Beef cattle production in the United States: A complex matrix of interconnected nutritional, health, and welfare management practices

by

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B.Sc., Universidad Autónoma de Nuevo León, 2006
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AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Diagnostic Medicine/Pathobiology
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Abstract

With the concerning predicted growth of the world population for the next decades it is evident that farmers, ranchers, and cattle feeders need to find alternative ways to increase food production globally and assure food provision for future generations. The United States has an impressive reputation in global beef production. Beef cattle production in the United States is a complex industry with thousands of operations differing in geographical location, environmental conditions, management practices, operative systems, feedstuffs used, type of cattle raised or fed, production type, cattle capacity, and design of facilities. Beef cattle feeding operations exist all across the United States, but the majority of the larger feedlot operations are located in the Great Plains region. Feeding cattle is considered a high-risk business driving cattle feeders to implement all technologies available with best management practices with the goal of improving sustainability and profitability of their operations through biological and economical efficiencies. Thus, it is theorized that profitability in the feedlot industry is achieved when cattle feeders meet the requirements of the basic production management factors, such as cattle health, nutrition, and welfare in an equilibrated fashion. The first objective of this research was to describe recommended practices made by veterinary consultants and practitioners who service clients with commercial beef cow-calf operations in the US and Canada in terms of vaccine protocols, health practices, and production practices to establish a benchmark for standard operating procedures used in the beef cattle industry. The second objective of this research was to provide a thorough description of outdoor cattle feeding facilities currently being used by feedlots in the High Plains region of the United States that would serve as a benchmark for those looking to build a new facility or enhance an existing cattle feedlot. The third objective of this research was to obtain descriptive data regarding feedlot cattle management practices and cattle health and use

it as a tool to make comparisons of cattle management practices between feedlots that might explain the difference in AIP incidence between feedlots in multiple locations. The fourth objective of this research was to evaluate the effects of periodic feeding of low-quality long-stemmed roughage in Holstein steers fed a steam-flaked corn-based finishing diet on dry-matter intake, ruminal dynamics, ruminal fermentation parameters, and fecal starch concentration.

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Dedication

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Preface

Chapters 2 and 3 in this dissertation entitled "A survey of recommended practices made by veterinary consultants to cow-calf operations in the United States and Canada" and "A survey to describe current cattle feedlot facilities in the High Plains region of the United States" were prepared and accepted for publication in *The Professional Animal Scientist Journal* on August 14th, 2017 and September 5th, 2016, respectively. Chapter 4, entitled "A survey to describe the relationship between animal, environmental, and management factors and the occurrence of atypical interstitial pneumonia (AIP) in feedlot cattle" was prepared for publication in *The Professional Animal Scientist Journal*. Chapter 5, entitled "Effects of pulse feeding low-quality roughage on performance and ruminal fermentation parameters of finishing Holstein steers" was prepared for publication in the *Journal of Animal Science*. The text and figures within these chapters are formatted according to the guidelines specified by the journal in which they are published or will be submitted for publication.

Chapter 1 – Beef Cattle Production in the United States: Behind the Scenes

Global Population and Animal Protein Demand

The world population has grown tremendously during the last century, going from roughly 2.5 billion people in the 1950's to almost 7.5 billion people today (U.S. Census Bureau, 2018). Furthermore, the world population is estimated to reach 8 billion people by 2025 (U.S. Census Bureau, 2018) and is projected to increase to over 9 billion people by 2050 as reported by the United Nations Department of Economic and Social Affairs in 2015. With these predictions in the forecast it is more than evident that there is a tangible need to find alternative ways to increase food production globally to cover the basic nutritional needs of future generations.

As part of the solution to feeding the world population by 2050, finding alternative ways and adopting new technologies to maximize efficiency of global food production is essential to guarantee that producers will have the ability to overcome the challenge of providing the world with a sustainable, wholesome, safe, affordable, and nutritious product in large enough quantities to meet the demands of the ever-growing global population (Capper and Hayes, 2012; Guyader et al., 2016). Over the next 40 yr, consumption of animal protein is expected to increase by more than 60% as a result of increased demand from developing countries (FAO, 2009). As the world population continues to rise, the number of people that enter the middle class also increases. This new wealthier middle class has a stronger economic power and higher living standards (Bloom, 2011), which results in an increased demand for animal protein sources as part of their daily diet.

U.S. Beef Cattle Industry: Overview

Ruminants play a major role in the human food supply chain globally, as they are almost the sole source of milk and contribute 29% of total meat production globally (Gerber et al., 2013). Raising cattle is no longer the only high risk business for cattle producers, but they are now in the scrutinized business of producing food, and to satisfy consumer's demand for animal protein, producers must strive to assure that beef supply is safe, wholesome, and affordable. Beef production in the United States is important to feeding a growing population worldwide and recently this is becoming increasingly important due to a substantial increase in production volumes as a result of a continued increase in the demand for animal protein globally. Although beef consumption has been gradually decreasing since the mid-1970s, when it was well over 32 kg per capita, to less than 26 kg today (USDA, 2017a), during 2016 the United States produced a total of 11.5 million tonnes of beef, making it the number one beef producer in the world (USDA, 2017b).

The beef industry in the United States has been producing high quality beef for a long period of time and has built an impressive reputation around the globe. The United States has the largest cattle industry in the world and is also the largest beef producer in the world (USDA, 2018a). Beef cattle operations in the United States represented a total of 103 million cattle as of July 1, 2017 (USDA, 2017c). In 2017, the calf crop in the United States was estimated at 35.8 million cattle, and all cows and heifers that have calved represented 41.1 million cattle according to the 2017 USDA Cattle report (USDA, 2018b). As a consequence, beef cattle production in the United States is a very complex and diverse industry with thousands of operations differing in geographical location, environmental conditions, management practices and systems, available feedstuffs, type of cattle fed, production type, feedlot capacity, and design of facilities (Simroth et al., 2017). The United States beef industry is roughly divided into three main production systems: cow-calf segment, pre-conditioning or backgrounding phase, and finishing phase or feedlot (Troxel et al., 2013).

Beef cattle production truly starts at the cow-calf operation, where weaned feeder calves are produced and sent to further grazing or feeding. It normally takes slightly over 2 yr from the time cows and heifers are bred until their offspring are ready for slaughter (Comerford et al., 2013). During this initial stage cows and heifers calve their offspring most commonly in the spring, at an average birth weight of 32 kg. Cow-calf pairs spend from 90 to 300 d together grazing pastures until calves are weaned at an average weight of 250 kg and sent to either a backgrounding operation, to a pre-conditioning facility, or directly to a feedlot (USDA, 2012). Cattle in cow-calf operations (bulls, cows, and calves) are typically managed primarily on pasture were they spend their life grazing. Supplementation with energy (grain) or protein supplements, and minerals is a frequent practice among cow-calf producers in order to provide balanced nutrition for their cattle. Currently, there are less than 32 million beef cows dispersed on over 725,000 farms and ranches throughout the United States (USDA, 2018b). As of 2012, there were almost 728,000 cow-calf operators in the United States according to the most recent Census of Agriculture (USDA, 2014). Although cow-calf operations are spread across the United States, the top 25 cow-calf operations during 2015, ranked by number of cows, were located in Florida, Texas, Wyoming, California, Hawaii, Idaho, Kansas, Missouri, and New Mexico (NCBA, 2015).

Not all calves produced on cow-calf operations will leave the farm or ranch to go directly to the finishing phase at the feedlot. The backgrounding phase is one of the intermediate stages of beef cattle production in which recently weaned calves put on body weight while grazing on pasture, crop residues, or fed in a dry-lot, utilizing low-cost, high-roughage rations (USDA, 2012). This phase lasts for a period of time of 90 to 100 d and usually calves will have a highly efficient growth and can be better defined as the process of growing and developing calves from weaning weights (~240 kg) to yearling weights (~350 kg) when calves are then ready to enter a feedlot for the finishing phase. Backgrounding operations expose and prepare weaned calves to eat from a feed bunk and drink from water tanks. Some of the basic principles of backgrounding calves are: (1) adding ~225 kg of body weight per calf, (2) intensive use of high-quality forage, rather than high-energy feed sources (i.e. grain), as the primary feed source, and (3) sorting cattle into more uniform groups by gender, weight, and quality, giving added value to cattle and facilitating marketing (Troxel et al., 2013). This production stage plays a vital role in the beef cattle production cycle as they grow and prepare calves for the complicated transition to the feedlot, without fattening, using lower cost feed ingredients (USDA, 2012).

Calves that are well-managed and acclimated prior to making their way through multiple marketing channels and ending up at the feedlot tend to experience less stress and substantially fewer health related challenges. This period of preparation is known as pre-conditioning and is another one of the intermediate stages of beef cattle production, in which calves are either sent to a pre-conditioning facility immediately after weaning or stay at the cow-calf operation after weaning and start a pre-conditioning program on-site (McBride and Mathews, 2011). Pre-conditioning is defined as a vaccination, nutritional, and management program designed to prepare recently weaned calves to efficiently cope with the multiple stresses of adjustment when they leave their point of origin, enter marketing channels, and start at the feedlot (Lincoln and Hinman, 1999). This phase of beef cattle production usually lasts between 30 and 45 d and calves are typically individually identified with an ear tag, vaccinated, dewormed, dehorned, castrated, and implanted (Wilson et al., 2017). During this short stage, calves are transitioned from feeding on their mothers to eating balanced, grain-based diets with high roughage levels from a feed bunk (Comerford et al., 2013). Besides training calves to eat from a feed bunk, during this stage calves may also be exposed to drink from a water trough or automatic waterer if they have not been previously exposed to any of these (USDA, 2012). The goal of pre-conditioning calves is to acclimate cattle to the conditions they will find at the feedlot, including feeding, watering, and effective preventive health management (USDA, 2012). These management practices will help calves experience a decreased stress load and an improved immune function after they arrive at the feedlot (Wilson et al., 2017), which ultimately adds value to cattle by producing healthier, better performing, and more uniform groups of feeder calves.

The final stage of beef production is finishing cattle at the feedlot. Feedlot cattle are usually finished in an open dry-lot consuming high-grain diets with limited amounts of roughage until they reach the point for slaughter. Cattle usually go on feed as yearlings weighing 350 kg lb in average and with a feedlot ADG $\geq$ 1.4 kg per day, and reaching an average final BW of 620 kg (USDA, 2018c). However, in some cases large-framed calves are finished on high-grain diets without a growing phase after weaning (Sindt et al., 1993), which results in these calves being younger during the finishing phase than their counterparts that follow a traditional yearling system approach. The feeding period often spans 150 to 180 d, although large-framed, late-maturing cattle require a longer period and small-framed, early-maturing cattle require less days to reach their market point (Cundiff et al., 1981; Troxel et al., 2013). Feeding periods of up to a year or more can occur when feeding Holstein calves or light-weight calves (150 kg arrival weight; USDA, 2011). Feedlot typically feed cattle a very palatable energy-dense ration, with the ultimate purpose of maximizing growth, and enhancing muscle growth and fat deposition in the most efficient way possible to produce high-quality beef carcasses. Beef cattle feeding operations exist all across the United States, but the majority of the larger feedlot operations are located in the Great Plains region, from Kansas, Colorado, and Nebraska to Texas and Iowa (Comerford et al., 2013; USDA, 2012). As of February 1, 2018, there were 11.6 million total cattle on feed in the United States fed in over 2,200 feedlots with a one-time capacity $\geq$ 1,000 cattle. As of February 1, 2018 Nebraska, Texas, Kansas, Colorado, and Iowa, in this order, represented the top 5 five states with more cattle on feed in the United States, feeding 80.1% of the total cattle on feed (USDA, 2018c).

Feeding cattle in a feedlot requires a monumental effort to achieve a consistent supply of quality beef that meets market demands for a premium quality product (USAID, 2008). Cattle feeding is a high risk business and maintaining profitability while producing a high-quality product is challenging for cattle feeders (Reinhardt et al., 2006). The beef industry faces decreasing profit margins and cattle feeders must make use of all available technologies as well as incorporate the use of best management practices that will ultimately improve the overall sustainability and profitability of the beef industry (Wilson et al., 2017). Profitability in the feedlot industry is achieved when cattle feeders meet the requirements of the basic production management factors, such as cattle health, nutrition, and welfare (Pusillo et al., 1991) in an equilibrated fashion.

Nutrition, Health, and Welfare Management Practices: Critical Control Points for Feedlot Cattle Performance

The feedlot phase is a unique and challenging period in cattle's life, during which commingling, transportation, arrival to a new place, and exposure to new feed contribute to increased stress (Simroth et al., 2017). Proper nutritional and health management of cattle is fundamental for maximizing profitability of the cattle feeding operation (Parish et al., 2008; Troxel et al., 2013). Feedlot consulting nutritionists and veterinary feedlot consultants make a wide array of health, nutrition, and management recommendations based on up to date scientific and technological advances that have significant impacts on the health, performance, and welfare of cattle in U.S. feedlots (Fike et al., 2017; Lee et al., 2015; Samuelson et al., 2016; Vasconcelos and Galyean, 2007). For a cattle feeding operation to be a profitable business it must have a flawless nutrition program (Sanson and Hixon, 1999), as the greatest production cost in a feedlot is feed for cattle (Richards and Hicks, 2007). An optimum, well-designed nutritional program is a vital component of a successful cattle feeding operation (Parish et al., 2008) and should take into account two main factors, proper amount of feed and the proper balance of nutrients in the diet that is delivered to cattle. Although it is vital that feeding and nutritional practices meet requirements of cattle and be economically competitive (Troxel et al., 2013), maintaining a profitable cattle feeding operation is increasingly difficult and providing an affordable and well-balanced ration is increasingly complicated (Reinhardt et al., 2006).

Roughage is usually added to high-concentrate finishing feedlot diets to improve rumination and to prevent digestive disturbances by sustaining a stable and healthy environment in the rumen (Galyean and Defoor, 2003; Gill et al., 1981). Diets with low fiber and high grain contents are fed to increase energy intake (Allen, 1997; Defoor et al., 2002; Galyean and Defoor, 2003), which typically results in improved efficiency. However, the high rate and extent of ruminal degradation of carbohydrates in this type of diets, which result in an increased production of organic acids and a decreased ruminal pH, can have a significant negative impact on animal productivity and health (Nagaraja and Titgemeyer, 2007; Owens et al., 1998). Metabolic disorders of digestive origin that can occur as a consequence of feeding high-grain, low-roughage diets to feedlot cattle, such as acidosis (Gonzalez et al., 2012; Nagaraja and Titgemeyer, 2007; Nagaraja and Lechtenberg, 2007a), bloat (Cheng et al., 1998; Galyean and Rivera, 2003), laminitis (Beauchemin and McAllister, 2006; Nagaraja et al., 1998), and liver abscesses (Nagaraja and Chengappa, 1998; Nagaraja and Lechtenberg, 2007b), have significant implications on animal health and feedlot profitability, and ultimately jeopardize animal welfare. Processed grains that have high rates of starch fermentation promote greater fluctuations in ruminal pH and intake, which leads to acidosis, rumenitis, and, subsequently, liver abscesses (Stock et al., 1987; Stock et al., 1990; Fulton et al., 1979). It is well documented that rumenitis resulting from acidosis is a predisposing factor for liver abscesses (Nagaraja and Lectenberg, 2007b). Feeding and nutritional management practices such as a sudden increase in dietary energy and poor bunk management, characterized by irregular feeding, can enhance acidosis and rumenitis (Elam, 1976) and eventually lead to a higher incidence of liver abscesses. Thus, adaptation of cattle to high-grain diets using step-up programs is critical to decreasing the risk of digestive metabolic disorders in feedlot cattle (Galyean and Rivera, 2003).

Antibiotics are typically fed to improve animal health, feed efficiency, and animal performance (Hales et al., 2017). One the most commonly used feed-grade antibiotics in finishing diets is tylosin phosphate, which is used to reduce incidence of liver abscesses in feedlot cattle (Nagaraja and Chengappa, 1998; Nagaraja and Lechtenberg, 2007b). Tylosin, a macrolide, is effective primarily against Gram-positive bacteria, but *Fusobacterium necrophorum* which is a Gram-negative bacteria is also sensitive (Lechtenberg et al., 1998; Nagaraja and Lechtenberg, 2007b). The mode of action of tylosin phosphate is a direct inhibitory effect on *Fusobacterium necrophorum* and *Arcanobacterium pyogenes*, two ruminal microbes responsible for liver abscess formation (Nagaraja et al., 1999). In addition to reduction in liver abscess incidence, feeding of tylosin has been shown to improve feedlot cattle performance and carcass attributes (Vogel and Laudert, 1994). Ionophores are fed to cattle to prevent diet-related digestive maladies and for the control of coccidiosis (Richards et al., 2015). Monensin sodium is the most commonly used ionophore in the beef cattle industry. Monensin alters rumen fermentation by inhibition of Gram-positive bacteria, improving nitrogen metabolism and reducing incidence of bloat and lactic acidosis (Duffield et al., 2012), as well as increasing propionate and reducing butyrate and acetate production, improving feed efficiency (Ellis et al., 2012). Monensin also has been shown to modulate feed intake, reduce dry-matter intake, and increase ruminal pH of feedlot cattle (Nagaraja et al., 1982, Stock et al., 1995) ultimately improving dietary energy utilization by cattle.

A successful cattle management program is the result of an equilibrated plan based on health, nutrition, and animal care and welfare advice (Parish et al., 2008). Adequate health management of feedlot cattle plays a vital role in reducing the negative effects that disease and parasites have on cattle performance and welfare. Veterinary practitioners provide constant advice and recommendations to beef cattle operations across the United States regarding health, well-being, and production practices to gain satisfactory health status and optimum cattle performance (Fike et al., 2017). An increase in preventative healthcare and management measures among beef cattle operations in the United States has been the result of an integrated proposal that advocates to improve health, performance, and profitability for the beef industry. Preventative health management programs that reduce cattle stress have been shown to reduce the incidence of bovine respiratory disease (**BRD**) in the feedlot (Cole et al., 1979; Roeber et al., 2001) and improve cattle performance both in the preconditioning period (Bolte et al., 2009) and the finishing phase (Peterson et al., 1989). Nutrition and stress are closely associated, as nutritional deficiencies can stress calves and environmental stressors can magnify nutritional deficiencies (Parish et al., 2008). Nutritionists should formulate diets for newly received and stressed cattle to compensate for decreased feed intake and known nutrient deficiencies (Galyean et al., 1999), which if not done appropriately, could compromise immune function (Cole, 1996) and potentially increase susceptibility to infection resulting in poor performance. Ideally, to improve the health and well-being of newly-weaned calves after arrival to the feedlot, all calves should be preconditioned prior to leaving the farm or ranch of origin (Wilson et al., 2017). Calves with a better health status and decreased levels of stress have stronger and better functioning immune systems at the time they are being transitioned from the farm to the feedlot via marketing channels. This should result in calves experiencing less stress and shrink during transportation, recover from stress in less time after arrival, have a decreased risk of BRD, and have a better performance in the feeding period (Wilson et al., 2017). The stress of transition from the farm to the feedlot creates multiple nutritional challenges for cattle and the longer that cattle are deprived of good-quality feed and water during this transition process, the greater the challenges to getting them back to optimal conditions (Reinhardt and Thomson, 2015).

Typically, newly received cattle at the feedlot are under severe stress associated with weaning and transportation, resulting in a suppressed immune system (Blecha et al., 1984) and a higher risk for disease. These events typically occur when the animal is exposed to disease and infectious agents as a result of commingling during marketing and transportation previous to arriving to the feedlot and pose serious challenges that can contribute to a high risk of BRD incidence. Nutrition can interact with these two stress related events, most likely as a result of pre-weaning nutritional deficiencies or through decreased feed intake associated with stress. Feed intake by stressed feeder calves is low (Cole, 1996), in particular during the first 2 wk after arrival to the feedlot (Galyean and Hubbert, 1995). Sowell et al. (1998) reported that sick steers had a 30% decrease in time at the feed bunk compared to healthy steers and feed intake differences were more notorious during the first 4 d after arrival (Sowell et al., 1998, 1999). Low feed intake makes it challenging to correct nutritional deficiencies of these calves, which could further compromise immune function (Cole, 1996) and potentially increase susceptibility to infection. As a strategy to improve the nutritional status of newly received calves and enhance immune function, diets with increased nutrient concentrations are optimal during the early receiving period when DMI of calves is low and risk for BRD is high (Fluharty and Loerch, 1995; Rivera et al., 2005). For the first 45 d after arrival, the greatest concern regarding the management of newly received, highly stressed calves is prevention and treatment of BRD. Stepping-up these calves to a high-grain diet to quickly may result in metabolic disorders of digestive origin such as acidosis, which can complicate the diagnosis of BRD or worsen it (Reinhardt and Thomson, 2015). Decreased feed intake of newly received calves can result in decreased protein consumption, which can cause an impairment of immune functions. Although BRD morbidity appeared to increase with increasing CP concentration in diets of newly received calves, an improvement in performance was observed with increasing dietary CP concentration (Galyean et al., 1999). Because of decreased intake by newly received calves, concentrations of most minerals and vitamins need to be increased in receiving diets (NRC, 1996; NASEM, 2016) to achieve an optimal immune function, reduced BRD morbidity, and enhanced performance by newly received calves (Duff and Galyean, 2007).

Over the last decade there has been a substantial increase in public awareness regarding the welfare of cattle in the beef industry, which has resulted in continuous efforts to improve production and management practices of beef cattle in all phases of production in the beef industry (Vasconcelos, 2017). Animal welfare and low-stress handling of cattle have become important components of cattle management in the beef industry over the past decades, although animal welfare programs continue to be implemented in every stage of production, the beef industry strives to continually look for ways to improve these programs (Edwards-Callaway, 2016). A sound processing protocol and proper handling during processing can improve the effectiveness of products administered during initial processing, promoting health and well-being throughout the feeding period (Noffsinger et al., 2015). Implementing cattle handling techniques that improve cattle safety and reduce stress in cattle feeding operations is critical because finishing cattle tend to be more prone to injury, exhaustion, heat stress, and lameness (Schwartzkopf-Genswein, 2016). This is an area in which the U.S. beef industry has made substantial improvements because managers have become more aware of the importance of animal welfare (Grandin, 2016) and continuously work to improve cattle care and comfort in aims of sustaining cattle performance and profitability of the operation (Bruns and Pritchard, 2006). The Beef Quality Assurance program is evidence that, for a long time, the beef industry has taken action and addressed increased interest to continually monitor and improve this issue (Walker, 2016). The beef industry, as a whole, needs to show to consumers and customers that the welfare of cattle continues to be a top priority issue for producers.

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Chapter 2 - A survey of recommended practices made by veterinary practitioners to cow-calf operations in the United States and Canada

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ABSTRACT

Practicing veterinarians (n=148) who service commercial beef cow-calf herds responded to a survey describing general recommendations made to their clients in terms of vaccine protocol, health, and production practices. Responding veterinarians represented 35 states in the US and 3 provinces in Canada. Over 50% of responding veterinarians devote over 50% of their practice to service commercial cow-calf producers. The largest group (33%) of veterinarians have been in practice for over 30 years. Thirty-nine percent of responding veterinarians serviced more than 10,000 cows. Genetic advice is provided by 54% of practicing veterinarians. When vaccinating at branding, the most common recommended vaccines are Clostridial (96%), IBR (94%), BRSV (91%), PI-3 (90%), and BVD Type 1 & 2 (78 and 77%, respectively). When vaccinating before weaning, the most common recommended vaccines are IBR (99%), BRSV (98%), BVD Type 1 & 2 (96%), PI-3 (93%), Clostridial (77%), and *M. haemolytica* (77%). When vaccinating after weaning, the most common recommended vaccines are BVD Type 2 (97%), IBR (97%), BVD Type 1 (96%), BRSV (96%), and PI-3 (91%). Over 60% of responding veterinarians recommended that the last preventative vaccine should be administered to cattle 7 to 21 d before loading/shipping. The largest number of respondents (38%) recommended that the earliest age their clients should wean their calves is 90 to 120 d. Castrating bull calves at an age of 0 to 7 d old was recommended by 34% of respondents. Calf nutrition is considered as extremely important during a pre-conditioning program by 82% of responding veterinarians.

Key words: beef, cow-calf, survey, veterinary practitioner

INTRODUCTION

Veterinary practitioners provide constant advice and recommendations to beef cow-calf operations across the United States and Canada regarding health, well-being, and production practices to gain satisfactory health status and optimum herd performance. Summarizing and reporting these recommendations provides valuable feedback to understand how best management practices are applied at the beef cow-calf herd level. These recommendations, over time, have been developed by academic researchers, practicing veterinarians, consulting veterinarians, and other animal health professionals. Currently, there are several published resources in the literature that provide recommendations made to feedlot managers by consulting veterinarians regarding animal health and well-being (Terrell et al., 2011; Terrell et al., 2014; Lee et al., 2015). In addition, similar publications exist for recommendations made by consulting nutritionists for nutritional recommendations in feedlot operations (Galyean, 1996; Galyean and Gleghorn, 2001; Vasconcelos and Galyean, 2007; Samuelson et al., 2016). Although there is limited and outdated published data (Sanderson et al., 2000) that provides a description of health and production practices employed by cow-calf producers, there is no published data that describes recommendations made by veterinary practitioners to cow-calf operations. Thus, the objective of this survey was to obtain descriptive data to describe recommended practices made by veterinary practitioners who service clients with commercial beef cow-calf operations in the US and Canada in terms of vaccine protocols, health practices, and production practices.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study as no animals were used. Approval to conduct this survey was granted by the Institutional Review Board at Kansas State University (IRB #8423).

Survey Participants

Veterinary practitioners were contacted for participation in this study based on their individual participation in professional veterinary organizations. A total of 1,200 veterinarians were randomly contacted through the Academy of Veterinary Consultants (AVC) and American Association of Bovine Practitioners (AABP) respective e-mail LISTSERVs. Veterinarians were sent an individual electronic invitation requesting their participation in the study. A total of 148 veterinarians completed this survey.

Data Collection

The survey was conducted during the month of September 2016. Data were collected using Kansas State University's web-based survey software Qualtrics Online (Qualtrics 2015, Version 2417833, Provo, UT). Invited veterinarians received a URL to access the survey via an email invitation. There was no information requested in the survey that identified individual veterinary practitioners, making responses completely anonymous. Participating veterinarians had 4 wk to access and complete the survey after receiving the original email invitation with the URL. An email reminder to complete the survey was sent to participants once at 2 wk after the survey was available to them.

The survey was composed of 42 questions covering areas of vaccine protocol, health practices, and production practices for beef cow-calf operations. Several questions gave the respondent the option to choose “Other” as an answer and type their response in a blank space. These responses were also included in the analysis.

Data Analysis

Response data collected from this survey were downloaded from the web-based survey software into a Microsoft Excel (Microsoft, Redmond, WA) spreadsheet for summarization and descriptive analysis. Graphs, tables, number of respondents per question, frequency of responses per question, means, minimum values, and maximum values were calculated for all questions using Microsoft Excel. Not all respondents answered all questions, therefore, the number of total responses to each individual question was expressed as a percentage of the number of answers to that question out of total survey responses.

RESULTS AND DISCUSSION

The United States produced a total of 11.5 million tons of beef during 2016, making it the number one beef producer in the world (USDA, 2017a). Beef cattle operations represented a total of 93.6 million cattle as of January 1, 2017 in the US (USDA, 2017b). In 2016, the calf crop in the US was estimated at 35.1 million cattle and all cows and heifers that have calved represented 40.6 million cattle according to the 2016 USDA Cattle report (USDA, 2017c). Currently, there are less than 32 million head of beef cows widely dispersed throughout the US on over 720,000 farms and ranches (USDA, 2017c).

