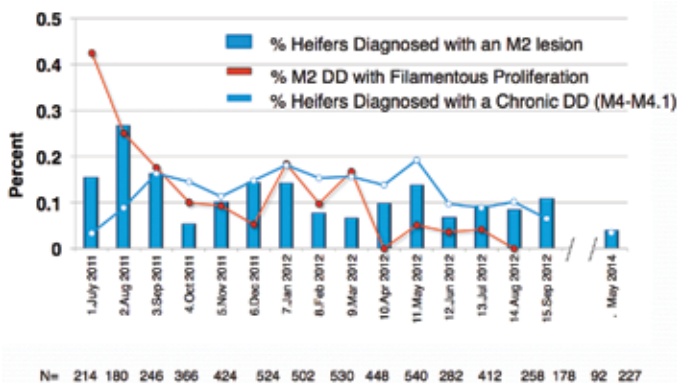
in multiparous cows using monthly milk recordings. Cha et al. (2010), taking into consideration losses to milk production having to do with treatment, reproductive performance, and treatment costs, calculated a loss of \$133 per DD case, attributing the most importance (40%) to treatment costs. Similarly, Wilshire and Bell (2009) calculated a cost of \$126 per DD case in the UK. However, these assessments are clouded by comparison of diseased cows with non-diseased cows, often in a single lactation. We know that DD and other causes of lameness affect higher producing animals more than lower producing ones, and we also know that the risk for repeated episodes of DD infection is higher in animals that have suffered the disease in the prior lactation (Oikonomou et al., 2013). We examined the losses in the first lactation between heifers uninfected during the rearing period (Type I) compared to animals repeatedly infected (Type III), controlling for early lactation milk yield, and found that Type III animals produced 740 lb (335 kg) less milk in their first lactation than Type I animals, and days open was extended by 25 days. The extent of this loss is remarkable and can be used to motivate the implementation of early prevention strategies during the rearing period.

A New Take on Control Strategies

DD control must start during the heifer-rearing period. Footbaths alone have relatively modest impact on control, with surveillance for fresh M2 lesions and prompt topical therapy being far more effective throughout the life cycle of the cow.

We have investigated the potential role for in-feed trace mineral supplementation in prevention of DD both in our experimental challenge model and in the field. A unique commercially available mix of organic trace minerals showed a strong tendency to reduce the proportion of feet affected by experimental M2 lesions (OR = 0.54 [0.18, 1.09]) compared to controls receiving traditional supplements (Gomez

et al., 2014), and further field studies have confirmed the efficacy of this product on commercial dairy farms, with the likelihood that this supplement serves to enhance the zone 2 epidermal skin barrier to DD infection. As an added bonus, supplemented heifers produced 420 lb (191 kg) more milk over the first lactation compared to controls reared on traditional supplements.

Prior to first calving we recommend a hoof-trim with an expanded modeling of the axial groove area of the outer claw of the rear foot. This appears to reduce the risk for DD in lactation, likely by modifying the micro-environment between the claws and improving hygiene. Regular routine trimming is also recommended at least twice per lactation in mature cows.

In order to enhance our understanding of herd dynamics of infection, we are working to capture lesion stage information in hoof-trimmer databases and new apps that serve to help record DD lesion types and allow prediction of likely increases in disease incidence.

We can track proliferation in M2 and M4 lesions to fine-tune the prevention program. Proliferation in M2s is suggestive that the herd is not identifying acute lesions quickly enough, which will impact the efficacy of treatment. Proliferation in M4 lesions is indicative of skin damage likely as a result of too aggressive a footbathing regime, perhaps with a chemical with too high or too low pH. We currently recommend baths with a pH no lower than 3.0. DD lesion stages can also be recorded at routine trims – and we recommend that herds keep track of M2 and M4 lesions at a minimum.

Footbaths remain an important part of control, but they need to be operated judiciously for both heifers and cows. Copper sulfate ($CuSO_4$) stands out as the most frequently tested chemical and, corresponding to its extensive use in the field (Cook et al, 2012), is also the chemical most frequently used as a comparison (control) group in research trials. Typically these trials confirm the efficacy of copper sulfate and

Figure 3. Comparison first lactation milk yield between heifers uninfected with DD during the rearing period (Type I) and those repeatedly infected (Type III).
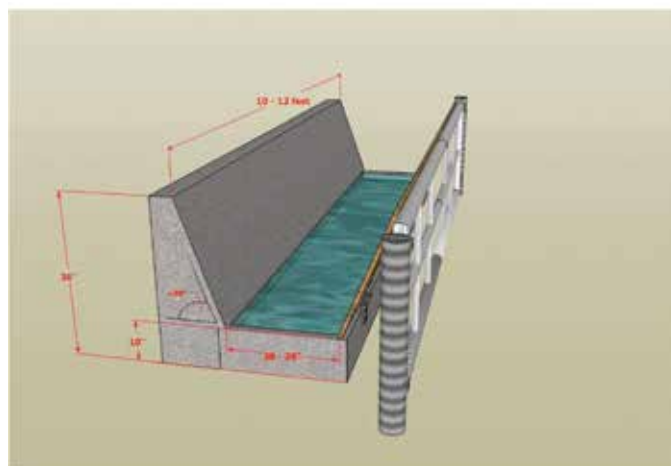
Figure 4. The 'ideal' footbath design.

formalin in footbaths, which tend to out perform other test products (Britt et al., 1996; Thomsen et al., 2008; Teixeira et al., 2010; Speigers et al., 2010, 2012; Smith et al., 2014). However, more recently, we have focused more on the design of the delivery system. From our research we have eliminated wash baths and recommend treatment baths that are 10-12' long, 24" wide at the base, with a 10" high step-in to ensure that all rear feet receive at least two immersions as cows pass through the bath (Cook et al., 2012). These baths when filled with solution to ~3-4" deep will contain 50 gallons, to minimize use and cost of chemicals. The side-walls are sloped to a width of 36" at a height of 36" above the floor. Larger farms will place 2 baths in parallel to deal with the high throughput of cows, and it is essential that the entry to the bath is direct from a narrow alley that serves to funnel the cows into the bath. Using a factorial study design including two footbath products (5% copper sulfate solution vs. a proprietary new footbath agent), and two footbath dimensions (7.5' (2.3 m) and 15' (4.6 m) long), Logue et al. (2012) were able to clearly demonstrate the greater efficacy of longer footbaths in preventing DD occurrence (OR = 2.49 to 3.3).

Improved contact time allows us to use lower concentrations of copper sulfate (2-3% vs 5-10%), and when associated with improved M2 surveillance, frequency of use can be reduced from 3-5 days per week to 2-3 days per week, with the inclusion of chemicals such as oil of thyme, tea tree oil or other types of product in the rotation, which pose fewer challenges for handling and disposal.

Finally, improved hoof hygiene, while difficult to achieve in practice is an essential goal for DD control at all ages.

Conclusions

Our research has created some new opportunities to refocus DD control efforts on the heifer rearing period and understand the importance of lesion stage identification in the treatment and prevention of acute stages of DD. Implementation of this control plan is having a significant impact on the incidence of DD in our dairy herds, creating a more sustainable solution to control for the future.

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Shaping her future – the colostrum contribution

Fernando Soberon,[1] PhD; **Melanie A. Soberon**,[2] PhD
[1]Shur-Gain U.S.A., Strykersville, NY 14145
[2]Cornell University, Ithaca, NY 14850

Abstract

Colostrum has long been valued as critical to new-born calf health, but its potential impact on the nutritional programming of the calf and consequently, her lifetime performance in milk production and health, are now areas of active research. New levels of importance and value are being attributed to colostrum, as scientists work to better understand the mechanisms and regulation of epigenetics, the influences of non-nutritional components of colostrum, and the impact of timely colostrum nutrition. Many of these benefits of colostrum were once attributed to passive transfer, but epigenetics and nutritional programming have revealed that there is much more in colostrum than IgG. Relaxin, leptin, insulin, IGF-I, IGF-II, prolactin, and lactoferrin are some of the nutritional and non-nutritional factors in colostrum that have a direct and indirect effect on the development and long-term gene expression of offspring. Researchers have shown that calves that received more colostrum at birth have higher average daily gains improved feed efficiency, higher dry matter intakes post-weaning, reduced time to conception and first calving, increased milk production during 2 lactations, and an increased survivability through second lactation.

