EVALUATING EFFECTS OF ZINPRO PERFORMANCE MINERALS® ON PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS FED FINISHING DIETS DESIGNED FOR NATURAL BEEF PRODUCTION

By

CHEYANNE COGGINS

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Oklahoma State University

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Thesis Approved:

J. Brad Morgan

Thesis Adviser

Deb VanOverbeke

Clint Krehbiel

A. Gordon Emslie

Dean of the Graduate College

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Over the past several years, the prevalence of natural and organic products, including meat, has been on the rise. Loosely defined, the difference between natural and organic products is that naturally raised animals cannot be given antibiotics or growth hormones while organic is a government certified program which requires the aforementioned with the addition of an organic diet with no pesticides. A consumer study conducted by Abt Associates Inc. (1997) showed that 43 percent of consumers considered hormones used in poultry or livestock production a serious health risk when asked specifically about them. According to Food Technology (Sloan, 1996), natural food product sales increased 22.7% in 1994 and 22.6% in 1995, reaching a total of $9.17 billion in sales. This shows that consumers are taking an active approach to eating foods that are supposed to be better for them.

As recently as January 2009, the United States Department of Agriculture (USDA) established and published a set of voluntary standards for naturally raised livestock. Prior to the publication of this standard, the definition of a natural meat product was not well defined. The standards give producers a way to distinguish their products to consumers seeking meat products from naturally raised livestock (USDA, 2009). The only requirements for the standard of naturally raised is that the animals must never be given growth promotants or antibiotics and must never be fed mammalian, avian and aquatic by-products derived from the harvest process. This standard was intended to be used alone or in conjunction with other marketing programs, such as “grass-fed” (USDA,

2009). Due to these guidelines, producers who wish to offer these types of products to consumers need a method of increasing performance and immune function of their cattle without the use of antibiotics and growth promoting hormones.

The introduction of a new form of trace mineral, which includes zinc in the form of zinc methionine, known as an organic or chelated form sparked research interest in the effects of this type of mineral on growth and performance of beef cattle. Organic minerals are thought to be more bioavailable and therefore are more effectively absorbed and utilized by the cattle. Research has shown that a slight increase in overall performance of the cattle can be seen with the use of organic trace minerals as well as improving some carcass characteristics, such as marbling, 12^{th} rib fat and ribeye area. However, no research has been published concerning the effects of trace mineral source on meat quality of finishing cattle, which is the intent of this study.

CHAPTER II

REVIEW OF LITERATURE

The Importance of Trace Minerals in the Diet of Beef Cattle

Trace minerals are essential to various functions of cattle, including growth of various tissues, immune function, and reproduction. Zinc and copper are especially important as enzyme co-factors in the immune system, which are necessary for immunoglobulin production. Manganese is also important to the immune system, and deficiencies can affect immunoglobulin enzyme activity by affecting T-cell and B-cell response (Coffey, 1993). Manganese has also been found to be important in conception and maintenance of pregnancy in cows. Deficiency of this mineral can lead to problems conceiving and carrying the fetus to full term. Copper and zinc are also important to reproductive efficiency with regards to follicle maturation time (Manspeaker and Robl, 1993).

Minerals, especially zinc, are essential for DNA replication, which is necessary for growth of tissues (Boling, 1993). Lack of essential minerals can also cause improper function of enzymes which are needed for protein synthesis. Nutrient absorption from the intestine and cellular uptake are dependent on minerals as well. Most minerals are dependent on each other through a synergistic relationship; therefore, the deficiency of just one mineral can retard growth, even if all other nutrient requirements are met (Boling, 1993).

During the finishing phase, trace minerals should be supplemented to the diet, especially when low-quality forages are provided as the roughage source (Bentley et al.,

1954). The addition of minerals, including iron, copper, cobalt, manganese and zinc, in cattle finishing rations has been shown to increase gains of both steers and heifers. This was specifically seen when the trace mineral mixture was added to corn-based rations compared to sorghum-based rations, which is most likely due to differences in trace mineral content of the grains (Oltjen et al., 1959). According to Bentley et al. (1954), improvements in growth and performance appear to be due to improved rumen function. Upon analysis of ruminal contents, cattle that were supplemented with amino acid chelated minerals had higher amylase and cellulase activity with decreased methane production (Boling, 1993). Therefore, chelated minerals may increase rumen efficiency.

Certain minerals have been shown to have an effect on adipogenesis and adipocyte differentiation (Kawachi, 2006). Zinc, in particular, has been shown to have insulin-like effects which promotes adipocyte differentiation, and enhances adipogenesis in 3T3-L1 adipose cells (Tanaka et al., 2001). Zinc has also been shown to promote adipocyte differentiation by inhibition of nitric oxide production (Kawachi, 2006). Magnesium has also been reported to increase marbling when fed above dietary recommended levels (Ramirez and Zinn, 2000 as cited by Kawachi, 2006).

The Effects of Trace Minerals on Growth and Performance of Beef Cattle

Several studies have been conducted in the past to determine the effects of an organic source of trace mineral on growth, reproductive performance and feedlot performance of cattle. According to Spears (1996), these organic forms of minerals are more bioavailable and, therefore, may be metabolized differently from inorganic forms,

which may alter some metabolic processes. This was observed by lower urinary zinc excretion in lambs given zinc methionine over zinc oxide (Spears, 1989) and in increased tissue zinc concentrations when zinc proteinate was supplemented to lambs at high concentrations over zinc sulfate (Cao et al., 2000). Rojas et al. (1995) also found that organic forms of zinc (zinc lysine and zinc methionine) have greater availability than zinc sulfate which is considered the most available inorganic source in sheep and suggested that these organic forms may be metabolized differently in some tissues.

Organic trace minerals can occur in many forms such as metal amino acid complexes, metal amino acid chelates, proteinates, and metal amino acid chelates, which are the least common (Spears, 1996). Current research has shown that some small differences can be seen in reproductive performance and growth of cattle consuming these types of organic trace minerals as well as some differences in carcass characteristics between organic and inorganic supplemented cattle.

Early research conducted by Greene et al. (1988) on zinc oxide compared to zinc methionine suggested that zinc source had no effect on average daily gain of the cattle. These results agree with Rust (1985) and Martin et al. (1987); however, this contradicts results of Spears and Samsell (1986) which showed higher average daily gains for heifers fed zinc methionine. Spears (1989) also observed that heifers tended to gain faster and more efficiently when supplemented with zinc methionine compared with zinc oxide over a 126-d feeding trial. Other studies involving zinc supplementation suggested that zinc source had no effect on average daily gain during the finishing period (Malcolm-Callis et al., 2000). Engle and Spears (2000) also observed no differences in overall performance, in terms of average daily gains, daily feed intake and feed:gain of growing and finishing

steers supplemented with copper sulfate, copper citrate, copper proteinate, or copper chloride (2000). Some differences were seen in average daily gains during the finishing phase, with Cu citrate calves gaining faster than Cu sulfate calves (Engle and Spears, 2000).

Ahola et al. (2005a) observed that trace mineral source of cows did not affect calf performance; however, females did show higher estrous cyclicity prior to artificial insemination, although pregnancy rate was not affected. This contradicts research by Stanton et al. (2000) and Kropp (1990) which showed that calves from cows receiving organic trace minerals, had higher pre-weaning average daily gains and greater weaning body weight. Ahola et al. (2004) also observed that over a two-year period, cows supplemented with an organic source of minerals had higher pregnancy rates than those supplemented with inorganic minerals when bred upon observed estrus; however, body condition was not affected by treatment. In that same study, calf performance was also assessed, and contradicting observations occurred between year one and year two (Ahola et al., 2004). In year one, cows in the inorganic group had more kilograms of calf weaned per cow exposed, and the converse was observed in year two (Ahola et al., 2004). In contrast, Muehlenbien and others (2001) reported no statistical differences in cow reproductive performance or weaning weights of their calves from cows supplemented with organic and inorganic sources of copper.