The cow-calf operation is considered the first stage of the beef production process and it takes slightly over two years from the time cows and heifers are bred until their offspring are ready for harvest (Comerford et al., 2013). As of 2012, there were nearly 728,000 cow-calf operators in the US according to the most recent Census of Agriculture (USDA, 2014). Although cow-calf operations are spread across the US, the top 25 cow-calf operations during 2015, ranked by number of cows, were located in: Florida, Texas, Wyoming, California, Hawaii, Idaho, Kansas, Missouri, and New Mexico (NCBA, 2015). Texas was the state with the greatest number of beef cows, calves under 500 lb, and the largest calf crop (4.5, 2.0, and 4.3 million, respectively; USDA, 2017c) for 2016; however, 9 out of the top 25 cow-calf operators in the country were in Florida during 2015 (NCBA, 2015).

An increase in preventative healthcare and management measures amongst beef cow-calf operations in the US has been the result of an integrated proposal that advocates to improve health, performance, and profitability for the beef industry. These recommended programs, commonly referred to as, preconditioning or backgrounding, focus on optimal cow herd nutrition and health, early castration and dehorning, anthelmintic treatment, proper and timely vaccinations for calves, and weaning calves 30 to 45 d prior to shipping (Kirkpatrick et al., 2008). Implementing preventative programs that reduces compounded stress have shown to reduce incidence of BRD in the feedlot (Cole et al., 1979; Roeber et al., 2001) and improve ADG in the preconditioning period (Bolte et al., 2009) and the finishing phase (Peterson et al., 1989).

Demographic Information

Table 1 provides general information and demographics of participating veterinary practitioners including states where they practice, proportion of their practice dedicated to cow-calf producers, years in practice, and number of beef cows serviced. One hundred and forty-eight veterinary practitioners responded to the survey, with most participants providing a response to the majority of questions. Responding veterinarians represented 35 states in the USA and 3 provinces in Canada. In the U.S., 11% of veterinarians practiced in KS, 10% in NE and IA, 6% in OK and SD, and 5% in MO, MN, and TX (the remaining states represented less than 5% of total responses). In Canada, veterinarians practiced in Alberta, Ontario, and Quebec, but these represented less than 5% of the total response.

Over 50% of responding veterinarians devoted more than 50% of their practice to service commercial cow-calf producers (Table 1). The largest group (33%) of veterinarians had been in practice for over 30 years. However, 26% of responding veterinarians had been in practice for only 0 to 5 years. Similarly, Coetzee et al. (2010) reported that nearly half of veterinarians (45.5%) participating in a castration method survey had been in practice for over 20 yr and the second largest group of participating veterinarians (15%) had been in practice only 1 to 5 yr. More than 10,000 cows were serviced by 39% of these veterinarians' practices, whereas 25% veterinarians serviced 5,000 to 10,000 cows each.

Vaccination Protocols

The most important component of a beef cattle herd health program is the use of vaccines as a management practice to avoid the spread of infectious diseases within the herd. Vaccinating cattle is a relatively common practice amongst cow-calf operations; however, not all U.S. cow-calf operations vaccinate their cattle, leaving a significant portion of the beef cattle population susceptible to multiple preventable diseases (USDA, 2010). According to the USDA (2010), during 2007 only 68.9% of cow-calf operations vaccinated cattle. However, the 2016 CattleFax Cow-Calf Survey, reported that 93% of surveyed operations in the United States have in place a vaccination plan for cattle and Waldner et al. (2013) reported that most (85.3%) of Canadian cow-calf producers vaccinate their calves before moving the herd to pasture.

When vaccinating calves for the first time at branding (Table 2), the most common recommended vaccines were Clostridial (96%), infectious bovine rhinotracheitis (**IBR**; 94%), bovine respiratory syncytial virus (**BRSV**; 91%), parainfluenza 3 (**PI-3**; 90%), and bovine viral diarrhea (**BVD**) Type 1 & 2 (78 and 77%, respectively). For type of vaccine used at this time, 80% of veterinarians recommended modified live virus (**MLV**) vaccines and 12% recommended killed vaccines at this time. Another vaccine used by veterinarians but was not listed was *Moraxella bovoculi* (2%).

When vaccinating calves for the first time before weaning (Table 3), the most common recommended vaccines were IBR (99%), BRSV (98%), BVD Type 1 & 2 (96%), PI-3 (93%), Clostridial (77%), and *Mannheimia haemolytica* (77%). Ninety percent of veterinarians recommended MLV vaccines and 10% recommended killed vaccines at this time. Brucellosis (1%) was other vaccine that was not listed and that was used by veterinarians before weaning.

When vaccinating calves for the first time after weaning (Table 4), the most common recommended vaccines were BVD Type 2 (97%), IBR (97%), BVD Type 1 (96%), BRSV (96%), and PI-3 (91%). For this period of time 93% of veterinarians recommended MLV vaccines and 7% recommended killed vaccines. Other vaccines used by veterinarians but that were not listed included Brucellosis (1%), *Brucella abortus* strain RB-51(**RB-51**; 1%), and Vibriosis/Leptospirosis combo (1%).

Results from this survey regarding recommended antigens to vaccinate calves are similar to USDA's Beef 2007-08 report (USDA, 2010), where over 50% of cow-calf operations administered a clostridial vaccine to calves before weaning, over 30% of operations administered IBR and BVD vaccines before weaning, and over 25% vaccinated calves for PI-3 and BRSV. Survey results are also in agreement with recommendations made by Comerford et al. (2013), whom suggested that any health program should include vaccination for IBR, PI-3, BRSV, BVD, *Haemophilus sommus*, Leptospirosis, and Clostridial diseases. Similarly, Waldner et al. (2013) reported that the most commonly used vaccines by Canadian cow-calf producers to vaccinate calves were Clostridial (84.6%) and BVD and IBR (55.6%). Furthermore, Woolums et al. (2014) reported that 87% of respondents to a survey of veterinarians that deal with nursing beef calf respiratory disease recommend a routine administration of respiratory vaccines to beef calves. However, USDA (2010) reported that during 2007, 60.6% of beef cow-calf operations did not vaccinate calves for respiratory disease from birth until the time they were sold and over 30% of all calves were on these operations. It is very probable that these recommendations are made with aims to the prevention of bovine respiratory disease (**BRD**), which is the most common cause of death for all production classes of cattle and calves in the United States (Woolums et al., 2013) and costs the beef industry millions of dollars every year on prevention, control, and death loss (Macartney et al., 2003). Radostits et al. (1994) and Woolums et al. (2014) reported that viruses isolated from calves affected with BRD included IBR, BRSV, BVD and PI-3; bacterial pathogens also isolated included *Mannheimia haemolytica*, *Pasturella multocida*, *Haemophilus somnus*, *Mycoplasma bovis*, and *Mycoplasma dispar*. Furthermore, in a survey of biosecurity practices of U.S. beef cow-calf producers, Sanderson et al. (2000) reported that 18% of producers vaccinated cattle against IBR, 17% vaccinated against BVD, 28% against Leptospirosis, 20% against campylobacteriosis, 42% against brucellosis (for heifers), and only 1.1% vaccinated cattle against Tritrichomonosis. The observed pattern of vaccination recommended by veterinarians and performed by beef cow-calf producers across the US is most probably due to the fact that vaccines for BRSV, BVD, PI-3, and IBR are commercially offered in a single injection vaccine.

Responding veterinarians (30%) recommended that the last preventative vaccine should be administered to cattle 7 to 14 d prior to loading/shipping/sold, 31% of veterinarians recommended to administer it 15 to 21 d, 21% of veterinarians 22 to 30 d, 15% of veterinarians 31 to 45 d, and only 3% of veterinarians recommended to administer the last preventative vaccines more than 45 d prior to loading or shipping. The majority of veterinarians (79%) recommended vaccinating bulls at the same time that cows get vaccinated (Table 5).

About 20% of cow-calf operations administered annual booster vaccines for cows and bulls during 2007 (USDA, 2010). In contrast, nearly all participating veterinarians (99%) in this study recommended annual booster vaccination for the female herd. The most commonly recommended antigens administered as annual boosters to the female herd were: IBR (99%), BVD Type 2 (98%), BVD Type 1 (97%), Leptospirosis (94%), PI-3 (86%), BRSV (81%), and Vibriosis (72%). Similarly, in 2007 over 23.8% of operations gave a BVD booster vaccine to cows and 20.3% to bulls (USDA, 2010). Furthermore, 28.10% of cow-calf operations regularly vaccinate cows and bulls against BVD, 24.6% against IBR, 22.6% against PI-3, 21.1% against BRSV, and 19.0% against *Campylobacter* (USDA, 2010). When administering booster vaccines to the beef herd, USDA (2010) reported that during 2007 over 60% of cow-calf operations used killed vaccines over MLV. A divergent trend was observed in this study, with 65% of participating veterinarians recommending a MLV vaccine and 35% recommended a killed vaccine when administering annual booster vaccines to the female herd (Table 5). Other antigens administered by a minority (11%) of veterinarians included: anaplasmosis, *Moraxella bovis*, *Escherichia coli*, rotavirus, coronavirus, perfringens, *Moraxella bovoculi*, anthrax, salmonella, and brucellosis. The use of a preventative scour vaccine for the breeding herd was recommended by 80% of veterinarians as part of the herd vaccination protocol (Table 5), with *Escherichia coli* (92%) being the most recommended antigen for the prevention of scours, followed by Coronavirus (88%) and Bovine rotavirus (87%; Table 5). Similarly, Waldner et al. (2013) reported that over 40% of Canadian beef producers administered preventative scour vaccination (*Escherichia coli*, Coronavirus, and Rotavirus) and over 57% of producers administered clostridial vaccines to the female herd for prevention.

Health Practices

Table 6 provides descriptive data regarding general health practices for the cow-calf herd recommended by veterinary practitioners. The most commonly recommended practices by veterinarians as part of the BVD total control program were vaccination (99%), biosecurity (76%), testing and removal of infected animals (62%), and quarantine (52%). When their clients were keeping calves past weaning for backgrounding or grazing before selling, 68% of veterinarians did not recommend to administer additional booster vaccines. Similarly, Woolums et al. (2013) reported that nearly 40% of cow-calf operations that had previously vaccinated calves against BRD pathogens administered booster vaccines to calves prior to weaning. When banding is recommended as a castration method, regardless of the time point at which castration was performed, 97% of veterinarians also recommended that calves receive a tetanus vaccine (Table 6). This is in agreement with survey data reported by Coetzee et al. (2010), where over 50% of responding veterinarians routinely used a tetanus toxoid injection at the time of castration. Similarly, in a research trial comparing different castration methods on growth performance of beef bulls, Rust et al. (2007) administered a vaccine containing a tetanus toxoid to cattle (n = 20) that were castrated using a high-tension elastic rubber band, with only 1animal developing the disease and dying during the study.

The most commonly recommended fly control methods were herd spraying (72%), oil-based back rubbers (63%), and dust bags (52%; Table 6). However, veterinarians also recommended alternative methods such as: pour-on products, fly tags, Permectrin CDS, feeding insect growth regulator (**IGR**), ear tags, LongRange^{TM}, spot spray, fly baits, environmental control (predator flies), dewormers, and manure, bedding, and bale management. Similarly, over half of the cow-calf producers in the US used a pour-on product for fly control (USDA, 2010). The use of insecticide-impregnated ear tags for fly control on cows and calves was also recommended by 76% of practicing veterinarians (Table 6).

Table 7 presents descriptive data regarding deworming practices recommended for the cow-calf herd by veterinary practitioners participating in this study. Nine out of every 10 operations in the USDA Beef 2007-08 publication reported to deworm all cattle and calves in the herd at least occasionally (USDA, 2010). Similar results are reported from this survey, where

93% of participating veterinarians recommended to deworming the female herd as a regular practice. From these veterinarians who recommended deworming the female herd, 96% recommended to do it 1 to 2 times per yr. Over 80% of cow-calf operations in the US followed this recommendation, with 5.1% of operations deworming cows less than once a yr, 38.2% of operations de-worming cows at least once a yr, and 43.5% deworming the cow herd more than once a yr (USDA, 2010). Furthermore, over 50% of veterinarians highly recommend the use of both injectable and pour on products for deworming of the female herd. Although the USDA reports that over 50% of cow-calf operations deworm calves once or more than once per year, nearly 40% of them do not ever de-worm calves (USDA, 2010). Deworming of calves was the second most common practice recommended by 64% of veterinarians at branding time, with injectable dewormers being the most recommended type by 84% of participating veterinarians for this period. The most common practice recommended by veterinarians before and after weaning was deworming of calves (76 and 81%, respectively); an injectable dewormer mas the most recommended type of dewormer recommended by 74% of veterinarians before weaning, whereas a pour-on was the most recommended (65%) type of dewormer after weaning (Table 7).

Production Practices

Genetic advice for ranchers and producers was provided by 54% of practicing veterinarians and the majority of veterinarians (83%) recommended that all family members and employees should be trained on low stress handling (Table 8). Administering a growth implant was the most common practice recommended at branding by 75% veterinarians. However, the same practice was selected as the second most common one recommended by veterinarians before and after weaning (58% and 56%, respectively). According to findings reported by USDA

(2008a), 9.8% of cow-calf operations in the United States gave calves an implant before weaning and 6.8% of operations implanted calves at weaning. The administration of probiotics to calves at branding and after weaning was only recommended by 1% of participating veterinarians (Table 8).

Creep feeding was recommended as a regular practice to clients by 60% of veterinarians (Table 8). In contrast, only 27% of cow-calf operations in the US reported that calves had access to creep feed (USDA, 2008a). A majority (54%) of veterinarians recommended that it would be best if calves knew how to eat from a feed bunk ("bunk broke") before marketing them or shipping to a backgrounding facility or a feedlot. Thirty-six percent of these veterinarians recommended to have "bunk broke" calves depending on each individual client ranch's situation, marketing strategy, or facilities (Table 8). According to data reported by the USDA (2008a, b), the most common type of individual calf identification used by nearly 40% of cow-calf operations was a plastic ear tag; at least 50% of calves were identified with a plastic ear tag in these operations. The use of an ear tag for calves as an identification method, which would include sire and dam information, was recommended by 69% of veterinary practitioners in this survey. In contrast, data from USDA (2008b) reports that only 20% of cow-calf operations used plastic ear tags on calves for herd identification with nearly 30% of all cattle and calves in the operation being ear tagged for this purpose.

The largest number of respondents (38%) recommended that the earliest age at which their clients should wean their calves was 90 to 120 d (Table 9). However, the last Beef report publication mentions that the average age at which calves were weaned on cow-calf operations was 207 d with an average weaning weight of 241 kg for all calves (USDA, 2008b). Three-fourths of all US operations' weaning age for calves is < 230 d of age (USDA, 2008a, b). The two most common weaning methods recommended by veterinarians were: a specific number of days weaned before selling (64%) and fence-line weaning (57%).

Castration of bull calves intended for beef production is a commonly performed management practice in livestock operations in the US, accounting to approximately 16 million procedures per yr (USDA, 2015). Bull calves are routinely castrated at livestock operations to decrease secondary sex characteristics, minimize aggressive behavior, facilitate management, and to improve beef quality (Faulkner et al., 1992; Rust et al., 2007; Gonzalez et al., 2010). At least 77% of all bull calves were castrated on almost 60% of all cow-calf operations in the US during 2007 (USDA, 2008a). The majority of participating veterinarians (34%) recommended castrating bull calves at an age of 0 to 7 days old, whereas 18% of veterinarians recommended to castrate at 2 to 3 mo of age, and 16% of veterinarians recommended castrating bull calves at branding (Table 9). These recommendations are in agreement with Bretschneider et al. (2005) who reported that, based on observations of stress response, the younger the calf is castrated the less stressful is the procedure. This is regardless of the method utilized, recommending that castration occurs at or shortly after birth. In contrast, data from USDA (2008a) reports that cow-calf operations in the US castrated calves at an average age of 77 d. However, most operations (74.5%), castrated bull calves at an age of < 93 d, but almost 20% of operations did not castrate calves until they were over 122 d old. Several methods of castration exist (Bretschneider et al., 2005; Coetzee et al., 2010) and each one of them has positive and negative attributes, but regardless of the preferred method of castration, cattle will undergo pain and stress during this procedure (Rust et al., 2007). The two most commonly used methods for castrating bull calves are either the surgical procedure or the rubber banding method (AVMA, 2014). Respondents were asked to rank castration methods from most to least preferred. Knife cut was selected as the preferred castration method at branding by 86% veterinarians (n = 132), banding was selected as the preferred method by 11% veterinarians (n = 114), burdizzo by 1% veterinarians (n = 73), and 27% (n = 22) of veterinarians' preferred recommendation at branding was to not castrate bull calves (Table 9). At weaning, knife cut was the preferred castration method recommended by 67% of veterinarians (n = 123), banding was the second-most preferred castration method for 25% of veterinarians (n = 106), burdizzo was the next most preferred castration method for 15% of veterinarians (n = 65), and 61% (n = 36) of veterinarians' preferred recommendation was to not castrate bull calves at weaning (Table 9). In agreement with results from this survey, USDA (2008a) reports that 49.2% of cow-calf operations in the US used a surgical method when castrating calves, 47.3% preferred to use banding, and only 3.5% of operations preferred to use the burdizzo technique to castrate calves. Furthermore, Coetzee et al. (2010) reported that the most frequently used method of castration by the majority (57%) of veterinarians was the surgical procedure followed by the banding procedure used by 44% of veterinarians.

Poor nutrition practices within the beef cow herd can have a significant negative impact on calf health in the following year after birth (Larson et al., 2004). Recommended nutrition management practices by veterinary practitioners are summarized in Table 10. Calf nutrition was considered as extremely important during a pre-conditioning program by 82% of responding veterinarians. The mineral status of the cow during pre-breeding and lactation stages was considered as extremely important by 63% of responding veterinarians as it is related to long-term calf health. Comerford et al. (2013) recommended providing cows with a trace mineral supplement and a source of Ca, P, Mg, and Se throughout the year. However, only 25% of veterinarians recommended to always supplement chelated minerals for the cow herd, although the majority (61%) of veterinarians only recommended chelated minerals "sometimes".

Injectable vitamins for the breeding herd were not recommended by 55% of veterinary practitioners (Table 10).

IMPLICATIONS

It is of upmost importance to the authors to highlight the limitations of survey data presented in this paper. This survey reports recommendations currently made by a portion of the consulting veterinarians and practitioners that service cow-calf operations. The practices and recommendations reported in this survey may change over time due to a variety of factors. Reporting summaries of practices and recommendations made by consulting veterinarians provide a benchmark for standard operating procedures used in the beef cattle industry and are useful resources for the industry and the scientific-academic community.

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Table 2.1. Descriptive data about general information and demographics of responding veterinarians (n = 148) to a survey of recommended practices to cow-calf operations in the United States and Canada.

Item	No. of responses	% of responses
States represented by responding veterinarians' practice (*n = 136; 93% response rate*)[2,3]		
Kansas	20	11.0%
Nebraska	19	10.4%
Iowa	18	9.9%
Oklahoma, South Dakota	11	12.0%
Missouri	10	5.5%
Minnesota, Texas	9	9.8%
Georgia	7	3.8%
Montana	5	2.7%
Alabama, Colorado, Illinois, Oregon, Virginia, Wisconsin	4	13.2%
Alberta[1], Arkansas, Florida, Idaho, North Carolina, North Dakota	3	9.9%
Arizona, Kentucky, Ohio, South Carolina, West Virginia	2	5.5%
Hawaii, Indiana, Louisiana, Michigan, Mississippi, Ontario[1], Pennsylvania, Quebec[1], Tennessee, Utah, Wyoming	1	6.0%
Proportion of veterinarians' practice that is devoted to cow-calf producers (*n = 146; 99% response rate*)		
< 10%	13	9%
11 to 25%	16	11%
26 to 50%	41	28%
51 to 75%	46	32%
> 76%	30	21%
Number of years that veterinarians have been in practice (*n = 147; 100% response rate*)		
0 to 5	38	26%
6 to 10	20	14%
11 to 15	13	9%
16 to 20	13	9%
21 to 25	2	1%
26 to 30	12	8%
> 30	49	33%
Number of beef cows serviced by practicing veterinarians (*n = 147; 100% response rate*)		
< 1,000	15	10%
1,001 to 2,500	17	12%
2,501 to 5,000	20	14%

5,001 to 10,000	37	25%
> 10,000	58	39%

[1]Canada

[2]The number of responses corresponds to the number of veterinarians that practice in each state.

[3]Percentage of total responses ($n = 136$); for rows with more than one state listed, the percentage showed reflects the sum of percentages from each individual state.

Table 2.2. Descriptive data about vaccination, antigens, and type of vaccine recommended by practicing cow-calf veterinarians for calves at branding time in the United States and Canada.

Item	No. of responses	% of responses
Antigens recommended for vaccinating calves for the first time at branding (*n = 137; 93% response rate*).		
Clostridial	131	96%
IBR	129	94%
BRSV	125	91%
PI_3	123	90%
BVD, Type 1	107	78%
BVD, Type 2	105	77%
Mannheimia haemolytica	62	45%
Moraxella bovis	43	31%
Pasturella multocida	36	26%
Histophilus somni	25	18%
Leptospirosis	7	5%
Others not listed[1]	7	5%
Mycoplasmal pneumonia	2	1%
Vibriosis	1	1%
Vaccine type recommended at branding time (*n = 137; 93% response rate*)		
Modified Live (MLV)	121	88%
Killed	16	12%

[1]*Moraxella bovoculi*, autogenous *Moraxella bovoculi*, castrate/dehorn.

Table 2.3. Descriptive data about vaccination, antigens, and type of vaccine recommended by practicing cow-calf veterinarians for calves before weaning in the United States and Canada.

Item	No. of responses	% of responses
Antigens recommended for vaccinating calves for the first time before weaning (*n = 139; 95% response rate*).		
IBR	137	99%
BRSV	136	98%
BVD, Type 1	134	96%
BVD, Type 2	134	96%
PI_3	129	93%
Clostridial	122	88%
Mannheimia haemolytica	107	77%
Histophilus somni	62	45%
Pasturella multocida	59	42%
Leptospirosis	14	10%
Moraxella bovis	13	9%
Others not listed[1]	5	4%
Mycoplasmal pneumonia	3	2%
Vaccine type recommended before weaning (*n = 141; 96% response rate*)		
Modified Live (MLV)	127	90%
Killed	14	10%

[1]Brucellosis

Table 2.4. Descriptive data about vaccination, antigens, and type of vaccine recommended by practicing cow-calf veterinarians for calves after weaning in the United States and Canada.

Item	No. of responses	% of responses
Antigens recommended for vaccinating calves for the first after weaning (*n = 120; 82% response rate*).		
BVD, Type 2	116	97%
IBR	116	97%
BVD, Type 1	115	96%
BRSV	115	96%
PI_3	109	91%
Clostridial	70	58%
Mannheimia haemolytica	59	49%
Histophilus somni	44	37%
Pasturella multocida	36	30%
Leptospirosis	18	15%
Moraxella bovis	14	12%
Mycoplasmal pneumonia	4	3%
Others not listed[1]	4	3%
Vibriosis	3	3%
Vaccine type recommended after weaning (*n = 122; 83% response rate*)		
Modified Live (MLV)	114	93%
Killed	8	7%

[1]Brucellosis, RB51, Vibriosis/Leptospirosis combo

Table 2.5. Descriptive data about vaccination protocol practices recommended by practicing cow-calf veterinarians in the United States and Canada.

Item	No. of responses	% of responses
Number of days prior to loading or shipping that the last preventative vaccine should be administered to calves (*n = 144; 98% response rate*)		
7 to 14	43	30%
15 to 21	45	31%
22 to 30	30	21%
31 to 45	21	15%
> 45	5	3%
Are bulls in the herd vaccinated at the same time as cows? (*n = 146; 99% response rate*)		
Yes	116	79%
No	30	21%
Annual booster antigens recommended for vaccinating the female herd (*n = 146; 99% response rate*).		
IBR	144	99%
BVD, Type 2	143	98%
BVD, Type 1	142	97%
Leptospirosis	137	94%
PI_3	125	86%
BRSV	118	81%
Vibriosis	105	72%
Clostridial antigens	63	43%
Moraxella bovis	29	20%
Others not listed[1]	16	11%
Histophilus somni	7	5%
Mannheimia haemolytica	3	2%
Pasturella multocida	2	1%
Mycoplasmal pneumonia	1	1%
Vaccine type recommended for annual booster vaccination of the female herd (*n = 146; 99% response rate*)		
Modified Live (MLV)	103	71%
Killed	56	38%
Is a preventative scour vaccine for the breeding herd recommended as a regular part of the herd health protocol? (*n = 146; 99% response rate*)		
Yes	117	80%
No	29	20%
Antigens recommended to use as preventative scour vaccine for the breeding herd (*n = 120; 82% response rate*)		
Escherichia coli	110	92%
Coronavirus	105	88%
Bovine rotavirus	104	87%

[1]Brucellosis, salmonella, anthrax, *Moraxella bovoculi*, Scourguard or Guardian, scours, *E. coli*, rotavirus, Coronavirus, perfringens, anaplasmosis, autogenous pinkeye, depends by region or need.

Table 2.6. Descriptive data about health practices recommended by practicing cow-calf veterinarians in the United States and Canada.

Item	No. of responses	% of responses
Recommended practices as part of BVD total control program (*n = 147; 100% response rate*)		
Vaccination	146	99%
Biosecurity	112	76%
Testing and removal[1]	91	62%
Quarantine	77	52%
Are additional booster vaccines recommended if clients keep calves past weaning? (*n = 136; 93% response rate*)		
Yes	43	32%
No	93	68%
Is administration of a tetanus vaccine recommended to clients when banding is used as a castration method? (*n = 140; 95% response rate*)		
Yes	136	97%
No	4	3%
Are insecticide-impregnated ear tags recommended for fly control on cows and calves? (*n = 145; 99% response rate*)		
Yes	110	76%
No	35	24%
Fly control programs recommended (*n = 136; 93% response rate*)		
Herd spraying	98	72%
Oil-based back rubbers	86	63%
Dustbags	71	52%
Other	37	27%
Individual animal paint ball application	14	10%

[1]For persistently infected animals

Table 2.7. Descriptive data about de-worming practices recommended for the cow-calf herd by practicing veterinarians in the United States and Canada.

Item	No. of responses	% of responses
Is de-worming of the female herd recommended? (*n = 146; 99% response rate*)		
Yes	135	93%
No	10	7%
Number of times per year recommended to de-worm the female herd (*n = 136; 93% response rate)*		
1 to 2	131	96%
> 2	3	2%
Other[1]	2	2%
Type of de-worming product most highly recommended for the female herd (*n = 143; 98% response rate*)		
Injectable	80	56%
Pour on	72	50%
Oral/paste	34	24%
De-worming practices recommended at branding time (*n = 76; 64% response rate*)[2]		
Injectable[3]	64	84%
Paste/oral[3]	14	18%
Pour on[3]	29	38%
De-worming practices recommended before weaning (*n = 86; 76% response rate*)[4]		
Injectable[5]	64	74%
Pour on[5]	39	45%
Paste/oral[5]	26	30%
De-worming practices recommended after weaning (*n = 62; 81% response rate*)[6]		
Pour on[7]	40	65%
Injectable[7]	36	58%
Paste/oral[7]	22	35%

[1]Depends on need and fecal exam; prior to turn out.
[2]For de-worming practices, number and percentage of responses correspond to the total number of responses (n = 119) to recommended practices at branding time.
[3]For type of de-wormer, percentage of responses are calculated from number of responses for "De-worming" (n = 76)
[4]For de-worming practices, number and percentage of responses correspond to the total number of responses (n = 113) to recommended practices before weaning.
[5]For type of de-wormer, percentage of responses are calculated from number of responses for "De-worming" (n = 86)
[6]For de-worming practices, number and percentage of responses correspond to the total number of responses (n = 77) to recommended practices before weaning.
[7]For type of de-wormer, percentage of responses are calculated from number of responses for "De-worming" (n = 62)

Table 2.8. Descriptive data about production practices recommended by practicing cow-calf veterinarians in the United States and Canada.