Key words: cattle, calf, colostrum

Résumé

On reconnait depuis longtemps le lien fondamental entre le colostrum et la santé des nouveaux nés chez les bovins. Néanmoins, l'impact potentiel du colostrum sur le développement nutritionnel du veau et donc sur la santé et la production de lait durant la vie sont des domaines tout récents de recherche. On attribue maintenant de nouvelles valeurs et une plus grande importance au colostrum suite aux percées par des chercheurs sur la régulation et les mécanismes épigénétiques, l'influence des composantes non-nutritionnelles du colostrum et l'impact du moment où l'on administre le colostrum. Plusieurs des bénéfices du colostrum étaient attribués par le passé au transfert passif. Toutefois, l'épigénétique et les programmes de nutrition ont montré que les IgG ne sont pas les seuls éléments importants dans le colostrum. Plusieurs facteurs nutritionnels et non-nutritionnels du colostrum, comme la relaxine, la leptine, l'insuline, l'IGF-I, l'IGF-II, la prolactine et la lactoferrine peuvent avoir un impact direct ou indirect sur le développement et l'expression à long terme des gènes chez la progéniture. Les chercheurs ont montré que les veaux qui recevaient plus de colostrum à la naissance avaient un gain moyen quotidien plus élevé, une plus grande efficacité alimentaire, une plus grande prise alimentaire de matières sèches suivant le sevrage, un plus petit intervalle de temps avant la conception et le premier vêlage, une plus grande production de lait durant les deux premières lactations et une plus grande survie jusqu'à la seconde lactation.

Introduction

The conversation of what factors influence and impact lifelong health, performance, and growth has been a dialogue of great interest throughout history, but with recent scientific assessments and technologies coupled with new observations and perspectives, our understanding has increased, and with it, the ability to better quantify and isolate those factors. Colostrum has long been valued as critical to newborn calf health, but its potential impact on the nutritional programming of the calf and even lifetime performance in milk production and health, are just now receiving recognition. The idea that 1 meal, the first meal of life, can impact an animal for its entire life, generates discussion of how an environmental factor such as nutrition, can alter an animal's genome.

The modulation of gene expression through biochemical mechanisms that do not alter the DNA sequence but permanently alter their ability to be transcribed has gained the attention of the medical and scientific community as a means to better understand development, disease, and performance.

Nutritional programming has been reported in multiple species, including insects, birds and mammals, but particularly in mammals, it provides a mechanism for the mother to continue to influence the development of offspring after birth through her colostrum and milk. This regulation can only occur during specific windows of opportunity that, as we better understand, open the possibility to enhance the performance of productive species as well as the possibility to predict and reduce the probability of certain diseases later in life.

Epigenetics

The concept of epigenetics is attributed to Conrad Hal Waddington, who in 1953 described epigenetics as an animal's useful response to an environmental stress that persists even after the environmental stress is removed. In some instances, the trait or response becomes permanent in that animal, regardless of the environment.[22] Different terms have been used to describe some of the effects controlled through epigenetic mechanisms including imprinting, metabolic programming, and nutritional programming. Some of

the environmental factors attributed in scientific literature for the generation of permanent epigenetic changes are temperature, grooming,[24] malnutrition,[12,15] and overnutrition.[9,13]

Epigenetics refers to the modification of DNA that results in changes in DNA expression but does not change the nucleotide sequence itself. Epigenetic changes are normal, natural phenomena that function through both short-term/temporary and long-term/permanent changes in gene expression. Some of these gene expression regulators can be inherited. Epigenetic mechanisms are used for gene regulation throughout fetal development, but are not limited to that period of time; normal events such as hibernation, pregnancy, and starvation use epigenetic mechanisms for homeorhesis. Scientists have been particularly interested in those changes to the epigenetic code, also known as the epigenome, that occur at 1 specific point in time during development, yet have future phenotypical implications.[1,9,12,13,15,19,24] For example, the amount of grooming a rat received from its mother as a pup has been shown to modify the adult rat's stress response. Pups that were groomed more by their mothers had higher methylation of the first exon of the promoter region for glucocorticoid receptor; this modification persisted for life and resulted in a greater affinity for NGFI-A as an adult rat.[24]

A well-researched event that has further illuminated the effects of nutritional programming is the famine during the Dutch Hunger Winter. Towards the end of the Second World War, Germany imposed a food restriction on the western part of Holland during what proved to be a particularly cold winter. Researchers have used this event to follow up and study the individuals that were conceived or in their mothers' womb during this period. Drastic nutritional restrictions during critical developmental stages in utero led to permanent effects on the methylation of the children's DNA, and was especially linked to the regulation of IGF-II. Individuals exposed to the famine during their peri-conception or mother's gestation, exhibited an increased risk for glucose intolerance, impaired insulin secretion, obesity, stress sensitivity, coronary heart disease, schizophrenia, anti-social behavior, and addiction[12] later in life.

Another well-studied example of nutritional programming is provided by honey bees. All bees in a hive share the same genetic composition. However, when there is time to produce a new queen, the larva selected to become the queen is fed a 'royal honey'; moreover, it is fed 10 times more than other larvae. This difference in nutrient intake during a critical developmental stage changes the epigenome of that 1 bee and instead of becoming a common worker, she grows twice as fast, will have a life expectancy 20 times higher than any other bee, and becomes the only female to develop her female reproductive organs.[9]

Epigenetics has now been proposed as a potential integral component in future disease diagnosis but equally importantly, it has provided a deeper understanding of the well-known environmental influence on genotypic performance. As more information becomes available, the possibility for programming desirable traits in production animals will open a new chapter in animal science and agricultural production.

The Traditional Attributes of Colostrum

Colostrum has traditionally been recognized as critical for adequate transfer of passive immunity in the newborn calf. It is well documented that calves with <10 mg/mL IgG in blood plasma (5.2 g/dL protein) during the first 2 days of life experienced higher rates of pre-weaning morbidity and mortality.[8] In an attempt to explain the effectiveness of colostrum against *Escherichia coli* infections in the gastrointestinal tract, researchers provided calves with either colostrum followed by *E. coli*, colostrum combined with *E. coli*, or *E. coli* alone. The calves that were administered *E. coli* alone had high levels of *E. coli* attachment in the intestine as well as *E. coli* present in the lymph; when colostrum and *E. coli* were administered simultaneously, there was no attachment of *E. coli* in the gut, but there were low levels of passive transfer. Finally, when colostrum had been fed prior to the *E. coli* challenge, there was no bacterial colonization in the gut and high levels of circulating antibodies.[23] These IgG benefits of colostrum may last for as long as 3 weeks, but eventually, the calf must depend on its own immune system. While colostrum is a valuable source of immunoglobulins, increasing amounts of literature are suggesting that factors in colostrum other than immunoglobulins are important for long-term productivity and feed efficiency in dairy calves.

Colostrum Beyond IgGs

Proper colostrum administration has consistently been measured through IgG plasma concentration in the calves. Using this assessment, many studies have compared the performance of calves with high versus low levels of passive transfer. This has led to the assumption that IgGs are the cause or promoters of long-term effects associated with feeding proper levels of quality colostrum. However, with new understandings of the potential implications of nutritional programming and its long-term effects, it is now crucial to evaluate colostrum for all of its constituents and not restrict its value to that of passive immunity. The long-term effects reported in scientific literature of feeding an increased quantity as well as higher quality of colostrum include increased average daily growth up to at least 180 days,[17,25] reduced time to first calving,[23] and increased milk and fat production during first lactation.[7,11] Most of these studies have sorted calves into different treatment groups based on their IgG plasma concentration; however, a few studies have evaluated the direct effect of quantity of colostrum rather than the passive transfer of IgGs.

Using Brown Swiss cattle, Faber et al measured the long-term effects of supplying 4 quarts versus 2 quarts of colostrum during the first feeding. Other than the amount

of colostrum followed by the feeding of transition milk, all calves were treated the same. Calves that consumed 4 quarts of colostrum had an average daily gain (ADG) of 0.4 lb (0.18 kg) or 22% greater gain than those calves that received only 2 quarts; there were no significant differences in calving age, but by the end of the calves' second lactation, the survival rate of calves that had consumed 4 quarts of colostrum was 12% higher (87% vs 75%). Moreover, of the cattle that survived to the end of second lactation, cows that had consumed more colostrum at birth produced 2,265 lb (1,029 kg) more milk than those that consumed less colostrum.[11]

The amount of colostrum consumed at birth was thought to have an interactive effect with the amount of milk or milk replacer (MR) offered during the pre-weaning period. In order to better understand this interaction, Soberon and Van Amburgh conducted a 2x2 experimental design where calves were offered either 4 quarts or 2 quarts of colostrum at birth, after which all calves were fed in a commingled pen with an automatic feeder. Half of the calves on each colostrum treatment were allowed to consume up to 12 quarts of milk replacer per day and the other half of the calves from each

treatment were offered 5 quarts per day. Results from this study are presented in Table 1. It is important to highlight for the purpose of this discussion that in this study every calf had plasma IgG levels above the 10 mg/mL, and only 2 out of 125 calves had IgG levels below 12 mg/mL; thus, in any other study, all of these calves would have been considered as having proper passive transfer. When calves were limit-fed 5 quarts per day, ADG pre-weaning, weaning weight, ADG to 80 days, and milk replacer consumption was not significantly different among colostrum treatments. However, when milk replacer was not restricted and calves were allowed to drink sufficient nutrients from milk replacer, calves that received 4 quarts of colostrum had higher ADG pre-weaning, higher weaning weights, higher milk replacer consumption, higher hip height gain by 80 days, and higher ADG post-weaning. In addition, regardless of the milk replacer treatment they were in, calves that consumed 4 quarts of colostrum had higher dry matter intake (DMI) post-weaning compared to calves that consumed only 2 quarts of colostrum.[19]

The incidence of clinical health events in this study was not different among treatments, which suggests the

Table 1. Weights, heights, average daily gains, and post-weaning dry matter intakes for calves (n = 125) fed either 4 quarts of colostrum and up to 12 quarts of MR (HH), 4 quarts of colostrum and 5 quarts of MR (HL), 2 quarts of colostrum and up to 12 quarts of MR (LH), or 2 quarts of colostrum and 5 quarts of MR (LL). Means and standard deviations shown.

