THE EFFECTS OF ORALLY ADMINISTERED MELOXICAM AND INJECTABLE TRACE MINERAL SUPPLEMENTATION ON WEIGHT GAIN, MORBIDITY AND MORTALITY IN NEWLY-RECEIVED, HIGH-RISK STOCKER CALVES AND ON SERUM TRACE MINERAL STATUS BEFORE AND AFTER INJECTABLE TRACE MINERAL APPLICATION

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Abstract

Crossbred bull calves at high risk for morbidity (n = 190; BW = 159 ± 68 kg) were received at a commercial stocker operation to evaluate the effects of meloxicam administered at the time of castration on performance and health through d 30 post-arrival. Calves were assigned randomly to receive either a whey-powder placebo (CON), 0.5 mg/kg BW meloxicam (LOW), or 1.0 mg/kg BW meloxicam (HIGH) administered orally. Calves were vaccinated, knife-castrated, and received experimental treatments on d 0. Meloxicam had no effect on ADG ($P \geq 0.63$), morbidity ($P = 0.66$), or mortality ($P = 0.62$). A second study was conducted using crossbred calves from the southeastern US and Mexico (n = 472; BW = 227 ± 45 kg) to evaluate effects of an injectable trace-mineral solution administered at time of arrival at a commercial stocker operation on animal performance, health, and serum concentrations of Cu, Mn, Se, and Zn on d 0 and d 45. Calves were assigned randomly to receive saline (CON; 1.0 mL/45 kg BW) or injectable trace mineral (ITM; 1.0 mL/45 kg BW) on d 0. Average daily gain from d 0 to d 42, overall ADG from d 0 to d 139, mortality, and morbidity were not different ($P \geq 0.31$) between treatments. Calves originating from the Southeastern US had greater ($P < 0.01$) overall ADG from d 0 to 139. There were no source effects ($P \geq 0.21$) on initial serum mineral concentrations for Mn or Zn; however, cattle originating in Mexico had lesser serum Cu ($P < 0.01$) and cattle originating in the Southeastern US tended to have lesser serum Se ($P = 0.06$). On d 45, there were no treatment differences ($P \geq 0.20$) in serum concentrations of Cu, Mn, or Zn but cattle that received ITM tended ($P = 0.09$) to have elevated serum Se concentrations compared to those that received CON.

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Chapter 1
Literature Review

Beef production in the United States is comprised of three phases: cow-calf, growing, and finishing. Stocker calves in the growing phase of production play an important role in beef production and marketing (Johnson et al., 2010). Stocker calves represent a segment of the industry in which weight gain has the potential to be inexpensive relative to the cow-calf and finishing phases of production (Peel, 2003). As in any business, the primary goal of a stocker cattle producer is to increase production outputs while minimizing input costs. Maintaining animal health and well-being is imperative to the success of a stocker operation. Stocker calves typically are purchased and received weighing 136 to 363 kg (Johnson et al., 2010). Components of a successful stocker production system include animal nutrition, pasture management, animal health, marketing, risk management, and business management (Johnson et al., 2010). In previous studies, stocker calves grazed on spring-burned native Flint Hills pastures exhibited an ADG of 0.68 to 0.82 kg (Barnhardt et al., 2006). Minimizing morbidity and mortality and maintaining maximum animal production can be accomplished with proper management of the aforementioned components.

Management Practices in Receiving Cattle

Common management practices upon receiving of high-risk stocker calves include dehorning, castration, vaccination, treatment for parasites, and metaphylactic antibiotic treatment (Coetzee et al., 2010; USDA-APHIS, 2010; USDA-APHIS, 2012). Stressed animals are likely to have depressed immune function (Richeson et al., 2009). Bovine respiratory disease (BRD) is the leading cause of morbidity and mortality and results in significant economic losses for the beef industry (Woolums et al., 2005). Calves from the southeastern United States arriving on ranches and feedlots in the Midwest are typically assembled from various small-scale cow-calf producers

who are unlikely to castrate or vaccinate (NAHMS, 1998). Richeson et al. (2009) found that high-risk cattle originating from auction markets gained less BW and exhibited increased morbidity and mortality when co-mingled with an individual that was persistently infected with bovine viral diarrhea virus. Animal performance and carcass quality are also decreased by BRD morbidity (Gardner et al., 1999). Grazing cattle with known management history may have decreased incidence of BRD (Duff and Galyean, 2007), compared to cattle with no known history.

Consumer interest in animal welfare and in pain associated with common beef-cattle management procedures is significant (Rollin, 2004). Castration and dehorning are considered painful procedures (Coetzee et al., 2010; Allen et al., 2013). Significant pain induces stress and contributes to immunosuppression (Anderson and Muir, 2005), morbidity, and mortality. The use of nonsteroidal anti-inflammatory drugs (NSAIDs) has been approved in the European Union. Flunixin meglumine is the only NSAID currently approved by the US Food and Drug Administration (FDA) for pain management in food animals; however, extra-label use is allowed under the Animal Medicinal Drug Use Clarification Act of 1994 (USDA-NASS, 1994). Non-steroidal anti-inflammatory drugs can be administered preemptively or post-surgically to mitigate painful procedures (Coetzee, 2013; Smith, 2013). Multimodal analgesics increase effectiveness of NSAID treatment (Repenning, et al., 2013).

Use of Non-Steroidal Anti-Inflammatory Drugs for Pain Mitigation

As consumer concern for animal welfare grows, it is imperative that the beef industry seeks methods to ensure proper animal handling and pain mitigation during normal operational practices. In a recent survey of bovine veterinarians in the US, 21% of respondents indicated that they administer analgesics at the time of castration (Coetzee et al., 2010). Currently,

NSAIDs are regularly used in beef cattle in the European Union both metaphylactically and post-operatively. Required withdrawals for meat and milk of cattle treated with meloxicam in the European Union are 15 days and 5 days, respectively (EMA, 2006). In the US, NSAIDs are allowed under the Animal Medicinal Drug Use Clarification Act of 1994, which permits extra-label use of NSAIDs in beef cattle when administered by a veterinarian (USDA-NASS, 1994). Oral meloxicam tablets are readily available and inexpensive (Smith, 2013), which makes meloxicam an appealing option for pain management.

Physiological Biomarkers and Behavioral Responses Indicative of Pain

Elevated levels of physiological biomarkers such as plasma concentrations of substance P and cortisol are indicative of pain response in mammals (Coetzee et al., 2013). Substance P is secreted by nerves, macrophages, and lymphocytes; it has inflammatory effects in immune and epithelial cells during viral infections of beef cattle (O'Connor et al., 2004). Cortisol is a glucocorticoid that has anti-inflammatory and immunosuppressive properties; cortisol concentrations in the blood are elevated in response to physical or psychological stress (Willet and Erb, 1972). Cortisol concentrations in serum are elevated during painful procedures such as castration (Thüer et al., 2007). Knife and band castration were shown to elevate both substance P and cortisol (Fisher et al., 1996; Earley and Crowe, 2002). Dehorning has also been associated with increased cortisol (Stafford and Mellor, 2005; Heinrich et al., 2009).

Non-steroidal anti-inflammatory drugs decrease inflammation by reducing prostaglandin synthesis through inhibition of cyclooxygenase (COX) and by stimulating release of prostaglandins that mediate inflammation (Anderson and Muir, 2005). Cyclooxygenase exists in two isoforms: COX-1, which is expressed in the central system, the peripheral nervous system, and the gastrointestinal tract, and COX-2, which becomes active only after cell damage and cell

death (Smith and Langenbach, 2001). Meloxicam (Metacam®, Boehringer Ingelheim LTD, Burlington, ON) is an NSAID from the oxicam class that exhibits preferential binding to COX-2 receptors (Coetzee, 2013); NSAIDs that are selective for COX-2 tend to create fewer negative gastrointestinal side effects than non-specific COX inhibitors (Radi and Khan, 2006). Other commonly used NSAIDs include flunixin meglumine, ketoprofen, and phenylbutazone, which are non-specific COX inhibitors (Anderson and Muir, 2005).