Item	No. of responses	% of responses
Genetic advice provided for clients (*n = 147; 100% response rate*)		
Yes	79	54%
No	68	46%
Is low-stress handling techniques training recommended for all family members and employees (*n = 144; 98% response rate)*		
Yes	119	83%
No	25	17%
Other practices recommended at branding time (*n = 119; 81% response rate*)		
Calfhood implant	89	75%
Probiotics	1	1%
Other practices recommended before weaning (*n = 113; 77% response rate*)		
Calfhood implant	65	58%
Other practices recommended after weaning (*n = 77; 52% response rate*)		
Calfhood implant	43	56%
Probiotics	1	1%
Is creep feeding regularly recommended to clients? (*n = 144; 98% response rate*)		
Yes	58	40%
No	86	60%
Should calves be "bunk broke" (know how to eat from a feed bunk) before marketing? (*n = 144; 98% response rate*)		
Yes	78	54%
No	14	10%
Maybe[1]	52	36%
Is ear tag identification (used for sire and dam identification) for calves recommended? (*n = 146; 99% response rate*)		
Yes	101	69%
No	45	31%

[1]Depends on the situation and characteristics of each individual operation.

Table 2.9. Descriptive data about castration method ranking and calf management practices recommended by practicing cow-calf veterinarians in the United States and Canada.

Item	No. of responses	% of responses
Earliest age ever recommended for weaning calves due to weather conditions or other cultural practices deemed necessary (*n = 143; 97% response rate*)		
31 to 60 d	4	3%
60 to 90 d	32	22%
90 to 120 d	55	38%
120 to 150 d	42	29%
>150 d	10	7%
Type of weaning protocol recommended to clients *(n = 143; 97% response rate*)		
Recommended number of days weaned	91	64%
Fenceline weaning	82	57%
Abrupt dry lot weaning or onto truck	15	10%
Two stage weaning with nose clips	12	8%
Recommended age for castration of bull calves (*n = 145; 99% response rate*)		
0 to 7 d	48	34%
< 1 mo	5	4%
1 to 2 mo	21	15%
2 to 3 mo	26	18%
> 3 mo	8	6%
Branding	22	16%
Other[1]	11	8%
Castration methods selected as best option for calves at branding time[2]		
1. Knife cut	113	86%
2. Banding	12	11%
3. Burdizzo	1	1%
4. Do not recommend	6	27%
Castration methods selected as best option for calves at weaning[3]		
1. Knife cut	82	67%
2. Banding	26	25%
3. Burdizzo	10	15%
4. Do not recommend	22	61%

[1]2 to 4 mo; 2 wk prior to weaning; 400 to 500 lb; soon as owner knows it will not be a breeding bull; Spring (100 to 400 lb); Turn out; < 300 lb; depends.

[2]Number and percentage of responses reported for each castration method represent the responses that selected each method as the best option: knife cut (n = 132), banding (n = 114), burdizzo (n = 73), do not recommend (n = 22)

[3]Number and percentage of responses reported for each castration method represent the responses that selected each method as the best option: knife cut (n = 123), banding (n = 106), burdizzo (n = 65), do not recommend (n = 36)

Table 2.10. Descriptive data about nutrition management practices for the cow-calf herd made by practicing veterinarians in the United States and Canada.

Item	No. of responses	% of responses
How important is nutrition for the calf during a pre-conditioning program or weaning? (*n = 146; 99% response rate*)		
Extremely important	119	82%
Very important	25	17%
Important	2	1%
How important is mineral status of the cow (pre-breeding and lactation) in relation to long-term calf health? (*n = 146; 99% response rate*)		
Extremely important	92	63%
Very important	38	26%
Important	13	9%
Somewhat important	3	2%
Are chelated minerals recommended for the cow herd? (*n = 146; 99% response rate*)		
Yes, always	36	25%
Sometimes	89	61%
Never	21	14%
Are injectable vitamins recommended for the breeding herd? (*n = 145; 99 response rate*)		
Yes	65	45%
No	80	55%

Chapter 3 - A survey to describe current cattle feedlot facilities in the High Plains region of the United States

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ABSTRACT

Facilities used by the feedlot industry have diverse designs and published data describing these designs are not found in the literature. Feedlot managers (n=43) responded to a survey describing general feedlot information, shipping and receiving areas, finishing pens, and hospital facilities currently utilized in the High Plains region of the U.S (TX, OK, NM, CO, KS,NE). Feedlots reported one-time capacities of: <10,000 animals (21%); 10,000 to 20,000 animals (26%); and >20,000 animals (53%). Cattle processing facility design and equipment utilized consisted primarily of crowding tubs (74%) and Bud Boxes (19%). Most feedlots (95%) reported 9.3 m^2/animal of pen space for receiving cattle, 68% of feedlots provided 13.9 to 18.6 m^2/animal of pen space for calves with elevated risk of respiratory disease, and 66% of feedlots provided 9.4 to 23.2 m^2/animal of pen space for finishing cattle. Bunk space of 22.9 to 30.5 cm/animal for calves at elevated risk of respiratory disease and bunk space of 22.6 to 30.5 cm/animal for finishing cattle were provided by 55% of feedlots. Linear water tank space of 7.6 to 15.2 cm/animal for finishing cattle was allowed by 27% of feedlots. Windbreaks (43%) and mounds (71%) were used in finishing pens of feedlots surveyed. Few feedlots (17%) provided shade in feeding pens although 50% provided shade in hospital pens. Dedicated health treatment facilities that were distinct from the post-arrival processing facility were reported in 66% of feedlots surveyed. These data benchmark characteristics of outdoor cattle feeding facilities in the High Plains region of the U.S.

Key words: beef cattle, feedlot, facilities, survey

INTRODUCTION

The beef industry, in particular the feedlot sector, is a very complex industry with great diversity in regard to geographical location, environmental conditions, management practices, available feedstuffs, type of cattle fed, production type, feedlot capacity (size), and design of facilities.

When building or remodeling a feedlot, defining the appropriate dimensions and type of feeding facilities for feedlot cattle fed in outdoor pens is important because the characteristics of these facilities have a significant impact on the performance, welfare, and health of cattle housed in those facilities, and also have a considerable impact on the building or remodeling project's budget (Boyles et al., 2015; Hatem et al., 2015). Currently, multiple sources can be found in the literature that provide recommendations with regard to design of facilities to be used in outdoor feeding facilities for feedlot cattle (Harner and Murphy, 1998; Higgins et al., 2013; Euken et al., 2015). However, the literature does not provide published data that describes the dimensions and type of feeding facilities currently used by the feedlot industry in outdoor feeding operations. Thus, the objective of this survey was to obtain descriptive data regarding outdoor cattle feeding facilities currently being used by feedlots in the High Plains region of the United States.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study as no animals were used. Approval to conduct this survey was granted by the Institutional Review Board at Kansas State University (IRB #7739).

Survey Participants

Feedlots were randomly selected and invited to participate in this study based on an existing database provided by Zinpro Corporation (Eden Prairie, MN) that contained contact information for 358 feedlots located in 6 states in the High Plains (Texas, Kansas, Nebraska, Oklahoma, New Mexico, and Colorado), with a minimum one-time capacity of 5,000 cattle. If the email address or phone number for a feedlot was missing in the original data base, their contact information was obtained either using the Beef Spotter (Spotter Publications, 2015) or electronic public databases to invite them to participate and to obtain their email address. Once all contact information was gathered for feedlots in the original database, an equal proportion of feedlots from each state were randomly selected from the database, and a final list of 247 feedlots was used to send an individual electronic invitation requesting their participation in the study.

Data Collection

The survey was conducted from June 2015 through September 2015. Data were collected using Kansas State University's web-based survey software Qualtrics Online (Qualtrics 2015, Version 2417833, Provo, UT). Invited feedlots received a URL to access the survey via an email invitation. There was no information requested in the survey that identified individual participants, so responses were completely anonymous. Participants had 13 wk to access and complete the survey after receiving the email invitation containing the URL. Reminders to complete the survey were sent to participants 3 times during the final 4 wk the survey was available. A total of 43 respondents completed this survey.

The survey was composed of 79 questions (see Appendix) divided into 4 categories, which included general information (7 questions); shipping and receiving area information (30 questions); cattle feeding pens information (33 questions); and hospital area information (9 questions).

Data Analysis

Response data collected from this survey were downloaded from the web-based survey system into a Microsoft Excel (Microsoft, Redmond, WA) spreadsheet for summarization and analysis. Graphs, tables, number of respondents per question, frequency of responses per question, means, minimum values, and maximum values were calculated for all questions using Microsoft Excel. Because not all respondents answered all questions, the number of total responses to a particular question is expressed as a percentage of the number of answers to that question out of total survey responses.

RESULTS & DISCUSSION

Benchmarking the beef industry's facility and management practices may provide insight for cattle feeders to compare their own facilities to others and shed light regarding opportunities for improvement. Beef cattle feeding operations exist across the United States, but the majority of the larger operations are located in the Great Plains region, from Kansas, Colorado, Nebraska, and Texas (Comerford et al., 2013). Five of the top 8 beef feeding states in the continental United States were selected as part of the 6 states included in this survey from which feedlots were invited to participate. As of January 1, 2015, 76.8% (8,165,000) of the total cattle on feed in the United States were fed in feedlots with a one-time capacity $\geq$ 1,000 cattle in these 5 states (USDA, 2015).

Extensive research has been done with regard to animal handling, housing, restraining facilities, and feeding facilities of multiple species, such as dairy (Samer et al., 2012; Pempek et al., 2013), swine (Gentry et al., 2002; Johnson et al., 2010), and poultry (Appleby et al., 2002; Struelens et al., 2010). Limited scientific research has been published regarding current outdoor feeding facilities used by the feedlot industry (Pritchard and Loe, 2007; Johnson et al., 2011; Pastoor et al., 2012).

Facility type and design, and housing systems are important factors to consider when building or expanding production livestock operations as they can affect animal performance, behavior (Hatem et al., 2015), welfare, and health (von Keyserlingk et al., 2012). Regardless of the reason for handling cattle or the type of production system (growing, backgrounding, or finishing), the design and type of facilities selected when building or expanding a feedlot should satisfy requirements of the individual cattle feeding operation. Appropriate facilities not only make cattle management easier, but also increase ease of procedures, making the operation more efficient, safer for employees, and better for animal welfare (Adams et al., 2014).

General Information

Forty-three feedlots returned the survey, with most participants providing a response to the majority of the questions. For the one-time full capacity of participating feedlots, 23 (53%) reported having a capacity in excess of 20,000 cattle, 11 (26%) feedlots reported a capacity of 10,000 to 20,000 cattle, and 9 (21%) feedlots reported a capacity of less than 10,000 cattle (Table 1). Twenty-six (60%) of the participating feedlots were finishing feedlots, whereas 17 (40%) were a combination of growing/backgrounding and finishing operations

Table 1 provides general information and demographics of participating feedlots including location, age of feedlot, most recent additions/upgrades, total area of feedlot facilities, capacity, type of feedlot, emergency power source, and frequency the water supply is tested. Out of the 43 feedlots completing the survey, 36 (84%) feedlots provided their geographical location of which 11 (31%) feedlots were located in Nebraska, 8 (22%) in Kansas, 8 (22%) in Texas, 5 (14%) in Colorado, 3 (8%) in Oklahoma, and 1 (3%) in Wyoming. Even though there was a 16% non-response rate for this question, the proportion of feedlots that provided their geographical location closely and accurately represented the original sample of feedlots that made up our original database. The percentage of feedlots from each state responding to the survey represented a very similar proportion of the feedlots from each state that were selected for this survey. However, there were two exceptions, the first one being feedlots from New Mexico, as no feedlots from this state responded to the survey, and the one feedlot from Wyoming who also responded to the survey, as there were no feedlots from this state included in our original database.

The largest percentage of feedlots surveyed were more than 20 yr old (38; 88%), 4 (9%) were 10 to 20 yr old, and 1 (2%) was 5 to 10 yr old. The age of the most recent addition to the feedlot was less than 5 yr old for 14 (33%) feedlots, 5 to 10 yr old for 14 (33%) feedlots, and greater than 10 yr old for 14 (33%) feedlots. Only 1 (2%) feedlot reported to not have any additions within the designated time frames. The feedlot footprint of 11 (26%) feedlots occupied less than 40.5 ha, 20 (47%) feedlots occupied 40.5 to 202.3 ha, and 12 (28%) feedlots occupied more than 202.3 ha for their facilities. The distance to the closest packing plant was reported by 41 out of the 43 participating feedlot managers. The closest packing plant was within 80.5 kilometers (km) for 22 (54%) of these feedlots, 82.1 to 241.4 km for 17 (41%) feedlots, and 241.4 to 482.7 km for 2 (5%) feedlots. An emergency power source was located on site for 36 (84%) feedlots, while 7 (16%) feedlots did not report having an emergency power source.

Shipping and Receiving Area

Descriptive data for receiving areas of participating feedlots is presented in Table 2. Twenty-three (53%) feedlots reported having designated alleys for shipping cattle at their facilities; whereas, 20 (47%) feedlots did not have designated shipping alleys. Of the feedlots that utilize shipping alleys, 11 (48%) participating feedlots had unsurfaced alleys, while 10 (43%) feedlots had a concrete surface in their shipping alley. Two feedlots reported a combination of both unsurfaced and concrete or concrete and wood chips for their shipping alley surface. Seventeen (40%) feedlots only had 1 loading/unloading chute, 20 (47%) feedlots had 2 to 3 loading/unloading chutes, 5 (12%) feedlots had 4 to 5 loading/unloading chutes, and 1 (2%)

feedlot reported having more than 5 loading/unloading chutes. Results from this survey revealed that larger feedlots have more than a single loading/unloading chute which is in agreement with recommendations by Grandin (1990). Having the ability to use multiple loading chutes at the feedlot may help improve cattle welfare during adverse environmental conditions by reducing the amount of time that cattle have to wait on the truck before being unloaded at the feedlot. Out of the 43 participating feedlots, 14 (33%) used their truck scale as a pen-scale for weighing cattle, while 29 (67%) did not use their truck scale as a pen-scale.

Receiving pens and facilities. Forty-one (95%) out of 43 participating feedlots had dedicated pens for receiving cattle in their facilities, while 2 (5%) feedlots indicated that they did not utilize dedicated pens for receiving cattle (Table 2). Receiving pen space allowance for cattle (m^2/animal) was reported by 42 feedlots. Four (10%) feedlots allowed less than 4.7 m^2/animal in receiving pens, 13 (31%) feedlots allowed 4.7 to 9.3 m^2/animal in receiving pens, 10 (24%) feedlots allowed 9.4 to 13.9 m^2/animal in receiving pens, 8 (19%) feedlots allowed 14 to 18.6 m^2/animal in receiving pens, and 7 (17%) feedlots allowed more than 18.6 m^2/animal in receiving pens. Over 50% of these feedlots allowed an average of 9.3 $\pm$ 3.76 m^2 (median = 9.35) per animal in receiving pens, which is agreement with Teter and Guyer (1973) who recommended a space allowance in receiving pens of 9.3 m^2 per animal. When feedlot managers were asked about the number of cattle per pen housed in receiving pens, the average number of cattle per pen in receiving pens was 116.4 $\pm$ 48.11 (median = 100), the minimum value was 35 cattle/pen, and the maximum value was 250 cattle/pen. Less than 50 cattle per pen were housed by 1 (3%) feedlot, 6 (15%) feedlots housed 50 to 75 cattle/pen, 13 (33%) feedlots housed 76 to 100 cattle/pen, 5 (13%) feedlots housed 101 to 125 cattle/pen, 7 (18%) feedlots housed 126 to 150 cattle/pen, 3 (8%) feedlots housed 151 to 175 cattle/pen, 1 (3%) feedlot housed 176 to 200 cattle/pen, and 3 (8%) feedlots housed more than 200 cattle/pen (Table 2). Harner and Murphy (1998) recommended that receiving pens should be built to handle no more than one truckload of cattle at a time, since it is easier to identify stressed or sick animals in smaller group sizes. Thus, depending on the size or weight of newly arrived cattle, receiving pens can have a pen capacity of 80 to 120 cattle. Eighteen (46%) feedlots followed the recommendation of Harner and Murphy (1998), housing 76 to 125 cattle per receiving pen. Newly arrived cattle remained less than 7 d in receiving pens for 32 (74%) participating feedlots, 7 to 14 d in receiving pens for 5 (12%) feedlots, 15 to 21 d in receiving pens for 3 (7%) feedlots, and more than 21 d in receiving pens for 3 (7%) feedlots (Table 2). Although providing adequate and sufficient shade in receiving pens to cattle upon arrival was recommended by Parish et al. (2008), in particular during hot and humid weather, only 2 (5%) out of 43 participating feedlots used shades in receiving pens with 41 (95%) not using shades in receiving pens. The receiving phase at the feedlot is a challenging period for cattle, during which commingling, transportation, and arrival to a new place contribute to increased stress. Using strategies such as shade in receiving pens can play an important role in reducing the negative effects of extreme heat conditions (Gaughan et al., 2009), improves cattle welfare, and increases comfort of newly received cattle, which would permit a quicker recovery and improved performance of cattle after arrival (Mader et al., 1999). The negative effects of heat stress on productivity of cattle housed in pens with no shade have been reported by Mitlöhner et al. (2001, 2002). Mitlöhner et al. (2001) reported that unshaded cattle spent less time ($P < 0.01$) standing and more time ($P < 0.01$) lying down than cattle housed in shaded pens. Furthermore, respiration rate was lower ($P < 0.05$) and DMI and ADG were greater ($P < 0.01$) for shaded cattle compared to unshaded cattle, although rectal temperature did not differ between shaded and unshaded cattle. Similarly, the provision of shade increased DMI, ADG, and final BW ($P < 0.05$) of cattle when compared to cattle housed in pens with no shade (Mitlöhner et al., 2002). These authors also reported a lower respiration rate and percentage of circulating neutrophils ($P < 0.01$), as well as a greater time spent lying down ($P < 0.05$) and less time spent standing ($P < 0.05$) for shaded cattle when compared to unshaded cattle.

Long-stem hay feeders were used by 18 (42%) feedlots in their receiving pens, while 25 (58%) feedlots did not use long-stem hay feeders in receiving pens. All feedlots had water tanks in their receiving pens and all but 2 feedlots utilized automatic filling water tanks. A majority of feedlots surveyed indicated concrete as the flooring in receiving facilities (72%) with others indicating unsurfaced floors (21%) or another type of flooring, including expanded metal, rubber matting, and unsurfaced pens and concrete in the processing barn. Out of the 31 feedlots that reported to have concrete flooring in their receiving facilities, 15 (48%) feedlots had a grooved surface on their concrete floors, 14 (45%) had a hatch/diamond surface, 1 (3%) feedlot had a smooth surface, and 1 (3%) feedlot had other type of flooring (rubber mats; Table 2).

Processing Barn Area. Cattle processing barns are an essential facility for every beef cattle feeding operation (Saskatchewan Ministry of Agriculture, 2004a) as they influence the efficiency with which routine health and management procedures are performed (implanting, vaccinating, castrating, tagging and dehorning; Bicudo et al., 2002). Results from this survey are presented in Table 3 and show that 41 (95%) feedlots had 1 to 3 processing barns in their facilities, which is expected when taking into consideration that 53% of responding feedlots have a one-time full capacity of more than 20,000 cattle. Larger cattle feeding operations require more efficient processing and handling of cattle which can be achieved with multiple processing barns. Most of participating feedlots (88%) had individual animal scales in their processing facilities. The shape of the cattle alley (snake; curved and side-walled lead-in alley into the squeeze chute) is critical for adequate cattle flow into the squeeze chute in the processing barn, which can have a significant impact on cattle processing efficiency. Results from this survey show that 72% of feedlots had curved snakes in their processing facilities, as recommended by Teter and Guyer (1973), Bicudo et al. (2002), and Saskatchewan Ministry of Agriculture (2004a). With regard to the sides of the snake, 29 (67%) participating feedlots had V-slant sides on their snake, 8 (19%) feedlots had adjustable sides on their snake, and 6 (14%) feedlots had straight sides on their snake.

Previous research recommended feedlots use a “tub” or crowding pen with solid sides to direct cattle into the snake (working chute or alley; Grandin, 1980, 1987; Saskatchewan Ministry of Agriculture, 2004a; Boyles et al., 2015). This recommendation was followed by 74% of feedlots that participated in this survey (Table 3). However, 19% of feedlots had adopted the use of a “Bud Box” to direct cattle into the squeeze chute. The Bud Box, as defined by Anderson and Ilse (2008), is a small staging pen that incorporates a blind-end rectangular pen at the end of the cattle flow where cattle will turn back to the direction they came from, flowing directly into the working alley. Saskatchewan Ministry of Agriculture (2004a) and Boyles et al. (2015) suggested bringing small groups of cattle, 8 to 10 animals, to the tub or Bud Box, instead of larger groups of cattle. Anderson and Ilse (2008) mentioned that the Bud Box should be loaded with the number of cattle that will fill the entire snake to the squeeze chute. Feedlot managers were asked how many cattle are brought to the tub or Bud-Box at one time. Thirteen (30%) feedlots brought less than 10 cattle at one time, 15 (35%) feedlots brought 11 to 15 cattle, 13 (30%) feedlots brought 16 to 20 cattle, and 2 (5%) feedlots brought 21 to 25 cattle at one time to the crowding tub or Bud Box. It is assumed that the capacity of the snake in the processing facilities of the 30

(70%) feedlots that brought more than 10 cattle to the tub or Bud Box at once was larger than 10 cattle (Table 3).

The type of flooring in processing facilities was included as a question in this survey (Table 3). Thirty-eight (88%) feedlots mentioned concrete as the type of flooring in processing facilities, 4 (9%) feedlots had a different type of flooring (rubber mats, slat and concrete, and concrete and wood chips), and 1 (2%) feedlot had unsurfaced floors in its processing facilities. Out of the 38 feedlots that had concrete floors in their processing facilities, 21 (57%) feedlots had a grooved surface, 11 (30%) had a hatch/diamond surface, 4 (11%) had a smooth surface, and 1 (3%) had a different surface (rubber mats).

Sorting Pens. Forty-one feedlots answered the question regarding presence of sorting pens in their facilities with 39 (95%) indicating they had sorting pens in their facilities; whereas, only 2 (5%) feedlots did not have sorting pens. Out of the 39 feedlots with sorting pens in their facilities, 16 (43%) feedlots had hydraulically operated sorting pens and 21 (57%) feedlots had manually operated sorting pens. Eleven (26%) feedlots had less than 3 dedicated sorting pens, 24 (57%) feedlots had 3 to 6 dedicated sorting pens, 6 (14%) feedlots had 7 to 10 dedicated sorting pens, and only 1 (2%) feedlot had more than 10 dedicated sorting pens. Water tanks were reported to be present in sorting pens for 27 (73%) feedlots; whereas, 10 (27%) did not have water tanks in their sorting pens.

Cattle Feeding Pens

High-health-risk calf pen space and bunk space. Spatial considerations for high-risk, highly-stressed cattle arriving at the feedlot should be taken into consideration, as these cattle require additional space to lay down and rest in order to recover from transportation as well as additional space at the feed bunk and water tank to have access to fresh feed, nourish themselves, and rehydrate (Reinhardt and Thomson, 2015). Participating feedlot managers were asked to describe pen space allowance (m^2/animal) in home pens for high-health-risk cattle during the starting period (Table 2), from which 68% of surveyed feedlots allowed 13.9 m^2 to over 18.6 m^2 per animal of pen space for high-health-risk cattle during the receiving period. This is double the pen space allowed for newly received low-health-risk cattle in their facilities. In agreement with findings from this survey, Wolfger et al. (2015) assigned 13.9 m^2 pen space per animal in a study using feeding behavior as an early predictor of bovine respiratory disease (BRD) in newly received cattle. Richeson et al. (2013) assigned a greater pen space per animal, (21.4 m^2/head), in a study assessing the effects of bovine viral diarrhea virus (BVDV) in newly received cattle. Bunk space allowances (cm/animal) in feedlots for high-health-risk cattle during the starting period varied (Table 2), with 1 (2%) feedlot allowing 15.2 to 20.3 cm/animal, 24 (56%) feedlots allowing 22.9 to 30.5 cm/animal, 15 (35%) feedlots allowing 33 to 43.2 cm/animal, and 3 (7%) feedlots allowing more than 45.7 cm of bunk space per animal.

Finishing cattle pen space, bunk space, water space. Feeding facilities should be designed and built to provide cattle with enough space for eating, drinking and moving around, a dry area to lay down and rest, and adequate shelter from wind, dust, sun, and rainfall (Saskatchewan Ministry of Agriculture, 2004b). Results from this survey are presented in Table 4 and indicate that the pen space allowance of 4 (10%) feedlots (4.7 to 9.3 m^2/animal) followed recommendations made by Stull et al. (2007), suggesting that pen space allowance of 7 m^2/animal is adequate in feedlots with a dry climate. A pen space allowance of 9.4 to 23.2 m^2/animal was provided by 27 (66%) feedlots, which is the common recommended pen space allowance for finishing beef cattle (Saskatchewan Ministry of Agriculture, 2010; Crawford, 2011; Euken et al., 2015) and follows the pen space allowance of 9.7 m^2 per animal for cattle > 650 kg suggested in the Guide for the Care and Use of Laboratory Animals (NRC, 2011). This findings are also in accordance with results reported in a survey by Samuelson et al. (2016), where feedlots allowed an average of 19.05 m^2 per animal in summer and 22.85 m^2 per animal in winter. Pen space allowances greater than 23.2 m^2/animal, as reported by 10 (24%) feedlots in this survey, are recommended (Teter and Guyer, 1973; Gaughan, 2009) for heavier cattle up to 453.6 kg of live weight (Saskatchewan Ministry of Agriculture, 2010) or for cattle housed in feedlots with high-moisture environmental conditions (Harner and Murphy, 1998).

Allowing sufficient feed bunk space per animal is critical during the finishing period of beef cattle, because having limited feed bunk space can impact feed consumption and negatively influence performance and efficiency of the cattle in the pen (Crawford, 2011; Anderson and O'Connor, 2012). However, Zinn (1989) reported that allowing 15 to 60 cm of feed bunk per animal did not affect performance of finishing steers, which raises questions in regard to what the appropriate feed bunk space for finishing cattle should be. Linear feed bunk space allowance for finishing cattle of 15.2 to 22.9 cm per animal was indicated by nearly 40% of the feedlots surveyed, which agrees with results reported in a survey by Samuelson et al. (2016) where feedlots allowed 21.6 cm per animal for finishing cattle. This is similar to recommendations published by Teter and Guyer (1973) and Stull et al. (2007). The most common feed bunk space allowance recommendation is 22.6 to 30.5 cm per animal (Saskatchewan Ministry of Agriculture, 2004c; Boyles et al., 2015; Euken et al., 2015). Similarly, the same amount of feed bunk space was allowed by 55% of feedlots in this survey.

Restricting access to drinking water will drastically reduce feed intake and ultimately decrease performance and efficiency (Landefeld and Bettinger, 2002; Amaral-Phillips, 2010;

Gadberry, 2013). Ten (24%) feedlots allowed a linear water tank space of less than 7.6 cm per animal in finishing pens (Table 4), which is in agreement with recommendations made by Mader et al. (1997), USAID (2008), and Boyles et al. (2015) who recommend 2.5 to 7.6 cm of linear water tank space for finishing cattle. Linear water tank space allowance of 7.6 to 15.2 cm per animal were reported by 11 (27%) feedlots in this survey, which might be a result of these feedlots being located in drier and warmer regions, as it has been recommended that a water tank space allowance of 7.6 cm per animal might be required for cattle in a hot environment (Mader et al., 1997). However, almost 50% of surveyed feedlot managers responded that they did not know the water tank space allowance measurement for finishing cattle in their pens (Table 4).