Treatment	HH	HL	LH	LL	
	Mean	Mean	Mean	Mean	Std dev
N	34	38	26	27	
Days on treatment	84.3	83.3	82.8	82.8	0.7
Birth wt, lb	97.1	95.8	92.2	95.5	1
Birth hip height, in	31.7	31.6	31.5	31.9	0.6
IgG concentration, mg/dl[§]	2,746[a]	2,480[b]	1,466[c]	1,417[c]	98
Weaning wt, lb	172.4[a]	140.0[b]	159.1[c]	137.7[b]	1.9
Weaning hip height, in	36.61[a]	34.89[b]	36.04[a]	35.27[b]	0.6
ADG pre-weaning (0 to 52 d), lb	1.74[a]	0.93[b]	1.48[c]	0.86[b]	0
ADG birth to 80 d, lb	1.72[a]	1.30[bc]	1.46[b]	1.17[c]	0
Total milk replacer intake, lb DMI[§]	97.9[a]	45.2[b]	90.2[c]	44.1[b]	1.2
Grain intake pre-weaning, lb[*§]	5.5[a]	26.5[b]	4.6[a]	21.4[b]	1.5
Feed efficiency pre-weaning[†*]	0.61	0.61	0.65	0.61	0
Hip height gain, pre-weaning, in/d	0.098[a]	0.063[b]	0.091[a]	0.063[b]	0
Hip height gain, birth to 80 d, in/d	0.083[a]	0.063[b]	0.071[c]	0.059[b]	0
ADG post-weaning[‡], lb	2.36[a]	2.14[ab]	1.94[b]	2.03[b]	0.1
DMI post-weaning[‡], lb/d	6.37[ab]	6.37[a]	5.69[c]	5.87[bc]	0.1
Feed efficiency post-weaning	0.33	0.34	0.34	0.36	0

[*]Data from 5 wk during the pre-weaning period was used in the analysis
[†]DMI includes milk replacer intake and grain intake from birth to weaning
[‡]Measured during 3 weeks after a 1-week adaptation period to pens
[§]Data is only reported for calves in the second block
[abc]Values within the same line with different superscripts differ $P < 0.05$

mechanism that triggered the increase in performance is more than can be attributed solely to passive transfer. Bartol et al coined a term that is very useful in understanding the possible mechanism working through colostrum; it is the *lactocrine hypothesis*.[1]

The Lactocrine Hypothesis

The 'lactocrine hypothesis' attributes the effects of milk-born factors, including colostrum, to the epigenetic development of specific tissues or physiological functions.[1] It has been described in multiple species including neonatal pigs, primates, and calves.[2,3,4,10,13,15,16] The term was first used by Bartol et al when his group was able to track the direct effects of relaxin found in sow milk on the development of the uterus. They showed an increased reproductive efficiency in sows that had been fed colostrum vs formula-fed sows.[1]

Other evidence for non-nutritional factors present in colostrum was presented by Burrin et al when they examined the effects of feeding colostrum, milk or formula with similar nutrient composition to colostrum to newborn piglets. Piglets that consumed colostrum had higher rates of skeletal protein synthesis as well as higher rates of protein synthesis in the jejunum.[5]

The evaluation of colostrum intake in calves showed significantly higher plasma levels of glucose in calves fed colostrum vs formula. This was due to an increased absorptive capacity since the gluconeogenic ability did not differ among the 2 groups of calves.[20] These results were further supported by an increased glycogen concentration in liver in colostrum-fed calves. Researchers also tested calves after a 15-hour feed deprivation period and observed that colostrum-fed calves had higher levels of circulating glucose and lower plasma urea concentrations, indicating lower levels of protein catabolism in colostrum-fed calves.[20]

The effects previously mentioned in this paper observed by Faber et al in Brown Swiss and those described by Soberon and Van Amburgh using Holstein calves that were fed either 2 or 4 quarts of colostrum at birth are most likely explainable through the lactocrine hypothesis, where non-nutritional factors present in colostrum might be responsible for the increase in feed efficiency, increased DMI, increased average daily growth, increase in milk production, and increased survival.

There are others that suggest these effects might be directly attributed to nutrient intake; this hypothesis is supported by data from Soberon et al that suggests that long-term effects such as increased milk production are a consequence more related to nutrient intake and pre-weaning growth rates than a single milk-born factor.[18] In most cases, the studies that support nutrient intake as the main factor for increased future productivity analyzed differences in intake during the first 30 to 60 days of life; therefore, the question remains as to the interaction of both nutrient intake levels and non-nutritional factors, given that each are provided within the right window of time or at the proper developmental stage.

Last Remarks on Colostrum

Colostrum is a highly concentrated source of nutrients and non-nutritional factors that are produced by the peri-parturient dam to be the first feed their progeny consumes. Colostrum, when compared to milk, is higher in fat (6.7% vs 3.7%), total protein (14% vs 3.2%), and IgG (3.2 vs 0.06 g/100 mL). Even though it is impressive to have 60 times more IgGs in colostrum than in milk, there is 155 times more IGF-I in colostrum than in milk. Colostrum also contains 18 times more prolactin, 100 times more insulin, 90 times more leptin, and 19 times more relaxin than milk. These are only a few of the non-nutritional factors that may have long-term implications in the development of newborn calves.

Conclusions

Colostrum has traditionally been valued for the passive transfer that it provides to calves. Although passive transfer is a valuable attribute of colostrum, it is now known that other factors present in colostrum, not directly related to immunity, have a great impact on the future performance of calves. Non-nutritional factors in colostrum are potential factors influencing the epigenome of newborn calves. The benefits of providing 4 quarts of colostrum within the first hour of birth have been observed to include improvements in ADG, increased DMI, reduced time to first breeding, reduced time to first calving, increased milk production, and increased survivability to second lactation. Colostrum is still important for passive transfer of immunity but its long-term benefits add to its value, making colostrum the 1 most important step in shaping the future of dairy cows.

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Sand lanes – get the gold standard for pennies

M. E. Hardesty, DVM, MS, Maria Stein Animal Clinic, Inc. Maria Stein, OH 45860

Abstract

Sand is the best bedding for freestall-housed dairy cows; however, sand-laden manure presents several handling issues. Well-designed sand lanes separate sand from manure, minimizing handling issues at relatively low costs. Reclaimed sand can be as clean, or cleaner than, new sand in well-designed and operated systems. Sand reclamation rates vary from 60 to 98%, so the design and operation of the sand lanes is important. Sand lanes can be used with flush barns and with barns that scrape alleys to flumes or collection pits. Advantages of each will be discussed.

Key words: cattle, dairy, housing

Résumé

La litière de sable offre le plus d'avantages pour les vaches laitières en stabulation libre. Toutefois, le fumier de vache chargé de sable est de manutention difficile. Des allées de sable bien conçues peuvent séparer le sable du fumier permettant ainsi de minimiser les problèmes de manutention à moindre coût. Le sable récupéré peut être aussi propre ou même plus propre que du sable nouveau dans les systèmes bien conçus et maintenus. Le taux de récupération du sable varie entre 60 et 98%. Il est donc important de bien concevoir et de maintenir les allées de sable. Des allées de sable peuvent être utilisées dans les fermes qui nettoient le fumier à grande eau ou dans les fermes qui transportent le fumier mécaniquement dans des fosses déversantes ou des canaux. Les avantages associés à chaque type seront discutés.