Pain response in animals can be quantified through behavioral indices, including chute exit velocity, subjective chute score, feed intake, time spent at the feed bunk, and time spent lying down. Such behavioral changes can be monitored with motion-recording devices (Theurer et al. 2012). The aforementioned behavioral changes have the potential to affect animal production. Repenning et al. (2013) treated weanling bulls with oral meloxicam before and after band castration and reported no treatment effects on subjective chute scores or chute exit velocities. Theurer et al. (2012) observed that Holstein calves administered oral meloxicam at the time of dehorning spent more time standing up and walking from d 1 through 5 following dehorning than calves that did not receive analgesic treatment.

The Approval and Use of NSAIDs in the United States

Flunixin meglumine, at a dosage of 2.2 mg/kg BW via *i.v.*, is the only NSAID currently approved by the FDA to treat cattle within the United States for BRD, inflammation associated with endotoxemia, and mastitis. Flunixin meglumine has a plasma half-life of 3 to 8 h, a meat withdrawal time of 4 d, and a milk withdrawal time of 36 h (Coetzee, 2013).

Ketoprofen can be used extra-label at a dosage of 3 mg/kg BW *i.v.* or *i.m.*; it has a plasma half-life of 0.42 hours (Coetzee, 2013). Ketoprofen is more effective in reducing serum cortisol

after castration than local anesthesia (Earley and Crowe, 2002). Ting et al. (2003), reported that a single *i.v.* dose of ketoprofen reduced cortisol levels in response to castration.

Phenylbutazone can be used extra-label at a dosage of 10 mg/kg BW with a follow-up dose of 5 mg/kg BW every 48 h, and has a plasma half-life of 40 to 55 h (Coetzee, 2013). Meloxicam can be used extra-label in the United States at a dosage of 0.5 mg/kg BW *i.v.* or 0.5-1.0 mg/kg BW orally; it has a plasma half-life of 27 h (Coetzee, 2013).

Use of Meloxicam to Mitigate Pain from Castration and Increase Animal Performance

The ease of oral NSAID administration and its relatively long half-life make meloxicam a promising candidate for analgesic use in the beef industry. The mean bioavailability of meloxicam after oral administration of 1 mg/kg BW is 100 % with a plasma elimination half-life of 27 h (Coetzee, 2013). The long half-life suggests that effects of meloxicam may last several days after a single treatment. Meloxicam is currently approved for use in beef cattle in the European Union and Canada for adjunctive therapy of acute respiratory disease, diarrhea, and acute mastitis when administered *i.v.* or *s.c.* at 0.5 mg/kg, or orally at 0.5 to 1.0 mg/kg (EMA, 2006). Van Engen et al. (2014) found that administering oral meloxicam to beef steers following transportation tended to reduce serum cortisol concentrations. Coetzee et al. (2012) reported that ADG was unaffected by oral meloxicam treatment upon receiving; however, subjective diagnosis of BRD was decreased in animals that received meloxicam. Conversely, oral meloxicam administered before and after band castration had no effect on animal performance or physiological responses (Repenning et al., 2013). In addition, Allen et al. (2012) found that administering oral meloxicam to Holstein calves in conjunction with a local anesthetic after dehorning decreased serum substance P, prostaglandin E_2, and cortisol. Meloxicam administered intravenously after dehorning resulted in decreased heart and respiratory rates (Heinrich et al.,

2009). No effect of timing of meloxicam administration was apparent in Holsteins when the drug was administered either prior to or at dehorning (Allen et al., 2013).

The castration procedure has a negative short-term effect on calf performance. Coetzee et al. (2012) reported that castration decreased ADG and DMI from d 1 to 14 following the procedure. In another study, castration tended to decrease ADG from d 0 to 14 but not from d 0 to 84 (Warnock et al., 2012). Massey et al. (2011) reported that cattle received as bulls with an average BW of 209 kg at the time of castration exhibited decreased ADG and increased morbidity relative to cattle that had been castrated during preconditioning; moreover, HCW was decreased and d-to-market was increased in animals that were castrated upon receiving compared to animals that were received as steers. Meloxicam administered subcutaneously to high-risk stocker cattle decreased the number of lung lesions at harvest and increased overall BW and ADG from d 70 until harvest (Friton et al., 2005). While meloxicam has been shown to decrease physiological biomarkers indicative of pain response, animal performance, morbidity, and mortality appear to be unchanged due to NSAID use.

Mineral Supplementation of Stocker Cattle

There are 17 minerals required by beef cattle including the microminerals Cu, Mn, Se, and Zn. The minimum requirements of growing and finishing beef cattle for Cu, Mn, Se and Zn are 10, 20, 0.1, and 30 ppm dietary DM, respectively (NRC, 2000). Stocker cattle are generally offered forage-based diets (Johnson et al., 2010); however, they may be fed up to 15% of diet DM in the form of concentrates (Greene, 2000). Mineral requirements of stocker cattle are generally met in large part by their diets; any deficiencies must be corrected by providing adequate supplementation (Greene, 2000).

Kansas native grasses vary in trace mineral content by stage of growth and season; that variability in addition to animal selectivity is important to recognize when identifying deficiencies (Arthington et al., 1994). Forage nutrient availability is dependent on plant species, maturity, season, and soil quality (Anderson and Fly, 1955; Kamstra et al., 1958; Smith and Owensby, 1978). Because of this variability, calves assembled from auction markets can potentially exhibit a range of mineral deficiencies. The most common way to meet minimum nutrient requirements and prevent mineral deficiencies in a stocker operation is to provide mineral supplementation (Greene, 2000). Mineral supplementation can be offered in a variety of forms, including oral drench, oral bolus, self-fed mineral supplements, and injectable supplements. The use of an injectable trace-mineral supplement (ITM) potentially bypasses gut-level antagonisms during the absorption process and can be used to elevate mineral status in preparation for periods of stress (Pogge et al., 2012).

Trace Minerals: Copper, Manganese, Selenium and Zinc

The trace minerals Cu, Se, Mn and Zn are commonly provided in mineral supplements. Trace mineral nutrition supports growth and immune function (Galyean et al., 1999; Underwood and Suttle, 1999; Suttle, 2010). Zinc in particular has been shown to improve animal health when provided in supra-nutritional concentrations during times of disease challenge (Chirase et al., 1991).

Copper functions as a component of enzymes (McDowell, 1992) associated with Fe metabolism, elastin and collagen formation, and melanin production (Pond et al., 2005). The presence of absorptive antagonists of Cu, such Mo and S, must be considered when adjusting dietary Cu concentration for dietary Cu availability. Dietary Cu requirements are increased by the presence of dietary Mo and S. The 10 mg/kg BW requirement provides adequate dietary Cu

as long as the diet does not exceed 0.25% S or 2 mg/kg BW Mo (NRC, 2000). Molybdenum metabolism forces Cu to bind with plasma albumin, hindering absorption (Thornton et al., 1972). Elevated dietary S may cause formation of Cu-sulfides, which also reduce Cu absorption (Suttle, 1974). Signs of Cu deficiency include anemia, ataxia, bone abnormalities, hair loss, cardiovascular lesions, hemorrhages, and reproductive failure (Pond et al., 2005).

Manganese plays an important role in bone formation, as it contributes to the formation of the organic bone matrix (Pond et al., 2005). Manganese also activates enzymes including hydrolases, kinases, transferases, and decarboxylases. Manganese requirements for reproduction are greater than those for growth and performance. Reproductive failure, poor skeletal development, and skeletal abnormalities are symptoms of Mn deficiency (NRC, 2000).