Feed bunk description. The width of the top section of the feed bunk was also of interest and respondents indicated that 2 (5%) feedlots had feed bunks less than 50.8 cm wide, 19 (46%) feedlots had feed bunks 53.3 to 63.5 cm wide, 14 (34%) feedlots had feed bunks 66 to 76.2 cm wide, and 6 (15%) feedlots had feed bunks 78.7 to 88.9 cm wide. In regard to the cattle-side height of the feed bunk, 1 (2%) feedlot had feed bunks less than 25.4 cm high, 19 (45%) feedlots had feed bunks 25.4 to 38.1 cm high, 16 (38%) feedlots had feed bunks 40.6 to 50.8 cm high, and 6 (14%) feedlots had feed bunks more than 50.8 cm high (Table 4). Forty-one out of 43 participating feedlot managers indicated whether the feed bunk bottom was flat or round. Sixteen (39%) feedlots used flat bottom feed bunks, 16 (39%) used round bottom feed bunks, and 9 (22%) feedlots had a combination of both in their finishing pens.

During times of high moisture conditions, it can be a challenge for cattle to move around the pen and approach the feed bunk and water tank due to muddy conditions in the pen. Having a concrete apron by the feed bunk, that preferably connects with a concrete apron around the water tank in the pen, will help with keeping the bunk and water tank area free of mud and will give cattle a solid surface to walk and step on when eating and drinking (Saskatchewan Ministry of Agriculture, 2004c, 2010; Higgins et al., 2013; Comerford et al., 2013). All surveyed feedlots used concrete aprons by the feed bunk (Table 5). Eleven (27%) of surveyed feedlots had 1.8 to 3.1 m wide concrete aprons as recommended by Stull et al. (2007); whereas, 23 (56%) feedlots followed other researchers' recommendations of having wider aprons at 3.4 to 4.9 m wide (Harner and Murphy, 1998; Boyles et al., 2015; Euken et al., 2015).

Water supply and delivery. Ground/well water was the primary water source for all of the 43 (100%) participating feedlots. Water supply was routinely tested for water quality parameters (i.e. livestock water suitability) by 37 (86%) participating feedlots while 6 (14%) feedlots did not routinely test their water supply. Of the 37 feedlots that routinely tested their water supply, 12 (33%) feedlots tested once every year, 10 (28%) feedlots tested twice every year, and 14 (39%) feedlots tested more than twice every year (Table 4).

Participating feedlot managers were asked about the location of the water supply in finishing pens (Table 4). Twenty-one (49%) feedlots had the water supply located in the pen, 19 (44%) feedlots had the water supply located in the fence line, and 3 (7%) feedlots had the water supply located in the bunk line. Thirty-nine (95%) feedlots had concrete aprons by the water tank in finishing pens and 2 (5%) feedlots did not have concrete aprons by the water tank in finishing pens (Table 5). Out of the 39 feedlots that had concrete aprons by the water tank, 1 (3%) feedlot had concrete aprons less than 1.5 m wide, 13 (36%) feedlots had concrete aprons 1.5 to 2.4 m wide, 11 (31%) feedlots had concrete aprons 2.7 to 3.7 m wide, 4 (11%) feedlots had concrete aprons 4 to 4.9 m wide, 4 (11%) feedlots had concrete aprons 5.2 to 6.1 m wide, and 3 (8%) feedlots had concrete aprons wider than 6.1 m by the water tank in their finishing pens.

Continuous flow water tanks were used in finishing pens by 32 (74%) participating feedlots, 5 (12%) feedlots used heated water tanks in their finishing pens, and 6 (14%) feedlots had a different type of water tank, including automatic with floats, both heated and continuous flow, and 2.4 m round concrete water tanks. Water tanks in finishing pens were cleaned or checked at a frequency of less than once every week by 3 (7%) participating feedlots, at least once every week by 25 (60%) feedlots, 2 times every week by 6 (14%) feedlots, 3 to 4 times every week by 3 (7%) feedlots, and on a daily basis by 5 (12%) feedlots.

Cattle comfort. Soil was used as the pen surface in finishing pens by 41 (100%) feedlots. Thirty-eight feedlot managers responded about the type of fencing used in finishing pens, where 19 (50%) feedlots used metal rods or posts for fencing, 15 (39%) feedlots used cable for fencing, and 4 (11%) feedlots used wood posts or rails for fencing in finishing pens. Mounds in finishing pens provide a dry and comfortable area for cattle to rest and lay down during wet conditions. Thirty (71%) feedlots in this survey utilized mounds in their finishing pens (Table 5), which is in agreement with recommendations made by Teter and Guyer (1973), Harner and Murphy (1998), and Boyles et al. (2015). Out of these 30 feedlots, 25 (92%) feedlots had 1 to 2 mounds per finishing pen, 1 (4%) feedlot had 2 to 3 mounds per finishing pen, and 1 (4%) feedlot had 1 mound in small pens and 2 to 3 mounds in large pens. Also, 10 (34%) feedlots had mounds that connect with the concrete apron by the feed bunk in finishing pens and mounds in 19 (66%) feedlots did not connect with the concrete apron by the feed bunk (Table 5).

During adverse environmental conditions, in particular during the cold months of the year, reduced performance can be a result of strong, cold winds blowing through the pen (Saskatchewan Ministry of Agriculture, 2010). Windbreaks are an effective tool to protect cattle against cold winds and reduce its negative impact on performance. Windbreaks were used by

43% of feedlots that responded to this survey. Harner and Murphy (1998) suggested that windbreaks be placed on the North and West sides of finishing pens as they protect an area 10 times the height of the windbreak. Feedlots that used wind breaks in finishing pens used corn stalk and hay bales, trees, metal sheet, aluminum, guard rail, wood slats, tin, corrugated metal, and earth berm as materials for wind breaks.

During the warmer months of the year and when fed in open pen feeding facilities, cattle health, welfare and performance can be greatly affected by heat stress caused by increased temperatures and solar radiation (Elam, 1971; Mader et al., 1999; Gaughan, 2009). The use of shades for cattle housed in outdoor pens is recommended by the Guide for the Care and Use of Laboratory Animals (NRC, 2011). Shading for cattle in finishing pens reduces the effects of extreme heat load on cattle (Gaughan, 2009). Only 17% of surveyed feedlots used shades in their finishing pens as a strategy to reduce heat stress and cattle discomfort due to high temperatures and solar radiation (Table 5), which is in agreement with findings reported in a survey by Samuelson et al. (2016), where consulting nutritionist reported that only 17% of the feedlots with which they consult use shades in their pens. In a series of summertime trials, Mader et al. (1999) observed that steers that were housed in pens with shade had greater ADG and were more efficient than steers housed in pens without shade. Similarly, greater DMI, ADG, and lower F:G of finishing feedlot steers housed in pens with shade compared to steers housed in pens with no shade was reported by Pusillo et al. (1991). Out of the 7 feedlots that used shades in finishing pens, 3 (50%) of these feedlots provided a coverage of 0.9 to 2.3 m^2 per animal of shade, which is in agreement with recommendations made by Bicudo et al. (2002) and Saskatchewan Ministry of Agriculture (2010), suggesting 1.9 to 2.8 m^2 of shade per animal in finishing pens. Feedlots that had shades in their finishing pens used canvas-type fabric, woven nylon tarps, steel, and tin as materials for shades. Out of 41 respondents, 16 (39%) feedlots used sprinklers in finishing pens for heat stress or dust control and 25 (61%) did not use sprinklers in finishing pens.

Feed alley, drover's alley, loading facility. Forty-one feedlot managers responded to questions regarding the width of feeding alleys, from which 2 (5%) feedlots had feeding alleys less than 4.6 m wide, 5 (12%) feedlots had feeding alleys 4.6 to 6.1 m wide, 9 (22%) feedlots had feeding alleys 6.4 to 7.6 m wide, 7 (17%) feedlots had feeding alleys 7.9 to 9.1 m wide, and 18 (44%) feedlots had feeding alleys more than 9.1 m wide. In regard to drover's alleys associated with finishing pens, out of 40 responding feedlots, 33 (82%) feedlots had drover's alleys and 7 (18%) feedlots did not have drover's alleys associated within finishing pens.

When asked what the greatest distance between a finishing pen and the load out area was in their facilities, 3 (7%) feedlots had a load out area less than 402.3 m away from their furthest finishing pens, 13 (32%) feedlots had a load out area 402.3 to 804.7 m away, 12 (29%) feedlots had a load out area 804.7 to 1,207 m away, 10 (24%) feedlots had a load out area 1,207 to 1,609.3 m away, and 3 (7%) feedlots had a load out area more than 1,609.3 m away from their furthest finishing pens (Table 4). Factors such as BW, heat stress, cattle handling, and distance from the pen to the loading facility should be considered as risk factors for the development of fatigued cattle syndrome (FCS; Thomson et al., 2015). Cattle that develop FCS exhibit a series of clinical signs, characterized by reluctance to move, decreased flight zone, muscle tremors, a shortened stiff gait, elevated blood lactate concentrations, low blood pH, and increased blood creatine kinase concentration (Frese, 2015). As reported in this survey, many finished cattle had to travel distances greater than 804.7 m (0.5 miles) to arrive at the loading facility from their home pen. Frese (2015) observed clinical signs of FCS in aggressively handled cattle over similar distances at the time of loading for transport to slaughter. Loading facility design and location should be considered by management in prevention of FCS in cattle.

Hospital Area

Having appropriate facilities for health evaluation and treatment of disease or injuries of cattle which are separated from processing facilities is ideal as this helps isolate sick cattle and prevents transmission of disease to healthy cattle. Also, having dedicated doctoring facilities at the feedlot allows medical procedures to be performed more efficiently, improves cattle welfare, and allows treatments to be administered as indicated by the Beef Quality Assurance (BQA) guidelines (Adams et al., 2014). In addition, cattle comfort is of premium importance for sick and injured animals to promote a quicker recovery (Teter and Guyer, 1973; Mader et al., 1999).

Forty-one feedlot managers responded to questions regarding their hospital and medical facilities and results are presented in Table 6. Designating a dedicated doctoring facility separate from processing facilities at the feedlot has been recommended (Teter and Guyer, 1973; Stull et al., 2007; Parish et al., 2008). Approximately, 2/3 of feedlots that participated in this survey provided a dedicated hospital facility indicating an opportunity for a third of the feedlots to improve in biosecurity. Twelve (29%) feedlots reported that the hospital doctoring facility was the same as their processing facility and 2 (5%) feedlots reported a different setup; one feedlot had both setups and the other feedlot doctored and returned cattle back to their home pen the same day.

Nearly all of the feedlots surveyed had dedicated hospital pens for cattle to recover from injury or disease (Table 6). Approximately half of the feedlots provided shades in their hospital pens, which were made of tin, steel, nylon tarps, snow fence or pipe, sheet metal, or wood slats according to responses from participating feedlot managers. Providing shade during times of heat stress is important for cattle suffering from BRD as they have decreased respiratory capacity to cool themselves (Teter and Guyer, 1973; Bicudo et al., 2002; Boyles et al., 2015).

Forty feedlot managers responded when asked about pen space allowance for cattle in hospital pens (Table 6). Of these 40 respondents, 5 (13%) feedlots allowed less than 4.7 m^2/animal in hospital pens, 9 (23%) feedlots allowed 4.7 to 9.3 m^2/animal, 15 (38%) feedlots allowed 9.4 to 13.9 m^2/animal, 6 (15%) feedlots allowed 14 to 23.2 m^2/animal, and 5 (13%) feedlots allowed more than 23.2 m^2/animal in hospital pens. As suggested by many research groups, all of the feedlots in our survey had water tanks in hospital pens (Harner and Murphy, 1998; Stull et al., 2007; Troxel et al., 2013), with the majority being automatically filled water tanks. Long-stem hay feeders were used in hospital pens by 46% of the feedlots surveyed.

IMPLICATIONS

It is important to highlight limitations of survey data, as this survey reports outdoor cattle feeding facilities currently used only by a portion of feedlots in the High Plains region. The reported facilities descriptions in this survey may change over time or geographical location due to a variety of factors. Most feedlots reported to have outdoor cattle feeding facilities within the published recommendations available for the various facility factors covered in this survey. Expanding, planning, or building cattle feeding facilities should take into account both published recommendations and practical experience to obtain the facility design that will better fit individual feedlot needs. This paper provides a thorough description of outdoor cattle feeding facilities in the High Plains region in the United States to serve as a benchmark for those looking to build a new facility or enhance an existing cattle feedlot.

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APPENDIX

Questionnaire provided to participating feedlots.

General

In what zip code is this feedlot located?

How old is the oldest part of this feedlot? (yr)

- < 5
- 5 - 10
- 10 - 20
- > 20

How old is the newest addition to this feedlot? (yr)

- < 5
- 5 - 10
- > 10
- No addition/renovation

What is the total area (acres) occupied by your facilities?

- < 100
- 100 - 500
- > 500

What type of feedlot is this?

- Growing/Backgrounding
- Finishing
- Both

What is the one-time full capacity of this facility? (cattle)

- < 1,000
- < 10,000
- < 20,000
- > 20,000

Do you have an emergency power source?

- Yes
- No

Shipping and Receiving Area

Do you have dedicated pens for receiving cattle?

- Yes
- No

How much space (ft^2/animal) do you allow cattle in receiving pens?

- < 50
- 50 -100
- 101 - 150
- 151 - 200
- > 200

Approximate stocking density (cattle/pen) of pens in receiving area:

How many days do cattle remain in the receiving pens?

- < 7
- 7 - 14
- 15 - 21
- > 21

Do you use shades in your receiving pens?

- Yes
- No

Approximate shade area (ft^2) provided per animal:

Are there long-stem hay feeders in your receiving pens?

- Yes
- No

Are there water tanks in your receiving pens?

- Yes
- No

What type of water tanks are there in your receiving pens?

- Manual fill
- Automatic fill

Are there any sorting pens in this facility?

- Yes
- No

What type of sorting pens do you have in this facility?

- Manual
- Hydraulic

Are there water tanks in your sorting pens?

- Yes
- No

What type of water tanks are there in your sorting pens?

- Manual fill
- Automatic fill

How many dedicated sorting pens do you have after the chute?

- < 3
- 3 - 6
- 7 - 10
- > 10

Is the snake in your facilities straight, curved, S-shaped or other?

- Straight
- Curved
- S-shaped
- Other (specify)

Are the sides in your snake:

- Straight
- V-slant
- Adjustable

Is there a tub or bud-box in your processing barn?

- Tub
- Bud-box
- Other (specify)

Number of animals normally brought to the tub/bud-box at one time:

- < 10
- 11 - 15

- 16 - 20
- 21 - 25
- 26 - 30
- > 30

Type of flooring in receiving facilities?

- Dirt
- Concrete
- Other (specify)

What is the surface of concrete floors in receiving facilities?

- Smooth
- Grooved
- Hatch/diamond
- Other (specify)

Type of flooring in processing facilities?

- Dirt
- Concrete
- Other (specify)

What is the surface of concrete floors in processing facilities?

- Smooth
- Grooved
- Hatch/diamond
- Other (specify)

Is there an individual animal scale in your processing facilities?

- Yes
- No

Does your truck-scale double as a pen-scale for weighing cattle?

- Yes
- No

How many loading/unloading chutes are in this feedlot?

- 1
- 2 - 3
- 4 - 5
- > 5

How many processing barns are in this feedlot?

- 1
- 2 - 3
- 4 - 5
- > 5

Is there a specific/designated shipping alley for shipping cattle?

- Yes
- No

Is your shipping alley:

- Dirt surface
- Concrete surface
- Other (specify)

Home pen space (ft^2) provided for high risk calves (per head) during starting period?

- < 100
- 100 - 150
- 151 - 200
- > 200

Home pen bunk space (inches/animal) allocated for high risk cattle (per head) during the starting period?

- < 6
- 6 - 8
- 9 - 12
- 13 - 17
- > 18

Finishing Pens/Yard

What is the average finishing pen space allowed for cattle (ft^2 /animal) in this facility?

- < 50
- 50 - 100
- 101 - 150
- 151 - 250
- > 250

Bunk space allocated (inches/animal) for finishing cattle?

- < 6
- 6 - 9
- 10 - 12
- > 12

What is the width (inches) of your feed bunk?

- < 20
- 21 - 25
- 26 - 30
- 31 - 35
- > 36

What is the average cattle side height (inches) of feed bunks in your yard?

- < 10
- < 15
- < 20
- > 20

Location of water supply used in finishing pens?

- Fence-line
- Bunk-line
- In-pen

What type of water tank is used in finishing pens?

- Continuous flow
- Heated
- Other (specify)

Primary water source of feedlot?

- Ground/well
- Surface
- Rural water

Do you routinely test your water supply?

- Yes
- No

Approximate number of times per year you test your water supply?

Approximate linear allowance for water source in pen (inches/animal)?

- < 3
- < 6
- < 9
- < 12
- Don't know

Frequency water tanks are cleaned/checked?

- Less than once a week
- Once a week
- 2 times a week
- 3 – 4 times a week
- Daily

Do you use shade in finishing pens for cattle?

- Yes
- No

What material are shades made of?

Approximate coverage of shade in pen (ft^2 /animal)?

- < 10
- < 25

- 25 - 50
- > 50

Are there mounds in the pens?

- Yes
- No

Approximate number of mounds per pen?

Approximate area/space (LxWxH) of mounds?

Are there concrete aprons in the pens by the feed bunks?

- Yes
- No

Approximate width/depth (ft) of aprons in the pens by the feed bunk?

Do mounds in the pens connect with the apron at the feed bunk?

- Yes
- No

Are there concrete aprons in the pens by the water tank?

- Yes
- No

Approximate width/depth (ft) of aprons in the pens by the water tank?

Are there any pens with wind breaks?

- Yes
- No

What material are wind breaks made of?

What type of fencing is used in the pens?

- Cable
- Metal rod/Post
- Wood post/Rail

What type of pen surface is used in the pens?

- Dirt
- Slatted concrete
- Bedded concrete
- Other (specify)

What is the greatest distance (yds) between a feeding pen and the load out area? (1 mile = 1,760 yds)

- < 440
- < 880
- < 1320
- < 1760
- > 1760

What is the distance (miles) to the closest packing plant/slaughter house?

- < 50
- 51 - 150
- 151 - 300
- > 300

Are there sprinklers in the pens for heat stress/dust control?

- Yes
- No

Approximate area (ft^2) covered by each sprinkler in the pens?

What is the width (ft) of your feeding alleys?

- < 15
- 15 - 20
- 21 - 25
- 26 - 30
- > 30

Are there drover's alleys on your finishing pens?

- Yes
- No

Are your feed bunks flat or round bottom?

- Flat
- Round
- Both

Hospital Area

Is your hospital/doctoring facility:

- The same as your processing facility
- Separate dedicated facility
- Mobile
- Other (specify)

Do you have dedicated hospital pen(s) in this facility?

- Yes
- No

Is there shading for cattle in your dedicated hospital pens?

- Yes
- No

What material are shades made of?

What is the approximate coverage (ft 2 /animal) of shade in hospital pens?

What is the average pen space allowed for cattle (ft 2 /animal) in hospital pens?

- < 50
- 51 - 100
- 101 - 150
- 151 - 250
- > 250

Are there water tanks in your hospital pens?

- Yes
- No

What type of water tanks are there in your hospital pens?

- Manual fill
- Automatic fill

Are there long-stem hay feeders in your hospital pens?

- Yes
- No

Table 3.1. General information and demographics of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
One-time full capacity (cattle) of feedlot	20	23	43	100
Location of participating feedlots *(n = 36; 84% response rate)*				
Nebraska	10	1	11	31%
Kansas	3	5	8	22%
Texas	0	8	8	22%
Colorado	2	3	5	14%
Oklahoma	1	2	3	8%
Wyoming	1	0	1	3%
Oldest part of the feedlot *(n = 43; 100% response rate)*				
> 20 yr	17	21	38	88%
10 to 20 yr	3	1	4	9%
< 10 yr	0	1	1	2%
Age of newest addition to the feedlot *(n = 43; 100% response rate)*				
< 5 yr	7	7	14	33%
5 to 10 yr	9	5	14	33%
> 10 yr	4	10	14	33%
No addition	0	1	1	2%
Total area (hectares) of feeding facilities *(n = 43; 100% response rate)*				
< 40.5	10	1	11	26%
40.5 to 202.3	10	10	20	47%
> 202.3	0	12	12	28%
Type of feedlot *(n = 43; 100% response rate)*				
Finishing only	10	16	26	60%
Backgrounding and Finishing	10	7	17	40%
Emergency power source on site *(n = 43; 100% response rate)*				
Yes	19	17	36	84%
No	1	6	7	16%

[1]Only 37 possible responses.

Table 3.2. Descriptive data about facilities in receiving area of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
Dedicated pens for receiving cattle *(n = 43; 100% response rate)*				
Yes	19	22	41	95%
No	1	1	2	5%
Number of cattle per pen in receiving pens *(n = 39; 91% response rate)*				
< 50	0	1	1	3%
50 to 75	4	2	6	15%
76 to 100	6	7	13	33%
101 to 125	3	2	5	13%
126 to 150	2	5	7	18%
151 to 175	1	2	3	8%
176 to 200	0	1	1	3%
> 200	2	1	3	8%
Space allowance (m^2/animal) in receiving pens *(n = 42; 98% response rate)*				
< 4.7	1	3	4	10%
4.7 to 9.3	6	7	13	31%
9.4 to 13.9	6	4	10	24%
14 to 18.6	1	7	8	19%
> 18.6	5	7	7	17%
Space allowance (m^2/animal) for high risk cattle during starting period *(n = 43; 100% response rate)*				
< 9.3	4	3	7	16%
9.3 to 13.4	3	4	7	16%
14 to 18.6	5	9	14	33%
> 18.6	8	7	15	35%
Bunk space (cm/animal) for high risk cattle during starting period *(n = 43; 100% response rate)*				
15.2 to 20.3	0	1	1	2%
22.9 to 30.5	10	14	24	56%
33 to 43.2	8	7	15	35%
> 45.7	2	1	3	7%
Days that cattle remain in receiving pens *(n = 43; 100% response rate)*				
< 7	15	17	32	74%
7 to 14	2	3	5	12%
15 to 21	2	1	3	7%
> 21	1	2	3	7%
Use of shades in receiving pens *(n = 43; 100% response rate)*				
Yes	1	1	2	5%
No	19	22	41	95%
Long-stem hay feeders in receiving pens *(n = 43; 100% response rate)*				
Yes	7	11	18	42%

No	13	12	25	58%
Water tanks in receiving pens *(n = 42; 98% response rate)*				
Yes	20	22	42	100%
No	0	0	0	-
Type of water tank in receiving pens[1] *(n^2 = 40; 95% response rate)*				
Automatic Fill	19	21	40	100%
Type of flooring in receiving facilities *(n = 43; 100% response rate)*				
Concrete	17	14	31	72%
Unsurfaced	1	8	9	21%
Other[3]	2	1	3	7%
Surface of concrete floors in receiving facilities *(n^4 = 31; 100% response rate)*				
Grooved	10	5	15	48%
Hatch/Diamond	5	9	14	45%
Smooth	1	0	1	3%
Other[5]	1	0	1	3%

[1]Automatic or Manual Fill

[2]Only 42 possible responses

[3]Expanded metal; rubber matting; unsurfaced pens, concrete in barn

[4]Only 31 possible responses

[5]Rubber mat

Table 3.3. Descriptive data about facilities in processing area of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
Number of processing barns in feedlot *(n = 43; 100% response rate)*				
1	13	10	23	53%
2 to 3	7	11	18	42%
4 to 5	0	2	2	5%
Individual animal scale in processing facilities *(n = 43; 100% response rate)*				
Yes	17	21	38	88%
No	3	2	5	12%
Shape of snake in processing facilities *(n = 43; 100% response rate)*				
Curved	13	12	25	58%
Straight	4	4	8	19%
S-shaped	1	5	6	14%
Other[1]	2	2	4	9%
Sides of snake *(n = 43; 100% response rate)*				
V-slant	14	15	29	67%
Adjustable	3	5	8	19%
Straight	3	3	6	14%
Tub or Bud-Box in processing barn *(n = 43; 100% response rate)*				
Tub	15	17	32	74%
Bud-Box	3	5	8	19%
Other[2]	2	1	3	7%
Number of cattle brought to tub/Bud-Box at once *(n = 43; 100% response rate)*				
≤ 10	9	4	13	30%
11 to 15	5	10	15	35%
16 to 20	6	7	13	30%
21 to 25	0	2	2	5%
Type of flooring in processing facilities *(n = 43; 100% response rate)*				
Concrete	17	21	38	88%
Other[3]	2	2	4	9%
Unsurfaced	1	0	1	2%
Surface of concrete floors in processing facilities *(n^4 = 37; 97% response rate)*				
Grooved	9	12	21	57%
Hatch/diamond	3	8	11	30%
Smoth	4	0	4	11%
Other[5]	0	1	1	3%

[1]All of the above; slight 90 curve.

[2]Both; Tub system with terret gate

[3]Rubber mat; slat in snake, concrete in barn; combined concrete and wood chips

[4]Only 38 possible responses

[5]Rubber mat

Table 3.4. Descriptive data about space allowance, feed bunk, water tank, and dimensions of facilities in finishing pens area of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
Space allowance (m^2/animal; *n = 41; 95% response rate)*				
4.7 to 9.3	1	3	4	10%
9.4 to 13.9	4	7	11	27%
14 to 23.2	8	8	16	39%
> 23.2	6	4	10	24%
Bunk space (centimeters/animal; *n = 41; 95% response rate)*				
15.2 to 22.9	6	10	16	38%
23.0 to 30.5	12	11	23	55%
> 30.5	1	2	3	7%
Width (centimeters) of feed bunk (*n = 41; 95% response rate)*				
< 50.8	1	1	2	5%
50.8 to 63.5	10	9	19	46%
63.6 to 76.2	6	8	14	34%
76.3 to 88.9	1	5	6	15%
Cattle-side height (centimeters) of feed bunk *(n = 42; 98% response rate)*				
< 25.4	0	1	1	2%
25.4 to 38.1	7	12	19	45%
38.2 to 50.8	10	6	16	38%
> 50.8	2	4	6	14%
Water space (centimeters/animal) *(n = 41; 95% response rate)*				
< 7.6	5	5	10	24%
7.6 to 15.2	5	6	11	27%
15.3 to 22.9	0	1	1	2%
Don't know	10	9	19	46%
Location of water supply *(n = 43; 100% response rate)*				
In-pen	12	9	21	49%
Fence-line	7	12	19	44%
Bunk-line	1	2	3	7%
Times/year water supply is tested *(n[1] = 36; 97% response rate)*				
Once	7	5	12	33%
Twice	4	6	10	28%
More than twice	7	7	14	39%
Greatest distance (meters) from feeding pen to loadout[1] *(n = 41; 95% response rate)*				
< 402.3	3	0	3	7%
402.3 to 804.7	5	8	13	32%
804.8 to 1,207	8	4	12	29%

1,208 to 1,609.3	3	7	10	24%
> 1,609.3	0	3	3	7%

[1]One mile = 1,609.3 m

Table 3.5. Descriptive data about dimensions of shades, mounds, and aprons in finishing pens area of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
Use of shade in finishing pens *(n = 42; 98% response rate)*				
Yes	4	3	7	17%
No	16	19	35	83%
Coverage of shade (m^2/animal) in finishing pens *(n = 6[1]; 86% response rate)*				
< 0.9	2	0	2	33%
0.9 to 2.3	2	1	3	50%
2.4 to 4.7	0	1	1	17%
Mounds in finishing pens *(n = 42; 98% response rate)*				
Yes	18	12	30	71%
No	2	10	12	29%
Number of mounds/pen *(n = 27[2]; 90% response rate)*				
1 to 2	14	11	25	92%
2 to 3	1	0	1	4%
Other[3]	0	1	1	4%
Concrete feed bunk aprons in the pen *(n = 42; 98% response rate)*				
Yes	20	22	42	100%
No	0	0	0	-
Width (m) of feed bunk aprons *(n = 41[4]; 98% response rate)*				
1.8 to 3.1	3	8	11	27%
3.2 to 4.9	11	12	23	56%
5.0 to 6.7	3	1	4	10%
> 6.7	2	1	3	7%
Mounds connect with feed bunk aprons in pen *(n = 29[5]; 97% response rate)*				
Yes	7	3	10	34%
No	10	9	19	66%
Concrete water tank aprons in the pen *(n = 41; 95% response rate)*				
Yes	19	20	39	95%
No	0	2	2	5%
Width (m) of water tank aprons *(n = 36[6]; 92% response rate)*				
< 1.5	0	1	1	3%
1.5 to 2.4	3	10	13	36%
2.5 to 3.7	6	5	11	31%
3.8 to 4.9	4	0	4	11%
5.0 to 6.1	3	1	4	11%
> 6.1	2	1	3	8%

[1]Only 7 possible responses

[2]Only 30 possible responses

[3]One mound in small pens; 2 to 3 mounds in large pens.