Introduction

Sand is recognized as the standard of bedding for freestall-housed dairy cows. Impact areas include improved milk production, improved SCC premium, reduced number of clinical mastitis cases, reduced number of lameness treatments, reduced cost of replacement heifers, and potentially reduced cost of bedding if recyled.[1] Recycled sand bedding can have issues with organic matter contamination. Sand lanes use gravity to separate sand-laden manure into heavier reusable sand and less-dense manure for disposal. These systems can be designed with a minimum of pumps and labor for all steps in the sand reclamation, and manure removal processes. The guidelines that follow are for conceptual purposes, and the services of a knowledgeable engineer and experienced builder are recommended.

Sand Lanes

Sand lanes are concrete alleys 11 to 12 feet (3.3 to 3.7m) wide, 10 inches (25.4 cm) to 4 feet (1.2 m) deep, and 150 to 300 feet (46 to 91 m) or longer used to separate sand from manure. Slopes range from flat with intermittent 1-inch (2.5 cm) "water falls" to .25% slope. Principles of operation are that sand-laden manure mixed with water will separate into its components by density differentiation over the course of a lane that allows deceleration of the suspension. The sand lane is usually accompanied by a dewatering floor that drains back into the sand lane.

A travel speed of 5 feet (1.5 m)/second will move sand, and it will settle out of suspension when the speed slows to 1½ feet (0.46 m)/second. At less than 1 foot (0.30 m)/second, solids will settle out of the suspension. Length of sand lane becomes important to provide space for the separation to occur due to flow rate deceleration. As sand accumulates in the lane, the flow rate will decrease. Sand is removed from the lanes every few days to weekly and placed on a dewatering floor. The best designed dewatering floors allow the liquid to drain back into the sand lane. Best management of the sand piles includes turning of the piles weekly for 2 to 4 weeks to promote liquid coming out of the sand. Dewatering floor should be sized to hold 6 weeks' capacity for turning reclaimed sand and receiving new sand.

Many experts suggest that organic material levels of 4 to 5% or higher in reclaimed sand is of questionable quality, while others report organic material levels as high as 9% without milk quality issues. Dairies that have an abundance of recycled sand tend to bed stalls more deeply than those that purchase new sand. This may be the reason for fewer milk quality issues. Flushing the sand with more water, or water with a lower level of total solids, decreases the organic material level in the sand. Water with 1 to 2% total solids is preferred.[3] Longer sand lanes facilitate flushing with more water. The skill of the loader operator at discerning sand that is clean from dirty sand is also a factor. Skilled operators may choose to push dirty sand to the front of the sand lane to be rewashed. This can compensate for a sand lane that is too short to some extent.

Adequate clean flush water for the sand lane is a common limitation of sand lanes. Twenty to 40 gallons (75.7 to 151 L) of flush water/cow/day is desired.[3] Most flush water is pulled from a lagoon by a floating pump that pulls water from 2 feet (61 cm) below the surface. This level is expected to be the cleanest water in an undisturbed lagoon. This system presents water supply problems whenever the

lagoon is pumped down. Some systems compensate for this by using storm and runoff collection-pond water during these times of shortage. Most have been surprised how quickly these supplies are depleted because these systems are not a closed loop. Our most common systems now being built are 2-stage lagoons separated by a weep wall. Separated manure from the sand lane flows into the first lagoon. A weep wall retains up to 60% of the solids in the first lagoon. Sloped screen and screw press separators retain 20% of the solids at best; cow manure is 13% total solids. The addition of flush water and retention of solids in the first lagoon can reduce flush water total solids to less than 2%. Flush water is taken from the second lagoon by a floating pump. Most of the pumping for field application is from the first lagoon. A valve can be closed between the 2 lagoons so water from the second lagoon is retained for flush when the first lagoon is pumped empty. Two-stage lagoons with a weep wall between them have fewer issues with odor because the flush water has lower levels of organic material. This is especially important in flush barns, as flush water is released every few hours and if this water has odor it creates an undesirable neighborhood situation.

Freezing temperatures can present challenges, but we have successfully operated sand separation lanes at 0° F (-17.7° C). Sand lanes that are placed deeper in the ground can be operated at colder temperatures than those on the surface. The deeper sand lanes require ramp access for a skid loader or payloader to remove the separated sand. Flush barns typically choose to flush more often at colder temperatures to have flow through the lanes, and flumes may be run continuously at subzero temperatures. The principle of moving water not freezing applies here. Flushing of holding pens may be suspended if there is not continuous traffic. Sand removed from lanes during freezing temperatures may not be clean enough without being rewashed.

Flush Barns

The simplest barns that use sand lanes are flush barns that use large volumes of water to flush alleys every 2 to 6 hours. Labor savings are significant and the barns can be very clean. Brown water is pumped from the lagoon into upright tanks. These tanks for a 250- to 400-cow barn will be 30,000 to 50,000 gallons (113,562 to 189,271 L). Valves open in the floor at the high end of the barn, and 5,000 to 8,000 gallons (18,927 to 30,283 L) of water travels down the alleys removing sand-laden manure. The next alley is usually flushed 30 minutes later. The sand-laden manure in flush water is collected at the end of the barn, travels to the sand lane, where it is separated. If there is enough elevation, the resulting manure solids flow directly into the lagoon. If there is not enough elevation advantage from barn-to-sand lane-to lagoon, then reception pits with pumps will be needed to transfer to the next stage. Reception pits are best constructed with minimal corners so agitation is effective.

Some of these pits are constructed with ramp access to clean them out mechanically. We have 1 reception pit that lowers a skid loader into it to clean it out.

Flush barns require 2% slope to maintain sufficient velocity or there are issues with sand accumulation in the alleys. If there is not enough flow or velocity, the area most likely not to be flushed is at the curb to the freestalls. This is the area that we most want to be clean because a cow's foot steps there last before entering the stall to lay down. If feet are dirty, they soil the beds and the teats of the cow. One barn with only 1½% slope has attached a scraper to their sand-leveling arm to move sand-laden manure away from the curb. Any sand-bedded barn should be leveled 2 or 3 times daily and the manure and wet spots should be cleaned out when cows are fetched.

Most of our new construction curbs are built in an overhang manner so the flush water can get behind the manure to get it moving. We also build the alleys with slope toward the curb so more of the water flow is toward the curb than down the center of the alley. This is more important at the lower end of the alley than at the top. If we slope the floor too much toward the curb at the top, there won't be enough flow on the rest of the alley at the bottom.

Scrape Barns

Sand lanes can be used in conjunction with barns that scrape alleys. This is a common retrofit to existing barns or new barns that present a challenge with sufficient slope for flush. Separation occurs when sand-laden manure is mixed with water. This can be done in flumes that transport manure from the barn or in short flumes outside the barn. Mixing flumes shorter than 20 feet (6.1 m) have difficulty sufficiently extracting manure from the sand. Scraping sand-laden manure into a reception pit, adding water, then pumping into a sand lane presents challenges with sufficient water volume and settling of sand in the reception pit. Transport flumes are the preferred of these systems. These flumes are prone to plugging if they have insufficient water flow, stop and start, have restrictions to flow in design, or have turns. Long flumes become plugged when flushed with high-organic-material water or they have restrictions to outflow because of a full pit.

Economics

Investment in sand lanes and the accompanying dewatering floors, pumps, and tanks range from $60,000 to $200,000 for our 150 to 2,000-cow herds. This does not include the costs of earthen lagoons that would be needed for almost any storage system. The cost of sand becomes a major factor in determining the feasibility of these systems. The Dairyland Initiative has a default value of $6/ton of sand and there are areas of the country where sand is less expensive than that. New sand would be recommended over recycled

sand in those areas. Concrete and mason sands both have few fines and can be separated using sand lanes.[2]

Costs for sand delivery 15 miles (24 km) from St. Henry, OH are $23/ton for concrete sand and $26.55/ton for mason sand in 18 to 20-ton loads. At $23/ton, sand costs 1.15 cents/lb (2.54 cents/kg). At 50 lb (22.7 kg) per cow/day, the cost of bedding is 57.5 cents per day or $210 per year. Reclaiming 95% of the sand makes the annual bedding costs $10.49, or a savings of $200/lb (2.54 cents/kg)/cow/year to apply toward the sand separation facility. The separation facility should last for 20 years with only the pumps and loaders as replaceable items. That means a 150-cow dairy that invests $60,000 in sand lanes would save $600,000 in 20 years with repairs on pumps and loaders, electricity, and some labor as the only expenses.