The effect of zinc source was assessed by Spears and Kegley in 2002, which showed differences between zinc oxide supplemented calves and zinc proteinate supplemented calves. During the growing phase, significant differences were seen between the control calves that were given no supplement, and the zinc supplemented

calves with regards to average daily gains. This would suggest that zinc, in any form is essential to early growth. During the finishing phase, zinc proteinate (15%) supplemented calves had higher average daily gains than zinc oxide supplemented calves and gained more efficiently (Spears and Kegley, 2002).

The effects of trace mineral supplementation in the presence of antagonists on calf performance were observed in stressed calves. Both source of trace mineral and level of intake were manipulated to determine if the type of mineral or amount received would affect growth and performance. This study observed that feed consumption, average daily gain and feed efficiency were not affected by trace mineral source and level (Stanton et al., 2001).

The Effects of Trace Minerals on Immune Function of Cattle

Trace minerals are an important factor of immune function. Both zinc and copper serve as essential enzyme co-factors in the immune system. Research has shown that deficiencies in these trace minerals can lead to decreased immune response (Coffey, 1993). Since cattle that are to be considered naturally raised are not to be given growth promotants or antibiotics, a possible method of boosting immune function is necessary to prevent increased morbidity and mortality in these cattle. It has been established that trace minerals are important to immune function, especially zinc, which in severe deficiency is known to cause immunosupression (Chesters, 1997). Spain (1993) observed that supplementation of zinc as 50 percent zinc proteinate resulted in fewer new mammary gland infections based on somatic cell counts and bacteriological culture of

milk samples (Spears and Kegley, 2002). Therefore, using organic or chelated forms of trace minerals, specifically zinc, may improve immune function.

In 2002, Spears and Kegley reported that zinc source had no effect on immune function, but suggested severe zinc deficiency reduced lymphocyte response in lambs as written by Droke and Spears (1993). Zinc requirements appeared to be higher in order to achieve maximum growth than for increased immune response in growing steers (Spears and Kegley, 2002).

The Effects of Trace Minerals on Carcass Characteristics of Feedlot Cattle

Although carcass characteristics of organic versus inorganic-supplemented animals have not been as thoroughly investigated, several studies have included these parameters. Early research conducted by Greene et al. (1988) showed that steers supplemented with zinc methionine, which is the organic form, exhibited more marbling and thus higher quality grades than those supplemented with zinc oxide. Zinc supplementation has been shown to increase quality grade and marbling with a tendency to increase yield grade and 12^{th} rib fat thickness as well. Along with this, supplementing with organic forms of zinc, such as zinc proteinate, increases hot carcass weights (HCW), dressing percentage, and ribeye area (Spears and Kegley, 2002). The response seen in this research was most likely due to the large difference in zinc concentrations of the control diet and the supplemented diets.

Research performed by Stanton et al. (2001) on varying levels and sources of trace minerals showed that while most of the carcass characteristics were not affected by

source or level, longissimus area of the organic-supplemented cattle was significantly larger than the inorganic-supplemented cattle. Level of supplementation also affected this parameter with the low organic having the largest ribeye area (REA) and the low inorganic having the smallest REA. Another study evaluating the source and level of trace minerals on carcass characteristics showed that fat thickness was affected by source and level as well as marbling. Those fed the high organic minerals had lower amounts of subcutaneous fat than those fed the low organic or low and high inorganic trace minerals. Also, animals fed the organic minerals at NRC (1996) recommended levels had higher amounts of marbling than the other treatment groups (Rhoads et al., 2003). This could be attributed to those animals being fatter. Ahola and others (2005b), observed no differences in carcass characteristics between non-supplemented cattle, organic supplemented cattle, or inorganic supplemented cattle. Cattle from both treatment groups in this study were supplemented at the NRC (1996) recommended levels for trace minerals.

Supplementation of copper may also have an effect on carcass characteristics in finishing steers. Engle et al. (2000) reported that dressing percentage, KPH percentage, REA, quality grade and yield grade were unaffected by copper supplementation and source. However, HCW and 12^{th} rib fat were lower, although marbling was not different with copper supplementation and source. This decrease in HCW and 12^{th} rib fat was most likely due to decreased gains seen in this study (Engle et al., 2000).

Consumer Acceptability of Beef Related to Warner-Bratzler Shear Force and Tenderness

Miller et al. (1995) stated that tenderness is the most important palatability attribute of meat and a primary determinant of meat quality (1987). Tenderness is considered to be one of the major factors of consumer satisfaction of meat products, along with juiciness, which can also affect tenderness ratings and flavor. Beef tenderness is influenced by several factors including collagen content, heat stability and myofibrillar structure of the muscle (Muchenje et al., 2009). Variations in tenderness can also be attributed to other factors such as breeding and feeding conditions (Miller et al., 1995).

Most often, Warner-Bratzler shear force (WBS) is used as a measure of tenderness in meat products, which is used to simulate the force it takes for a person to bite a piece of meat. Typically, as WBS decreases, consumer acceptability, by way of tenderness ratings, increases (Miller et al., 1995). In 2001, Miller et al. established a scale of consumer thresholds for beef tenderness. These researchers determined that strip steaks having a WBS value of 3.0 kg or less were considered tender and would have a consumer acceptability rating of 100 percent (Miller et al., 1995). It was also established that steaks with a WBS between 4.3 and 4.9 kg would decrease the consumer acceptability rating to below 86 percent (Miller et al., 1995). This suggested that steaks with an average WBS value of approximately 4.6 kg or greater would be unacceptable to consumers and would be considered “tough” (Miller et al., 1995). They also observed that steaks with a WBS of 4.9 kg were rated as slightly tough or moderately tough, which could be explained by the influence of flavor and juiciness which differed between the samples (Miller et al., 2001).

Marbling may also be a factor in consumer acceptability related to tenderness. In 2003, Platter et al. discovered a moderate to high correlation among marbling scores, WBS values and consumer palatability ratings. However, they observed a relatively weak relationship between marbling score and overall consumer acceptability, according to the low adjusted R^2 value (Platter et al., 2003). This shows that even though marbling is the primary predictor used for palatability of beef, it may not always hold true. Marbling typically helps to increase juiciness of the cooked product and allows for increased doneness without being detrimental to tenderness ratings (Platter et al., 2003).

Consumer Acceptability of Beef Related to Lean Color

Meat color is directly related to pH of the muscle tissue. Kropf (1980) and Hedrick (1994) suggested that consumers consider lean color to be the most important factor when purchasing meat products as reported by Page et al. (2001). Color of the lean surface and discoloration are determined by the state of the myoglobin molecule, which is the pigment factor in muscle tissue, much like hemoglobin in blood. The iron molecule on the myoglobin contains a free binding site where various compounds have the ability to attach based on their affinity for the iron molecule. In muscle tissue and meat that has not been exposed to air, either through vacuum packaging or prior to cutting, no ligand is attached to the free binding site. This is known as deoxymyoglobin and is purple in color. Once the lean surface has exposed to air, oxygen begins to bind to the free site and forms oxymyoglobin, which causes the development of the bright cherry red color in beef. This is what consumers typically associate with fresh meat. In both of these cases

(deoxymyoglobin and oxymyoglobin), the iron molecule is in the reduced, or ferrous form. Once the iron undergoes oxidation through loss of an electron, it becomes the ferric form and causes discoloration of the meat. A layer of this metmyoglobin is found between the surface oxymyoglobin and the interior deoxymyoglobin, which gradually thickens and moves toward the surface of the lean. Development of metmyoglobin and ultimately surface discoloration is dependent on temperature, pH, oxygen partial pressure, reducing activity and sometimes, microbial activity (Mancini and Hunt, 2005). This surface discoloration is associated with discounts of nearly 15% of all retail beef, totaling annual revenue losses of approximately $1 billion (Smith et al., 2000).