Selenium metalloenzymes prevent oxidative damage to body tissues (Hoekstra et al., 1974) and deiodinates thyroxine to make it metabolizable (Arthur et al., 1990). The functions of Se and Vitamin E are related; when a diet is deficient in Vitamin E, additional Se is required to prevent muscle abnormalities (Miller et al., 1988). White muscle disease, or nutritional muscular dystrophy, is common in Se-deficient calves. If the heart muscle is affected, Se deficiency can result in mortality. Because there is a narrow margin between Se deficiency and Se toxicity, it is also important to consider availability of the Se source (Pond et al., 2005).

Zinc activates various metalloenzymes and is also an essential component of important enzymes responsible for nucleic acid, protein, and carbohydrate metabolism (Hambidge et al., 1986). The absorption of Zn is negatively affected by increased dietary calcium concentrations (Pond et al., 2005). Signs of Zn deficiency include reduced growth, reduced feed intake, reduced feed efficiency, listlessness, skin lesions, and alopecia (NRC, 2000).

Avoiding Trace Mineral Deficiency through Supplementation

There are two types of mineral deficiencies. Type 1 deficiencies are caused by inadequate nutrient availability, while Type 2 mineral deficiencies are caused by antagonistic relationships between minerals which prevent normal absorption. Both of these types of deficiencies need to be considered when selecting a mineral supplementation program. Bioavailability of mineral supplements can vary. For example, inorganic selenite is less metabolizable than natural Se-containing sources such as yeasts (Pehrson et al., 1989). Mineral chelates may be absorbed from the gut at greater rates than inorganic mineral sources (McDowell, 1996).

Supplementing minerals through the diet has variable effectiveness, depending on intake by each individual animal (Arthington and Swenson, 2004). Injectable trace mineral (ITM) supplements are another option available to producers that allows for targeted dosage and known delivery. Injectable sources of Cu, Mn, Se and Zn that are provided during initial processing of high-risk calves allow for rapid absorption and the possibility of improved health and animal performance. Arthington and Havenga (2012) found that administration of ITM to beef calves increased serum Cu, Se and Zn and increased bovine herpes virus-neutralizing antibody titers post-vaccination, compared to the control group. Improvements in reproduction and performance of cow-calf pairs have been observed following the administration of ITM. In cows and calves grazing native range, the use of an ITM improved AI pregnancy rates and subsequent calving distribution (Mundell et al., 2012).

Effects of Trace Mineral Supplementation on Morbidity and Animal Performance

Richeson and Kegley (2011) reported that administering ITM at initial processing of high-risk heifers improved ADG, improved feed efficiency, and decreased incidence of BRD. Genther and Hansen (2014b) reported that mild mineral deficiencies were induced in some cattle

by shipping stress and ITM was administered to evaluate effects on animal performance and carcass characteristics. Average daily gain was improved in ITM-treated steers compared to untreated steers when both groups had documented trace-mineral deficiencies; however, there was no difference in ADG between treatment groups when no deficiency was detected. In another study conducted by Genther and Hansen (2014a), liver Cu and Se concentrations decreased over time in steers with documented dietary deficiencies in those minerals following ITM administration; this was interpreted to indicate that supplemental, injectable Cu and Se were metabolized directly rather than stored. These researchers also reported that superoxide dismutase activity was increased with administration of ITM.

Arthington et al. (2014) administered ITM to heifer calves following weaning and transport and found that ADG decreased in calves that received the ITM treatment versus the control; however, liver concentrations of Cu, Se, Mn and Zn, and humoral immune responses were greater in calves that received ITM treatment. Risk of BRD incidence has a greater effect than mineral supplementation on morbidity and treatment costs during receiving and on ADG and DMI during the finishing phase (Clark et al., 2006). Ward and Spears (1999) fed steers a low-Cu diet and concluded that stress had a greater effect on immunity than Cu status. Before weaning, ITM had no effect on calf BW gain; however, treated calves had increased concentrations of liver Cu and Se and lesser liver Fe compared to untreated calves. After weaning, ITM-treated calves had increased liver concentrations of Cu, Se, and Zn and decreased ADG compared to untreated calves. Stocker heifers treated with ITM had greater antibody titers and ADG than untreated heifers 177 d after treatment (Arthington and Havenga, 2012). This indicates that while BRD has a greater effect on morbidity and ADG than mineral

supplementation, treatment with ITM may reduce the effect of BRD on animal health and performance.

Other studies have observed potential breed effects on mineral utilization. Pogge et al. (2012) found that after administering ITM, Simmental steers had lesser plasma Mn than Angus steers; liver concentrations of Se and Cu in both breeds increased after receiving ITM. Littledike et al. (1995) found that Limouisin cattle exhibited greater liver Cu and Zn levels than Braunvieh, Charolais, Gelbvieh, Hereford, Red Poll, Pinzgauer and Simmental cattle; moreover, they found no difference in serum Cu or Zn concentrations between breeds.

The trace mineral status of incoming cattle plays a role in the magnitude of response to trace mineral supplementation. Deficient animals have had greater response to ITM than animals with adequate trace mineral statuses (Genther and Hansen, 2014a). This indicates that geographical source of incoming cattle may also affect the magnitude of response to trace mineral supplementation, as species of forages and soil-mineral availability vary by region (Anderson and Fly, 1955; Dargatz and Ross, 1996). Trace mineral supplementation in the form of ITM allows for targeted delivery at known dosages and is not dependent on animal intake (Arthington and Swenson, 2004). While ITM supplementation has been shown to increase trace mineral status and decrease morbidity in beef cattle, its effects on animal performance have been equivocal.

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Chapter 2
Effects of meloxicam administered orally at time of castration on weight gain, morbidity and mortality in newly-received, high-risk feedlot calves

Abstract

A 30-d trial was conducted using crossbred bull calves (n = 190; initial BW = 350 ± 150 lbs) received at a commercial stocker operation to evaluate effects of meloxicam administered at the time of castration on performance and health. Bull calves at high risk for bovine respiratory disease (BRD) were sorted into 3 groups based upon individual purchase BW and assigned randomly to treatments within weight blocks: pasteurized sweet-whey placebo (CON), 0.5 mg/2.2 lb (0.5 mg/kg) BW meloxicam (LOW), or 1.0 mg/2.2 lb (1.0 mg/kg) BW meloxicam (HIGH). Calves received experimental treatments, were vaccinated, surgically castrated, and dehorned (if warranted) on d 0. Individual BW was recorded on d 7 and d 30. Morbidity and mortality were documented throughout the 30-d trial. Individuals identified as having BRD by feedlot personnel were treated according to site protocol. Average daily gain across all treatment groups was -0.15 lbs (0.07 kg) from d 0 to 7 and was 2.01 lbs (0.91 kg) from d 8 to 30. There were no treatment differences ($P \geq 0.63$) in ADG. There were no effects ($P \geq 0.62$) of treatment on mortality or morbidity. Treatment of bull calves with meloxicam immediately prior to castration did not affect calf performance or health.

Key Words: calves, castration, morbidity, oral meloxicam, performance

Introduction

Castration is used commonly in the beef industry to reduce animal aggression and to improve carcass quality; however, it is associated with short-term reduction in ADG and an increase in morbidity[3]. These problems are more prominent in heavier, mature animals than in

young animals[5, 13, 19]. The additional stress that an animal experiences due to castration can, in some instances, compromise immune responses against bovine respiratory disease (BRD). Steers not having to withstand the additional stress of castration tend to exhibit lower incidence of BRD and better ADG than bulls castrated upon arrival[11].

Growing awareness of issues regarding animal welfare and pain management in livestock animals prompts the consideration of safe, economical, and effective compounds for pain mitigation. The use of non-steroidal anti-inflammatory drugs (NSAIDs), alone or in conjunction with local anesthetics, reduces the pain response caused by castration[7]. Meloxicam, a member of the oxicam class of NSAIDs, is used commonly in small-animal medicine for its analgesic properties[15]. Currently, flunixin meglumine is the only NSAID approved by the United States Food and Drug Administration (FDA) for pain management in food animals; however, extra-label use is allowed under the Animal Medicinal Drug Use Clarification Act [18]. Orally-administered meloxicam given 24 h prior to castration moderated physiological stress indicators during the first 14 d post-castration and decreased incidence of morbidity[4]. Meloxicam is currently used in the European Union and can be used extra-label in the US for adjunctive therapy of acute respiratory disease, diarrhea, and acute mastitis[8].