Conclusions

Sand is the gold standard of bedding for freestall-housed cows. Well-designed sand lanes use gravity to separate sand from manure. Reclaimed sand is processed on a dewatering floor until it is dry enough for use. The organic material in reclaimed sand is decreased when sand is flushed with larger volumes of cleaner water. Sand lanes can be operated during freezing temperatures with some adjustments. Flush barns with 2% or more slope can reduce labor and create a clean cow environment. Scrape barns can also use sand lanes by mixing the sand-laden manure with water in a flume or reception pit. Sand lanes can give a 10-to-1 economic return over their lifetime.

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Avoiding drug residues in cattle – clearance time considerations in sick cows

Geof W. Smith, DVM, PhD, Dipl. ACVIM
Department of Population Health and Pathobiology, North Carolina State University, Raleigh, NC 27607

Abstract

Prevention of drug residues in the beef and dairy industries is a major concern as both meat and milk from cattle are widely consumed by humans around the world. This paper will address the keys to avoiding residues; however, there are several things that can change the half-life of a drug and thus affect the withdrawal time. These factors can include route of drug administration, volume administered at each injection site, drug formulation, and disease. The focus of this presentation will be to discuss what is known about disease-induced alterations in the pharmacokinetics of drugs and how clearance time in many cases may be delayed resulting in residue violations. Withdrawal times are generally based on pharmacokinetic studies done in healthy animals; however, there is strong evidence that these times may not always be appropriate in cows with clinical disease. Since pharmaceutical companies must conduct trials to demonstrate the efficacy of various drugs for treating a specific disease or condition during the approval process, it seems logical that pharmacokinetic and residue studies could be done using the same animals or under similar conditions.

Key words: cattle, residues, withdrawal time

Résumé

Prévention des résidus de médicaments dans le secteur de l'élevage des bovins est une préoccupation majeure comme le lait et la viande provenant de bovins sont largement consommés par les êtres humains partout dans le monde. Ce document abordera les touches pour éviter les résidus; toutefois, il y a plusieurs choses qui peuvent changer la demi-vie d'un médicament et, par conséquent, affecter les délais de retrait. Ces facteurs peuvent inclure la voie d'administration de la drogue, le volume administré à chaque site d'injection, la formulation des médicaments, et la maladie. L'objectif de cette présentation sera de discuter de ce qui est connu sur les altérations induites par la maladie dans la pharmacocinétique des médicaments et comment le temps de clairance dans de nombreux cas peut être retardé en résidus résultant de violations. Les périodes de retrait sont généralement fondées sur les études pharmacocinétiques effectuées chez les animaux en bonne santé; toutefois, il existe de fortes preuves que ces délais peuvent ne pas toujours être appropriée dans des vaches avec la maladie clinique. Étant donné que les sociétés pharmaceutiques doivent conduire des essais cliniques pour démontrer l'efficacité de divers médicaments pour traiter une maladie ou un état spécifique au cours du processus d'approbation, il semble logique que la pharmacocinétique et les études de résidus pourrait être fait en utilisant les mêmes animaux ou dans des conditions similaires.

Minimizing Residues in Meat and Milk

Some of the major reasons for residues in cattle include: 1) not following the directions for correct treatment or dose of drug to be administered; 2) failure to follow the appropriate meat withdrawal period after treating cattle; 3) treatment of the animal not recorded on a written record; 4) poor or improper animal identification; 5) extralabel or illegal drug use (using a drug not approved for the animal being treated); or 6) administering a drug in a different way than indicated on the label. Given the frequent use of therapeutic drugs on cattle operations and the potential involvement of farm workers in administering these drugs, veterinarians should be encouraged to set up written protocols for their herds to minimize variability in therapy and inappropriate drug selection or dosing. Unfortunately this is not commonly done in the industry. A survey done in Washington state indicated that only about 25% of farms had written protocols in place for treating common diseases.[18] This is similar to a survey in Pennsylvania where 21% of farms had defined treatment protocols and only 32% of producers sought veterinary advice prior to treating sick cattle.[20] In addition, only about 50% of farms kept any type of written record of antimicrobial use on the farm. Another study found that the lack of adequate treatment records was the most commonly identified reason for residues in New York State.[21] Other major reasons were failure in the understanding of how to properly use drugs by farm personnel and a poor relationship between veterinarians and producers.

In addition, milk residue violations are frequently associated with the following: 1) accidentally milking a treated cow into the bulk tank; 2) milking a cow that has received a dry-cow antibiotic formulation into the bulk tank; 3) pipeline not diverted from bulk tank when milking cows treated with antibiotics; 4) milk put in tank before the appropriate withdrawal period has ended; and 5) extralabel treatment (milk put into bulk tank without an appropriate withdrawal period). Farms with high somatic cell count levels have been reported to have a much higher rate of antibiotic residue

violations, and larger dairy farms have also been shown to have higher rates of residues.[23] In the United States, there are Milk and Beef Quality Assurance Programs which identify critical control points for residue prevention. The programs are designed to be used by cattle producers and their veterinarian as training on how to avoid drug residues. These are voluntary programs in the United States; however, once a farm has a residue violation, they may be required to complete the program in order to regain their ability to sell milk. The critical control points outlined in the program are as follows:

Practice healthy herd management – In this part of the training, the veterinarian evaluates the housing, sanitation, nutrition and reproductive programs, biosecurity, and newborn calf care already present on the farm. Since disease prevention is often more cost-effective than disease treatment, step 1 is designed to help the veterinarian and producer review things like milking management, hoof care, and vaccination programs. Through the process of completing an evaluation of the current herd health management program, ways to improve herd management and reduce the actual number of disease treatments may be identified.

Establishing a valid veterinarian-client-patient relationship (VCPR) - Having a valid relationship between the veterinarian and producer is always helpful when drugs are being used, and is mandatory in many countries if drugs are used in an extralabel manner. A standard definition of a VCPR is as follows:

The veterinarian has assumed the responsibility for making clinical judgments regarding the health of the animal(s) and need for medical treatment, and the client (owner or other caretaker) has agreed to follow the instructions of the veterinarian

There is sufficient knowledge of the animal(s) by the veterinarian to initiate at least a general or preliminary diagnosis of the medical condition of the animal(s). This means that the veterinarian has recently seen and is personally acquainted with the keeping and care of the animal(s) by virtue of an examination of the animal(s) and/or by medically appropriate and timely visits to the premises where the animals(s) are kept.

The veterinarian is readily available or has arranged for emergency coverage or follow-up in case of adverse reactions or failure of the regimen of therapy.

Another part of this portion of the training is to help producers understand the difference between over-the-counter drugs, approved prescription drugs, and extralabel drug use. Producers should have labels on all of their drugs stating the name of the drug, directions for use, prescribed withholding interval, and any cautionary statements. Part of the veterinarian's job is to educate producers on which drugs can be legally used in cattle and which drugs are inappropriate. All drugs on the farm should have labels stating the name of the drug, directions for use, prescribed withholding interval, and any cautionary statements.

Use only approved drugs with veterinarian's guidance – The veterinarian thoroughly reviews the list of prohibited drugs with the producer to ensure that these are never being used on the farm. For example – drugs prohibited for use in the United States include diethylstilbestrol, chloramphenicol, nitroimidazole (including metronidazole), sulfonamides (in adult dairy cattle, with the exception of sulfadimethoxine which is approved), nitrofurans (including topical use), clenbuterol, dipyrone, phenylbutazone, fluoroquinolones (with the exception of approved drugs and indications), and glycopeptides (such as vanomycin).

Maintain milk quality – This part of the training reviews the farm's milking procedures, waste management, and sanitary conditions. Since it is difficult or impossible to improve the quality of milk in the processing plant or retail locations, quality is generally determined at the dairy. The veterinarian reviews cow cleanliness, milking procedures, milk cooling, and also reviews milk quality reports with the producer, monitoring such things as somatic cell counts and bacteria counts.

Make sure all employees are adequately trained – Since there are often many different drugs present on a farm and there are many different routes of administration for drugs in cattle, it is critical that all employees be trained on how to administer drugs properly. Making sure only approved employees have access to drugs and making sure they know how to follow treatment protocols and how to maintain treatment records is vital to avoiding residue violations. As farms continue to get larger, more and more employees are involved in treating sick cattle. Both the veterinarian and the herd manager must ensure all employees have a good understanding of proper drug administration.

Administer all drugs properly and identify all treated animals – There are several routes of administration commonly used to administer drugs to cattle including oral, topical, subcutaneous, intramuscular, intravenous, intramammary, and intrauterine. The veterinarian should review each of these with the producer and make sure they understand how to give drugs via each route. The veterinarian also makes sure the farm is somehow identifying animals when they are treated, such as using leg bands, neck bands, or colored marks. In the beef industry, it is important to make sure all shots are administered in the cervical (neck) region and not in the muscles that represent higher quality cuts (steaks or roast). It is also important to use subcutaneous administration when allowed by label instead of intramuscular.