According to Muchenje et al. (2009) most color measurements are taken using the Commission International De I'Eclairage (CIE) color system, which utilizes the L*, a* and b* coordinates on the color scale. L* values measure light to dark (100 = white, 0 = black); a* measures redness/greenness (positive = red, negative = green) and b* measures yellowness/blueness (positive = yellow, negative = blue). Zhang et al. (2005) showed that higher pH values of meat correlate to lower L*, a*, b*, hue angle (degrees) and chroma (saturation) values. This can be seen in Dark, Firm and Dry (DFD) beef which typically has abnormally high pH values (Muchenje et al., 2009; Page et al., 2001). Page et al. (2001) also showed that lean maturity is most highly correlated with L* values.

Trained sensory panels for color can also be utilized to determine consumer acceptability based on visual appearance and discoloration of the product. In 2001, Carpenter et al. reported a strong association between color preference and purchasing intent with consumers discriminating against beef that was not red in color. These authors also observed that meat packaged with film contact, such as with polyvinyl chloride film

(PVC) overwrap was perceived to be more red than when packaged with headspace, as with modified atmosphere packaging (MAP) (Carpenter et al., 2001). Fat and bone color can also contribute to overall product appearance (Mancini and Hunt, 2005). According to Arnold et al. (1992), a subjective color panel should be used to apply inferences to the human assessment of beef discoloration. They also noted that using the days to threshold method, the data from visual panels and spectrophotometry gives similar estimates of retail display life for longissimus steaks (Arnold et al., 1992). Therefore, in order to correctly assess visual lean color and consumer acceptability of meat, both objective and subjective methods of color measurement should be used.

Currently, no research has been performed to determine if source of trace mineral has an effect on lean color or retail-case life; however, one could hypothesize that it would have little, if any, affect. Typical factors that affect meat color include enzymes, diet (forage vs. grain) and age of the animal as well as pre-harvest handling (Muchenje et al., 2009). Even if consumers prefer naturally raised or grass-fed beef for the perceived health reasons (Abt Associates Inc., 1997), Muir et al. (1998) reported that meat from grass-fed animals is darker than from grain-fed animals. This could have some effect on consumer preference if purchasing a “natural, grass-fed” product. Walshe et al. (2006), showed that steaks from conventionally raised beef were more lipid and color stable than those from organically raised beef. This was thought to be due to the organic steaks having a higher fat content within the muscle tissue (Walshe et al., 2006).

Statement of the Problem

In order for cattle to be considered “naturally raised” at harvest, they cannot be fed any animal byproducts, or given any antibiotics or growth promoting hormones. Due to this, cattle feeders are faced with the challenge of decreased performance and increased morbidity and mortality. Little is known about how this approach to production affects meat quality and there is limited research has been done on effects on carcass quality and prevalence of liver abscesses.

Approach to the Problem

Since previous research (Spears and Samsell, 1986; Spears, 1989; Spears, 1996; Stanton et al., 2000; Spears and Kegley, 2002) has shown that an organic or chelated form of mineral can increase performance and immune function as well as improving some carcass characteristics, we wanted to investigate the effect of these minerals in a natural production system. Meat quality was also a concern, and therefore several factors were considered including retail-case life, tenderness, and trace mineral content of the meat.

CHAPTER III

EVALUATING EFFECTS OF ZINPRO PERFORMANCE MINERALS® ON PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS FED FINISHING DIETS DESIGNED FOR NATURAL BEEF PRODUCTION

C.L. Coggins, D.L. VanOverbeke, B.P. Holland, C.R. Krehbiel, C.K. Larson, and J.B. Morgan

ABSTRACT

One hundred sixteen steers, (harvest 1, n = 42 and harvest 2, n = 38, and harvest 3, n = 36, respectively) were used to evaluate the effect of organic Zinpro Performance Minerals® on performance, carcass characteristics, tenderness and retail-case life of longissimus steaks. Steers were blocked by initial weight and assigned one of two treatment groups, inorganic (ING) or Zinpro (ZPM) trace mineral supplements, at weaning. Each group was fed to a compositional endpoint and harvested at a commercial facility. Strip loins (IMPS #180) were collected upon harvest and aged for 14 d. Carcass characteristics, retail-case life, Warner-Bratzler shear force (WBS), and trace mineral content were evaluated. In group one, carcass adjusted average daily gain (ADG) and dry matter intake (DMI) were greater ($P < 0.05$) for ING steers and gain to feed (G:F) tended to be greater ($P = 0.06$) for the entire trial period compared to ZPM steers. In harvest group two, body weight (BW), ADG, DMI and G:F were similar among treatments; however, ING steers tended to gain more efficiently ($P = 0.07$) than ZPM steers. Only DMI tended to be greater ($P = 0.09$) in ING steers for the entire trial period with all other measurements being similar ($P > 0.05$). No differences ($P > 0.05$) were observed between

treatment groups for strip loin steak WBS and cooking loss percentage. In harvest group one, ING had significantly ($P < 0.05$) greater hot carcass weights (HCW) and tended to have more 12^{th} rib fat ($P = 0.07$) than ZPM. Kidney, pelvic and heart fat percentage (KPH) tended to be lower ($P = 0.07$) in ING compared to ZPM. All carcass traits were similar in harvest group three. No differences ($P > 0.05$) were found for liver condemnation percentages. No differences ($P > 0.05$) were found for the subjective color evaluation or a* and b* values between treatments. Steers in ING initial harvest group had higher ($P < 0.05$) L* values than the organic contemporaries. Trace mineral analysis revealed no differences ($P > 0.05$) between treatments for Ca, Na, Fe, Cu, or Mn content. In harvest group one, Zn content tended to be greater ($P = 0.07$) and Ni was greater ($P < 0.05$) in ING. For harvest group two, S, Mg, K and P were greater ($P < 0.05$) for ING compared with ZPM. Supplementing with an organic source of trace minerals while eliminating antibiotics and growth hormones can be done without any negative effects on carcass quality or tenderness.

INTRODUCTION

With increased consumer demand for naturally raised or finished beef, cattle must not be supplemented with or given antibiotics, and they must not be given growth promotants in order to meet these qualifications. This, in turn, decreases feedlot performance and may also affect morbidity and mortality. Previous research has shown some increased performance when cattle are supplemented with an organic form of trace minerals, especially when zinc methionine was supplemented as the zinc source. These minerals are known as chelates and can exist as metal amino acid complexes (e.g. zinc

methionine), proteinates, metal amino acid chelates, or metal polysaccharide complexes (Spears, 1996). Zinpro performance minerals are a mixture of metal amino acid complexes which includes zinc, manganese, copper and cobalt (Zinpro, 2006).