The objective of this trial was to determine the post-castration effects on BW gain, morbidity, and mortality in high-risk, crossbred, auction-sourced stocker calves when meloxicam was administered orally at the time of castration.

Materials & Methods

This trial was conducted according to Kansas State University Institutional Animal Care and Use Committee Protocol # 2939 and took place in a commercial feedlot in southeast Kansas

between April 2012 and June 2012. Intact bull calves (n = 190; initial BW = 350 ± 150 lbs) were purchased from various auction markets in the southeastern United States.

Prior to shipment, calves were mass-medicated with a long-acting penicillin[a] (2 mL/150 lb (2 mL/68 kg) BW); given an *i.m.* injection of vaccine against infectious bovine rhinotracheitis, bovine viral diarrhea Types 1 and 2, parainfluenzavirus-3 and bovine respiratory syncytial virus[b] (2 mL/bull); and given an intranasal vaccine against infectious bovine rhinotracheitis, parainfluenzavirus-3 and bovine respiratory syncytial virus[c] (2 mL/bull). Calves arrived in 3 truckloads at 1 wk intervals. Subject animals exhibited considerable phenotypic diversity, varied in health status, and covered a wide BW range within receiving dates.

Prior to arrival at the feedlot, purchase BW of calves were obtained and used to stratify individual animals into three BW blocks (200 to 299, 300 to 399, and 400 to 499 lbs). Within each BW block, treatments were assigned randomly to individuals in groups of 3 utilizing a computerized random-number generator. One bull in each group was assigned randomly to 1 of 3 treatments: non-medicated control, low-dose meloxicam, or high-dose meloxicam. The appropriate number of meloxicam tablets[d] (NDC 29300-125-01, Lot # GMMH10091) required for each dosage were added to dry, pasteurized, sweet-whey powder[e] and inserted into gelatin capsules[f] (Size #10 Capsules). Boluses were made to treat steers based on median target weights of 250 lbs, 350 lbs and 450 lbs for BW blocks 1, 2, and 3, respectively. Treatment dosage levels were made to be equivalent to 0 mg/lb (0 mg/kg) BW for control, approximately 0.5 mg/2.2 lb (0.5 mg/kg) BW for low-dose meloxicam, or approximately 1.0 mg/2.2 lb (1.0 mg/kg) BW for high-dose meloxicam. Non-medicated boluses for the control treatment contained only whey powder.

Following arrival of each group at the feedlot on consecutive Saturdays, calves were placed in pens by truckload, fed prairie hay and allowed *ad libitum* access to water. On the following Monday (d 0), all subject animals were individually weighed; given an intranasal modified live vaccine containing antigens for infectious bovine rhinotracheitis virus and parainfluenzavirus-3[g] (2 mL/bull); given an *i.m.* vaccine containing antigens for infectious bovine rhinotracheitis, bovine virus diarrhea Types 1 and 2, parainfluenzavirus-3, and bovine respiratory syncytial virus vaccine[b] (2 mL/bull); given a topical dewormer[h] (1 mL/22 lbs (1 mL/10 kg) BW); and injected with a metaphylactic antibiotic[i] (1.5 mL/100 lb (1.5 mL/45 kg) BW).

All bulls were castrated on d 0 and test treatments were administered at the time of castration. On d 0, calves were placed into pastures at a stocking rate of 3 animals per acre and were supplemented with dried distillers' grains. Animals were observed daily by full-time feedlot employees who were blinded to treatments. Animals were considered morbid if they appeared lethargic or unthrifty; they were treated for BRD according to standard feedlot protocol.

On d 7, all subject animals were brought in from their pastures and reweighed; given a second dose of the intranasal modified live vaccine containing antigens for infectious bovine rhinotracheitis virus and parainfluenzavirus-3[g] (2 mL/bull); a second dose of the *i.m.* vaccine containing antigens for infectious bovine rhinotracheitis, bovine virus diarrhea Types 1 and 2, parainfluenzavirus-3[b] (2 mL/bull); a *Clostridium chauvoei-septicum-novyi-sordellii-perfringens* types C & D bacterin-toxoid[j] (5 mL/calf); and were metaphylactically treated with tilmicosin[k] (1.5 mL/100 lbs (1.5 mL/45 kg) BW). After revaccinating on d 7 calves were placed back out into their respective pastures; final BW were collected and recorded on d 30.

Statistical Analysis:

All processing and treatment data were recorded into a computer database[l] immediately upon administration and transferred to a computer spreadsheet[m] to await export for statistical analysis. Performance and health data were analyzed with the MIXED and GLIMMIX procedures of SAS[n], respectively. Tests for equal variance were analyzed with the GLM procedure of SAS[n] using Levene's Test. Initial BW was utilized as a covariate for all analyses of equal variance. During the GLIMMIX procedure, the logit function was used to analyze binary observations (morbidity and mortality). Linear and quadratic contrasts were used to evaluate incidence of morbidity and mortality. The relationships between ADG, treatment, and time were analyzed using pairwise comparisons. Probability values were determined using the type III tests of fixed effects; *P*-values ≤ 0.05 were considered significant whereas *P*-values ranging from 0.05 to 0.10 were considered indicative of trends.

Results and Discussion

Calf BW on d 0 tended ($P = 0.07$) to be different between treatments (Table 2.1); however, there were no treatment differences ($P = 0.42$) in final BW. All treatment groups lost BW between d 0 and d 7. Though ADG improved across all treatments from d 8 to 30, there was no effect ($P \geq 0.63$) of meloxicam on ADG from d 0 to 7, d 8 to 30, or from d 0 to 30 (Figure 2.1). Neither rates of morbidity nor mortality were affected ($P \geq 0.62$) by treatment (Table 2.2) throughout this trial.

In previous research, NSAIDs reduced morbidity and pain response in calves exposed to dehorning[17] and castration[7]. Repenning et al.[14] administered oral meloxicam to weanling Holstein bull calves before and after band castration and reported no effect on ADG. Meloxicam had no effect on quiescence (measured via movement-monitoring devices) in Holstein calves

following dehorning [17]. Administration of ketoprofen before castration of bull calves reduced blood cortisol levels [7].Conversely, the timing of oral meloxicam administration relative to cautery dehorning in Holstein calves had no effect on blood cortisol levels [1]. Sodium salicylate therapy following induced episodes of bovine synovitis had no effect on performance[10]. Coetzee et al. found that orally-administered meloxicam given 24 h in advance of castration had no effect on ADG or DMI in castrated calves at high risk for BRD[6].

Genetic and phenotypic variance in animals can also impact feed intake and efficiency. Genetic selection has been shown to result in increased feed intake and feed efficiency in Angus cattle[2]. Furthermore, age and maturity have been shown to affect the rate of absorption of meloxicam in ruminants and pre-ruminants with more mature animals exhibiting longer drug absorption periods[12].

Calves originating from the southeastern United States are typically assembled from several different small-scale cow-calf producers and are less likely to be vaccinated or castrated than calves which originate from large-scale cow-calf producers[13]. Conditions under which calves are commingled from multiple sources places them at greater risk for poor growth performance, BRD morbidity, and BRD mortality[16]. Morbidity caused by BRD also decreases carcass quality[9]. The calves involved in this study represented a wide range of phenotypic diversity and maturity as is common in stocker calf production. The diversity in maturity and BW exhibited by these animals, in combination with the high-risk for BRD, most likely affected animal health and performance to a greater extent than the experimental treatment.