[4]Only 42 possible responses

[5]Only 30 possible responses

[6]Only 39 possible responses

Table 3.6. Descriptive data about hospital area of participating feedlots

Item	≤ 20,000 cattle	> 20,000 cattle	No. of responses	% of responses
Hospital doctoring facility is: *(n = 41; 95% response rate)*				
Separate dedicated facility	10	17	27	66%
Same as processing facility	9	3	12	29%
Other[1]	0	2	2	5%
Dedicated hospital pen(s) in facility *(n = 40; 93% response rate)*				
Yes	18	20	38	95%
No	1	1	2	5%
Use of shades in dedicated hospital pens *(n = 38[2]; 100% response rate)*				
Yes	10	8	18	47%
No	8	12	20	53%
Space allowance (m^2/animal) in hospital pens *(n = 40; 93% response rate)*				
< 4.7	3	2	5	13%
4.7 to 9.3	7	2	9	23%
9.4 to 13.9	6	9	15	38%
14 to 23.2	2	4	6	15%
> 23.2	1	4	5	13%
Water tanks in hospital pens *(n = 40; 93% response rate)*				
Yes	19	21	40	100%
No	0	0	0	-
Type of water tanks in hospital pens *(n = 40; 93% response rate)*				
Automatic fill	17	21	38	95%
Manual fill	2	0	2	5%
Long-stem hay feeders in hospital pens *(n = 39; 91% response rate)*				
Yes	9	9	18	46%
No	9	12	21	54%

[1]Both; doctor, and return to home pen on same day

[2]Only 38 possible answers

Chapter 4 - A survey to describe the relationship between animal, environmental, and management factors and the occurrence of acute interstitial pneumonia in feedlot cattle

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ABSTRACT

Feedlot managers and consulting veterinarians (n=14) responded to a survey describing general feedlot management practices, cattle, facilities, and animal health to better understand the risks associated with incidence of acute interstitial pneumonia (AIP) in feedlot cattle. Participating feedlots were located in Kansas, USA (21%) and Alberta, Canada (79%). A one-time full capacity of 20,000 to 30,000 cattle was reported by 46% of feedlots. The majority (85%) of feedlots perform necropsies to all deaths. Feedlots reported that the highest incidence of AIP (0.09%) occurred during summer. In average, during AIP peak season, feedlots had 46 AIP cases for every 27,842 cattle on feed per week. The average AIP incidence and mortality for the Alberta feedlots from May through September was of 0.06 and 0.01%, respectively; values for AIP incidence and mortality were highest for the month of June, 0.09% and 0.02%, respectively. The Kansas feedlots reported an average AIP incidence and mortality of 0.09 and 0.03%, respectively; values for AIP incidence were highest for the month of June (0.14%) and values for AIP mortality were highest for the months of June and July (0.04%). Average days-on-feed at death for cattle dying from AIP was of 161 d for Kansas feedlots and 173 d for the Alberta feedlots. In Alberta, 71% of feedlots reported that all cattle dying from AIP were heifers, whereas 29% of feedlots indicated that all cattle dying from AIP were steers. In the Kansas feedlots, 18% of all cattle dying from AIP were heifers and 82% were steers.

Key words: atypical interstitial pneumonia, AIP, cattle, feedlot, survey

INTRODUCTION

Atypical interstitial pneumonia (**AIP**) is a non-infectious respiratory disease that affects beef cattle. This disease has also been identified as acute interstitial pneumonia, acute bovine pulmonary edema and emphysema, fog fever, and dust pneumonia (Popp et al., 1998; Woolums et al., 2005b). While the causative agents of AIP for grazing cattle have been already identified, widely studied, and discussed (Blood, 1962; Breeze and Carlson, 1982; Doster, 2010), the causative agents of AIP in finishing feedlot cattle continue to be a mystery. Feedlot cattle affected with AIP, however, have been reported to be predominantly heifers (Ayroud et al., 2000; Loneragan et al., 2001a; Stanford et al., 2006), usually relatively late in the feeding period (Loneragan et al., 2001b) and near to their market weight before slaughter (Valles et al., 2016), and will have its peak prevalence during the hotter and dryer months of the year (Jensen et al., 1976; Ayroud et al., 2000; Woolums et al., 2005a).

In 2013, the National Animal Health Monitoring System reported that during 2011 71.8% of all feedlots in the U.S. had cattle affected with AIP; 2.8% of cattle at those feedlots were affected with AIP at some point during the feeding period (USDA, 2013b). According to Amosson et al. (2006), following bovine respiratory disease (**BRD**), AIP is one of the most costly diseases that affect feedlots ($23.60 and $21.70 per treatment, respectively; APHIS, 2013). In addition to the loss of the animal, economic costs include the value of a large amount of feed, yardage, interest, and any other investments in the animal (Loneragan et al., 2001b).

There are numerous publications (Doster et al., 1978; Curtis, 1979; Bingham et al., 1999; Ayroud et al., 2000; Booker et al., 2008; Doster, 2010) which have described lung lesions in cattle suffering from AIP, possible ways to try to treat or prevent AIP, and many possible agents which may contribute to the occurrence of AIP. Throughout the literature, multiple factors such as heat stress, dust, gender, feed additives, enzymes, toxins, virus, parasites, toxic gases, and allergens have been listed as possible causes of AIP in cattle (Sorden et al., 2000; Doster, 2010). However, in the last ten years there has not been a new report of cattle management practices in feedlots which might influence the occurrence of AIP and can be used to compare operating procedures between feedlots. Given that AIP is a very costly disease for the feedlot industry, further research is warranted to clearly determine the causal agents and etiology of this disease affecting finishing feedlot cattle. Thus, the objective of this study was to obtain descriptive data about cattle management practices and cattle health data from participating feedlots and use the data as a tool to make comparisons of cattle management practices between feedlots that might explain the difference in AIP incidence between feedlots.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study as no animals were used. Approval to conduct this survey was granted by the Institutional Review Board at Kansas State University (IRB #7942).

Survey Participants

A data base of 13 consulting veterinarians containing their contact information and location of their practice was put together. An individual electronic invitation containing an executive summary of the project was sent to each consulting veterinarian requesting their participation in the study. Consulting veterinarians were contacted by phone to personally invite them to participate in the survey five days after the email invitation was sent. Those consulting veterinarians who agreed to participate in the study were sent a document packet through regular mail.

Data Collection

The survey was conducted from June 2016 through September 2016. Consulting veterinarians who agreed to participate in the study were sent a packet through regular US Postal Service. Each consulting veterinarian requested a specific number of "individual survey packets" depending on how many of their feedlot clients where to be invited to participate in the project. Each feedlot received one of these packet, which included a survey, 5 monthly health assessment forms, and a pre-labeled and stamped envelope to return the documents to this research group. Monthly health assessment forms were meant to be filled out with health data from the months of May through September of 2016. Both the survey and monthly health assessment forms were pre-coded by this research group with a unique identifying code that would only allow to match surveys and monthly health assessment forms from each feedlot without giving any particular indication of feedlot identity. There was no data requested in the survey that identified individual participating feedlots, so responses were completely anonymous. Once that feedlots received their individual packets, they could immediately fill out the survey and eventually fill out the monthly health assessment forms at the end of each month. Once all documents were completely filled out, feedlots placed those in the envelope included in the packet and put it in the mail to be sent back to the research group.

The survey was composed of 55 questions divided into 7 categories, which included general feedlot description (2 questions), cattle description (6 questions), feeding facilities description (11 questions), nutrition program and ingredients description (21 questions), health description (4 questions), processing protocols (4 questions), and vaccination protocols (7 questions). Monthly health assessment forms included were composed of 9 questions requesting information of number of head-days, AIP cattle data (diagnosed, treated, railed, dead), and cattle deaths related to BRD, digestive disorders, and other causes. For cattle diagnosed as dying of AIP causes, the following data was requested for each individual animal: gender, days on feed (DoF) at death, in-weight, and previous treatment history.

Data Analysis

Response data collected from the survey was put into a Microsoft Excel (Microsoft, Redmond, WA) spreadsheet for summarization and analysis. Graphs, tables, number of respondents per question, frequency of responses per question, means, minimum values, and maximum values were calculated for all questions using Microsoft Excel. Because not all respondents answered all questions, the number of total responses to a particular question is expressed as a percentage of the number of answers to that question out of total survey responses. Animal health data collected from monthly health assessment forms was put into a Microsoft Excel spreadsheet for summarization and analysis.

RESULTS AND DISCUSSION

Despite technological advances, economic losses attributed to AIP, and the many years that this disease has been affecting finishing beef cattle across U.S. and Canadian feedlots, its exact etiology affecting cattle in commercial feedlots has not been identified. The reasons for feedlots having high incidence of AIP and feedlots within close proximity having a low or no incidence of AIP are truly unknown, but it is speculated that a synergism of environmental, nutritional, physiological, and health factors result in the manifestation of AIP in finishing beef cattle at commercial feedlots. Although multiple risk factors such as dust (Ayroud et al., 2000), long-fed cattle (Jensen et al., 1976; Hjerpe, 1983; Ayroud et al., 2000), BRSV (Collins et al., 1988; Glock and DeGroot, 1998; Woolums et al., 2004), pancreatitis (Valles et al., 2016), 3-MI (Stanford et al., 2006), heat stress (Ayroud et al., 2000), gender (heifers vs. steers; Ayroud et al., 2000; Valles et al., 2016), bronchopneumonia (Sorden et al., 2000; Woolums et al., 2004; Valles et al., 2016), and feeding MGA to heifers (Stanford et al., 2006) have been associated with AIP in feedlot cattle, none of them have been truly identified as the determinant and ultimate triggering cause of AIP (Neary, 2017).

The occurrence of AIP in grazing cattle has been attributed to the content of the amino acid L-tryptophan present in rapid-growing lush forages, particularly when these are consumed by cattle that have been switched from a low-quality diet or pasture to a high-quality one (Blood, 1962; Doster, 2010). Although increased levels of breakdown products of L-tryptophan have been found in the lungs of feedlot cattle affected with AIP (Loneragan et al., 2001a), feedlot diets typically do not contain high levels of highly digestible protein or L-tryptophan. When consumed by cattle, this essential amino acid is metabolized by ruminal bacteria to indoleacetic acid, which is further metabolized by *Lactobacillus spp.* to 3-methylindole (**3-MI**; Honeyfield and Carlson, 1990; Loneragan et al., 2001a). From the rumen, 3-MI is diffused to circulating blood and transported to the lungs, where cytochrome P450 (CYP450) enzymes and prostaglandin H synthetase in Clara cells and type II alveolar epithelial cells convert 3-MI to 3-methyleneindolennine (**3-MEIN**), which is a pneumotoxic metabolite, causing edema in pneumocytes and necrosis of the bronchiolar and alveolar epithelium (Sorden et al., 2000; Woolums et al., 2001). Beef cattle can also be affected by AIP when fed moldy sweet potatoes. It has been identified in different parts of the world that when moldy sweet potatoes are fed to beef cattle these develop AIP. Mold in sweet potatoes contains the pneumotoxic compound 4-ipomeanol, which has been identified as the responsible agent for triggering the onset of AIP in beef cattle fed moldy sweet potatoes (Vickers et al., 1960; Peckham et al., 1972; Doster et al., 1978; Wilson et al., 1981; Hill and Wright, 1992; Medeiros et al., 2001).

Cattle affected by AIP will have a sudden onset of labored breathing (Woolums, 2015) and then develop clinical signs such as an extended neck and lowered head to facilitate breathing, excessive salivation, frothy mouth, grunting, panting, open mouth breathing, and refusal to travel (Blood, 1962; Doster, 2010), as well as displaying an aggressive behavior when being approached for handling (Loneragan and Gould, 1999). Cattle that display AIP-like symptoms tend to respond poorly to treatments (Woolums et al., 2005b) and at necropsy, lungs grossly display edema and emphysema (Doster, 2010).

Demographic Information

Table 1 provides demographic information of participating feedlots, including location, type of soil, type of feedlot, type of cattle fed, one-time full capacity, percentage of steers, heifers, and dairy cattle fed, and percentage of high- and low-risk cattle fed. All responding feedlots reported their geographical location and represented one state in the USA and one province in Canada. According to Canadian Beef™ as of January 1, 2017, Canada had a total cattle inventory of roughly 12 million cattle, from which approximately 2 million were feedlot cattle (steers and heifers). Canfax© reported that 74% of all feedlot cattle in Canada was finished in Western Canada, from which the province of Alberta had 41% of the total cattle inventory (STATCAN, 2017a) with a total of 1,152,300 cattle on feed (STATCAN, 2017b). In the United States, beef cattle operations represented a total of 93.6 million cattle as of January 1, 2017 (USDA, 2017a) and all cattle on feed represented 13 million cattle according to the 2016 USDA Cattle Report (USDA, 2017b). Kansas was reported as the third state with more cattle on feed (2.3 million) as of January 1, 2017 in the United States, only behind Nebraska and Texas (2.47 and 2.43 million cattle, respectively; USDA, 2017b). Out of the 14 feedlots completing the survey, 79% feedlots were located in Southern Alberta, Canada, 14% were in West Kansas, USA, and 7% feedlots were located in Southwest Kansas, USA. A soil with a 25% or more clay content is preferred over a soil that has mostly sand or fractured rock structure for feedlot cattle feeding facilities (Henry et al., 2007). The majority (86%) of feedlots reported to have clay soil type in their feeding facilities, whereas 7% reported a clay-gravel mix and 7% reported a clay-loam-sand mix for soil type in their feeding facilities. Results from this survey revealed that all feedlots have predominantly clay soil types at their feeding facilities, which is in agreement with soil type data reported by the Office of Science of the U.S. Department of Energy and the Alberta Agriculture and Forestry Ministry.

Fed Cattle Description

Eighty-six percent of responding feedlots reported to be mixed yards (feeding both calves and yearling cattle) and 14% reported to be only yearling cattle feeding yards. The majority (93%) of responding feedlots reported that the type of cattle fed in their facilities was beef, whereas 7% of feedlots reported to feed a mixture of beef, dairy, and Mexican cattle in their facilities (Table 1). Similar to findings from this survey, a feedlot study (USDA, 2013a) that collected data of feedlots from 12 central and western states reported that 80.2% of feedlots fed only beef breeds, 17.5% of feedlots fed both beef and dairy breeds, and 2.3% of feedlots fed only dairy breeds. The one-time full cattle capacity was reported by 93% of participating feedlots, from which 8% reported to have a capacity of less than 8,000 cattle, 31% feedlots reported a capacity of 10,000 to 20,000 cattle, 46% feedlots reported a capacity of 20,000 to 30,000 cattle, and 15% feedlots reported to have a cattle capacity in excess of 30,000 cattle. Based on the one-time full capacity of the feedlot, 28.6% of feedlots fed 0 to 25% steers in their facilities, 14.3% fed 26 to 50% steers, 28.6% fed 51 to 75% steers, and 28.6% fed 76 to 100% steers in their facilities. For heifers, 42.9% feedlots reported to feed 0 to 25% heifers in their facilities, 21.4% feedlots fed 26 to 50% heifers, 21.4% feedlots fed 51 to 75% heifers, and 14.3% feedlots fed 76 to 100% heifers in their facilities. For dairy breeds, only 0 to 25% dairy breed cattle was fed by 7% of responding feedlots.

Cattle received at a feedlot can be classified into two different categories: low-risk or high-risk cattle. Low-risk cattle are those cattle that have been vaccinated, weaned at least 30 d, and are bunk broke (aka pre-conditioned cattle) before arriving to the feedlot. These cattle are under very low levels of stress and are ready to go into the feedlot. In contrast, high-risk cattle are those cattle that have had no vaccinations, do not know what feed or a feed bunk is, and were recently weaned (sometimes on the truck on the way to the sale barn) when they arrive to the feedlot. These category of cattle are under significantly high levels of stress, which results in a significant immunosuppression and decreased performance (Lovaas and DiLorenzo, 2012). As a percentage of total cattle fed in their facilities, 43% of responding feedlots fed 0 to 25% high-risk cattle, which is similar to findings reported in a survey by Samuelson et al. (2016) where 28% of cattle received by feedlots was classified as high-risk. Twenty-nine percent of feedlots surveyed fed 26 to 50% high-risk cattle, 21% fed 51 to 75% high-risk cattle, and 7% fed 76 to 100% high-risk cattle in their feeding facilities. Regarding low-risk cattle, 7% of responding feedlots reported to feed 0 to 25% low-risk cattle, 36% fed 26 to 50% low-risk cattle, 21% fed 51 to 75%, and 36% fed 76 to 100% low-risk cattle in their feeding facilities (Table 1).

Feeding Facilities Description

Feedlots who responded to this survey also reported some general aspects of their feeding facilities (Table 2). Findings of a feedlot facilities survey by Simroth et al. (2017) reported that only 39% of surveyed feedlots used sprinklers in finishing pens for dust mitigation. Similarly, results from this survey revealed that sprinklers were used for dust mitigation in pens by only 29% of responding feedlots. The majority of responding feedlots (86%) reported that pens are scraped for manure removal twice per year, whereas 7% of responding feedlots scrape pens once a year and other 7% of responding feedlots scrape pens for manure removal more than twice per year. The use of shades for cattle housed in outdoor pens is recommended by the *Guide for the Care and Use of Laboratory Animals* (NRC, 2011). Observations made by Mader et al. (1999) show that finishing cattle perform better when housed in pens with shade vs. cattle housed in pens with no shade, however, none of the feedlots that responded to this survey used shades in finishing pens. In a survey of feedlot facilities, Simroth et al. (2017) reported that shades were used by 17% of surveyed feedlots as a strategy to reduce heat stress and dust. Similarly, Samuelson et al. (2016) reported in a consulting nutritionist survey that only 17% of feedlots consulted use shades in their pens. Mounds not only provide a dry area for cattle to rest comfortably during wet conditions, but also allows cattle to get above ground level during hot weather conditions and catch a breeze that could help reduce the effects of an elevated heat load. Following recommendations made by Harner and Murphy (1998) and Boyles et al. (2015), 93% of feedlots participating in this survey had mounds in their finishing pens. This is also in agreement with findings reported on a survey by Simroth et al. (2017) were 71% of surveyed feedlots used mounds in their finishing pens.

When feedlots were asked about the number of cattle per pen housed in finishing pens 93% of feedlots responded, from which 7.7% of feedlots reported to house less than 200 cattle per pen, 84.6% of feedlots house 201 to 250 cattle per pen, and 7.7% of responding feedlots house more than 250 cattle per pen in their feeding facilities. The common recommended pen space allowance for finishing beef cattle ranges from 14 to 23 m^2 per animal (Saskatchewan Ministry of Agriculture, 2010; Crawford, 2011; Euken et al., 2015). Space allowed (m^2/animal) in finishing pens was reported by 100% of responding feedlots, who reported 14.03 to 23.23 m^2

of space allowance per animal in finishing pens, following the minimum suggested pen space allowance of 9.7 m^2/animal for cattle >650 kg in the *Guide for the Care and Use of Laboratory Animals* (NRC, 2011). Similarly, Simroth et al. (2017) reported that a majority of surveyed feedlots provide a pen space allowance of 9.4 to 23.2 m2/animal for finishing cattle. These findings are also in accordance with results reported in a survey by Samuelson et al. (2016), where feedlots allowed an average of 19.05 m^2/animal in summer and 22.85 m^2/ animal in winter.

One of the main factors that determines finishing cattle performance at the feedlot is feed consumption, which can be greatly affected by feed bunk space. Cattle that have limited feed bunk space during the finishing period can have decreased performance and efficiency due to a reduction in feed intake driven by cattle competing for space to eat at the bunk (Anderson and O'Connor, 2012). The most common feed bunk space allowance recommendation is 22.6 to 30.5 cm per animal (Saskatchewan Ministry of Agriculture, 2004c; Boyles et al., 2015; Euken et al., 2015). Similarly, a survey of feedlot cattle facilities reported that feedlots most commonly allow a bunk space of 23 to 30.5 cm per animal (Simroth et al., 2017), however, a slightly lower linear feed bunk space allowance (17.78 to 22.86 cm per animal) was indicated by 93% of feedlots surveyed, whereas a linear bunk space allowance of 33.02 to 38.10 cm per animal was reported by only 7% of responding feedlots.. Furthermore, our findings are in agreement with findings reported in a survey by Samuelson et al. (2016) where feedlots allowed 21.6 cm per animal for finishing cattle.

Surveyed feedlots also reported on linear water space allowance for finishing cattle (Table 2). Feed intake is directly related to water intake in feedlot cattle, thus having finishing cattle in a pen with restricted access to water can potentially reduce feed intake having a detrimental effect in efficiency and performance (Landefeld and Bettinger, 2002; Gadberry, 2013). Regardless of this, 93% of responding feedlots allowed a linear water tank space of less than 2.54 cm per animal, even less than the 2.5 to 7.6 cm of water tank space per animal minimum recommendation made by USAID (2008). Mader et al. (1997) has recommended to use linear water tank space allowances greater than 7.6 cm per animal for cattle fed in regions with hot and dry weather. Linear water space allowance of 10.16 to 15.24 cm per animal for finishing cattle was reported by 7% of surveyed feedlots, which might indicate that these feedlots are located in a zone that suffers of dry and hot weather conditions. Similarly, Simroth et al. (2017) reported that 27% of surveyed feedlots allow a linear water space of 7.6 to 15.2 cm per animal in finishing pens.

The orientation of the feed bunk in finishing pens was also of interest for the researchers, and 100% of participating feedlots reported their feed bunk orientation. Berg and Kline (2013) mentioned that feed bunk orientation at the feedlot should best fit terrain slope and drainage of the pens, as this may avoid excessive construction costs. However, it is recommended to have bunks oriented N-S with an E-W sloping lot, as this will avoid having ice or snow accumulate on the north side of the bunk during winter (Henry et al., 2007; Wendling, 1999) or have cattle exposed to severe winds (Harner and Murphy, 1998). Thirty-six percent of feedlots reported that 100% of their feed bunks have a E-W orientation, 36% of surveyed feedlots reported that 100% of their feed bunks have a N-S orientation, 14% of responding feedlots had 90% of their feed bunks with a N-S orientation and 10% of their feed bunks with a E-W orientation, 7% of responding feedlots reported to have 50% of their feed bunks with a N-S orientation and 50% of their feed bunks with a E-W orientation, and 7% of responding feedlots reported to have 75% of their feed bunks with a N-S orientation and 25% of their feed bunks with a E-W orientation in finishing pens of their facilities (Figure 1).

Dust emissions from feedlots can be an environmental hazard during long and dry seasons of the year (Sweeten, 1999). With feedlots establishing in drier regions and the variable stocking densities of cattle in finishing pens, the generation of dust becomes an important issue that cattle feeders must pay attention in an attempt to reduce health issues in cattle and a negative environmental impact. Usually, the most severe dust situation occurs in the late afternoon close to dusk when cattle that have been resting during the hotter hours of the day become more active and playful when temperatures and wind velocity decrease (Queensland Department of Agriculture and Fisheries, 2011; Sweeten, 1999). Furthermore, dust particles, like silica, can cause direct irritation to the alveolar epithelium when breath by cattle which can contribute to the pathogenesis of AIP in regions with high-silica soils (Woolums et al., 2001). Dust can be controlled in feedlots by increasing the stocking rate during the dryer season of the year, by the use of sprinklers in pens, or by scraping off the top dry layer of the manure pack from the pen surface (Grandin, 2016). Participating feedlots were asked to describe their dust situation in the feeding facility by season of the year (Table 2). For Spring, 86% of responding feedlots reported minimal dust situation and 14% of feedlots reported a dusty environment for Spring season. During Summer, 36% of feedlots reported a dusty environment, 57% of surveyed feedlots reported having dusty conditions during the evenings, and 7% of responding feedlots reported to have very dusty conditions during the Summer season in their feeding facilities. For Fall, 79% of responding feedlots reported a minimal dust situation, 14% of feedlots reported having dusty environment, and 7% of participating feedlots reported to have a very dusty condition during the Fall season. Minimal dust conditions were reported by 93% of surveyed feedlots for the Winter season and only 7% of responding feedlots reported to have dusty conditions during this same season (Table 2).

Finishing Cattle Performance

Animal performance at the feedlot is a reflection of the efficiency with which cattle convert pounds of feed to pounds of live body or carcass weight (Radunz, 2010). At the same time, this efficiency is driven by two factors, ADG and DMI of cattle (Carstens and Tedeschi, 2006), which are two of the most important factors that determine how efficient and profitable a feedlot is (Lunn, 2006; Cruz et al., 2010; Shreck et al., 2008). Daily DMI in feedlot cattle can be described as the total amount of feed (grain, roughage, minerals, etc.) that an animal consumes in a day, excluding moisture. Feed efficiency, on the other hand, can be explained as the kilograms of dry matter required to produce 1 kilogram of body weight (Reiling, 2011). Cattle require certain amounts of different nutrients every day, such as protein, energy, fiber, minerals, and vitamins. To meet specific nutrient requirements, the percentage of nutrients in the diet is based on the quantity of feed consumed daily, however, DMI is a factor that must be estimated before an animal's diet can be properly calculated (Wieland, 2002).

Table 3 shows finishing cattle performance at the feedlot as it was also described by surveyed feedlots. Target and actual DMI of finishing cattle was reported by participating feedlots and although results varied and some feedlots were meeting their targeted DMI, the majority of feedlots were not accurately meeting their DMI targets. Seven percent of feedlots reported a target DMI of 9.1 kg per d with an actual DMI of 10.5 kg per d for finishing cattle, 7% of feedlots reported a target DMI of 9.5 kg per d with an actual DMI of 9.5 kg per d, 7% of feedlots reported a target DMI of 9.7 kg per d with an actual 9.7 kg per d, and 79% of responding feedlots reported a target DMI of 10.0 kg per d with an actual DMI ranging from 9.1 to 10.0 kg per d for finishing cattle fed in their facilities. Target and actual average daily gain (ADG) for finishing steers and heifers were also reported by surveyed feedlots (Table 3). When asked about steers' ADG, 7% of participating feedlots reported a target ADG of 3.1 kg per d with an actual ADG of 3.2 kg per d, 14% of feedlots reported a target and actual ADG of 3.5 kg per and 79% of surveyed feedlots reported a target and actual ADG of 3.7 kg per d for finishing steers fed in their facilities. On the other hand, 7% of surveyed feedlots reported to have a target ADG of 2.9 kg per d and an actual ADG of 2.8 kg per d for finishing heifers, 79% of feedlots reported a target and actual ADG of 3.0 kg per d, and 14% of participating reported a target and actual ADG of 3.5 kg per d for finishing heifers fed in their facilities. Feed efficiency (F:G) of finishing cattle, target and actual, reported by surveyed feedlots is also shown on Table 3. Seven percent of responding feedlots have a target F:G of 5.8 and an actual F:G of 6.2, 7% of feedlots have a target F:G of 6.0 and an actual F:G of 6.0, 79% of feedlots have a target F:G of 6.0 and an actual F:G ranging from 5.5 to 6.5, and 7% of surveyed feedlots were less efficient reporting a target F:G of 6.8 with an actual F:G of 6.6 for finishing cattle fed in their facilities. The F:G values reported by feedlots in this survey are in agreement with Reiling (2011) and Shike (2013) who reported that typically, an industry standard for feedlot cattle would be a F:G value of about 5.8 or higher.