It has also been shown that supplementation of cattle with an organic or chelated trace mineral can have an effect on carcass characteristics such as decreasing 12th rib fat thickness (Rhoades et al., 2003), increasing marbling (Greene et al., 1988), and increasing yield with greater hot carcass weights, dressing percentage and ribeye areas (Spears and Kegley, 2002). Currently, no known previous research has been conducted on the effect of trace mineral source on meat quality.

The objectives of this study were to determine if Zinpro performance minerals could improve animal growth and performance and carcass characteristics, without the addition of antibiotics or ionophores or the administration of growth implants, and if ZPM had any effect on meat quality, including retail-case life, tenderness and trace mineral content.

MATERIALS AND METHODS

Animals

Three sets of weaned steer calves (n = 43, n = 38 and n = 37, respectively) were obtained from the University of Arkansas spring and fall calving herds for three consecutive calving seasons. These cows are currently being utilized to evaluate the effects of Availa® 4 mineral compared to an isoinorganic mineral on cow and calf performance. All calves were subjected to a 42 d conditioning program that included vaccination and trace mineral nutrition treatments. Calves remained in their designated groups from which they originated at birth, inorganic (ING) or ZPM (Availa-4), throughout the study, and these represent the three harvest groups mentioned later.

Treatment Allotment

Approximately 1 h after arrival at Willard Sparks Beef Research Center, individual body weights were taken and recorded. Cattle were processed approximately 24 h after arrival including vaccinations for viral respiratory pathogens and deworming. Calves were sorted into pens, blocked based on body weight into two blocks (block 1 = light weight, block 2 = heavy weight) and randomly assigned a pen. Pens were randomly assigned to treatments, and each treatment group consisted of 4 pens per harvest group.

Diet

No inophores or antibiotics were fed during the study and no implants were given so that cattle could qualify as “natural fed cattle at harvest.” Feeding of experimental diets began 1 d after processing and pen allotment. Feed (Table 2) was mixed every 3 to 5

days and stored in a commodity bay. Feed was hand weighed, and delivered twice daily. Steers were gradually adapted to a final 91% concentrate diet in a step-up fashion. Diet samples were taken and 28 d intervals. Samples were composited, and analyzed for N, starch, ash (AOAC, 1990), ADF (Goering and Van Soest, 1970) and mineral content.

Animal Health

All steers were monitored daily for clinical signs of morbidity by a licensed veterinarian and qualified feedlot personnel. Evaluators assigned a severity score of 1 to 4 during evaluation. Any animal with a severity score of 2 or greater and a rectal temperature of 40^{o}C or higher received an antimicrobial according to label directions, using the correct body weight obtained for the proper dosage. For a severity score of 3 or 4, regardless of rectal temperature, cattle received an antimicrobial. These cattle were then removed from the study due to restrictions on antibiotic treatment.

Data Collection

Interim shrunk body weights were collected and recorded at 28-d intervals. These weights were recorded at 28, 56, 84, 112 and 140 d on feed to assess performance of the cattle. Other measurements taken prior to harvest included average daily gain (ADG), feed consumption per pen, dry matter feed conversion per pen, morbidity and mortality. The cattle were harvested in three groups, according to the group they were received in. All black-hided cattle were harvested at a commercial facility (Creekstone Farms, Inc., Arkansas City, KS), and all other cattle (n = 4) were harvested at Oklahoma State University Food and Ag Products Center (FAPC). Carcass measurements were obtained

by trained Oklahoma State University personnel, which included hot carcass weight, longissimus muscle area and marbling score of the split lean surface at the $12^{th}/13^{th}$ rib interface, percentage of kidney, pelvic and heart (KPH) fat, fat thickness at the ¾ measure opposite the split lean surface between the 12^{th} and 13^{th} rib, USDA yield and quality grades, and liver condemnation percentages.

Strip Loin Collection and Sample Preparation

After carcass data collection, carcasses were fabricated according to Institutional Meat Purchasing Specifications (IMPS; USDA, 1996), and strip loins (IMPS #180) were individually identified, collected, vacuum packaged, returned to FAPC and aged 14 d postmortem at approximately 2^{o}C. Following aging, the anterior end of the strip loins were faced, and two 100 g samples from each strip face were obtained, vacuum packaged and placed in a blast freezer (-20^{o}C) for subsequent trace mineral analysis. The anterior 2.54 cm steak was then cut and packaged for simulated retail display. The next 2.54 cm steak was cut, vacuum packaged and frozen at -20^{o}C for subsequent shear force analysis.

Trace Mineral Analysis

Samples for trace mineral analysis were cut into cubes and frozen in whirl-paks. These were then ground, weighed, and submitted to the Oklahoma State University Soil, Water, and Forage Analytical Laboratory for trace mineral analysis. The samples were digested on a digestion block at 125^{o}C for 4 h using 10 mL of 10% trace-metal-grade nitric acid. Upon digestion the samples were brought to a volume of 50 mL with deionized water and read using Inductively Coupled Plasma (ICP) Spectroscopy. All

trace mineral analysis was performed on an as-is basis, which included zinc, manganese, copper. Analysis of macro-minerals included calcium, sodium, phosphorus, iron and sulfur.

Warner-Bratzler Shear Force

Steaks were allowed to temper for 24 h at 4^{o}C prior to cooking. Steaks were broiled in an impingement oven (model 1132-000-A; Lincoln Impinger, Fort Wayne, IN) at 180^{o}C for approximately 13 minutes to a final internal temperature of 70^{o}C. Individual steak weights were recorded prior to and following cooking to determine cook loss percentages. After steaks were allowed to cool for at least two hours to 25^{o}C, six 1.27 cm diameter cores were removed parallel to the muscle fiber orientation from each steak. Each core was sheared once by a Warner-Bratzler head attached to an Instron Universal Testing Machine (model 4502; Instron Corp., Canton, MA) at a crosshead speed of 200 mm/min. Peak force (kg) of cores were recorded by an IBM PS2 (Model 55 SX) using software provided by the Instron Corp. (Canton, MA).

Simulated Retail Display and Color Evaluation

After the retail display steaks were over-wrapped with PVC, the steaks were placed in retail display cases maintained at 2^{o}C ± 1, under lighting conditions (Phillips Delux Warm White Florescent lamps, 24 h/d, the surface of the meat was exposed to 900 to 1365 lux) recommended by AMSA (1991) to simulate retail display conditions. Each steak was objectively and subjectively evaluated for color attributes at 12 h intervals during retail display.

Objective Color Evaluation

Color of each steak was measured using a HunterLab MiniScan XE hand-held spectrophotometer equipped with a 6 mm aperture (HunterLab Associates, Inc., Reston, VA) to determine values for CIE L* (brightness; 0 = black, 100 = white), a* (redness/greenness; positive values = red, negative values = green), and b* (yellowness/blueness; positive values = yellow, negative values = blue) following procedures of the Commission Internationale de I'Eclairage (CIE, 1976). Three readings for each of L*, a* and b* were averaged for each steak at the beginning of retail display and once every 12 h during display.

Subjective Color Evaluation

Color was subjectively evaluated by a 6 person trained panel of Oklahoma State University personnel; panelists were trained using a system of open discussion and a procedure outlined by Lavelle et al. (1995). Evaluators assigned scores to each steak for muscle color, overall appearance and surface discoloration at each evaluation time. Muscle color (oxygenated pigment) was characterized on an 8-point scale (8 = extremely bright cherry red; 1 = extremely dark red) as outlined in the Guidelines for Meat Color Evaluation (AMSA, 1991). Scores for overall appearance (8 = extremely desirable; 1 = extremely undesirable) and surface discoloration (7 = 100% discoloration; 1 = no discoloration) were also assigned according to AMSA (1991) guidelines. Steaks were evaluated until at least 80% of the steaks were assigned a mean overall appearance score of 3 (moderately undesirable) or lower.