Conclusion:

Meloxicam did not have an effect on animal performance or animal health in high-risk feedlot calves. In a production setting, the use of oral meloxicam administered at the time of

castration did not offer benefits to outweigh the cost of treatment and additional stress placed on the animal.

Endnotes

[a]Bactracillin G® Benzathine, Aspen Veterinary Resources LTD., Liberty, MO
[b]Bovi-Shield Gold 5®, Zoetis, Florham Park, NJ
[c]Enforce 3®, Zoetis, Florham Park, NJ
[d]Meloxicam tablets USP 15mg, Unichem Pharmaceuticals USA Inc., Rochelle Park, NJ
[e]Sweet whey powder, Kraft Foods, Deerfield, IL
[f]Torpac® gelatin capsules, Torpac Inc., Fairfield, NJ
[g]Nasalgen®, Merck Animal Health Inc., Summitt, NJ
[h]Dectomax® Pour-On, Zoetis, Florham Park, NJ
[i]Excede®, Zoetis, Florham Park, NJ
[j]Ultrabac 7®, Zoetis, Florham Park, NJ
[k]Micotil 300®, Elanco, Greenfield, IN
[l]Cattle Data Systems® 2012, Cattle Data Systems Inc., Enid, OK
[m]Excel® 2010, Microsoft, Redmond, WA
[n]SAS Version 9.4, SAS Inst. Inc., Cary, NC

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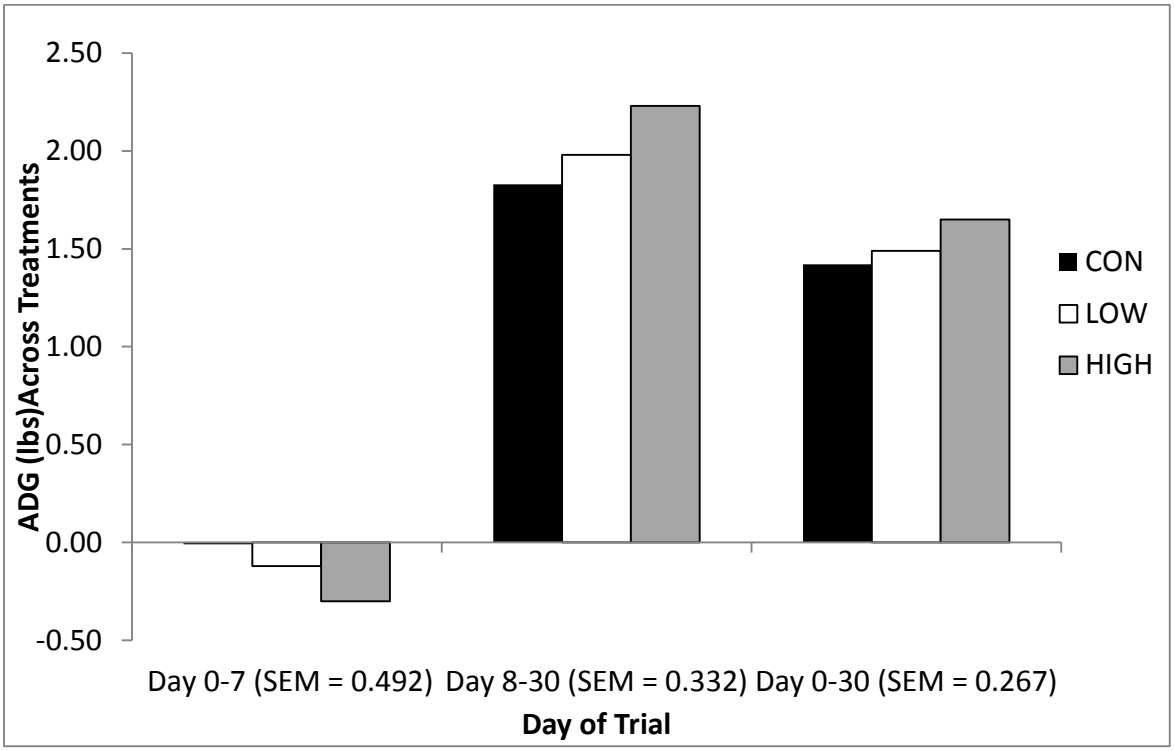
Figures and Tables

Figure 2.1. Receiving ADG in high-risk feedlot calves after being given oral meloxicam at a HIGH or LOW dose, or a placebo treatment (CON)[1] at time of castration on d 0



Treatment[1]: CON = control (placebo); LOW = 0.5 mg/2.2 lbs; HIGH = 1.0 mg/2.2 lbs

SEM = the largest SEM of all three treatments

P-values for Treatment Effect: Day 0 to 7 = 0.90; Day 8 to 30 = 0.63; Day 0 to 30 = 0.79

Table 2.1. Effects of orally-administered meloxicam on initial BW and BW on d 30 after receiving oral meloxicam at a HIGH or LOW dose, or a placebo treatment (CON) at time of castration on d 0

	Treatment[1]				
Item	CON	LOW	HIGH	SEM[2]	*P*-value
Day 0, lbs	355	371	360	6.8	0.07
Day 30, lbs	399	415	408	10.4	0.42

Treatment[1]: CON = control (placebo); LOW = 0.5 mg/2.2 lbs; HIGH = 1.0 mg/2.2 lbs

SEM[2] = the largest SEM of all 3 treatments

Table 2.2. Morbidity and mortality observed in high-risk feedlot calves during a 30-d receiving period after being given oral meloxicam at a HIGH or LOW dose, or a placebo treatment (CON) at time of castration on d 0

	Treatment[1]				
Item	CON	LOW	HIGH	SEM[2]	*P*-value
Mortality, %	11.95	6.03	0.17	29.480	0.62
Morbidity, %	12.25	19.51	17.35	7.030	0.66

Treatment[1]: CON = control (placebo); LOW = 0.5 mg/2.2 lbs; HIGH = 1.0 mg/2.2 lbs
SEM[2] = the largest SEM of all 3 treatments

Chapter 3
The effects of injectable trace mineral supplementation on the performance and health of high-risk stocker cattle grazed on native Flint Hills pastures

Abstract

Crossbred beef calves at high risk of developing bovine respiratory disease (BRD) and originating in the southeastern United States and Mexico (n = 472; initial BW = 227 ± 45 kg) were assigned randomly within geographical source to receive an *s.c.* injection of trace-mineral solution (15 mg/mL Cu, 10 mg/mL Mn, 5 mg/mL Se, and 60 mg/mL Zn; ITM) at a dose of 1.0 mL/45 kg BW or an equivalent control dose of 0.9% saline (CON) upon arrival at the ranch. Calves were then allowed to graze on native tallgrass pastures and were observed daily for clinical signs of disease. Trace mineral status was evaluated using serum collected on d 0 and d 45. Final BW was recorded upon shipment at the end of the grazing season (average time on pasture = 139 d, range = 124 to 164 d). There were no treatment × source interactions ($P \geq 0.23$) for ADG from d 0 to d 42, d 43 to d 139, or d 0 to d 139; therefore, main effects of treatment and source were reported. Average daily gain from d 0 to d 42, and overall ADG were not affected ($P \geq 0.31$) by treatment. Average daily gain from d 43 to d 139 was greater in animals that did not receive ITM compared to those that did (P = 0.04). Neither morbidity nor mortality was affected ($P \geq 0.32$) by treatment. There was no effect ($P \geq 0.21$) of animal origin on initial serum concentrations of Mn and Zn; however, calves originating from Mexico had lesser ($P < 0.01$) initial serum Cu and tended ($P = 0.06$) to have greater initial serum Se. Levels of serum Cu, Mn, and Zn on d 45 did not differ ($P \geq 0.20$) between treatments; however, animals given ITM tended ($P = 0.09$) to have greater concentration of serum Se on d 45 versus calves administered CON. In

this study, administration of ITM upon receiving of high-risk crossbred beef calves did not affect overall ADG, morbidity, or mortality. Stocker calf source influenced both ADG and initial trace mineral status upon arrival. Treating with ITM may affect serum selenium concentrations.