Maintain and use proper treatment records on all treated animals – The Food and Drug Administration in the United States requires that producers maintain drug treatment records for 2 years on all animals. These records should be easily accessible by anyone who works with the animals. The producer should be able to show where all drug purchases were either used or disposed. The treatment record should contain the date of treatment, drug used, animal identification, dosage, route of administration, indi-

vidual who administered the drug, and withdrawal period for meat and milk.

Use of drug screening tests – There are various "on-farm" screening tests that are available for use by producers to screen milk for antibiotics. Examples of these rapid assays include Beta Star Plus,[a] Delvotest,[b] SNAP antibiotic residue test,[c] and various Charm II assays.[d] Proper use of drug screening assays, particularly when a drug has been used in an extralabel manner, is strongly encouraged. In this step of the program, a veterinarian reviews how producers identify withholding intervals and assesses whether or not they are correctly using drug screening tests in certain situations. Appropriate use of milk residue test kits on farms has been associated with a significant reduction in the risk of milk residue violations.[14]

Implement employee/family awareness of proper drug use to avoid marketing adulterated dairy products - Many residues result when 1 person treats the animal and someone else does the milking. In addition to maintaining accurate drug treatment records, it is important the all farm employees understand the importance and cost of drug residues and how to avoid them. The use of part-time labor to milk cows was found to be 1 of the most significant risk factors on dairy farms with a high risk of milk residue violations.[14] Therefore all employees should understand how to read drug labels, how to fill in drug treatment records, and how to identify treated cattle.

Complete the milk and beef residue prevention protocol annually – To truly minimize residues, the training discussed above should be reviewed on a yearly basis to ensure everyone on the farm understands how to use drugs appropriately on the dairy farm. Overall the most effective ways to minimize drug residues is through education between the veterinarian and farm manager, and between the manager and farm employees. Establishing a valid relationship between producer and veterinarian should be the first goal, whereby the veterinarian visits the farm regularly, has a thorough knowledge of the diseases and organisms that occur most commonly on the dairy, and establishes written treatment protocols for various diseases that may occur. The veterinarian should also educate the manager and all farm employees on proper drug storage, drug labeling, how to properly administer drugs, identification of treated animals, how to maintain and understand treatment records, and how to establish both meat and milk withdrawal times. Also the proper use of "on-farm" antibiotic screening assays can help reduce the risk of drug residues.

The Effects of Disease on Drug Clearance

In general, drug residues in cattle can be attributed to: 1) failure to adhere to the recommended withdrawal times, 2) poor record keeping, 3) inadvertently administering the wrong drug, dose or dosing via an unapproved route of administration, 4) extra-label drug use without an appropri-

ate withdrawal interval or 5) altered clearance of drugs in diseased animals.[9] Examples of extended withdrawal times when drugs are given by unapproved routes of administration include ceftiofur crystalline free acid (13-day slaughter withdrawal when given in the ear – but can result in residues for up to 90 days when given intramuscularly or 130 days when given subcutaneously somewhere other than the ear. Our laboratory has also shown that the pharmacokinetics and clearance of flunixin was significantly slower when given by the IM or SC routes as compared the approved IV route.[7]

The main goal of drug use in veterinary medicine is to treat diseased animals. Food and Drug Administration guidelines state that that meat withdrawal times be determined using residue data from the target tissue of 20 animals, with 5 animals being slaughtered at each of 4 evenly distributed time points. For milk withdrawal times, 20 animals are used with milk collected from all animals at evenly spaced time points. However, it is not required that animals used in these residue studies have the clinical disease for which the drug is being approved, and healthy animals are generally utilized in these studies. These studies provide the basis for the development of dosage regimens and determination of a withdrawal time, assuming no changes in the dose-effect relationship and pharmacokinetics in diseased animals. This implies that the pharmacokinetic behavior of a drug remains the same in diseased and healthy animals. However, diseased states can profoundly alter the pharmacokinetic behavior of a drug. The most profound differences in pharmacokinetic responses are generally associated with hepatic, renal, and cardiovascular disease, but other processes such as inflammation, endotoxemia, and stress can also significantly alter a drug's absorption, distribution, metabolism, and elimination.[13] In ruminants much of the literature has focused on describing the effect of disease on the pharmacokinetics of various antimicrobials. For example, differences in pharmacokinetics were noted between febrile and afebrile goats administered norfloxacin. The clearance was significantly reduced in 28 febrile goats compared to afebrile goats.[6] Similarly, a 47% reduction in enrofloxacin clearance was observed in febrile goats following an intravenous injection of endotoxin.[17] There was a reduction from 28.8% to 8.5% in the metabolic conversion of enrofloxacin to ciprofloxacin in febrile goats; which is likely responsible for the reduced clearance. As a result of the reduction in clearance; the elimination half-life and mean residence time were prolonged.[17] In another study where febrile goats were administered marbofloxacin, both the volume of distribution and clearance were significantly reduced compared to healthy animals. Consequently, mean residence time was significantly greater in febrile goats.[24]

A study conducted by Lucas et al found that mammary health status had an influence on the pharmacokinetics of azithromycin.[12] Quarters with subclinical mastitis caused by *Staphylococcus aureus* had significantly lower drug clearance from the mammary gland, a greater milk elimination half-life, and longer mean residence time in milk for

azithromycin. Differences in drug pharmacokinetics have also been described for oxytetracycline in cows with theileriosis.[10] Following intramuscular administration, infected cattle had significantly prolonged absorption, elimination half-life, mean residence time, area under the curve, and bioavailability as compared to oxytetracycline administration in healthy cows. Another example is theophylline where in a field trial, 5 out of 20 calves with respiratory disease died after administration whereas all 20 calves treated with a placebo survived.[15] A subsequent study showed calves with pneumonia had significantly higher plasma concentrations of theophylline as compared to healthy calves.[16] Likewise, a greater secretion of ceftriaxone into milk was also noted in cows with metritis as compared to control cows following intravenous administration.[1]

Differences in pharmacokinetics and milk elimination of drugs have also been observed for intramammary preparations used to treat mastitis. Mastitis produces physical and chemical changes both in the milk and the mammary gland itself that have the potential to alter distribution and elimination of drugs through the mammary gland.[3] Inflammation of the mammary gland leads to vascular permeability changes that often enhance systemic absorption and perhaps distribution of drugs into the udder. For example, gentamicin is not detected in the plasma following intramammary administration in normal quarters; however, the drug is well absorbed in cows with mastitis.[22] Similarly in studies using polymyxin B, the drug was not found in the blood or untreated quarters following intramammary administration in normal cattle; however, significant systemic absorption was seen in cows with experimentally induced coliform mastitis.[25] Lastly, a study using an intramammary preparation of cefoperazone sodium reported significantly greater systemic drug absorption, milk half life, and mean residence time in cows with subclinical mastitis compared to healthy controls.[26]

A more recent study showed that in in cows with clinical mastitis, the clearance of flunixin was significantly slower than seen in healthy cows, and residues persisted beyond the approved withdrawal time even following proper administration of the drug.[8] To go along with this, a recent surveillance study found that cows culled because of disease or that had evidence of disease at slaughter had a significantly higher incidence of violative tissue flunixin concentrations than did healthy dairy cows.[2] Since 2005, the USDA Food Safety Inspection Service has reported an increasing number of flunixin residue violations in meat from dairy cattle. This increase in the number of violations attributable to flunixin residues has led to flunixin becoming the second most common residue violation (behind only penicillin) in cull dairy cattle. Although the reason for the high number of flunixin residue violations isn't well understood, this is a direct example of where disease-induced alterations in drug clearance could be causing delayed clearance and prolonged residues. Or stated simply, the withdrawal time for flunixin established in healthy cattle may not be appropriate follow-

ing administration in cows with clinical mastitis, which is one of the indications the drug is approved for. Although more work needs to be done, there is clear evidence that health status may alter drug pharmacokinetics and in part be responsible for the high number of residue violations seen in cull cows.[2] Animals in which a disease process has altered either distribution or clearance deserve increased attention to ensure complete drug withdrawal.[13,19] Since pharmaceutical companies must conduct trials to demonstrate the efficacy of various drugs for treating a specific disease or condition during the approval process, it seems logical that pharmacokinetic and residue studies could be done using the same animals or under similar conditions.

As we move into the future, farms are becoming larger in size. This means larger numbers of cows on 1 facility and a greater number of employees involved in the cattle industry. We also have newer and more sensitive analytical methods that are capable of rapidly detecting even small concentrations of drugs that might be present in meat or milk samples. Globally, we are seeing a larger and larger number of milk samples tested for residues every year, which is a trend expected to continue as technology improves. So scrutiny of meat and milk is at an all-time high, which is expected to further increase in the future. All employees involved in the cattle industry should be reminded that drug residues are a significant public health concern, and the meat and milk products get a negative image when reports of drug residue violations become public. It is in the best financial interest of both veterinarians and livestock producers to take positive steps towards reducing and eliminating meat and milk residues.