Statistical Analysis

Only data from cattle that completed the study was analyzed using SAS Release 9.1 (SAS Institute Inc., Cary, NC) with a significance level of $\alpha = 0.05$; means were separated by TRT using LS means. All performance data was analyzed using the Proc Mixed procedure with pen as the experimental unit. Data for carcass characteristics, cook loss, and Warner-Bratzler Shears were analyzed using the Proc Mixed procedure with treatment (TRT) and block (BLK) as fixed effects and animal ID as a random effect. Color data was analyzed using repeated measures with hour of display as the repeated measure. All carcass data was initially analyzed as a pooled set of data over all harvest groups and after finding harvest group to be significant with no harvest group x treatment interaction, these groups were then separated.

CHAPTER IV

RESULTS AND DISCUSSION

Performance

Although 118 steers entered the study, one died and one was removed from the trial after being treated with antibiotics. All data from these 2 steers was removed from analysis. The largest differences for average daily gain (ADG), dry matter intake (DMI), and gain to feed (G:F) were seen in harvest group one (Table 3). Although no significant differences were seen for final body weight (BW), steers in ING were initially greater in BW ($P < 0.05$) than the ZPM steers. They also had greater BW at 28 d ($P < 0.05$); however, there were no differences in the remaining 28 d interval weights. Although there was a significant difference in the carcass adjusted ADG, no differences were seen throughout the 195 d trial period. Dry matter intake was significantly greater ($P < 0.05$) in the ING steers throughout the trial, being significant at the final stages of feeding rather than early in the trial. Adjusted gain to feed tended to be greater ($P = 0.06$) in the ING steers throughout the trial with significance occurring at 57 to 112 d and 29 to 195 d.

Although no differences ($P > 0.05$) were observed between the two treatments for BW, ADG, DMI or G:F in group two (Table 4), steers in ING tended to gain more efficiently ($P = 0.07$) from 29-56 d of the 152 d trial. Average Daily Gain and G:F were similar between the treatments in group three; however, DMI tended to be greater ($P = 0.09$) in ING steers than ZPM throughout the 187 d trial with the largest difference seen

from 141 to 187 d. There was also a significant difference seen for BW at day 84 with ING being greater ($P < 0.05$) than ZPM.

Carcass Characteristics

No significant differences ($P > 0.05$) were observed for marbling or liver condemnation rates in all three harvest groups (Tables 6 through 8). This data was similar to work performed by Malcolm-Callis et al. (2000), Stanton et al. (2001) and Ahola et al. (2005b) where source of mineral had no effect ($P > 0.05$) on marbling scores and subsequent quality grades. This is different, however, than a study comparing zinc methionine and zinc oxide where zinc methionine supplemented steers had greater marbling scores than zinc oxide supplemented steers (Greene et al., 1988). There was a trend for greater REA in the heavy weight block of harvest groups one ($P = 0.09$) and three ($P = 0.07$), but no difference ($P > 0.05$) between the two treatments within harvest group two (Table 7). For 12^{th} rib fat thickness, the cattle in the inorganic treatment tended ($P = 0.07$) to have greater amounts of 12^{th} rib fat within the initial harvest group than the ZPM cattle (Table 6). This was also seen, as expected, for preliminary yield grade (PYG), which is directly related to 12^{th} rib fat thickness. In harvest group one; the ING cattle had significantly greater ($P < 0.05$) hot carcass weights (HCW) than the ZPM cattle, which was most likely due to more 12^{th} rib fat in ING cattle (Table 6). These results were similar to Rhoades et al. when cattle fed organic minerals at 1.5 times the NRC recommended levels had less ($P < 0.05$) 12^{th} rib fat than those fed organic minerals at the NRC recommended levels or cattle fed inorganic minerals (2003). Malcolm-Callis et al. similarly found that steers supplemented with an organic source of zinc had less (P

< 0.10) 12th rib fat than those supplemented with zinc sulfate (2000). However, this is contradicted by a study from Greene et al. which reported that zinc oxide supplemented steers tended to have less (P < 0.10) 12th rib fat than zinc methionine supplemented steers (1988). In this study in harvest group one, ZPM cattle tended (P = 0.07) to have slightly greater amounts of kidney, pelvic and heart fat percentage (KPH) than their ING contemporaries (Table 6). No differences (P > 0.05) were observed between treatments in harvest group two or three (Tables 7 and 8). No differences (P > 0.05) were observed for PYG, fat thickness, YG, marbling, or percentages of quality grades for harvest group three (Table 8).

Cook and Shear Data

No significant differences (P > 0.05) were seen for cook loss or WBS between treatments (Table 9). When treatment groups were analyzed together, harvest group two had greater (P < 0.05) shear force values than the initial harvest group, and therefore had less tender steaks. This was most likely due to the greater amount of marbling in harvest group one. Within harvest group three, no significant differences were found between the treatments for cook loss percentage or shear force. All three harvest groups and treatments were within an acceptable range for tenderness having WBS values of 3.75 kg or less as seen in Table 9.

Lean Color Data

In harvest group one, L* values were significantly greater (P < 0.05) in the ING group than the ZPM group; therefore, the steaks were lighter in color within the ING

treatment (Figure 10). This could be due to differences in marbling scores between the two groups. In harvest group three, there no significant differences ($P < 0.05$) between treatments. No significant differences ($P > 0.05$) were observed for a* or b* values between treatments in all three harvest groups (Figures 13 through 18). No differences ($P > 0.05$) were observed for lean color, surface discoloration, or overall appearance using the subjective color evaluation for all three harvest groups (Figures 1 through 9).

Trace Mineral Analysis

No significant differences ($P > 0.05$) were observed for calcium, sodium, iron, copper, or manganese between treatments in harvest groups one and two (Tables 10 and 11). In harvest group one, there was a trend ($P = 0.07$) for the inorganic treatment group to have higher levels of zinc in the muscle tissue than the organic group. Also in the initial harvest group, nickel was significantly higher ($P < 0.05$) in the inorganic group (Table 10). In harvest group two, sulfur, magnesium, potassium and phosphorus were higher ($P < 0.05$) in the inorganic group than ZPM (Table 11). This could be due to the increased utilization of the minerals by the animal, so less would be deposited in the muscle tissue. No significant differences were found between the treatments within harvest group three for any of the minerals listed above (Table 12).

CHAPTER V

CONCLUSION

It may be beneficial for cattle being fed for “naturally raised beef” to be supplemented with a chelated or organic form of trace mineral; however, additional research needs to be conducted on the effects on performance, carcass characteristics, and especially meat quality. Zinpro performance minerals decreased dry matter intake in all trials while having limited effects on ADG with some increased gain to feed; therefore supplementing with Zinpro Performance Minerals would be more cost effective. Organic minerals have a tendency to decrease 12^{th} rib fat while still maintaining marbling amounts. In terms of meat quality, Zinpro performance minerals had no significantly negative effects on retail-case life or tenderness. Some decrease in lightness of the meat was seen, but without negative effects on acceptability of the steaks. Further research is needed to confirm these results.

Table 1. Arrival date, days on feed, and number of animals received.