Key Words: calves, injectable trace mineral, morbidity, performance, supplement

Introduction

Although acute symptoms of trace mineral deficiencies are rarely observed in production settings, subclinical symptoms of deficiency are observed as poor animal health, performance, and reproductive failure (Underwood and Suttle, 1999; Suttle, 2010). Variability in initial mineral status, absorption efficiency, and stress among individual animals can cause a wide range of mineral statuses within a group of calves (Duff and Galyean, 2007). Forage nutrient availability also plays a role in contributing to trace mineral deficiency (Greene, 2000), as native forages are typically low in trace minerals (Umoh et al., 1982).

Adequate supplementation of trace minerals is necessary to maximize animal health and performance (Chirase et al., 1991; Galyean et al., 1995; Arthington et al., 2014). Mineral requirements for stressed and high-risk cattle are greater than that of non-stressed cattle due to the interactive relationship between stress and dry matter intake (NRC, 1996). Stress can aggravate mineral deficiencies (NRC, 1996) and contribute to immunosuppression (Galyean et al., 1999; Anderson and Muir, 2005; Richeson et al., 2009), morbidity (Richeson et. al., 2009), and can result in mortality (Edwards, 1996). Trace mineral supplementation may improve animal health and performance during times of stress (Pogge et al., 2012).

With injectable trace minerals, the amount of trace mineral administered to the animal is consistent and not susceptible to the variability associated with free-choice intake (Arthington

and Swenson, 2004; Duff and Galyean, 2007). Products of this type have improved feed efficiency and increased DMI (Clark et al., 2006) and ADG (Richeson and Kegley, 2011) of beef calves fed in confinement.

The objective of this study was to evaluate the effects of ITM in newly-received, high-risk stocker calves on morbidity, mortality, ADG, and serum mineral concentrations.

Materials and Methods

A 139-d trial was conducted according to Kansas State University Institutional Animal Care and Use Committee Protocol #3404. This study took place on a commercial ranch in the Flint Hills of Kansas in the late winter through early summer of 2014. Crossbred beef calves at high risk for developing BRD (n = 472; initial BW = 227 ± 45 kg) were purchased from auction markets in the southeastern United States and Mexico and were received in 6 truckloads on consecutive weeks between February 14 and March 23. Prior to shipment from their respective points of origin, calves were administered vaccinations for *Haemophilus somnus, Manheimia haemolytica*, *Pasturella* bacterin-toxoid (2 mL/calf; Pro-Bac 3®, Vetbio, Inc., San Angelo, TX), bovine respiratory syncytial virus, parainfluenza 3, and infectious bovine rhinotracheitis (2 mL/calf; Enforce 3®, Zoetis, Florham Park, NJ). Tulathromycin (1.1 mL/45 kg BW; Draxxin®, Zoetis, Florham Park, NJ) was also administered to all calves prior to shipment to the ranch.

Upon arrival at the ranch on d 0, calves were hot-iron branded and were vaccinated for bovine respiratory syncytial virus, parainfluenzavirus-3, infectious bovine rhinotracheitis, and bovine viral diarrhea types 1 and 2 (2 mL/calf; Bovishield Gold 5®, Zoetis, Florham Park, NJ), and were dewormed topically with doramectin (1 mL/10 kg BW; Dectomax® Pour-On, Zoetis, Florham Park, NJ).

Calves were blocked by arrival date and gonad status (i.e., bull or steer), and assigned randomly within geographical source to receive an *s.c.* injection of trace-mineral solution (ITM; Multimin 90®, Multimin USA, Fort Collins, CO) at a dose of 1.0 mL/45 kg BW or an equivalent dose of 0.9% saline (CON; Amtech, IVX Animal Health Inc., St. Joseph, MO) during post-arrival processing; ITM contained 15 mg/mL Cu, 10 mg/mL Mn, 5 mg/mL Se, and 60 mg/mL Zn. Both ITM and CON treatments were administered in the left side of the neck. At that time, blood samples were collected from a subset of cattle originating from the southeastern US (n = 44) and Mexico (n = 48) that equally represented both treatments. Blood samples were collected from the tail vein in trace mineral tubes (BD Vacutainer® Trace Element Serum Plus Blood Collection Tubes, Becton, Dickinson and Co., Franklin Lakes, NJ). Blood samples were kept refrigerated for 48 h, placed in a centrifuge (Model J-6B Centrifuge, Beckman Coulter, Inc., Pasadena, CA) at 1,081 × *g* for 8 min and serum was poured off into clean trace mineral tubes and frozen.

After calves were processed and received experimental treatments on d 0, they were placed in winter pastures at an average stocking rate of 1 animal per 1.21 ha, and provided with brome hay and a loose mineral supplement containing chlortetracycline (Table 3.1; targeted intake = 350 mg/calf each day; Aureomycin 50®, Zoetis, Inc., Kalamazoo, MI).

Animals were brought in from their winter pastures, revaccinated, and intact animals were castrated after an average of 20 d (range = 10 – 30 d) on pasture. Booster vaccinations were administered to all calves for bovine respiratory syncytial virus, parainfluenzavirus-3, infectious bovine rhinotracheitis, and bovine viral diarrhea types 1 and 2 (2 mL/calf; Bovishield Gold 5®, Zoetis, Florham Park, NJ) and given a *Clostridium chauvoei-septicum-novyi-sordellii-perfringens* types C & D bacterin-toxoid (5 mL/calf; Ultrabac 7®, Zoetis, Florham Park, NJ).

Following revaccination and castration, animals were placed back in their respective winter pastures.

After an average of 42 d post-arrival (range = 37 – 46 d), calves were brought in from winter pastures, weighed, and were given a growth-promoting implant (36 mg/calf zeranol; Ralgro®, Merck Animal Health Inc., Summitt, NJ). Blood samples were collected during this phase of processing on d 45 from 37 of the 44 animals originating from the southeastern US in the group that had initial blood drawn on d 0 (7 of the southeastern calves which had been bled on d 0 died prior to d 45). No samples were drawn from calves originating from Mexico at this time. Blood samples from d 45 were kept refrigerated for 48 h, placed in a centrifuge (Model J-6B Centrifuge, Beckman Coulter, Inc., Pasadena, CA) at 1,081 × *g* for 8 min and serum was poured off into clean trace mineral tubes and frozen. Frozen serum samples from d 0 and d 45 were then shipped to Iowa State University College of Veterinary Medicine for trace mineral analysis, via inductively-coupled plasma mass spectrometry.

A majority of the calves (n = 376) were turned out onto native Flint Hills summer pastures following d 42 and were provided with loose mineral containing chlortetracycline (Table 3.1; Aureomycin 50®, Zoetis, Inc., Kalamazoo, MI). Of the 472 calves utilized in this study, 96 calves that equally represented both treatment groups remained in winter pastures for 7 more d; they were subsequently turned out into summer pastures on d 49.

Morbidity and mortality were recorded throughout the study. Animals were observed daily by full-time ranch employees who were blinded to treatments. Animals were considered morbid if they exhibited lameness or appeared to be unthrifty or depressed. Morbid animals were treated with either tilmicosin (1.5 mL/45 kg BW; Micotil 300®, Elanco, Greenfield, IN) or a broad-spectrum cephalosporin (1.5 mL/45 kg BW; Excede®, Zoetis, Florham Park, NJ).

On d 139, animals were brought in from their summer pastures and final BW was recorded.

Statistical Analysis:

Tests for homogeneity of variance between treatments were conducted using the GLM procedure of SAS (SAS Version 9.4 Inst. Inc., Cary, NC) via the Levene's Test for equal variance; residuals from the analysis for covariance model of baseline serum mineral concentrations were utilized as covariates for d 0 and d 45 serum mineral analyses. Unequal variance between treatments was detected for d 0 BW, d 139 BW, d 0 to d 42 ADG, d 43 to d 139 ADG, and overall ADG ($P \leq 0.09$) and was accounted for in the analyses using the Satterthwaite Approximation to compute the denominator degrees of freedom, and the Tukey-Kramer test to adjust for multiple comparisons in the least squared means within the MIXED procedure of SAS.