Endnotes

[a]Neogen, Lansing, MI
[b]DSM Food Specialties, The Netherlands
[c]IDEXX Labs, Inc., The Netherlands
[d]CharmSciences, Lawrence, MA

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Tips and tools for dairy practitioners to take an active role in a dairy's foot health program

Gerard Cramer, DVM, DVSc
University of Minnesota, St. Paul, MN 55108

Abstract

There are copious opportunities for veterinarians to get involved in providing foot health services. The type of services that could be offered include; lame cow detection and treatment, comprehensive hoof trimming, monitoring or training of farm staff and routine monitoring of hoof health data. These opportunities come with their own unique set of barriers and challenges. However, veterinarians are ideally positioned to overcome these challenges and, at the current time, there is limited competition for these type of services thus veterinarians should consider foot health management as a practice growth opportunity.

Résumé

Il existe d'abondantes possibilités de vétérinaires à s'impliquer dans la prestation de services à la santé des pieds. Le type de services qui pourraient être offerts incluent : détection de vache et traitement boiteux, globale ou de surveillance de fraisage, de sabot à la formation de personnel agricole et la surveillance de routine des données sur la santé de sabot. Ces possibilités sont livrés avec leur propre ensemble d'obstacles et défis. Toutefois, les vétérinaires sont idéalement placés pour surmonter ces défis et, à l'heure actuelle, il y a une concurrence limitée pour ces types de services vétérinaires ainsi devrait envisager la santé des pieds comme pratique de gestion des opportunités de croissance.

Introduction

As the dairy industry evolves, the role of the veterinarian continues to change with it. Traditionally, veterinarians are trained in a large number of basic and advanced clinical skills, yet increasingly these types of veterinary tasks are being performed by on farm staff. As a veterinary profession we have reacted to this shift by providing more consultative services. To provide these services successfully Nordlund (2012) [13] described several characteristics of successful veterinarians; they have intricate knowledge of herd data and, instead of having all the answers, they have positioned themselves as part of the management team so they can play a significant role in evaluating and implementing outside advice. Not surprisingly, veterinarians have gravitated towards providing services in areas that they have interest in and sufficient clinical skills. Typically these interest areas have included treatment and reproductive protocols, nutritional and feeding management as well as young stock and milking management to name a few. One area that has received very little attention from practicing veterinarians is foot health management. This lack of attention is somewhat surprising as lameness is a painful, costly disease that affects the productivity of cows through its effect on milk production, culling, and reproductive performance [1,2,4]. In addition, lameness is also a major animal welfare concern as it is prevalent [5,9] and highly visible to the consumer. The objective of this paper is to illustrate what opportunities exist and what skills and tools veterinarians need to successfully provide foot health services and become part of a farm's foot health team.

Lame cow detection services

Lame cow detection services are probably the easiest services for veterinary clinics to provide. It is well established that the majority of lameness cases do not get noticed by on farm staff [5,15] yet it is has been shown that early treatment reduces the number of lame cows in the herd [6,12]. In the UK lame cow detection services are being offered with some success in conjunction with hoof trimming services by some veterinary practices [3]. There is more variation in herd size here in North America and for this reason the feasibility of providing this service is likely dependent on herd size. Providing lame cow detection services for larger herds is more difficult as locomotion scoring requires a lot of time to complete. Alternative scoring systems have been suggested [7,10] that veterinarians can use while providing other routine services like pregnancy diagnoses thus reducing time required for detection. Veterinary technicians could also be a valuable resource in providing this service. The investment in skills for lameness detection are minimal and would only require training in lame cow diagnosis.

Lame cow trimming

Most veterinarians provide some lame cow services as part of their regular practice. Expanding this service with an investment in a chute and tools to increase safety and efficacy could be a viable option. Currently, the majority of farms would benefit from veterinarians providing this service as hoof trimmers are typically too busy to provide acute lame cow services. Because hoof trimmers are so busy, there is no competition for this service either. As veterinarians we have additional tools to treat lame cows including intravenous regional anesthesia and surgical options that can improve

the outcome and reduce the severity of lameness. The skills necessary to provide lame cow trimming include proficiency in hoof trimming, and knowledge of surgical techniques for severe foot lesions. Providing lame cow trimming services also dovetails well with providing lame cow detection services and has the potential to create significant change in a herd's lameness prevalence.

Providing comprehensive hoof trimming services

In certain geographical areas, having veterinary clinics employ hoof trimmers to provide regular preventative hoof trimming services would be beneficial to producers as they would not normally have access to hoof trimming services due to the scarcity of trimmers. This is not an opportunity that is without risk, and thus would require significant investments in equipment and training. There would also be a significant time investment required before a hoof trimmer employed by a clinic has the skills to be proficient and the number of clientele has increased sufficiently to keep the trimmer busy. In areas where hoof trimmers are common, providing hoof trimming services has the potential to adversely affect the relationship with existing hoof trimmers. Veterinarians that offer comprehensive hoof trimming services need to be aware of this risk and work on maintaining a professional relationship with other hoof trimmers. To create this professional relationship with hoof trimmers it is important to know who the hoof trimmer is for each one of your dairies and communicate with that person on a regular basis. The skills required to provide comprehensive hoof trimming services are significant as it would require knowledge and skills in hoof trimming techniques as well as an extensive knowledge about lameness to support the clinic's hoof trimmers.

Training and monitoring on farm staff

Possibly the greatest opportunity for veterinarians to get involved in hoof health is for them to provide training and monitoring programs for on farm staff. There is a significant need for veterinarians to get involved in training staff especially considering the turnover of employees and paucity of training programs that exist. There are several training schools that exist specific to hoof trimming, however what is truly needed on farm is a follow up program where people trained at these schools have someone that provides them with feedback and ensures there is no procedural drift down the road. Veterinarians are ideally suited to provide this feedback due to the relationship they have with farms and their routine presence on farms. Other areas that can offer opportunities for veterinary involvement are the development of treatment protocols and lameness detection programs. The skills required to develop these protocols and programs are varied. To be a competent hoof trimming trainer requires a significant skill set, however having the knowledge of what

is an appropriate functional hoof trim can be a good starting point to develop protocols and programs.

Monitoring hoof health data

An area that has not been actively pursued by veterinarians is the area of actively monitoring hoof health on a routine basis. Traditionally hoof trimming records have been used retrospectively to investigate after foot health problems have occurred. With the advent of electronic recording devices for foot lesions, creating records has become more manageable but the use of electronic devices by hoof trimmers is still highly variable. An additional complicating factor when using hoof health data is the lack of standardization in coding and recording of lesions [16]. Several different chute side recording devices exist, however it is not always possible to link up data from these devices with on farm recording systems. With all these issues in recording hoof health, there are many opportunities for veterinarians to get involved. As a starting point, veterinarians can work with hoof trimmers and farm staff to establish and standardize the recording systems.

Record keeping systems can easily become very complicated thus veterinarians need to ensure that it is kept simple enough that the farm staff are likely to adopt it and use it properly. To keep record keeping simple, herd level monitoring systems can be developed to capture digital dermatitis, sole ulcers, white line disease and thin soles. An "other" category can be added to keep track of minor lesions. Simply tracking these 4 main lesions would capture the majority of lameness causes. Once a data recording system has been established, it becomes possible to set data driven goals, evaluate the process to achieving those goals, and make evidence based decisions.

With comprehensive recording systems, routine monitoring becomes possible. Initial monitoring for foot health starts with asking the question, "Have things changed recently?" Figure 1 shows a sample report that veterinarians use to quickly monitor foot health over a specified time period on a routine basis. If this initial screening report indicates a potential change in foot health status, further questions can then be asked from the foot lesion data collected. Further analysis of foot lesion data requires it to be linked with cow demographic data. Once this link exists it is possible to investigate foot health further by determining the distribution of lesions in different risk periods and age groups. In larger herds that have a routine trimming schedule, monitoring should also determine if the timing of hoof trimming is occurring according to the farm's stated goals. Figure 2 shows 2 examples of a routine monitoring report. Similarly, a simple report that shows the total number of hoof trimmings and lame cows per week could serve as a useful initial monitor in larger herds.

For veterinarians, the natural progression to getting involved in monitoring foot health is to work with farms to investigate problem areas and develop preventative practices

to minimize the impact of lameness. The skills necessary to get involved in monitoring hoof health data are an interest in records analysis and sufficient knowledge of foot lesions to identify and act on the data.