In the middle of the summer, windy days in addition to hot temperatures and dry ambient conditions can lead to fluctuations in DMI of finishing cattle, most commonly reductions in DMI as a result of these adverse weather conditions (Minton, 1987; Lunn, 2006). In a series of feedlot trials, when cattle were exposed to more than 6 h per day of temperatures above 30°C daily feed intake was depressed 10 to 35% when fed a 70% digestibility diet (NRC, 1981). Surveyed feedlots also reported the average loss in DMI for both steers and heifers when these windy, hot-dry conditions happened at their facilities. For finishing steers, 7% of feedlots reported a DMI reduction of less than 2%, 86% of feedlots reported a 2 to 5% reduction in DMI, and 7% of feedlots reported a DMI reduction greater than 5% for finishing steers during windy, hot-dry conditions. An increased reduction in DMI was reported for finishing heifers, with 14% of surveyed feedlots reporting a DMI reduction of less than 5%, 79% of feedlots reported a DMI reduction of 5 to 10%, and 7% of participating feedlots reported a DMI reduction greater than 10% for finishing heifers during windy, hot-dry conditions (Table 3). Results from this survey suggest that heifers are more susceptible than steers to hot-dry and windy conditions experiencing greater loses in DMI than steers. Furthermore, based on NRC (1981), it is assumed from our results that given the reductions in DMI reported the majority of participating feedlots experienced at least 6 h of temperatures at or above 30°C during dry-hot and windy days.

Dietary Ingredients and Nutrition Program

Surveyed feedlots provided a general description of their nutrition program and ingredients used to formulate diets fed to finishing cattle (Table 4). The majority of participating feedlots (93%) have 5 rations fed to finishing cattle and 7% of feedlots have a total of 6 rations fed to finishing cattle. Ninety-three percent of responding feedlots reported to feed cattle a total of 3 times per day and only 7% of surveyed feedlots offer finishing cattle a total of 2 feedings per day. In contrast, Samuelson et al. (2016) reported that a majority of feedlots (54%) feed cattle twice a day, whereas 48.5% of feedlots feed cattle three times a day. Furthermore, Schutz et al. (2011) fed yearling steers a standard high-concentrate steam-flaked corn based finishing diet to determine whether feeding frequency (1, 2 or 3X per day) had any effect on feedlot performance and carcass characteristics. These authors found that ADG was similar for steers fed 1X or 2X per day; however, ADG ($P < 0.03$) and ADFI ($P < 0.04$) were greater for steers fed 3X daily, F:G was similar for all 3 treatment groups, and steers fed 3X had a greater HCW ($P < 0.01$) than did steers fed 1X or 2X.

Seventy-seven percent of surveyed feedlots reported that the protein level of the finishing diet ranged from 9 to 12%, which is slightly lower than the CP concentration of 13 to 14% recommended by consulting nutritionists (Samuelson et al., 2016). However, the protein level of the finishing diet reported by 23% of feedlots surveyed followed recommendations made by consulting nutritionists (Samuelson et al., 2016), ranging from 13 to 15%. The most commonly used source of protein in the finishing diet of responding feedlots was dried distillers grains plus solubles (DDGS; 92%), followed by canola meal (83%), urea (8%), and plant protein (8%). Similar to these findings, Samuelson et al. (2016) reported that 100% of feedlots in their survey used corn by-products as the primary protein source for finishing diets, whereas oilseed meals were used as the secondary protein source by 50% of feedlots. Ninety-two percent of feedlots reported to use other sources of protein in finishing diets such as corn, high-moisture corn, corn silage, forage, and grain. Ninety-two percent of surveyed feedlots reported to used DDGS as their most common by-product in finishing diets and 8% of feedlots reported to use WDGS as the most common by-product in finishing diets fed to cattle in their facilities. Conversely, Samuelson et al. (2016) reported that wet distillers grains plus solubles (WDGS) was the primary grain by-product used by 70.8% of feedlots and DDGS was used as the primary grain by-product by 16.7% of feedlots. In our survey, 83% of feedlots reported to use tallow as the most common by-product in finishing diets, which was used as the main source of added fat in finishing diets by 29.2% feedlots in a survey by Samuelson et al. (2016). Ninety-three percent of feedlots participating in our survey reported to use a trace mineral and vitamin premix in the finishing diet fed to cattle.

It has been reported in the literature that there might be a relationship between the use of certain feed additives in diets fed to finishing beef cattle and the manifestation of AIP at feedlots that use these additives (Ayroud et al., 2000; McAllister, 2002; Popp et al., 1998; Woolums et al., 2001). Hammond et al. (1982) reported that monensin sodium, an ionophore, reduced the development of AIP in grazing cattle, however, there is evidence that it does not have the same effect in feedlot cattle (Ayroud et al., 2000; Loneragan et al., 2001a). In contrast, melengestrol acetate (MGA®), a synthetic progestin compound with glucocorticoid activity primarily used as an estrus suppressant for heifers (NCBI, 2017), has been associated with AIP occurrence in feedlot heifers based on epidemiologic evidence (Constable et al., 2017; McCallister, 1999; Woolums et al., 2001). Melengestrol acetate was used as an estrus suppressant in the finishing diets fed to heifers by 93% of participating feedlots. Similarly, in a survey by Woolums et al. (2005a,b), MGA® was included in the finishing heifer diet by 75% of participating feedlots that reported cattle placements dying of AIP. Monensin sodium was used as the ionophore supplemented in the finishing diet by all surveyed feedlots, which was similar to the findings reported by Samuelson et al. (2016) and Woolums et al. (2005b), where 100% and 97% of surveyed feedlots, respectively, used monensin as their primary ionophore. The most commonly used antimicrobial for liver abscess control in feedlot cattle in the United States is tylosin phosphate (Nagaraja and Lechtenberg, 2007; Reinhardt and Hubbert, 2015). Seventy-nine percent of feedlots participating in our survey reported to use tylosin phosphate as the macrolide supplemented for control of liver abscesses in finishing diets fed to cattle. Ractopamine hydrochloride was used as the β-adrenergic agonist (β-AA) supplemented in the finishing diet by 93% of surveyed feedlots, where as 7% of feedlots do not use a β-AA in their finishing diets. Similar results were published by Samuelson et al. (2016), reporting that nearly 85% of feedlots use some type of β-AA in their finishing diet, from which 96% reported to use ractopamine hydrochloride. Chlortetracycline was reported to be used by 92% of surveyed feedlots as an additional feed-grade antibiotic included in finishing diets fed to cattle, whereas only 3% of feedlots surveyed by Samuelson et al. (2016) use chlortetracycline in finishing diets. Furthermore, 92% of surveyed feedlots also reported to use tylosin phosphate, and 85% of feedlots reported to use monensin sodium as an additional feed-grade antibiotic included in finishing diets. Other feed additives included in finishing diets reported by surveyed feedlots were organic zinc by 92% of feedlots and tallow by 8% of surveyed feedlots (Table 4).

Table 5 provides a description of grain and roughage usage, as well as grain processing methods, used in finishing diets fed to cattle of participating feedlots. The main grain source used in the finishing diet was barley for 79% of surveyed feedlots and corn for 21% of feedlots, which was expected as a majority of responding feedlots were located in Alberta and barley is most commonly used as the primary grain source in finishing diets (Ayroud et al., 2000). In a survey of U.S. feedlots, Woolums et al. (2005b) reported that corn was the primary grain source used in finishing diets by 86% of surveyed feedlots and 14% of feedlots reported to use barley or other grains in their finishing diets. Similarly, findings from the nutritional consultant survey by Samuelson et al. (2016) reported that the corn was the primary grain source used by all feedlots surveyed in finishing diets, whereas only 8% of feedlots reported to use barley in their finishing diets. The most common grain processing method reported was dry-rolling (with tempered grain) by 79% of surveyed feedlots, steam-flaking was reported as the main grain processing method used by 21% of feedlots, and 14% of feedlots reported to use high-moisture grain ensiling as their main grain processing method used. Samuelson et al. (2016) reported that for 71% of feedlots steam-flaking was the primary grain processing method used, followed by high-moisture ensiling (17%), and dry-rolling (13%). Grain processing methods used by feedlots was also reported by Woolums et al. (2005b), who found that dry-rolling was the primary used method by 47% of feedlots, followed by steam-flaking (40%) and high-moisture ensiling (25%). Corn silage was reported by 79% of surveyed feedlots as the main roughage source used in the finishing diet, 79% of feedlots reported barley silage as the main roughage source, 14% of feedlots reported alfalfa, and 14% or responding feedlots reported to use silage (unspecified plant type) as the main roughage source in the finishing diet. Corn silage was the primary roughage source used in finishing diets by 38% feedlots, followed by corn stalks (29%) and alfalfa hay (21%) in a survey published by Samuelson et al. (2016). Similarly, Vasconcelos and Galyean (2007) reported corn silage as the primary roughage source used in finishing diets by 41% of surveyed feedlots, followed by alfalfa (31%), and sorghum silage (7%). In contrast, a feedlot survey by Woolums et al. (2005b) reported that hay was the primary roughage source used for finishing diets by 81% of feedlots, only followed by silage (67%). The roughage level fed to finishing cattle was reported by all surveyed feedlots, with 79% of feedlots reporting a range of 8 to 10% of roughage fed in their finishing diets, 7% of feedlots reported a range of 10 to 12% of roughage, and 14% of feedlots reported to feed more than 12% of roughage in the finishing diet fed to cattle in their facilities. These findings agree with those of Samuelson et al. (2016), as they reported that 8 to 10% roughage was the typical inclusion rate used by feedlots in finishing diets both for summer (50%) and winter (42%).

Growth Promotant Implant Strategies

Growth promotant implants have been widely used in the beef cattle industry since the early 1950's as a safe and effective growth-promoting tool (FDA, 2017). In general terms, implants increase DMI and ADG, with a subsequent improvement in F:G. Implants have been shown to increase ADG up to 20 to 25%, improve F:G up to 15 to 20%, increase HCW by 5 to 10%, and reduce the cost of production by 10% (Duckett and Owens, 1997; Loy and Lundy, 2016; Reinhardt, 2007). These improvements in animal performance are of great benefit for the beef industry, particularly improving production efficiency and reducing production costs (Johnson and Beckett, 2014).

Surveyed feedlots also reported a description of growth promotant implant strategies used in finishing cattle (Table 6). All surveyed feedlots reported to administer cattle a second implant during the feeding period, in agreement with feedlot survey data published by Woolums et al. (2005b) who reported that all surveyed feedlots administered a terminal implant. Our findings are also similar to findings made by Samuelson et al. (2016) who reported that 71% of feedlots use a two-implant program. Surveyed feedlots (100%) reported that the initial implant was administered to steers at 1 days-on-feed (DoF). Furthermore, 79% of participating feedlots reported to use a trenbolone acetate (TBA) initial implant for steers, 7% of feedlots used Revalor-IS, 7% of feedlots used Component E-S with Tylan, and 7% of feedlots reported to use Component TE-IS with Tyaln as their initial implant for steers. Steers were administered their terminal implant (re-implant) on their last 80 DoF by 92% of surveyed feedlots and 8% of feedlots administered the terminal implant to steers on their last 70 DoF. At re-implant, 79% of surveyed feedlots reported to use a TBA terminal implant for steers, similar to the 81% of feedlots that reported to use TBA terminal implants for steers in a survey done by Woolums et al. (2005b). Furthermore, 14% of feedlots participating in this survey used Component TE-200 and 7% of responding feedlots used Revalor-200 as the terminal implant for steers (Table 6). Heifers received their initial implant at 1 DoF, as reported by 100% of responding feedlots. Seventy-nine percent of surveyed feedlots reported to use a TBA initial implant for heifers, 7% of feedlots used Component E-H, 7% of feedlots used Component TE-IH with Tylan, and 7% of responding feedlots used Revalor-IH as the initial implant for heifers fed in their facilities. Heifers fed in 92% of surveyed feedlots received their terminal implant on the last 80 DoF and 8% of feedlots reported to re-implant heifers on their last 70 DoF. When asked about terminal implants used for heifers 79% of surveyed feedlots reported to use a TBA terminal implant, which is in agreement to previous reports published in a survey by Woolums et al. (2005b), where 80% of feedlots administered a terminal implant containing TBA to heifers. In addition, 14% of feedlots in our survey used Component TE-200 and 7% of feedlots reported to use Revalor-200 as the terminal implant for heifers fed in their facilities (Table 6).

Cattle Processing Protocols

A rest period was required by all (100%) surveyed feedlots for long haul (> 8 hr) cattle prior to processing after arrival at the feedlot (Table 7), following recommendations made by Noffsinger et al. (2015). The length of the rest period varied by feedlot and 79% of responding feedlots allowed less than 12 hr of rest period, 7% of feedlots allowed a rest period ranging from 12 to 24 hr, and 14% of feedlots allowed a rest period in excess of 24 hr for long haul cattle prior to processing after arrival at the feedlot. In contrast, Samuelson et al. (2016) reported that the majority of feedlots (67%) allowed cattle to rest for 12 to 24 hr prior to processing after arrival, whereas 29% of feedlots allowed more than 24 hr of rest, and 4% of feedlots allowed cattle less than 12 hr of rest prior to processing. Furthermore, Terrell et al. (2011) reported that the majority (65%) of feedlot veterinary consultants recommended that long-haul cattle had a rest period of 24 hr prior to processing after arrival. In most commercial feedlots large variations in animal weight, size, and finish point can be observed within a pen (Cooper et al., 2000). So, with the only purpose of improving cattle uniformity and ease of sale (Trenkle, 2001), feedlots can use multiple strategies to sort cattle at different time points of the feeding period and group them by specific traits (Kokonoff et al., 2015). Participating feedlots (100%) reported on the period of time at which they would sort cattle. Cattle were sorted at arrival by 7.1% of participating feedlots, 64.3% of feedlots sorted cattle at re-implant, 21.4% of feedlots sorted cattle at both arrival and re-implant, and 7.1% of responding feedlots do not sort cattle at their facilities. In contrast, Samuelson et al. (2016) reported that only 44% of feedlots sorted cattle into outcome groups, from which 31% sorted cattle at arrival and 30% sorted cattle at re-implant. The use of an injectable mineral supplement was not reported by any of the responding feedlots (Table 7).

Cattle Vaccination Protocols

Having vaccine protocols in place and the correct administration of vaccines are cornerstones to biosecurity for the beef industry (Lee et al., 2015). Cattle vaccination protocols were also of interest for the researchers and surveyed feedlots were asked to provide a brief description of these (Table 8). When a group of newly arrived cattle show symptoms of respiratory disease or are at a high-risk of developing it, a common practice by feedlots is to treat all animals in the group to prevent a respiratory disease outbreak in their facilities (USDA, 2013b). This practice is usually known as metaphylaxis and provides a very effective method to decrease the incidence of respiratory disease of cattle of different risk levels (Duff and Galyean, 2007). All of responding feedlots (100%) use metaphilaxis only for high-risk cattle, which is in agreement with recommendations given by feedlot veterinary consultants who recommend metaphilaxis for high-risk cattle (Lee et al., 2015). The NAHMS 2011 Feedlot study reported that although 59% feedlots use metaphilaxis as a common practice to prevent respiratory disease outbreaks, 93% of them use it for high-risk cattle and 30% use it for low-risk cattle (USDA, 2013b). Furthermore, Woolums et al. (2005b) reported that 61% of surveyed feedlots use metaphilaxis and Samuelson et al. (2016) reported that 83% of feedlots use metaphilaxis for high-risk cattle.

Re-vaccinating cattle is a common practice by feedlots and provides individuals not responding initially to the first dose of the vaccine, due to high levels of stress, the opportunity to have an immunological response and acquire some level of protection against disease. Only high-risk cattle was re-vaccinated by 100% of surveyed feedlots, which is in agreement with recommendations made by feedlot veterinary consultants published by Terrell et al. (2011) and

Lee et al. (2015). When cattle was revaccinated, 79% of surveyed feedlots do it at re-implant, following recommendations made by 83% of feedlot veterinary consultants (Terrel et al., 2011). Although it is commonly recommended that cattle get re-vaccinated between 7 to 14 d after initial vaccination (Stokka and Goldsmith, 2015; Terrell et al., 2011), only 14% of feedlots participatin in our survey re-vaccinated cattle between 10 to 14 d post-vaccination. Furthermore, 7% of feedlots re-vaccinate cattle at 10 and 21 d post-vaccination, similar to the recommendations made by consulting veterinarians to re-vaccinate cattle at 21 d (Lee et al., 2015). Surveyed feedlots (86%) reported the antigens used for re-vaccinating cattle, from which 100% re-vaccinate for infectious bovine rhinotracheitis (IBR) and 92% of feedlots re-vaccinate for parainfluenza-3 (PI-3). These findings are in agreement with recommended protocols for re-vaccinating cattle made by feedlot veterinary consultants (Lee et al., 2015; Terrell et al., 2011). Vaccines used for high-risk cattle were reported by 93% of surveyed feedlots. The antigens used by feedlots for vaccinating high-risk cattle are: IBR (100%), bovine respiratory syncytial virus (BRSV; 100%), bovine viral diarrhea type 1 (BVD-1; 100%), bovine viral diarrhea type 2 (BVD-2; 92%), PI-3 (92%), clostridials (92%), *Mannheimia haemolytica* (85%), *Histophilus somni* (77%), and *Pasteurella multocida* (8%). Ninety-three percent of responding feedlots reported the antigens used for vaccinating low-risk cattle (Table 8). The antigens used by surveyed feedlots for vaccination of low-risk cattle are: Clostridials (100%), IBR (100%), PI-3 (92%), BRSV (15%), BVD-1 (15%), and BVD-2 (8%). Results from this survey in regards to the antigens used to vaccinate both low- and high-risk cattle are in agreement with vaccination protocols used by the feedlot industry published in the literature (Woolums et al., 2005b; USDA, 2013b), as well as with recommendations made by feedlot veterinary consultants (Lee et al., 2011; Terrell et al., 2011). None of surveyed feedlots reported to administer liver abscess vaccines to cattle fed in their facilities.

Cattle Health Description

Acute interstitial pneumonia has been identified as one of the main causes of lost profit for the feedlot industry in the United States and western Canada, with an incidence as high as 2.8% of all placed cattle (Constable et al., 2017). It was of interest for the researchers to know what the average AIP incidence by season of the year was, so participating feedlots were asked to give a description of the incidence of AIP in finishing cattle fed in their facilities by season of the year (Table 9). Overall, the mean AIP incidence for winter was of 0.06% with a maximum of 0.15% and a minimum of 0.00%, the mean AIP incidence for spring was 0.08% with a maximum of 0.14% and a minimum of 0.04%, for summer the mean AIP incidence was 0.09% with a maximum of 0.13% and a minimum of 0.02%, and for fall the mean AIP incidence was 0.03% with a maximum of 0.06% and a minimum of 0.00%. When analyzed by geographical location, the mean AIP incidence for winter was 0.04% for feedlots in West Kansas and 0.06% for feedlots in Southern Alberta, the mean AIP incidence for spring was 0.05% for West Kansas and 0.09% for Southern Alberta, for summer the mean AIP incidence for West Kansas was 0.10% and 0.09% for Southern Alberta, and for fall the mean AIP incidence was 0.04% for West Kansas and 0.03% for Southern Alberta feedlots. Overall, results from this survey show that AIP incidence by season as reported by participating feedlots was similar between Kansas and Alberta feedlots. However, findings from this survey show that AIP incidence in participating feedlots was slightly higher during spring and summer months, which is in agreement with previous publications in the literature reporting a higher AIP incidence in feedlots during spring and summer months (Ayroud et al., 2000; Constable et al., 2017; Gould and Loneragan, 1999; Jensen et al., 1976; McAllister, 2000; Vogel et al., 2015; Woolums et al., 2001, 2005a).

Surveyed feedlots were asked to report, as accurately as possible, the number of AIP cases out of total cattle on feed on a “bad week” during AIP peak season (Table 9). On average, feedlots reported to have 46 cases of AIP out of 27,842 cattle on feed during AIP peak season. This resulted in a calculated AIP incidence of 0.17%, which is higher than the 0.03 to 0.15% range of AIP incidence in feedlots reported by Loneragan and Gould (2000), but significantly lower than the 1.3% of cattle treated for AIP reported in a survey of feedlots by Woolums et al. (2005b). The minimum number of AIP cases was 10 and the maximum reported was 97 during AIP peak season. The minimum cattle on feed was reported as 7,685 and the maximum was 100,000 cattle on feed during AIP peak season. Looking at these data from a geographical standpoint, the Kansas feedlots reported having an average of 35 AIP cases and 70,000 cattle on feed on a bad week during AIP peak season which equated to an average AIP incidence of 0.04%. The Alberta feedlots’ average AIP incidence equated to 0.25%, reporting an average of 50 AIP cases and 20,177 cattle on feed on a bad week during AIP peak season.

Often cattle are diagnosed with AIP by feedlot doctoring personnel after a visual evaluation of clinical symptoms, however, AIP is a result of a pathologic condition that can only be accurately confirmed by a histopathologic evaluation of lung tissue samples from an affected animal obtained usually at necropsy (McAllister, 2013; Woolums, 2015). As part of the health management description, surveyed feedlots were asked to report the percentage of total deaths that were necropsied at the feedlot. Less than 10% of total deaths were necropsied by 7.7% of participating feedlots, 50 to 75% of total deaths were necropsied by 7.7% of feedlots, and 100% of total deaths were reported to be necropsied by 84.6% of surveyed feedlots (Figure 2). Similarly, data reported from an AIP survey of United States feedlots indicated that 65% of all cattle deaths were necropsied (Woolums et al., 2005b). Furthermore, 65% of feedlot veterinary consultants from the United States and Canada responding to a survey by Lee et al. (2015) reported that necropsies are performed on all cattle deaths in the feedlots they consult.

Each surveyed feedlot was asked to provide a monthly animal health assessment form for the months of May, June, July, August, and September. Data reported on these monthly health assessments were used to understand demographic data and seasonality patterns on deaths by geographical location of surveyed feedlots. Data reported by the Alberta feedlots (Table 10) show that the average AIP incidence and mortality for the five month period was of 0.06 and 0.01%, respectively. Values for AIP incidence and mortality were highest for the month of June, 0.09% and 0.02%, respectively. These data is in agreement with indications made by Loneragan and Gould (2000), reporting that AIP incidence for feedlot cattle typically ranges from 0.03 to 0.15%. Similarly, Gould and Loneragan (1999) examined 139,000 cattle placements at a single feedlot and reported an AIP incidence of 0.1% and an AIP mortality of 0.09%. The average BRD incidence reported by feedlots in Alberta for the same period was 0.8%, with the highest values reported for the month of September (1.6%). The average BRD mortality was reported to be 0.02%, with the highest values reported for the months of May and June (0.03%). Furthermore, the average percent of cattle deaths due to digestive disorders during these five months was reported as 0.03%, with the highest values reported for the month of August (0.04%; Table 10). Surveyed feedlots in Alberta reported that the average days-on-feed for cattle dying due to AIP was of 173 d, however, Ayroud et al. (2000) and Constable et al. (2017) reported that in Alberta, the average cattle dying from AIP have been on feed for 114 d in average.. Furthermore, 71% of feedlots in Alberta reported that all cattle dying from AIP were heifers, whereas 29% of feedlots indicated that all cattle dying from AIP were steers. These data are in agreement with multiple previous publications reporting that the majority of cattle dying from AIP are heifers and that these are at least 3 times more susceptible to be affected by AIP than steers (Ayroud et al., 2000; Constable et al., 2017; Gould and Loneragan, 1999; Woolums et al., 2001, 2005a).

Overall for the Kansas feedlots, the average AIP incidence and mortality was of 0.09 and 0.03%, respectively (data not shown). Loneragan and Gould (2000) indicated that AIP incidence ranges from 0.03 to 0.15% for feedlot cattle, which is in agreement with our findings. Gould and Loneragan (1999) examined 139,000 cattle placements at a single feedlot and reported an AIP incidence of 0.1% and an AIP mortality of 0.09%, similar to data reported by these feedlots. Woolums et al. (2005a) indicated that Kansas feedlots participating in a survey reported that 0.13% of all cattle deaths were due to AIP. Values for AIP incidence were highest for the month of June (0.14%) and values for AIP mortality were highest for the months of June and July (0.04%). Average BRD incidence and mortality for the same 5 month period was of 2.68 and 0.27, respectively. The highest values for BRD incidence was reported for the month of September (4.08%) and highest values for BRD mortality were reported for the month of June (0.38%). In survey by Woolums et al. (2005b), feedlots reported that 13% of all cattle placed on feed were treated for BRD and 0.8% of these cattle died from BRD. Similarly, USDA (2013b) reported that 16% of cattle placed on feedlots were treated for BRD and Constable et al. (2017)

indicated that BRD cases at the feedlot level typically account for 65 to 79% of total morbidity and 44 to 72% of total mortality. In agreement with these authors, a retrospective study of feedlot closeouts that looked at 73 million cattle from 2005 to 2014 by Vogel et al. (2015) reported that mortality due to respiratory disease in the feedlot accounted for 47% of total mortality or 0.12% of monthly cattle occupancy at feedlots. Furthermore, surveyed feedlots reported that the average percent of cattle deaths due to digestive disorders was of 0.09% and the highest values were reported for the month of July (0.10%). Woolums et al. (2005b) reported that 1.6% of all cattle from surveyed feedlots were treated for digestive disorders and 0.3% of all cattle placements died from digestive disorders. Similarly, Vogel et al. (2015) that deaths due to digestive disorders were higher in late spring and accounted for 0.04% of monthly occupancy and for almost 20% of total mortality. Average days-on-feed at death for cattle dying from AIP for all Kansas feedlots was reported to be 161 d, which can be considered to be a point in time later in the feeding period and is in agreement with previous publications reporting that AIP deaths happen in cattle towards the end of the feeding period (Constable et al., 2017; Hjerpe, 1983; Jensen et al., 1976; Valles et al., 2016; Woolums et al., 2005a). However, Woolums et al. (2004) reported that cattle dying of AIP in Kansas and Colorado feedlots had been on feed for an average of 136 d, slightly earlier in the feeding period compared to findings from our survey. Similarly, Loneragan et al. (2001b) reported that cattle dying of AIP in feedlots in the High Plains region had been on feed for an average of 127 d. Kansas feedlots also reported the gender of cattle dying from AIP, indicating that in average, 18% of all cattle dying from AIP were heifers and 82% were steers. Interestingly, the previous findings for Kansas feedlots in our survey are in contrast with all the published literature (Ayroud et al., 2000; Constable et al., 2017; Gould and Loneragan, 1999; Loneragan et al., 2000, 2001a; McAllister, 2013; Stanford et al., 2006; Valles et al., 2016; Vogel et al., 2015; Woolums et al., 2001, 2004, 2005a,b) reporting that the majority of feedlot cattle being affected and dying from AIP are heifers.

Data for the Kansas feedlots was divided into Southwest and West Kansas regions in order to illustrate any differences in health data by geographical location (Table 11). Data reported by the Southwest Kansas feedlots show that the average AIP incidence and mortality for the five month period was of 0.07 and 0.03%, respectively. Values for AIP incidence were highest for the month of July (0.12%) and values for AIP mortality were highest for the month of June (0.05%). The average BRD incidence and mortality reported by the Southwest Kansas feedlots for the same period of time was of 3.45 and 0.46%, respectively. The highest values reported for BRD incidence were for the month of September (5.7%) and the highest values for BRD mortality were reported for the month of June (0.71%). Cattle deaths due to digestive disorders reported by these feedlots was of 0.10%, with the highest values reported for the month of July (0.12%; Table 11). The average days-on-feed at death for cattle dying from AIP for the Southwest Kansas feedlots was of 120 d. These feedlots reported that from all cattle dying from AIP, 12% were heifers and 88% were steers.