Body weights and ADG were analyzed using the MIXED procedure of SAS with animal as the experimental unit, treatment and source as fixed effects, and arrival date and castration status as random effects. The incidence of morbidity and mortality were analyzed with PROC FREQ procedure of SAS with animal as the experimental unit, castration status and arrival date as random effects, and treatment and source as fixed effects. Standard error for the incidence of mortality was calculated from PROC FREQ values due to uneven frequency of morbidity and mortality across sources and treatments. Initial BW upon arrival was utilized as a covariate for all binary analyses. Conditional independence between treatment and source for morbidity and mortality data was confirmed using the Cochran-Mantel-Haenszel Chi-square test for independence ($P \geq 0.96$). Origin effect on initial serum mineral concentrations (d 0) and the comparisons for d 0 to d 45 trace mineral serum concentrations were analyzed with the GLM procedure of SAS with treatment as the covariate for the d 45 analysis.

Probability values were determined using the type III tests of fixed effects; *P*-values ≤ 0.05 were considered significant and *P*-values ranging from 0.05 to 0.10 were considered indicative of trends.

Results and Discussion

Animal Performance, Morbidity and Mortality:

There were no treatment or source effects ($P \geq 0.14$) on d 0 BW in calves used in this study. There was no treatment effect ($P = 0.95$) for d 139 BW but a source effect ($P < 0.01$) was observed with the cattle originating from the southeastern US having greater final BW than those from Mexico. A treatment × source interaction was observed in d 139 BW ($P = 0.03$); CON-treated cattle originating from the southeastern US were 6.95 kg heavier than those that received ITM, whereas ITM-treated cattle originating from Mexico were 5.53 kg heavier than those that received CON.

All calves lost weight during the first 42 d following arrival at the ranch; no differences ($P = 0.54$) between treatments were observed. From d 43 to d 139, calves that did not receive ITM treatment gained more weight than calves that received ITM ($P = 0.04$). The reason for this decrease in performance is unclear. Overall ADG was not different between treatments ($P = 0.31$; Table 3.3).

Arthington et al. (2014) found no difference in ADG in beef calves receiving no ITM or an ITM containing the same mineral concentrations as the current study, administered at 1 mL/calf at 0, 100, and 200 d of age. Calves in that study were allowed access to free-choice mineral supplement. Those authors then shipped the calves 1,600 km following weaning; ADG during the first 14 d post-shipment was decreased in calves that had received ITM versus the control. Mundell et al. (2012) reported that cow and calf BW were not affected by ITM treatment

(1.0 mL/90 kg administered to cows; 1.0 mL/45 kg administered to calves) when using the same product as the current study; however, pre-breeding BCS change was greater in cows receiving ITM than in cows that received saline. Cows and calves had access to free-choice mineral in that study. These results indicated that access to free-choice mineral may mask any potential treatment effect of ITM on animal performance.

When no additional form of trace mineral supplementation was provided, Arthington et al. (2014; a separate trial from the trial previously discussed) reported that overall ADG tended to increase in heifers that received ITM compared to those that received the control. Richeson and Kegley (2011) found that when withholding all other forms of trace mineral supplementation and administering either a control treatment or one of two different ITM treatments (10 mg/mL Cu, 20 mg/mL Mn, 5 mg/mL Se, and 20 mg/mL Zn; or 16 mg/mL Cu, 10 mg/mL Mn, 5 mg/mL Se, and 48 mg/mL Zn) at the same dosage level as the current study to highly stressed beef calves, overall ADG (d 0 to d 55) was greater in animals receiving either of the two ITM treatments versus the control. Berry et al. (2000) found that administering ITM containing 10 mg/mL Cu, 20 mg/mL Mn, 5 mg/mL Se, and 20 mg/mL Zn at a constant dosage level of 3 mL/calf (mean BW = 144 kg) upon arrival and prior to castration increased overall ADG and feed conversions compared to the control in crossbred calves that were not allowed access to other forms of mineral supplementation.

There were no differences ($P \geq 0.32$) in mortality or morbidity in calves that received ITM treatment compared to those that received the CON treatment (Table 3.4). Clark et al. (2006) reported no decrease in morbidity or mortality when administering ITM containing approximately five times the mineral concentration administered in the current study (5 mL/266 kg BW; 75 mg/mL of Cu, 50 mg/mL of Mn, 25 mg/mL of Se, and 200 mg/mL of Zn) versus

negative controls. Conversely, Berry et al. (2000) found that the administration of ITM containing 10 mg/mL Cu, 20 mg/mL Mn, 5 mg/mL Se, and 20 mg/mL Zn at a constant dosage level of 3 mL/calf (mean BW = 144 kg) administered upon arrival and prior to castration tended to decrease morbidity in crossbred calves. Heightened humoral immune response of cattle that received ITM compared to those that received control treatments has been reported when ITM was administered at approximately half of label dosage recommendations (0.5 mL/45 kg; Arthington et al., 2014), at slightly less than label dosage recommendations (1 mL/68 kg; Genther and Hansen, 2014), and at label dosage recommendations with a ITM containing 20 mg/mL less of Zn (1 mL/45 kg; Arthington and Havenga, 2012).

Morbidity due to BRD can result in up to 82% of death loss, depending on severity of the illness (Edwards, 1996). Treatment costs can vary depending on severity and nature of illness (Johnson et al., 2010); therefore, by reducing the incidence of morbidity, treatment costs can also be reduced (Perino, 1992). Cattle at high risk for BRD exhibit increased rates of fever and treatment costs (Clark et al., 2006). Calves in the current study were considered at high risk for BRD, which likely affected the rate of morbidity and mortality more than ITM treatment.

Serum Trace Mineral Concentrations:

Serum mineral concentrations on d 0 exhibited equal variance ($P \geq 0.11$) across treatment for Cu, Se, and Zn; however, variance across treatments tended ($P = 0.07$) to be unequal for serum Mn concentration on d 0. Initial serum concentrations of Cu ($P < 0.01$) were related to calf origin; calves of Mexican origin had lesser serum Cu concentrations than calves from the southeastern US. Conversely, calves originating out of the southeastern US tended ($P = 0.06$) to have lesser serum Se concentration. Initial serum concentrations of Mn and Zn were not different ($P \geq 0.21$) between sources (Table 3.5).

Source of incoming stocker calves is likely to impact initial trace mineral status as forages native to specific areas and climates have different nutrient compositions (Anderson and Fly, 1955; Dargatz and Ross, 1996). Individual animal selectivity can cause variation in nutrient intake (Arthington et al., 1994) and season can play a role in nutrient availability from forages (Umoh et al., 1982; Arthington et al., 1994). Soil profile and local environmental differences can also affect nutrient availability (Anderson and Fly, 1955). Cattle originating from the southeastern US were found to be more likely to be marginally or severely deficient in Se than cattle originating from the central and western regions of the US (Dargatz and Ross, 1996).

There were no differences ($P \geq 0.20$) between treatments for Cu, Mn, or Zn serum concentrations on d 0 and d 45 in cattle originating from the southeastern US. There was a trend ($P = 0.09$) indicating an increase in serum Se concentration on d 45 versus d 0 (Table 3.6). Serum mineral concentrations on d 45 exhibited equal ($P = 0.27$) variance among treatments.

Pogge et al. (2012) reported that plasma concentrations of Cu, Mn, Se, and Zn peaked within the first 24 h following treatment with ITM at the same concentration and dosage as the current study. They further reported that plasma concentrations of Cu, Mn and Zn returned to baseline concentrations within the first 24 h following ITM treatment; however, Se remained elevated through 24 h post-injection. This may have indicated that Cu, Mn, and Zn were rapidly absorbed for use or stored in the liver. In the current study, animals receiving both treatments were allowed access to loose mineral and the same types of forage, possibly indicating that the increase in serum Se concentration on d 45 was attributable to ITM.