Barriers to Involvement.

There are barriers that may exist for veterinarians to get involved in foot health programs. One commonly cited barrier is lack of knowledge about lameness. Even though there is a lack of knowledge about effective trimming and treatment strategies [14], veterinarians have access to a significant body of knowledge that is sufficient to gain the skills necessary to make a difference in a dairy's lameness risks. Two other commonly cited barriers are a lack of safe and effective facilities to work on feet and lack of client's willingness to pay for these services. Both these are valid concerns. In an ideal world every farm would have facilities to safely handle lame cows. However, if veterinarians are serious about getting involved in hoof care, an investment in a hoof trimming chute is minor compared to some of our other investments

such as an ultrasound machine. This willingness to invest in equipment can also overcome the willingness to pay barrier as shortage of farm staff time, skilled labor and equipment have been shown to be some of the barriers for farmers to address lameness[8,11]. Furthermore, work in the UK has also shown that veterinary involvement in developing foot health plans is less likely to result in the implementation of adverse practices that would increase the risk of lameness [17].

Conclusion

There are a variety of options for veterinarians to get involved in foot health. Several levels of involvement exist and they each come with their own challenges and skill set requirements. There are also various barriers that exist for increased veterinary involved in foot health. However, veterinarians are ideally positioned to overcome these challenges and, at the current time, there is limited competition for these type of services thus veterinarians should consider foot health management as a practice growth opportunity.
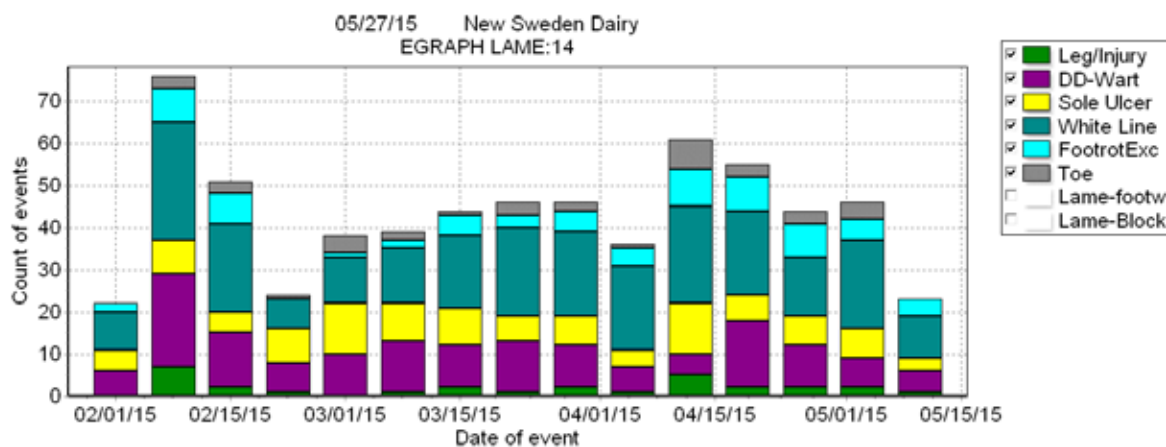
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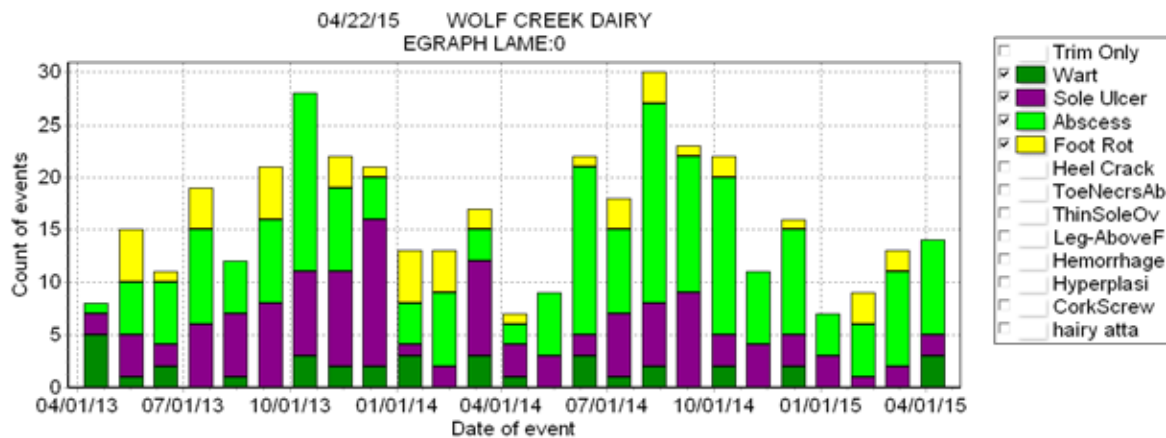
B

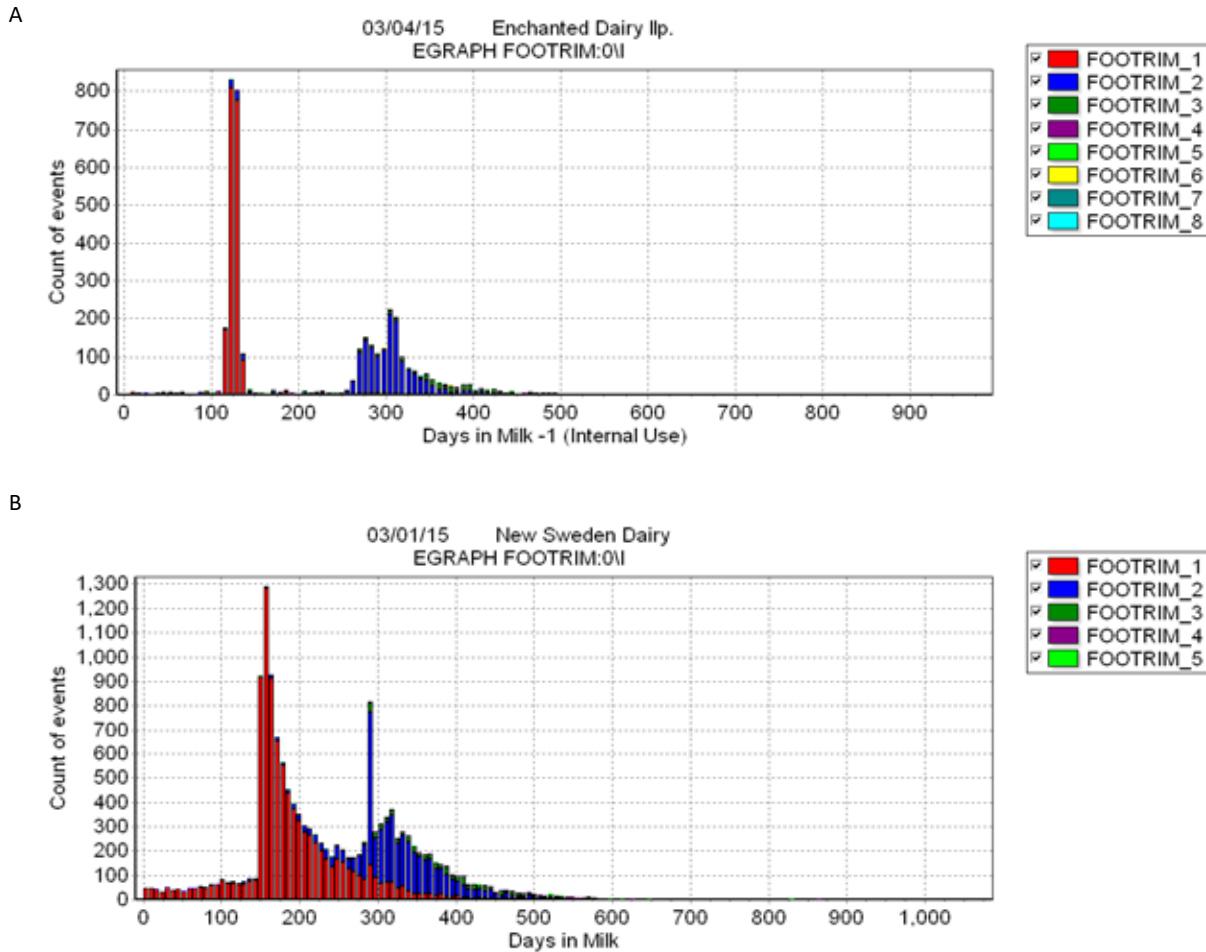**Figure 1.** Two example reports showing how a hoof health can be monitored.

A

B

Figure 2. Comparison of 2 dairies' reports to evaluate if the dairy's stated preventative hoof trimming schedule is being followed.

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