	Date Received	DOF	Initial BW, kg	Number of Animals	
				Inorganic[a]	Organic[a]
Load 1	9/5/2007	195	266 ± 24.9	17	26
Load 2	1/30/2008	152	293 ± 30.3	22	16
Load 3	8/21/2008	187	275 ± 29.6	19	18

[a]Organic treatment contained Availa 4 during the adaptation period and zinc methionine for the remainder of the feeding period. Inorganic treatment diet was formulated to contain equal concentrations of zinc, manganese, copper, and cobalt or zinc from traditional sources to the Organic treatment diets during the adaptation and finishing periods, respectively.

Table 2. Experimental diets and nutrient composition.

Item	Step 1	Step 2	Step 3	Finisher
Dry rolled corn	47.0	52.0	57.0	61.5
DDGS	5.0	10.0	15.0	20.0
Synergy 19-14	3.5	3.5	3.5	4.5
Ground Alfalfa	40.0	30.0	20.0	10.0
Dry supplement	4.5[a]	4.5[a]	4.5[a]	5.0[b]
Nutrient Composition[c]				
Dry matter, %	86.8	86.9	87.0	86.8
NEm, Mcal/kg	1.84	1.93	2.02	2.12
NEg, Mcal/kg	1.15	1.23	1.30	1.37
Crude protein, %	14.7	14.9	15.02	15.25
Fat, %	4.2	4.7	5.3	6.0
NDF, %	24.9	23.1	21.2	18.9
Calcium, %	0.89	0.75	0.60	0.70
Phosphorus, %	0.31	0.33	0.35	0.37
Zinc, mg/kg	74.0	74.0	74.1	93.2
Cobalt, mg/kg	1.95	1.95	1.95	0.1
Copper, mg/kg	29.7	31.7	33.7	32.8
Manganese, mg/kg	54.7	52.0	49.4	40.1

[a] Pelletted supplement contained, for the Inorganic treatment: ground corn, 61.4%; wheat middlings, 16.7%; calcium carbonate, 14.4%; salt, 5.6%; thiamine 10, 1.20%; zinc sulfate, 0.3267%; copper sulfate, 0.1667%; manganous oxide, 0.1089%; vitamin (A-30,000 IU/g), 0.0711%; vitamin E, (50%), 0.0489%; and cobalt carbonate, 0.0089%. Supplement for the Organic treatment contained: ground corn, 59.7%; wheat middlings, 16.7%; calcium carbonate, 14.4%; salt, 5.6%; thiamine 10, 1.20%; and Availa 4 (Zinpro, Inc.), 2.28%.

[b] Pelletted supplement contained for the Inorganic treatment: ground corn ,49.8%; calcium carbonate, 26.0%; wheat middlings 15.0%; salt 5.0%; potassium chloride 2.4%; thiamine 10, (1.0880%); zinc sulfate, 0.4000%; copper sulfate, 0.1200%; manganous oxide, 0.0700%; vitamin A (30,000% IU/g), 0.0640%; vitamin E (50%), 0.0440%. Supplement for the Organic treatment contained: ground corn ,48.8%; calcium carbonate, 26.0%; wheat middlings 15.0%; salt 5.0%; potassium chloride 2.4%; thiamine 10, (1.0880%); copper sulfate, 0.1200%; manganous oxide, 0.0700%; vitamin A (30,000% IU/g), 0.0640%; vitamin E (50%), 0.0440%, and zinc methionine (Zinpro, Inc.).

[c] All values on a DM basis, except DM, and calculated using NRC (2000) values.

Table 3. Feedlot performance of steers fed inorganic or organic complexes of trace minerals (Load 1).

	Inorganic	Organic	SEM[a]	*P* > F
BW, kg				
d 0	282.2	258.3	16.52	<0.001
d 28	320.4	297.4	14.53	0.001
d 56[b]	359.9	361.5	18.46	0.97
d 84[b]	413.1	410.6	9.98	0.92
d 112[b]	442.3	450.7	4.09	0.24
d 140[b]	483.8	498.1	5.38	0.15
d 168	523.9	512.3	14.96	0.27
d 195[b]	541.4	547.6	5.78	0.52
Adj. Final[b]	543.4	545.9	5.52	0.78
ADG, kg/d				
0 – 28	1.36	1.39	0.12	0.85
29 – 56	1.87	1.83	0.16	0.83
57 – 84	1.79	1.86	0.07	0.49
85 – 112	1.09	1.38	0.11	0.08
113 – 140[b]	1.49	1.57	0.17	0.46
141 – 168	0.91	1.03	0.22	0.38
169 – 195	1.11	0.84	0.14	0.16
29 – 195	1.40	1.42	0.03	0.52
0 – 195	1.39	1.42	0.03	0.52
Adj. 0 – 195	1.41	1.40	0.73	0.03
DMI, kg/d				
0 – 28	8.20	7.22	0.25	0.03
29 – 56	10.11	8.90	0.55	0.17
57 – 84	10.65	10.13	0.23	0.16
85 – 112	10.73	10.49	0.32	0.61
113 – 140	10.35	10.09	0.42	0.62
141 – 168	10.16	10.18	0.27	0.97
169 – 195	10.57	9.78	0.19	0.03
29 – 195	10.43	9.90	0.19	0.09
0 – 195	11.28	10.57	0.20	0.05
G:F, kg:kg				
0 – 28	0.167	0.194	0.016	0.27
29 – 56	0.187	0.212	0.026	0.51
57 – 84	0.168	0.184	0.004	0.03
85 – 112	0.101	0.132	0.007	0.02
113 – 140[b]	0.147	0.163	0.014	0.49
141 – 168[b]	0.106	0.086	0.009	0.22
169 – 195	0.105	0.087	0.014	0.36
29 – 195 [b]	0.133	0.145	0.003	0.08
0 – 195	0.124	0.134	0.003	0.04
Adj. 0 – 195	0.125	0.133	0.002	0.06

[a]Standard error of the least squares means.
[b]Initial body weight included as a covariate.

Table 4. Feedlot performance of steers fed inorganic or organic complexes of trace minerals (Load 2).

	Inorganic	Organic	SEM[a]	*P* > F
BW, kg				
d 0	291	293	24.22	0.50
d 28	348	347	26.34	0.88
d 56[b]	397	400	4.76	0.65
d 84[b]	446	447	5.75	0.87
d 112[b]	488	486	3.12	0.61
d 152[b]	529	535	6.57	0.58
Adj. Final	538	526	26.77	0.58
ADG, kg/d				
0 – 28	2.05	1.96	0.10	0.55
29 – 56	1.70	1.92	0.20	0.21
57 – 84	1.75	1.69	0.18	0.81
85 – 112	1.52	1.38	0.16	0.57
113 – 152	1.03	1.22	0.13	0.34
29 – 152	1.45	1.52	0.05	0.34
0 – 152[b]	1.56	1.60	0.04	0.58
Adj. 0 – 152	1.63	1.53	0.10	0.52
DMI, kg/d				
0 – 28	8.48	8.43	0.68	0.91
29 – 56	10.95	10.65	1.29	0.60
57 – 84	12.00	11.87	0.66	0.87
85 – 112	11.52	11.28	0.43	0.58
113 – 152	10.15	10.38	0.16	0.36
29 – 152	11.06	10.98	0.54	0.84
0 – 152	10.58	10.51	0.56	0.84
G:F, kg:kg				
0 – 28	0.243	0.232	0.011	0.34
29 – 56	0.157	0.180	0.007	0.07
57 – 84	0.145	0.144	0.016	0.95
85 – 112	0.132	0.123	0.015	0.68
113 – 152	0.101	0.118	0.012	0.39
29 – 152	0.132	0.139	0.004	0.35
0 – 152	0.148	0.153	0.005	0.38
Adj. 0 – 152	0.154	0.147	0.010	0.68

[a]Standard error of the least squares means.
[b]Probability of significance of using initial BW as a covariate.