Arthington and Havenga (2012) reported that when ITM containing 20 mg/mL less Zn than in the current study was administered at the same dosage level, Mn concentrations were not affected by ITM treatment although serum Cu, Se, and Zn levels were greater in steers that

received ITM versus control. Pogge et al. (2012) found that 15 d following administration of ITM, Se and Cu plasma concentrations increased in animals that received ITM versus animals that received saline. Richeson and Kegley (2011) reported that plasma Cu and Zn were not affected 28 d following the administration of 1 of 2 different ITM treatments. Genther and Hansen (2014) found that liver Cu and Se levels were increased through at least d 30 following ITM treatment at a dosage level of 1.0 mL/68 kg containing the same mineral concentrations as the current study. Similar to the current study, Arthington et al. (2014) reported an increase in Se concentrations only following the administration of ITM containing the same mineral concentrations as the current study at one-half of the label recommended dosage.

Conclusion:

In this study, the administration of ITM supplement did not affect animal performance or health status. By understanding the common trace mineral deficiencies at the point of origin, adequate mineral supplementation can be determined to normalize trace mineral status. Injectable trace mineral supplementation in conjunction with a loose mineral supplement had no effect on animal health or ADG; but elevated levels of serum Se in animals that were marginally deficient.

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Figures and Tables

Table 3.1 Composition of mineral supplement provided to high-risk stocker cattle receiving either injectable trace mineral (ITM) or saline (CON) on d 0

Ingredient	% of Supplement[1] Composition
Bulk Salt	57.0
Dried Distillers Grains	10.0
Limestone Fine Fre Flo	8.0
Monocalcium Phosphate, 21%	6.5
Microlite[2]	5.4
Zinc Sulfate, 35.5%	1.3
Copper Sulfate, 25%	0.5
EDDI Premix[1], 9.2%	0.5
Suppli-K[3]	0.5
Nutrient composition, (calculated)	
Salt, %	57.00
Ca, %	4.12
P, %	2.07
K, %	0.32
Mg, %	0.46
I, %	0.04
Cu, ppm	1,250
Zn, ppm	4,600

[1]ADM Alliance Nutrition Inc., Quincy, IL
[2]Micro-Lite LLC, Chanute, KS
[3]Bill Barr & Company, Overland Park, KS
Supplement also included: Aureomycin 50 Granular CTC50 (Zoetis Inc., Kalamazoo, MI), Dust Away[1], Liquapro Mill Blend 7-Molasses[1], and Red Iron Oxide

Table 3.2 Effects of treatment and source on initial (d 0) and final (d 139) BW in high-risk stocker cattle receiving either injectable trace mineral (ITM) or saline (CON) on d 0

	Treatment[1]			Source			*P*-value	
Day	CON	ITM	SEM[2]	SE US	MEX	SEM[2]	Treatment	Source
Day 0, kg[3]	250	254	2.2	250	253	2.9	0.14	0.45
Day 139, kg[3]	350	350	2.3	370	330	2.7	0.95	< 0.01

[1]Treatment: CON = 0.9% saline, 1.0 mL / 45 kg; ITM = MultiMin 90, 1.0 mL / 45 kg including 15mg/mL of Cu, 10 mg/mL of Mn, 5 mg/mL of SE, and 60 mg/mL of Zn
[2]SEM: largest of the two treatments and two sources, if different
[3]Treatment by Source Intractions: Day 0, $P = 0.02$; Day 139, $P = 0.05$
SE US: n = 314; MEX: n = 158

Table 3.3 Effects of treatment, source, and treatment × source on ADG in high-risk stocker cattle receiving either injectable trace mineral (ITM) or saline (CON) on d 0

	Treatment[1]			Source			*P*-value		
Variable	CON	ITM	SEM[1]	SE US	MEX	SEM[2]	Treatment	Source	Treatment × Source
ADG 0-42, (kg)	-0.36	-0.32	0.040	0.13	-0.80	0.046	0.54	< 0.01	0.87
ADG 43-139, (kg)	1.22	1.16	0.017	1.15	1.23	0.017	0.04	< 0.01	0.23
ADG 0-139, (kg)	0.73	0.71	0.015	0.82	0.62	0.019	0.31	< 0.01	0.44

[1]Treatment: CON = 0.9% saline, 1.0 mL / 45 kg; ITM = MultiMin 90, 1.0 mL / 45 kg including 15mg/mL of Cu, 10 mg/mL of Mn, 5 mg/mL of SE, and 60 mg/mL of Zn
[2]SEM: largest of the two treatments and two sources, if different
SE US: n = 314; MEX: n = 158

Table 3.4 Effects of treatment and source on morbidity and mortality in high-risk stocker cattle receiving either injectable trace mineral (ITM) or saline (CON) on d 0

	Treatment[1]			Source			*P*-value	
Variable	CON	ITM	SEM[1]	SE US	MEX	SEM[2]	Treatment[3]	Source[3]
Morbidity, %	4.66	2.54	1.372	4.14	2.53	1.249	0.32	0.44
Mortality, %	1.69	1.69	0.839	2.55	0.00	0.890	1.00	0.06

[1]Treatment: CON = 0.9% saline, 1.0 mL / 45 kg; ITM = MultiMin 90, 1.0 mL / 45 kg including 15mg/mL of Cu, 10 mg/mL of Mn, 5 mg/mL of SE, and 60 mg/mL of Zn
[2]SEM: largest of the two treatments and two sources
SE US: n = 314; MEX: n = 158
[3]Independence of source and treatment could not be rejected by a Cochran-Mantel-Haenszel test ($P \geq 0.96$)

Table 3.5 Effect of geographical source on initial serum concentrations of Cu, Mn, Se and Zn on d 0 in high-risk stocker cattle from the Southeastern United States (SE US) and Mexico (MEX)

Mineral	SE US	MEX	SEM[3]	*P*-value
Cu[1]	1.03	0.77	0.029	< 0.01
Mn[2]	16.86	8.31	4.870	0.21
Se[2]	62.89	79.06	6.027	0.06
Zn[1]	0.87	0.87	0.046	0.92

[1]Mineral concentrations measured in parts per million (ppm)
[2]Mineral concentrations measured in parts per billion (ppb)
[3]SEM = largest of the two treatments
SE US: n = 44; MEX: n = 48
Treatment: CON = 0.9% saline, 1.0 mL / 45 kg; ITM = MultiMin 90, 1.0 mL / 45 kg including 15mg/mL of Cu, 10 mg/mL of Mn, 5 mg/mL of SE, and 60 mg/mL of Zn

Table 3.6 Serum concentrations of Cu, Mn, Se and Zn in high-risk stocker cattle received from the Southeastern United States on d 45 after receiving either injectable trace mineral (ITM) or saline (CON) on d 0

		Treatment[1]			
Mineral	Day 0 Concentration	CON	ITM	SEM[4]	*P*-value
Cu[2]	1.03	1.16	1.29	0.072	0.20
Mn[3]	13.86	3.90	3.89	0.323	0.98
Se[3]	62.89	105.61	113.47	3.247	0.09
Zn[2]	0.87	0.78	0.71	0.034	0.21

[1]Treatments: CON = 0.9% saline, 1.0 mL / 100 lbs; ITM = MultiMin 90, 1.0 mL / 100 lbs including 15mg/mL of Cu, 10 mg/mL of Mn, 5 mg/mL of SE, and 60 mg/mL of Zn
[2]Mineral concentrations measured in parts per million (ppm)
[3]Mineral concentrations measured in parts per billion (ppb)
[4]SEM = largest of the two treatments
SE US: n = 37; MEX: n = 0