For the same five month period the West Kansas feedlots, on the other hand, reported an average AIP incidence of 0.11% and AIP mortality of 0.03%. The highest values reported for AIP incidence were for the month of June (0.23%) and the highest values for AIP mortality were for the month of July (0.06%). The average BRD incidence and mortality reported by the West Kansas feedlots was of 1.91 and 0.07%, respectively. The highest values reported for incidence and mortality of BRD were for the month of September, 2.4 and 0.09%, respectively. The average cattle mortality due to digestive disorders in West Kansas feedlots during the five month period was reported to be 0.07%, with the highest values reported for the month of July (0.09%; Table 11). The average days-on-feed at death for cattle dying from AIP for the West Kansas feedlots was of 169 d. These feedlots reported that from all cattle dying from AIP, 24% were heifers and 76% were steers.

IMPLICATIONS

The authors would like to highlight the limitations of survey data presented in this paper. This survey reports management and health data from only a small portion of feedlots. The management practices and health outcomes reported in this survey might differ over time or geographical location due to a variety of factors.

Acute interstitial pneumonia has been recognized as an important cause of death in feedlot cattle and loss of profit for the beef industry for decades. The causative agents of AIP or factors triggering it have not been identified and given its sporadic occurrence and low incidence, as well as the likely interaction of multiple predisposing factors, multidisciplinary research is warranted to elucidate its exact etiology and pathogenesis.

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Table 4.1. General information and demographics of participating feedlots.

Item	No. of responses	% of responses
Geographical location of participating feedlots (*n = 14; 100% response rate*)		
S Alberta (Canada)	11	79%
SW Kansas	1	7%
W Kansas	2	14%
Type of soil in feeding facilities (*n = 14; 100% response rate*)		
Clay	12	86%
Clay, Gravelly	1	7%
Clay, Loam, Sandy	1	7%
Type of feedlot (*n = 14; 100% response rate*)		
Mixed yard[1]	12	86%
Yearling yard	2	14%
Type of cattle fed (*n = 14; 100% response rate*)		
Beef	13	93%
Beef, Dairy, and Mexican	1	7%
One-time full capacity of feedlot (*n = 13; 93% response rate*)		
< 10,000	1	8%
10,000 to 20,000	4	31%
20,000 to 30,000	6	46%
> 30,000	2	15%
Based on one-time full capacity of feedlot, the percentage of: (*n = 14; 100% response rate*) [2,3]		
Steers		
0 to 25%	4	28.6%
26 to 50%	2	14.3%
51 to 75%	4	28.6%
76 to 100%	4	28.6%
Heifers		
0 to 25%	6	42.9%
26 to 50%	3	21.4%
51 to 75%	3	21.4%
76 to 100%	2	14.3%
Dairy		
0 to 25%	1	7%
26 to 50%	0	-
51 to 75%	0	-
76 to 100%	0	-
Percentage of total cattle considered as: (*n = 14; 100% response rate*)[2,3]		
High-risk		
0 to 25%	6	43%

26 to 50%	4	29%
51 to 75%	3	21%
76 to 100%	1	7%
Low-risk		
0 to 25%	1	7%
26 to 50%	5	36%
51 to 75%	3	21%
76 to 100%	5	36%

[1]Calf and yearling yard

[2]Number of responses per range for each category represent the number of respondents out of the total number of respondents (n = 14) for this question.

[3]Percentage of responses per range for each category represent the percentage of responses within each individual category out of the total number of respondents (n = 14) for this question.

Table 4.2. Description of feeding facilities of participating feedlots.

Item	No. of responses	% of responses
Use of sprinklers in pens for dust mitigation (*n = 14; 100% response rate*)		
Yes	4	29%
No	10	71%
Times per year manure is hauled or pens are cleaned? (*n = 14; 100% response rate*)		
Once	1	7%
Twice	12	86%
More than twice	1	7%
Stocking density (cattle/pen) of finishing pens (*n = 13; 93% response rate)*		
< 200	1	7.7%
201 to 250	11	84.6%
> 250	1	7.7%
Space allowance (m^2/animal) in finishing pens (*n = 14; 100% response rate*)		
14.03 to 23.23	14	100%
Bunk space allowance (cm/animal) in finishing pens (*n = 14; 100% response rate)*		
17.78 to 22.86	13	93%
33.02 to 38.10	1	7%
Water space allowance (cm/animal) in finishing pens (*n = 14; 100% response rate*)		
< 2.54	13	93%
10.16 to 15.24	1	7%
Use of shades in finishing pens (*n = 14; 100% response rate*)		
Yes	0	-
No	14	100%
Mounds in finishing pens (*n = 14; 100% response rate*)		
Yes	13	93%
No	1	7%
Description of dust situation in the feeding facility by season (*n = 14; 100% response rate*)[1,2]		
Spring		
Minimal	12	86%
Dusty	2	14%
Summer		
Dusty	5	36%
Dusty evening	8	57%
Very dusty	1	7%
Fall		
Minimal	11	79%
Dusty	2	14%
Very Dusty	1	7%
Winter		

Minimal	13	93%
Dusty	1	7%

[1]Number of responses for each category represent the number of respondents out of the total number of respondents (n = 14) for this question.
[2]Percentage of responses for each category represent the percentage of responses within each individual category out of the total number of respondents (n = 14) for this question.

Table 4.3. Description of feedlot performance of cattle fed in participating feedlots.

Item		No. of responses	% of responses
Target and actual dry-matter intake (kg/d) of finishing cattle (*n = 14; 100% response rate*)			
Target	Actual		
9.1	10.5	1	7%
9.5	9.5	1	7%
9.7	9.7	1	7%
10	9.1 to 10	11	79%
Target and actual average daily gain (kg/d) of finishing steers (*n = 14; 100% response rate*)			
Target	Actual		
3.1	3.2	1	7%
3.5	3.5	2	14%
3.7	3.7	11	79%
Target and actual average daily gain (kg/d) of finishing heifers (*n = 14; 100% response rate*)			
Target	Actual		
2.9	2.8	1	7%
3.0	3.0	11	79%
3.5	3.5	2	14%
Target and actual feed efficiency of finishing cattle (*n = 14; 100% response rate*)			
Target	Actual		
5.8	6.2	1	7%
6.0	6.0	1	7%
6.0	5.5 to 6.5	11	79%
6.8	6.6	1	7%
Average loss (%) in dry-matter intake of steers during windy/hot/dry days (*n = 14; 100% response rate*)			
< 2		1	7%
2 to 5		12	86%
> 5		1	7%
Average loss (%) in dry-matter intake of heifers during windy/hot/dry days (*n = 14; 100% response rate*)			
< 5		2	14%
5 to 10		11	79%
> 10		1	7%

Table 4.4. Description of nutrition program and ingredients used by participating feedlots.

Item	No. of responses	% of responses
Number of rations fed to finishing cattle (*n = 14; 100% response rate*)		
5	13	93%
6	1	7%
Number of feedings per day (*n = 14; 100% response rate*)		
2	1	7%
3	13	93%
Protein level of finishing diet (*n = 13; 93% response rate*)		
9 to 12	10	77%
13 to 15	3	23%
Main protein source used in finishing diet (*n = 12; 86% response rate*)[1]		
Urea	1	8%
Plant protein	1	8%
DDGS	11	92%
Canola meal	10	83%
Other[2]	11	92%
By-products used in finishing diet (*n = 12; 86% response rate*)[3]		
Wet distiller's grains plus solubles	1	8%
Dried distillers' grains plus solubles	11	92%
Tallow	10	83%
Trace mineral/Vitamin premix used in finishing diet? (*n = 13; 93% response rate*)		
Yes	13	100%
Ionophore used in finishing diet? (*n = 14; 100% response rate*)		
Monensin sodium[4]	14	100%
Melengestrol acetate (MGA) used in finishing diet? (*n = 13; 93% response rate*)		
Yes	13	100%
Macrolide used in finishing diet? (*n = 11; 79% response rate*)		
Tylosin phosphate	11	100%
Beta adrenergic agonist used in finishing diet? (*n = 14; 100% response rate*)		
None	1	7%
Ractopamine hydrochloride	13	93%
Other feed-grade antibiotics used in finishing diet (*n = 13; 93% response rate*)[5]		
Monensin sodium	11	85%
Tylosin phosphate	12	92%
Chlortetracycline	12	92%
Other feed additives used in finishing diet (*n = 12; 86% response rate*)		
Tallow	1	8%
Organic Zinc	11	92%

[1,3,5]Respondents could provide more than one answer. Number and percentage of responses represent the proportion of respondents that chose each answer.

[2]Corn, high-moisture corn, corn silage, forage, grain.

[4]Rumensin®, Elanco Animal Health, Greenfield, IN.

Table 4.5. Description of grain and roughage usage in finishing diets fed to cattle of participating feedlots.

Item	No. of responses	% of responses
Main grain source in finishing diet (*n = 14; 100% response rate*)		
Corn	3	21%
Barley	11	79%
Grain processing method used (*n = 14; 100% response rate*)[1]		
Steam-flaking	3	21%
High-moisture ensiling	2	14%
Dry-rolled (with tempered grain)	11	79%
Main roughage source in finishing diet (*n = 14; 100% response rate*)[2]		
Alfalfa	2	14%
Corn silage	11	79%
Barley silage	11	79%
Silage (unspecified)	2	14%
Percentage of roughage fed in finishing diet (*n = 14; 100% response rate*)		
8 to 10	11	79%
10 to 12	1	7%
> 12	2	14%

[1,2]Respondents could provide more than one answer. Number and percentage of responses represent the proportion of respondents that chose each answer.

Table 4.6. Description of growth promoting implant strategies used in cattle of participating feedlots.

Item	No. of responses	% of responses
Initial implant administered to steers (*n = 14; 100% response rate*)		
Revalor-IS[1]	1	7%
Component E-S with Tylan[2]	1	7%
Component TE-IS with Tylan[3]	1	7%
TBA	11	79%
Days-on-feed at which initial implant is administered to steers (*n = 13; 93% response rate*)		
1	13	100%
Implant administered to steers at re-implant (*n = 14; 100% response rate*)		
Revalor-200[4]	1	7%
Component TE-200[5]	2	14%
TBA	11	79%
Days-on-feed at which terminal implant is administered to steers (*n = 13; 93% response rate*)		
Last 70 days-on-feed	1	8%
Last 80 days-on-feed	12	92%
Initial implant administered to heifers (*n = 14; 100% response rate*)		
Revalor-IH[6]	1	7%
Component TE-IH with Tylan[7]	1	7%
Component E-H[8]	1	7%
TBA	11	79%
Days-on-feed at which initial implant is administered to heifers (*n = 13; 93% response rate*)		
1	13	100%
Implant administered to heifers at re-implant (*n = 14; 100% response rate*)		
Revalor-200[9]	1	7%
Component TE-200[10]	2	14%
TBA	11	79%
Days-on-feed at which terminal implant is administered to heifers (*n = 13; 93% response rate*)		
Last 70 days-on-feed	1	8%
Last 80 days-on-feed	12	92%

[1,4,6,9]Merck Animal Health, Intervet Inc., Madison, NJ.
[2,3,5,7,8,10]Elanco Animal Health, Greenfield, IN.

Table 4.7. Description of cattle processing protocols of participating feedlots.

Item	No. of responses	% of responses
Rest period required for long haul (> 8 hr) cattle prior to processing? (*n = 14; 100% response rate*)		
Yes	14	100%
Length (hr) of rest period prior to processing (*n = 14; 100% response rate*)		
< 12	11	79%
12 to 24	1	7%
> 24	2	14%
Use of injectable mineral supplement (*n = 14; 100% response rate*)		
No	14	100%
When do you sort cattle? (*n = 14; 100% response rate*)		
Arrival	1	7.1%
Re-implant	9	64.3%
Arrival and re-implant	3	21.4%
Don’t sort	1	7.1%

Table 4.8. Description of cattle vaccination protocols of participating feedlots.

Item	No. of responses	% of responses
Vaccines used for high-risk cattle (*n = 13; 93% response rate*)		
Infectious Bovine Rhinotracheitis	13	100%
Bovine Respiratory Syncytial Virus	13	100%
Bovine Viral Diarrhea, Type 1	13	100%
Bovine Viral Diarrhea, Type 2	12	92%
Parainfluenza-3	12	92%
Clostridials	12	92%
Mannheimia haemolytica	11	85%
Histophilus somni	10	77%
Pasteurella multocida	1	8%
Vaccines used for low-risk cattle (*n = 13; 93% response rate*)		
Clostridials	13	100%
Infectious Bovine Rhinotracheitis	13	100%
Parainfluenza-3	12	92%
Bovine Respiratory Syncytial Virus	2	15%
Bovine Viral Diarrhea, Type 1	2	15%
Bovine Viral Diarrhea, Type 2	1	8%
Metaphilaxis used for: (*n = 13; 93% response rate*)		
High-risk cattle only	13	100%
Which cattle gets re-vaccinated? (*n = 13; 93% response rate*)		
High-risk cattle only	13	100%
Time period at which cattle is re-vaccinated (*n = 14; 100% response rate*)		
10 days	1	7%
14 days	1	7%
10 and 21 days	1	7%
At re-implant	11	79%
Vaccines used for re-vaccination (*n = 12; 86% response rate*)		
Infectious Bovine Rhinotracheitis	12	100%
Parainfluenza-3	11	92%
Liver abscess vaccines administered to cattle? (*n = 14; 100% response rate*)		
No	14	100%

Table 4.9. Descriptive statistics on AIP incidence in cattle of participating feedlots (*n = 13; 93% response rate*).

Overall AIP incidence (%) by season of the year[1]				
Item	**Winter**	**Spring**	**Summer**	**Fall**
Mean	0.06	0.08	0.09	0.03
Standard Error	0.01	0.01	0.01	0.005
Median	0.05	0.08	0.09	0.03
Mode	---	0.12	0.12	---
Standard Deviation	0.04	0.03	0.03	0.02
Minimum	0.00	0.04	0.02	0.00
Maximum	0.15	0.14	0.13	0.06

Average AIP incidence (%) by season of the year and geographical location[1]				
Location	**Winter**	**Spring**	**Summer**	**Fall**
West Kansas	0.04	0.05	0.10	0.04
Southern Alberta	0.06	0.09	0.09	0.03

Weekly AIP cases out of total cattle in feedlot during AIP peak season		
Item	**AIP cases**	**Total cattle on feed**
Mean	45.69	27,842
Median	40.00	18,988
Mode	40.00	---
Range	87.00	92,315
Minimum	10.00	7,685
Maximum	97.00	100,000
Sum	594.00	361,942

Average weekly AIP cases out of total cattle on feed during AIP peak season by geographical location		
	AIP cases	**Total cattle on feed**
West Kansas	25	70,000
Southern Alberta	50	20,177

[1]AIP incidence reported by feedlots reflects the percentage of deaths due to AIP per month of each season, also referred to as "month to date" incidence.

Table 4.10. Description of AIP and BRD incidence and mortality by month of participating feedlots in southern Alberta, Canada (n = 11).

Item	May	June	July	August	September
AIP Incidence, %	0.056	0.085	0.060	0.050	0.040
AIP Mortality, %	0.011	0.020	0.011	0.010	0.008
BRD Incidence, %	0.749	0.774	0.541	0.455	1.580
BRD Mortality, %	0.028	0.034	0.021	0.010	0.014
Digestive Mortality, %	0.029	0.026	0.028	0.037	0.021

Table 4.11. Description of AIP and BRD incidence and mortality by month and geographical location of participating feedlots in Kansas, USA (n = 2).

	Southwest Kansas				
Item	**May**	**June**	**July**	**August**	**September**
AIP Incidence, %	0.073	0.046	0.117	0.041	0.059
AIP Mortality, %	0.012	0.046	0.026	0.000	0.044
BRD Incidence, %	2.7	3.6	1.9	3.4	5.7
BRD Mortality, %	0.45	0.71	0.40	0.47	0.28
Digestive Mortality, %	0.11	0.08	0.12	0.10	0.10

	West Kansas				
	May	**June**	**July**	**August**	**September**
AIP Incidence, %	0.082	0.226	0.044	0.100	0.080
AIP Mortality, %	0.022	0.042	0.059	0.030	0.012
BRD Incidence, %	2.0	1.9	1.1	2.1	2.4
BRD Mortality, %	0.08	0.06	0.06	0.06	0.09
Digestive Mortality, %	0.05	0.07	0.09	0.08	0.06

Figure 4.1. Bunk orientation in finishing pens. (*n = 14; 100% response* rate).

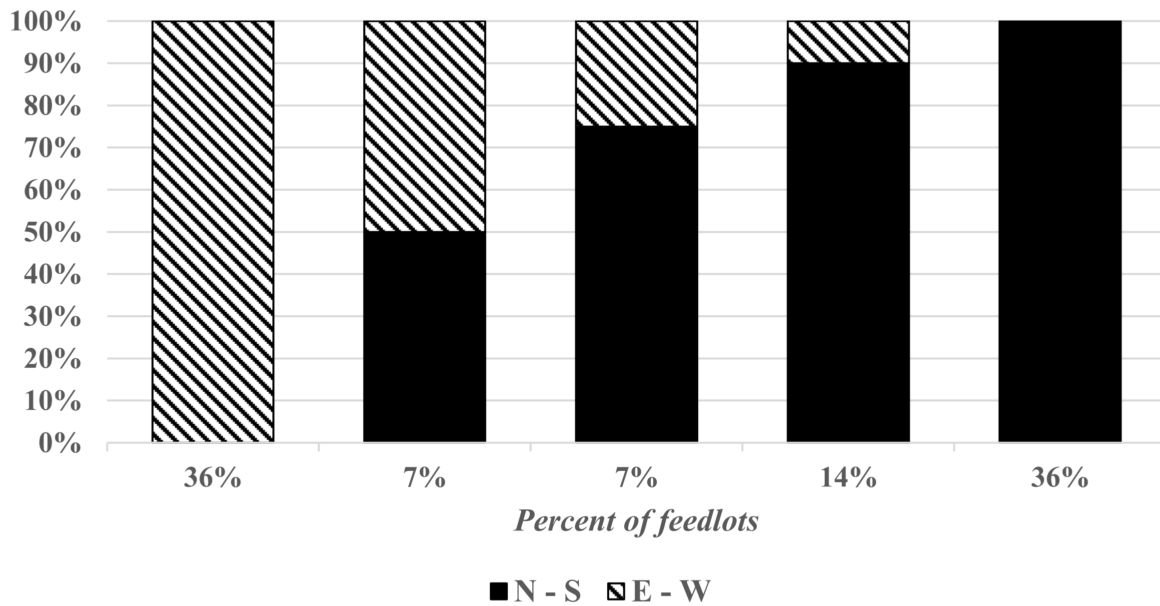
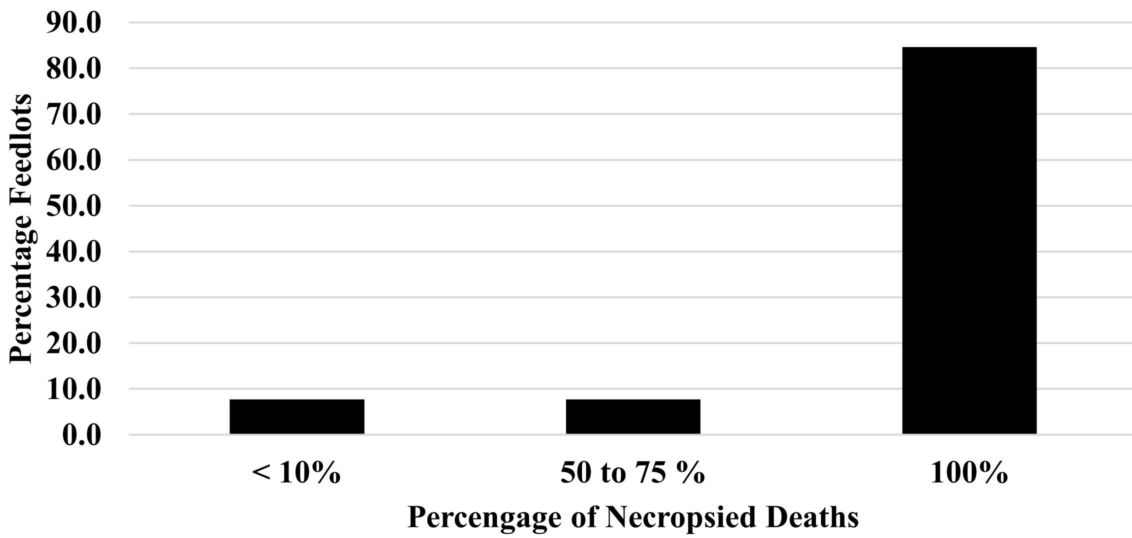


Figure 4.2. Percentage of cattle deaths necropsied by participating feedlots (*n = 13; 93% response* rate).



Chapter 5 - Effects of periodic feeding long-stemmed, low-quality roughage on intake, ruminal fluid dynamics, ruminal fermentation parameters, and fecal starch concentration of finishing Holstein steers

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ABSTRACT

Roughage is a vital constituent of the ruminant diet to maximize animal performance and gastrointestinal health of feedlot cattle. Defining fiber requirements for feedlot cattle is vital but not easily accomplished, as the optimal roughage concentration in finishing diets is influenced by multiple factors. The objective of this study was to evaluate the effects of periodic feeding of low-quality long-stemmed roughage, provided by corn stalks (CS), in Holstein steers fed a steam-flaked corn (SFC)-based finishing diet on intake, ruminal fluid dynamics, ruminal fermentation parameters, and fecal starch concentration. Six ruminally cannulated Holstein steers were used in a 2 x 6 Latin rectangle experiment consisting of two 27 d experimental periods, with 17 d for adaptation and 4 days for sample collection. Dietary treatments included a positive control consisting of a traditional SFC-based finishing diet with 8% roughage and a high-roughage diet (HR) consisting of 0.225% of body weight dry-matter basis of CS fed once per week in addition to the concentrate diet fed daily. Periodic feeding of CS had no effect ($P \geq 0.41$) on DMI of finishing steers. Average daily intake of CS was not different ($P \geq 0.46$) between experimental periods. Ruminal fluid dynamics were not affected ($P \geq 0.18$) by periodic feeding of CS. Ruminal fermentation parameters, pH and volatile fatty acid (VFA) concentrations, of steers were not affected ($P \geq 0.56$ and $P \geq 0.15$, respectively) by periodic feeding of CS. Fecal starch concentration was not different ($P = 0.18$) between treatments in this experiment.

Key words: Holstein, roughage, ruminal dynamics, fermentation, intake

INTRODUCTION

Roughage is a vital constituent of the ruminant diet that helps to maximize animal performance and gastrointestinal health, particularly of feedlot cattle. Roughage is added to high-concentrate finishing diets in minimal levels to stimulate chewing, which is associated with increased saliva production (Loya-Olguin et al., 2008). Adding roughage and increasing NDF concentration of feedlot diets increases chewing time, saliva production, and ruminal motility (Allen, 1997; Armentano and Pereira, 1997; Clark and Armentano, 1999). In consequence, an increase in the NDF concentration of the diet should increase ruminal pH and reduce the time that pH is low (Galyean and Hubbert, 2014). Small increases in the concentration of roughage in the diet and changes in fiber content of roughage sources could potentially increase DMI by feedlot cattle (Galyean and Defoor, 2003). As a consequence of an increased DMI, increased saliva production as a result of greater chewing during eating and rumination could aid in buffering the acidity of the ruminal environment of cattle fed high-concentrate diets (Owens et al., 1998).

Both roughage level and source influence DMI and, in consequence, NEg intake (Defoor et al., 2002), which has a significant effect on performance and carcass characteristics of feedlot cattle. The effects of larger changes in roughage level (> 5% of DM) on DMI might simply reflect energy dilution (Galyean and Defoor, 2003), so that adding a bulky and fibrous roughage source to a high-concentrate diet should increase DMI of cattle as the animal is compensating for the diluting effect of increased NDF and maintaining the same energy intake (Galyean and Hubbert, 2014). Defining fiber requirements for feedlot cattle is vital but not easily accomplished, as the optimal roughage concentration required in finishing diets changes continuously for many reasons such as source, availability, price, and interaction with other ingredients in the diet (Hales et al., 2014). Also, adjusting dietary fiber with a wide variety of ingredients and by-products can influence multiple aspects of the diet, which can generate different interrelated animal responses. Low roughage levels increase the incidence of digestive upsets in feedlot cattle, compromising ruminal tissue integrity (Steele et al., 2011), increasing the risk of liver abscesses (Nagaraja and Chengappa, 1998) and other nutritionally related disorders (Galyean and Rivera, 2003). However, most finishing diets generally contain 6.0 to 12.0% (DM basis) roughage (Samuelson et al., 2016).

Morine et al. (2014a, b) evaluated the effects of feeding varying concentrations of NDF on ruminal pH and DMI. Increasing NDF can increase ruminal pH, indicating a less acidic environment that could potentially lead to increased DMI and ultimately improved performance. Fiber from long forages has well-known gross physical effects in rumen mat formation and stimulation of rumen motility and chewing (Armentano and Pereira, 1997). Galyean and Hubbert (2014) reported some unpublished work that indicated a numerical increase in DMI in cattle fed 0.225% of BW on a dry matter basis of low quality roughage once per week on top of a finishing diet, indicating a potential response from interval feeding of a low quality roughage to finishing cattle. Hales et al. (2013) reported that a 4% increment in roughage level (2 to 6% alfalfa hay) increased ADG and DMI of finishing steers, but further increasing roughage level (10 and 14%) decreased gain and had little effect on DMI. Similarly, Bartle and Preston (1991) reported that increasing the roughage level from 2 to 10% after d 84 of the finishing period stimulated feed intake and steer performance, whereas an increase in roughage content of the diet (10 to 20%) also resulted in increased DMI of finishing steers (Bartle and Preston, 1992). Similar results are reported by Gill et al. (1981) and Kreikemeier et al. (1990), who saw an increased DMI by finishing steers offered diets with increasing roughage levels. The traditional approach for adding roughage to feedlot finishing diets is to choose a level and source of roughage and feed it for the duration of the feeding period (Bartle and Preston, 1992; Galyean and Hubbert, 2014), but more research in determining frequency and concentration of physically effective NDF added to finishing diets is needed. Galyean and Hubbert (2014) also suggested that more research is needed to determine the relationship between NDF, chewing time, saliva production, ruminal pH, and DMI in feedlot cattle fed high-concentrate diets.

The increasing concern of antibiotic resistance to human and animal health has caused the FDA to restrict the use of medically important antibiotics in animal production. The main concern is associated with daily use of feed-grade antibiotics in animal feeds and one that has been deemed as medically important to both humans and animals by the FDA, WHO, and CDC is tylosin phosphate. In midst of these challenging regulations for the use of tylosin phosphate for the prevention and control of liver abscesses in beef cattle production in the near future new strategies need to be found to control and prevent liver abscess incidence. Having this in mind, we hypothesized that increasing roughage intake by finishing cattle could play a role, through some mechanism, in improving ruminal health and ultimately aid in reducing liver abscess prevalence. Bartley et al. (1981) suggested that the most important attribute of roughage is its scratch factor effect, which plays an important role in maintaining health and integrity of the ruminal papillae and ruminal epithelium. Providing cattle with a source of roughage that has an effective scratch factor in the rumen could be a very effective method of reducing liver abscess prevalence (Reinhardt and Hubbert, 2015). Offering finishing cattle a roughage source that provides a reduced scratch factor can potentially result in an altered structure of the ruminal papillae and compromise rumen function. A healthy and morphologically normal looking ruminal epithelium will result in a larger absorptive surface, hence, higher rates of nutrient absorption (Nagaraja and Lectenberg, 2007), leading to increased rates of VFA absorption and having the potential to positively influence ruminal pH. Providing cattle with a roughage source that has an effective scratch factor, could also potentially influence rumination, increasing mastication activity, which ultimately results in an increase in saliva production with high buffering capacity. These two factors, increased VFA absorption and increased saliva production, could play an important role in liver abscess control and prevention in feedlot cattle. Thus, the objective of this study was to evaluate the effects of periodic feeding of low-quality long-stemmed roughage in Holstein steers fed a SFC-based finishing diet on intake, ruminal fluid dynamics, ruminal fermentation parameters, and fecal starch concentration.

MATERIALS AND METHODS

All procedures and live animal use protocols for this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee (IACUC #3772).