Table 5. Feedlot performance of steers fed inorganic or organic complexes of trace minerals (Load 3).

	Inorganic	Organic	SEM[a]	*P* > F
BW, kg				
d 0	274	275	23.23	0.93
d 28[b]	317	309	3.66	0.18
d 56[b]	368	360	12.84	0.10
d 84[b]	422	401	5.46	0.04
d 112[b]	457	440	7.70	0.18
d 140[b]	485	473	5.91	0.21
d 187[b]	542	527	7.09	0.18
Adj. Final[b]	544	526	9.30	0.22
ADG, kg/d				
0 – 28	1.51	1.22	0.28	0.18
29 – 56	1.82	1.82	0.18	0.99
57 – 84	1.96	1.47	0.24	0.17
85 – 112	1.22	1.41	0.16	0.44
113 – 140	1.00	1.18	0.27	0.62
141 – 187	1.22	1.14	0.08	0.55
29 – 195	1.42	1.37	0.04	0.44
0 – 187[b]	1.43	1.35	0.04	0.18
Adj. 0 – 187[b]	1.44	1.34	0.05	0.22
DMI, kg/d				
0 – 28	7.19	6.57	0.54	0.50
29 – 56	9.39	9.01	0.68	0.34
57 – 84	10.68	10.01	0.35	0.23
85 – 112	10.32	9.60	0.39	0.24
113 – 140	10.31	9.79	0.25	0.19
141 – 187	9.47	8.84	0.22	0.09
29 – 187	9.97	9.38	0.22	0.08
0 – 187	9.55	9.00	0.25	0.09
G:F, kg:kg				
0 – 28	0.206	0.179	0.026	0.29
29 – 56	0.196	0.205	0.032	0.76
57 – 84	0.185	0.144	0.027	0.19
85 – 112	0.118	0.147	0.015	0.19
113 – 140	0.096	0.123	0.023	0.51
141 – 187	0.128	0.129	0.009	0.96
29 – 187	0.142	0.146	0.003	0.42
0 – 187	0.150	0.150	0.002	0.91
Adj. 0 – 187	0.150	0.149	0.004	0.86

[a]Standard error of the least squares means.

[b]Initial body weight included as a covariate.

Table 6: Carcass Data (Harvest group 1)

Item	Inorganic	Organic	SEM	P-Value
HCW, kg	362.28[a]	344.45[b]	6.15	0.006
FT	0.70	0.61	0.05	0.07
PYG	3.77	3.55	0.12	0.06
KPH	1.92	2.28	0.19	0.07
REA	12.11	12.04	0.27	0.80
YG	3.79	3.52	0.19	0.16
Marbling[1]	680.25	651.70	37.51	0.45

[a,b] Means within a row with uncommon superscripts differ ($P \leq 0.05$)

[1]Marbling scores were determined by the USDA grading service using a scale of: 300-390 = Slight (USDA Select), 400-490 = Small (USDA Choice^{-}), 500-590 = Modest (USDA Choice^{0}), 600-690 = Moderate (USDA Choice^{+}), 700-790 = Slightly Abundant (USDA Prime^{-}), 800-890 = Moderately Abundant (USDA Prime^{0}), 900-990 = Abundant (USDA Prime^{+})

Table 7: Carcass Data (Harvest Group 2)

Item	Inorganic	Organic	SEM	P-Value
HCW, kg	346.23	330.77	12.24	0.21
FT	0.60	0.55	0.04	0.25
PYG	3.44	3.28	0.11	0.17
KPH	1.63	1.75	0.12	0.35
REA	11.80	12.00	0.35	0.57
YG	3.43	3.23	0.17	0.23
Marbling[1]	444.38	468.75	22.46	0.29

[1]Marbling scores were determined by the USDA grading service using a scale of: 300-390 = Slight (USDA Select), 400-490 = Small (USDA Choice^{-}), 500-590 = Modest (USDA Choice^{0}), 600-690 = Moderate (USDA Choice^{+}), 700-790 = Slightly Abundant (USDA Prime^{-}), 800-890 = Moderately Abundant (USDA Prime^{0}), 900-990 = Abundant (USDA Prime^{+})

Table 8: Carcass Data (Harvest Group 3)

Item	Inorganic	Organic	SEM	P-Value
HCW, kg	349.39	337.48	7.82	0.14
FT, cm	1.43	1.24	0.12	0.14
PYG	3.37	3.18	0.13	0.16
KPH	1.84	2.15	0.19	0.12
REA, cm	33.02	33.30	1.09	0.82
YG	3.03	2.76	0.20	0.19
Marbling[1]	460.00	484.00	32.13	0.46

[1]Marbling scores were determined by the USDA grading service using a scale of: 300-390 = Slight (USDA Select), 400-490 = Small (USDA Choice^{-}), 500-590 = Modest (USDA Choice^{0}), 600-690 = Moderate (USDA Choice^{+}), 700-790 = Slightly Abundant (USDA Prime^{-}), 800-890 = Moderately Abundant (USDA Prime^{0}), 900-990 = Abundant (USDA Prime^{+})

Table 9: Cook loss percentage and Warner-Bratzler Shear Force

	Item	Inorganic	Organic	SEM	P-Value
Harvest Group 1	Cook loss[1]	22.76	23.31	0.83	0.51
	WBS	3.30	3.37	0.13	0.59
Harvest Group 2	Cook loss[1]	31.12	30.66	0.93	0.62
	WBS	3.75	3.52	0.20	0.23
Harvest Group 3	Cook loss[1]	26.98	27.04	0.62	0.91
	WBS	3.53	3.45	0.12	0.52

* No significant differences were found

[1] Measurements taken by weights prior to and after cooking

[a] Cook loss = (final weight – initial weight/ initial weight) * 100%

Table 10: Trace Mineral Content of Longissimus Steaks (Harvest Group 1)

Item	Inorganic	ZPM	SEM	P-Value
Copper	0.657	0.857	0.22	0.38
Zinc	33.40	30.37	1.63	0.07
Manganese	0.15	0.12	0.03	0.73
Iron	16.31	15.49	1.47	0.15
Nickel	1.12[a]	0.80[b]	0.13	0.02
Calcium	0.0079	0.0078	0.001	0.97
Sodium	0.069	0.068	0.008	0.85
Magnesium	0.023	0.023	0.001	0.45
Phosphorus	0.265	0.242	0.03	0.46
Sulfur	0.21	0.20	0.008	0.20
Potassium	0.37	0.36	0.015	0.30

[a, b] Columns with unlike superscripts differ by $P < 0.05$

Table 11: Trace Mineral Content of Longissimus steaks (Harvest Group 2)

Item	Inorganic	ZPM	SEM	P-Value
Copper	0.600	0.944	0.27	0.20
Zinc	39.33	37.75	3.26	0.63
Manganese	0.034	0.025	0.013	0.54
Iron	13.54	13.30	0.76	0.75
Nickel	0.24	0.15	0.09	0.33
Calcium	0.0064	0.0059	0.0006	0.43
Sodium	0.053	0.051	0.002	0.16
Magnesium	0.023^{a}	0.022^{b}	0.0004	0.02
Phosphorus	0.189^{a}	0.180^{b}	0.004	0.02
Sulfur	0.210^{a}	0.190^{b}	0.004	0.004
Potassium	0.345^{a}	0.312^{b}	0.016	0.04