Animals, Experimental Design, and Treatments

Six ruminally cannulated Holstein steers (initial BW = 597 ± 32 kg) were used in a 2 x 6 Latin Rectangle design consisting of two periods (597 and 653 kg BW at the initiation of period 1 and 2, respectively). Each experimental period lasted 27 d, with 17 d for adaptation and 10 days for sample collection (samples were collected on day 18, 21, 24, and 27 of each experimental period). Steers were housed individually in 3.6 x 18 m partially covered outdoor pens equipped with individual feed troughs and individual water tanks. Dietary treatments included a positive control consisting of a traditional SFC-based finishing diet (Table 1) with 8% roughage and a high roughage diet (**HR**) consisting of 0.225% of body weight (BW) dry-matter (DM) basis of low-quality long-stemmed roughage provided by corn stalks (CS) fed once per week in addition to the CTRL diet fed daily. Tylosin phosphate was not included in the finishing diet fed to cattle. Steers had constant access to CS, which was provided in a separate feeder adjacent to the bunk were concentrate was fed on days 1, 8, 15, and 22 of each experimental period. Cattle were fed to ad libitum intake at 0800 h each day and weighed at the beginning of each 27-d period.

Sampling

Concentrate, Hay, and Orts. Concentrate and CS offered and orts were measured and recorded daily. Concentrate samples were collected daily and composited weekly for DM determination, and then composited by period. Corn stalk samples were collected once weekly (on every day that fresh CS were offered to cattle) for DM determination and then composited by period. Concentrate and CS samples were dried in a forced-air oven at 100°C for 24 h (Isotemp® Premium Ovens, model 737F; Fisher Scientific, Dubuque, IA) for DM determination and then retained for determination of chemical composition.

Feed and Roughage Intake (Dry Matter Intake). Dry matter intake for both feed and roughage was calculated for each individual steer for each one of the experimental periods. Daily feed DM samples, weekly CS DM samples, and weight from dried orts were used to calculate the average daily DMI by cattle in each pen for each experimental period. Daily DMI for each individual steer was calculated by subtracting orts DM from concentrate DM offered.

Ruminal Fluid Dynamics. Fluid dilution rate of digesta from the rumen was measured using cobalt-ethylenediamine tetraacetic acid (Co-EDTA) as a liquid flow marker. Methods used to prepare Co-EDTA solutions were those of Uden et al. (1980) and Galyean (2010). On the morning of d 18 of each experimental period a 200 mL dose of a Co-EDTA solution (1.05 g of cobalt) was delivered intraruminally to each steer via the ruminal cannula immediately before feeding. Whole ruminal fluid samples (?? mL) were collected via ruminal cannulas at 0, 3, 6, 9, 12, 18, and 24 h after feeding. Ruminal fluid samples were strained through 4 layers of cheese cloth and transferred into a 50-mL plastic centrifuge tube and immediately frozen at -20°C for later analysis of Co concentration.

Ruminal pH and VFA. On days 21, 24, and 27 of each experimental period rumen content samples were obtained at 0, 3, and 6 h post-feeding to determine ruminal pH and VFA concentration. Ruminal fluid samples were strained through 4 layers of cheese cloth and collected into a 250-mL container. Ruminal fluid pH was immediately measured using a portable pH meter (iCooker Digital pH Meter//Cardy Twin pH Meter, Model B-213, Spectrum Technologies, Inc., Plainfield, IL). After pH was measured, a 200-mL aliquot was transferred into a plastic container and acidified with 2 mL of 6.0 *M* HCl. Ruminal fluid samples were then frozen at -20°C for later analysis of VFA concentration.

Fecal Starch. On days 21, 24, and 27 of each experimental period fecal samples were obtained at 6 h post-feeding to determine fecal starch content. Approximately 100 g of fecal material were collected at one time via rectal palpation. Fecal samples were stored in Whirlpack-type bags and immediately frozen at -20°C for later analysis of starch content.

Analytical Procedures

Co-EDTA. Ruminal fluid samples were thawed at 4°C for 12 h and then centrifuged at 20,000 *x g* for 20 min at 4°C. Supernatant fraction was collected and analyzed for Co concentration. Cobalt concentrations in rumen fluid samples were determined by atomic absorption spectroscopy (AAnalyst 100, Perkin Elmer Inc., Waltham, MA). Ruminal fluid dynamics were calculated as suggested by Grovum and Williams (1973) and Galyean (2010). Fluid dilution rate was determined by regression of the natural logarithm of the ruminal Co concentration on time. The fluid dilution rate was calculated using the absolute value of the slope of the regression equation. Ruminal fluid volume was then determined by dividing the Co dose by the antilogarithm of the marker concentration at time zero. Total turnover time was calculated from the inverse of the fluid dilution rate, and fluid flow was calculated by multiplying the ruminal fluid volume by the fluid dilution rate.

Ruminal Volatile Fatty Acid Concentration. Ruminal fluid samples were thawed at 4°C for 12 h and then centrifuged at 10,000 *x g* for 10 min. One milliliter of the supernatant fraction was mixed with 0.25 mL of a 25% meta-phosphoric acid solution and frozen to promote better protein precipitation. Samples were then thawed and centrifuged at 17,000 *x g* for 15 min. Supernatant fraction was collected and transferred to 12 x 32 mm vials and used for VFA analysis. Volatile fatty acid concentrations in rumen fluid samples were determined by gas chromatography (GC; HP 5890, Hewlett-Packard Co., Wilmington, DE) using a packed column (1.83 m by 6.35 mm, 4 mm ID glass, packed with GP 10% SP-1200/1% H_3PO_4; Supelco # 1-1965, Bellefonte, PA) and flame ionization detection.

Fecal Starch. Starch concentration in fecal samples was determined using enzymatic hydrolysis following the procedure described by Schwandt et al. (2016). Wet fecal samples were dried at 60°C for 48 h in a forced-air oven and then ground through a 1-mm screen. Duplicate samples of 100 mg were weighed into 35-mL screw cap tubes with Teflon lined screw caps. All tubes received 25 mL of acetate buffer and 50 µL of heat stable α-amylase (specify product) and mixed gently. Tubes were then placed in a 95°C water bath for 30 min and shaken during incubation. Tubes were then transferred to a 60°C water bath, allowed to cool for 15 min, received 100 µL of glucoamylase, and incubated overnight. Tubes were then removed from the water bath, centrifuged at 5 *x g* for 10 min, and supernatant fraction was transferred into a vial and refrigerated. Glucose analysis was performed using the BioTek Power Wave XS plate reader and Wako Glucose Autokit (Wako Pure Chemical Industries, 99703001), and starch content was calculated from the glucose values obtained.

Statistical Analysis

Data were analyzed as a Latin rectangle using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included fixed effects of treatment and period. Steer was included as a random effect. Fecal starch data was analyzed as a repeated measures over time analysis and the subject included pen x period, with pen as random effect and day was included as a fixed effect in the model. Analyses of rumen fermentation parameters (pH and VFA) were performed using a doubly repeated measures over time (day and sampling time) analysis and the subject included pen x period. The model statement included treatment, day, sampling time, and period as fixed effects, and pen was included as random effect. The best fit covariate structure was chosen based on the lowest Akaike and the lowest Bayesian information criterion statistics (for pH, acetate, isobutyrate, valerate, isovalerate, and acetate:propionate ratio: direct product unstructured covariance matrix; for butyrate and propionate: direct product compound symmetry covariance matrix). The Kenward-Roger method was used to adjust degrees of freedom in the models. Mean separation was performed using the LSMEANS statement with PDIFF option and adjusted using Tukey's test in SAS. Significance was declared at $P \leq 0.05$, and trends were declared at $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

Altering methods of roughage delivery, such as feeding a lower level of dietary roughage with intermittent delivery of additional dietary roughage or coarser forms of roughages that stimulate chewing or alter digesta passage rate, might provide a means of decreasing overall roughage use without compromising animal health and performance (Galyean and Hubbert, 2014). A common practice by feedlots is to process roughages to increase digestibility and improve handling when included in finishing diets. Its inclusion is limited mainly due to its cost per unit of energy, however, increasing particle size of roughage or feeding additional long-particle roughage to cattle may allow to reduce dietary roughage inclusion without affecting performance and maintaining or improving ruminal health (Gentry et al., 2016).

No treatment x day or treatment x day x hour interactions were observed for any of the evaluated parameters in this study; therefore, only main effects, if any, will be discussed.

Dry Matter Intake

Concentrate and total daily DMI are presented in Table 2. Concentrate intake by beef cattle fed high-energy, grain-based diets is controlled by metabolic factors rather than ruminal fill, but small increases in dietary roughage concentration or increases in the fiber content of roughage sources typically results in increased DMI (Galyean and Defoor, 2003). In this study, however, periodic feeding of low-quality long-stemmed roughage had no effect ($P > 0.41$) on concentrate or total daily DMI. Each steer in the HR treatment was offered 1.25 kilograms of additional roughage weekly in average. Steers did not eat all of the available roughage at once, instead they ate small amounts of roughage every day in addition to concentrate. Average weekly

CS intake was 0.744 kg by steer, which equated to 0.106 kg per day. Figure 5.1 shows the average CS daily intake pattern for each 7 d period. In addition, average daily intake of CS by steers in this study was not different ($P \geq 0.46$; SEM=0.03) between experimental periods (0.12 vs. 0.10 kg/d for period 1 and 2, respectively; data not shown). Similarly, Weiss et al. (2017) observed that roughage inclusion level and particle size had no effect on DMI of cannulated steers fed a SFC-based diet with wet corn gluten feed (**WCGF**) inclusion, and using CS as roughage source. Loya-Olguin et al. (2008) reported that no differences were detected in DMI when feeding SFC-based diets with increasing forage levels to ruminally cannulated Holstein steers. However, in a companion study, Loya-Olguin et al. (2008) observed contrasting results; finishing steers fed a SFC-based diet had increased DMI as dietary forage level increased from 8 to 14%. Furthermore, several reports have been published in the literature (Crawford et al., 2008; Morine et al., 2014b; Morrow et al., 2013) in which increasing dietary roughage level in high-grain finishing diets had no effect on DMI of ruminally cannulated beef cattle.

Cattle fed high-concentrate diets typically increase DMI when a bulky, fibrous ingredient is added to a finishing diet (Galyean and Hubbert, 2014) or when additional roughage sources dilute energy concentration of the diet (Bartle et al., 1994; Galyean and Defoor, 2003). This theory is put into practice by consulting nutritionists who increase dietary roughage levels during the winter to stimulate DMI (Vasconcelos and Galyean, 2007; Samuelson et al., 2016). Steers on the HR treatment on this study may not have been able to increase DMI to compensate for such a dilution of the dietary energy content due to a ruminal physical fill, as suggested by Owens et al. 1998), although physical fill would rarely limit intake of high-grain diets (Galyean and Defoor, 2003). However, at the different time points that rumen fluid samples were collected during this experiment it was observed that rumens from steers on the HR treatment were not completely full. Although a rumen mat, of approximately 2 to 2.5 inches thick, could be observed, completely full rumens were never really observed. An important factor to consider when trying to define optimal total roughage intake (dietary and additional) by finishing cattle is defining the maximum roughage level before reaching the point where physical restriction will limit a further increase in DMI. The similarities in DMI by cattle observed in this study may be attributed to the heavier weights of cattle at the time of starting experimental periods. Cattle could have been close to or reached their maximum intake potential at this time, which could have limited a further increase in DMI as result of feeding CS. Furthermore, the finishing diet included WCGF as the second major ingredient, a high-fiber byproduct that could have potentially play a role in ruminal bulk fill at higher feed intakes.

For finishing diets that do not contain distiller's grains, similar to the diet used in this study, inclusion of roughage up to approximately 15% of dietary DM typically results in increased DMI by cattle (Kreikemeier et al., 1990; Defoor et al., 2002). However, several studies (Sindt et al., 2003; Farran et al., 2006; Parsons et al., 2007) reported that roughage inclusion may be reduced without negatively affecting cattle performance when feeding finishing diets containing WCGF. Wet corn gluten feed is a high-fiber feedstuff that contains extensively fermentable fiber (Blasi et al., 2001) because its fiber is not lignified (Galyean and Hubbert, 2014). Dietary roughage source and concentration can both influence DMI of finishing cattle (Guthrie et al., 1996). Bartle and Preston (1991) and Bartle et al. (1994) reported that large increases in dietary roughage level stimulated DMI by finishing steers, however, according to Galyean and Defoor (2003) it is doubtful that small variations in dietary roughage source or level affect energy density enough to account for large shifts in DMI as a result of these variations.

Ruminal Fluid Dynamics

Ruminal fluid dynamics were calculated using Co-EDTA as a liquid flow marker. Co-EDTA has been shown to be a reliable external marker in high-concentrate diets for liquids (Sindt et al., 1993), and it is widely used to measure ruminal liquid dilution rate for research purposes (Arias et al., 2013; Klein et al., 2015, Siverson et al., 2014).

Ruminal fluid dynamics (Table 3) in this study, including fluid dilution rate, fluid flow rate, rumen fluid volume, and turnover time, were not affected ($P \geq 0.18$) by periodic feeding of CS to finishing Holstein steers. Although fluid dilution rate is typically greater for diets with a high content of roughage as opposed to concentrate (Goetsch and Galyean, 1982) and ruminal fluid kinetics are affected by roughage type and level (Poore et al., 1990), no differences were observed between treatments in this experiment. In agreement with findings from this study Loya-Olguin et al. (2008) reported that forage level (8 vs 14%) had no effect on ruminal fluid dynamics of cannulated Holstein steers. Similarly, Crawford et al. (2008) reported that ruminal fluid dynamics did not differ between treatments when feeding typical high-grain finishing diets with increasing dietary roughage levels to ruminally cannulated steers. Furthermore, Shain et al. (1999) reported no differences in ruminal dilution rate of liquid, corn, or forage when 10% alfalfa hay, 5.6% wheat straw, or 5.4% corn cobs was added to dry-rolled corn-based diets with similar dietary NDF.

Changes in passage of dietary components from the rumen could be related to changes in DMI resulting from differences in roughage source and level (Galyean and Defoor, 2003). As DMI intake increases, ruminal liquid volume, DM percentage in ruminal contents, and total passage rate typically increase (Galyean et al., 1979; Van Soest, 1982). However, because no differences in DMI by cattle were observed in this experiment as a result of periodic feeding of

CS, the similarities in ruminal fluid dynamics between the two treatments can be expected to a certain degree. Slower fluid dilution rate has been observed with increased concentrate in the diet (Cole et al., 1976b; Goetsch and Galyean, 1982), whereas an increased proportion of roughage in the diet should increase the fluid dilution rate (Owens and Isaacson, 1977). Owens et al. (1998) noted that an increase in dietary roughage content will result in an increase in chewing time and a subsequent increase in saliva production from increased chewing, which could be expected to increase ruminal fluid dilution rate (Russel and Chow, 1993).

Ruminal Fermentation Parameters

Effects of long-stemmed roughage feeding on ruminal fermentation characteristics of finishing Holstein steers are presented in Table 4. Ruminants require roughage in their diets to maximize production and to maintain gastrointestinal health by sustaining a stable environment in the rumen. Ruminal pH is very responsive to meals and chewing behavior, typically decreasing following meals and increasing during rumination (Allen, 1997). Increasing the amount of roughage in the diet has been shown to increase time spent chewing, saliva secretion, and the amount of buffer in the rumen (Beauchemin and Yang, 2005). Therefore, increasing roughage intake by finishing cattle should increase ruminal pH and decrease the daily fluctuation in ruminal pH. However, ruminal pH of cannulated Holstein steers was not affected ($P \geq 0.56$) by periodic feeding of CS in this study (Table 4). Similar to results from this study, Morrow et al. (2013) observed that increasing dietary hay concentration did not affect pH of ruminal cannulated heifers, although they observed a tendency of ruminal pH to increase from 0 to 3 h post-feeding. Cole et al. (1976a) noted that dietary roughage addition had no effect on ruminal pH or total VFA concentration, whereas Zinn et al. (1994) reported that increasing dietary roughage concentration increased ruminal pH. Benton et al. (2015) observed an increase in ruminal pH as dietary roughage inclusion increased in high-grain diets fed to cannulated steers. Felix and Loerch (2011) also observed an increase in ruminal pH as roughage inclusion was increased in dry-rolled corn diets containing 60% dried distiller's grains fed to cannulated steers. Morine et al. (2014a,b) reported that ruminal pH of finishing steers increased linearly as roughage NDF increased from 3.5 to 11%, and Weiss et al. (2017) observed a significant increase in ruminal pH for cattle consuming increasing (5 vs. 10%) dietary roughage inclusion rates. Furthermore, multiple publications (Calderon-Cortes and Zinn, 1996; Crawford et al., 2008; Shain et al., 1999; White and Reynolds, 1969) have reported that ruminal pH of finishing beef cattle increases as dietary roughage concentration increases.

Individual ruminal VFA concentrations for acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate, total VFA, and acetate:propionate ratio (**A:P**) are reported in Table 4. Periodic feeding of CS to finishing Holstein steers had no effect ($P \geq 0.15$) on individual VFA concentration, total VFA, or A:P ratio in this study. In agreement with our findings, Cole et al. (1976a) reported that roughage addition had no effect on ruminal total VFA concentration. Loya-Olguin et al. (2008) reported that forage level (8 vs 14%) had no effect on total VFA, propionate concentration, and A:P ratio of cannulated Holstein steers; however, ruminal acetate concentration increased with increasing forage level. Similarly, Crawford et al. (2008) observed that roughage concentration had no effect on total VFA concentration or molar proportions of propionate, butyrate, valerate, isobutyrate, or isovalerate when finishing steers were fed a SFC-based diet with increasing levels of corn silage, but molar proportion of acetate tended to increase with increasing roughage concentration. Furthermore, in a companion metabolism trial, Crawford et al. (2008) observed that total VFA concentration was not affected when finishing steers were fed a corn-based diet (HMC:DRC blend) with increasing levels of alfalfa hay. However, molar proportion of acetate increased linearly, molar proportion of propionate responded quadratically (highest at 9%), and molar proportion for butyrate and A:P responded quadratically (lowest at 9%) to increasing roughage inclusion (Crawford et al., 2008). Nonetheless, Zinn et al. (1994) reported that increasing dietary roughage concentration decreased total VFA. Kreikemeier et al. (1990), in contrast, reported an increase in total VFA concentrations with increased dietary roughage concentration. Shain et al. (1999) reported an increase in ruminal acetate concentration and A:P ratio when steers were fed diets with wheat straw compared with diets containing no roughage. Similarly, Weiss et al. (2017) observed greater total VFA concentrations for diets with lower roughage concentration (5 vs. 10%); molar proportions of acetate and A:P were greater, and molar proportions of propionate were lower for cattle fed diets containing a higher concentration of roughage.

Fecal Starch

Fecal starch concentration was not affected ($P = 0.18$) by feeding long-stemmed low-quality roughage to finishing Holstein steers in this experiment (Table 5). In agreement to our findings, Crawford et al. (2008) reported no differences in fecal starch excretion of cattle fed SFC-based diets with increasing roughage level. Similarly, forage particle size and inclusion rate (5 vs. 10% CS) did not affect fecal starch concentration of finishing steers fed a SFC-based diet with WCGF (Gentry et al., 2016). Furthermore, Choat et al. (2002) observed that finishing diets with increasing dietary roughage concentration replacing DRC did not affect fecal starch output by finishing steers. Xiong et al. (1991) reported that dietary roughage level (9 vs. 18%) had no effect on fecal starch excretion of finishing steers.

In contrast, Weiss et al. (2017) observed that fecal starch concentration of finishing steers increased with increasing dietary roughage concentration. Shifts in the site of starch digestion from the rumen to the intestines could be associated with increased dietary roughage through an increased rate of passage of the grain portion of the diet (Owens and Goetsch, 1986). Cole et al. (1976a) reported a trend for decreased ruminal and total tract starch digestibility for diets based on whole-shelled corn as the level of cottonseed hulls was increased from 0 to 21% of the diet. Similarly, Turgeon et al. (1983) reported that fecal starch decreased linearly as roughage level increased in high-grain diets fed to finishing steers.

IMPLICATIONS

Although it is well documented that dietary roughage source and level can have important effects on DMI, ruminal fermentation parameters, ruminal digesta dynamics, and fecal starch concentration of feedlot cattle fed high-concentrate diets, no differences as a result of feeding additional long-stemmed, low-quality forage were observed in this experiment. Factors such as cattle type, cattle weight, level of long-stemmed low-quality forage fed, and duration of adaptation periods could have been the cause for the similarities observed between treatments in our experiment. However, it is important to note that no negative effects on intake or fermentation parameters were observed as a result of cattle eating additional long-stemmed roughage. Optimal roughage source and level of feedlot diets depends on a multitude of factors, including cattle breed or type, DMI level, total starch availability, rate of starch digestion, dietary protein and fat source and concentration, and feeding management. An alternative approach to decrease overall roughage use in feedlot diets is to find a different strategy to incorporate roughage into finishing diets, while increasing or maintaining cattle performance and having the potential to improve ruminal health and reducing metabolic disorders of digestive origin. Further research is warranted to test the approach used in this experiment but using beef cattle of lighter weights, increasing periodicity of feeding additional forage, considering an increased level of additional roughage, or a longer adaptation period of cattle to treatments.

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Table 5.1. Ingredient and calculated nutrient composition of finishing diet (DM basis, except DM)

Item	
Ingredient, % of DM	
Steam-flaked corn	67.4
Wet corn gluten feed	22.0
Bromegrass hay	8.0
Limestone	1.80
Urea	0.48
Supplement[1]	0.32
Calculated[2] nutrient values	
DM, % as fed	77.3
CP, % of DM	13.0
TDN, % of DM	87.8
NDF, % of DM	17.2
ADF, % of DM	7.8
Ether extract, % of DM	3.3
NEm, Mcal/kg DM	2.17
NEg, Mcal/kg DM	1.50

[1]Supplement was formulated to meet or exceed vitamin and mineral requirements established by the NRC (2000) and provided 44 mg/kg of monensin (Elanco Animal Health, Greenfield, IN).

[2]Nutrient values were calculated from tabular values obtained from the Nutrient Requirements of Beef Cattle, Eight Revised Edition (NASEM, 2016).

Table 5.2. Voluntary concentrate and total daily dry-matter intake of finishing Holstein steers

	Treatment[1]			
Item	Control	High roughage	SEM	*P*-value
Intake, kg/d				
Concentrate, DM	10.03	10.02	0.11	0.96
Total daily DM	10.03	10.13	0.11	0.41

[1]Control = steam-flaked corn-based finishing diet with 8% roughage; High roughage = 0.225% of body weight dry-matter basis of low-quality long-stemmed roughage provided by corn stalks fed once per week in addition to the Control diet fed daily.

Table 5.3. Effect of long-stemmed roughage feeding on ruminal fluid dynamics of finishing Holstein steers

	Treatment[1]			
Item	Control	High roughage	SEM	*P*-value
Dilution rate[2], %/h	8.95	7.57	2.06	0.54
Flow rate[2], L/h	9.92	10.99	0.67	0.18
Volume[2], L	125.8	144.5	14.16	0.26
Turnover[2], h	13.49	13.37	2.04	0.95

[1]Control = steam-flaked corn-based finishing diet with 8% roughage; High roughage = 0.225% of body weight dry-matter basis of low-quality long-stemmed roughage provided by corn stalks fed once per week in addition to the Control diet fed daily.

[2]Calcualted from marker (Co) concentration in rumen fluid samples collected at 0, 3, 6, 9, 12, 18, and 24 h after marker infusion.

Table 5.4. Effect of long-stemmed roughage feeding on ruminal fermentation characteristics of finishing Holstein steers

	Treatment[1]			
Ruminal	Control	High Roughage	SEM	*P*-value
pH				
Average	5.87	5.94	0.12	0.56
0 h	6.69	6.80	0.16	0.98
3 h	5.53	5.57	0.16	0.99
6 h	5.39	5.47	0.17	0.99
VFA, m*M*				
Total	96.68	95.57	5.67	0.85
Acetate	48.97	49.23	2.84	0.93
Propionate	32.06	30.88	3.51	0.74
Butyrate	10.80	11.26	1.01	0.66
Isobutyrate	0.66	0.60	0.07	0.43
Valerate	2.23	2.40	0.53	0.75
Isovalerate	1.95	1.19	0.49	0.15
Acetate:propionate	1.66	1.68	0.13	0.88

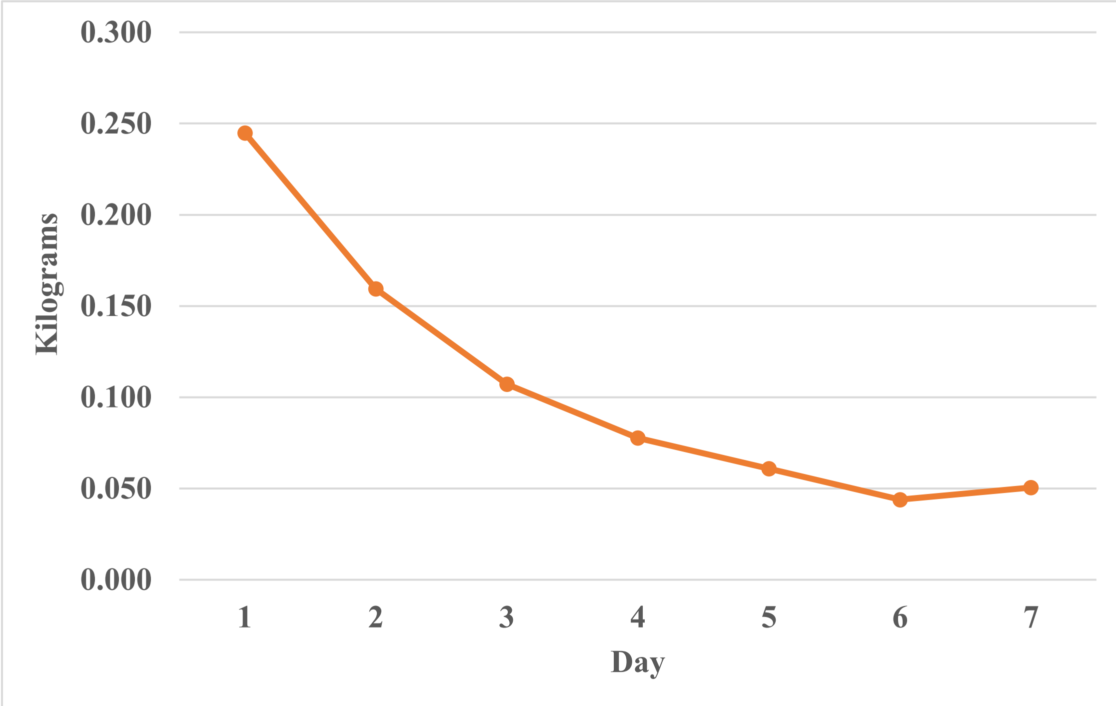
[1]Control = steam-flaked corn-based finishing diet with 8% roughage; High roughage = 0.225% of body weight dry-matter basis of low-quality long-stemmed roughage provided by corn stalks fed once per week in addition to the Control diet fed daily.

Table 5.5. Effect of long-stemmed roughage feeding on fecal starch content of finishing Holstein steers

Fecal output	Treatment[1]		SEM	*P*-value
	Control	High Roughage		
Starch, %	2.97	4.45	0.95	0.18

[1]Control = steam-flaked corn-based finishing diet with 8% roughage; High roughage = 0.225% of body weight dry-matter basis of low-quality long-stemmed roughage provided by corn stalks fed once per week in addition to the Control diet fed daily.

Figure 5.1. Average daily[1] intake of corn stalks by cannulated finishing Holstein steers.



[1]Fresh corn stalks were offered once a week every Monday (day 1, 8, 15, and 22 of each experimental period, respectively). Any corn stalks remaining in the bunk on the morning of d 1 (fed the previous week) were weighed to calculate daily intake and discarded before offering fresh corn stalks for that week.