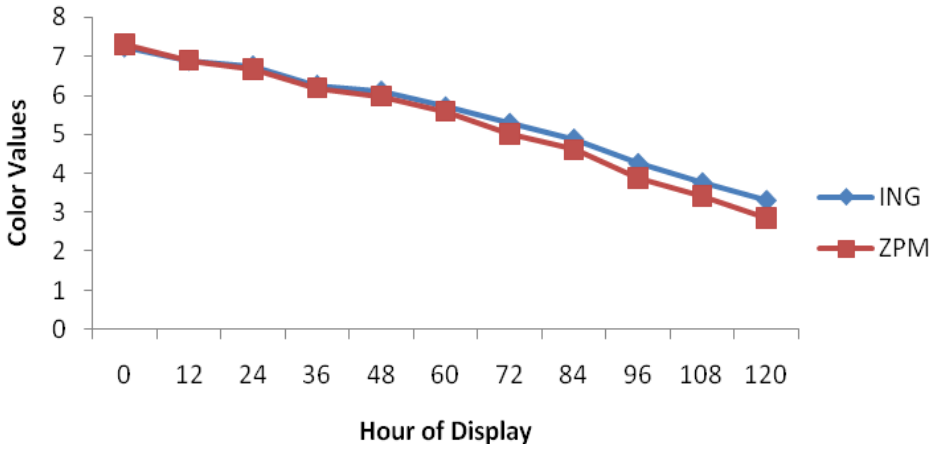
[a, b] Columns with unlike superscripts differ by $P < 0.05$

Table 12: Trace Mineral Content of Longissimus steaks (Harvest Group 3)

Item	Inorganic	ZPM	SEM	P-Value
Copper	0.38	0.29	0.09	0.35
Zinc	34.63	36.58	1.98	0.33
Manganese	0.016	0.023	0.013	0.62
Iron	13.51	14.07	0.82	0.50
Nickel	0.12	0.07	0.07	0.52
Calcium	0.004	0.004	0.0004	0.96
Sodium	0.049	0.049	0.002	0.88
Magnesium	0.018	0.018	0.001	0.93
Phosphorus	0.205	0.206	0.006	0.92
Sulfur	0.21	0.21	0.005	0.53
Potassium	0.34	0.34	0.009	0.92

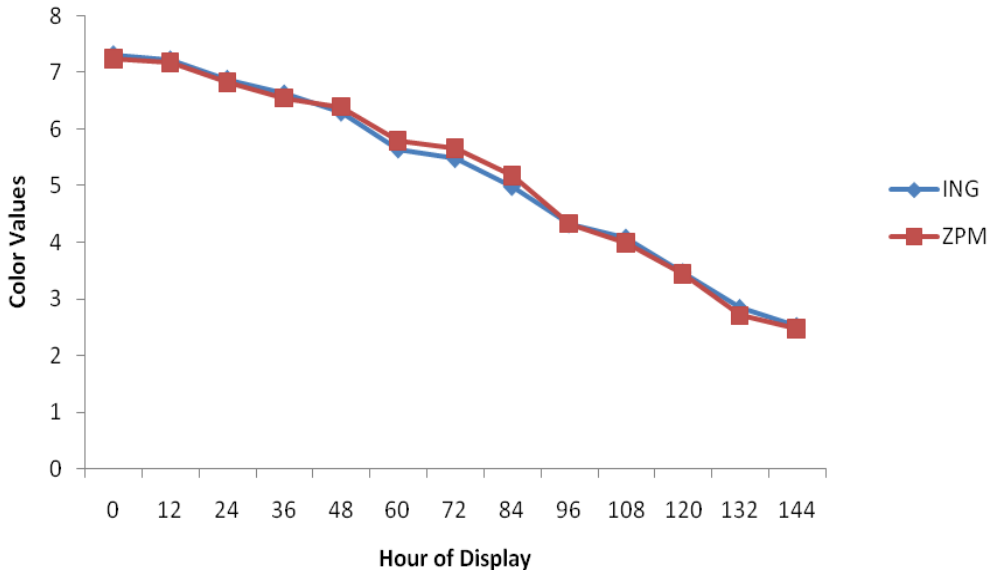
* No significant differences

Figure 1: The influence of trace mineral source on muscle color of steaks for the retail display of harvest group 1



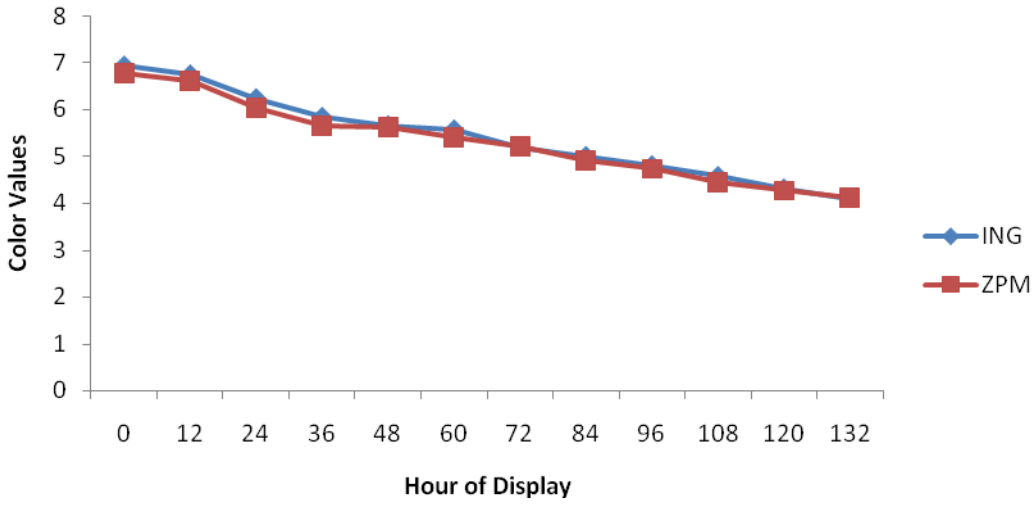
Muscle color scale: 8 = extremely bright cherry red, 1 = extremely dark red

Figure 2: The influence of trace mineral source on muscle color of steaks for the retail display of harvest group 2



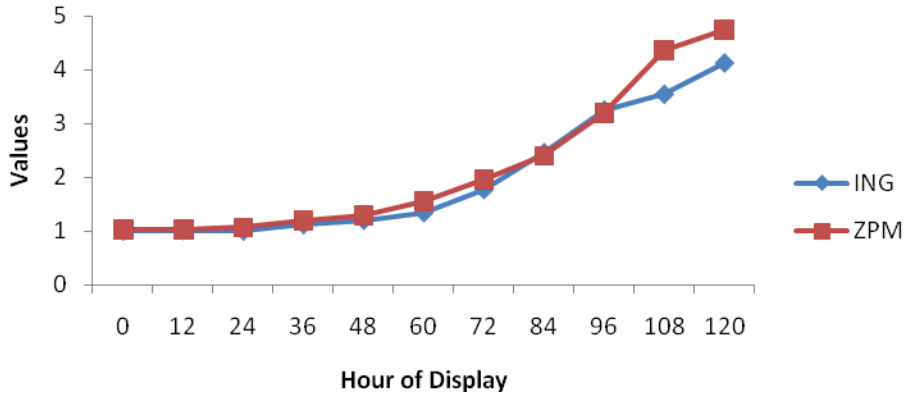
Muscle color scale: 8 = bright cherry red, 1 = extremely dark red

Figure 3: The influence of trace mineral source on muscle color of steaks for the retail display of harvest group 3



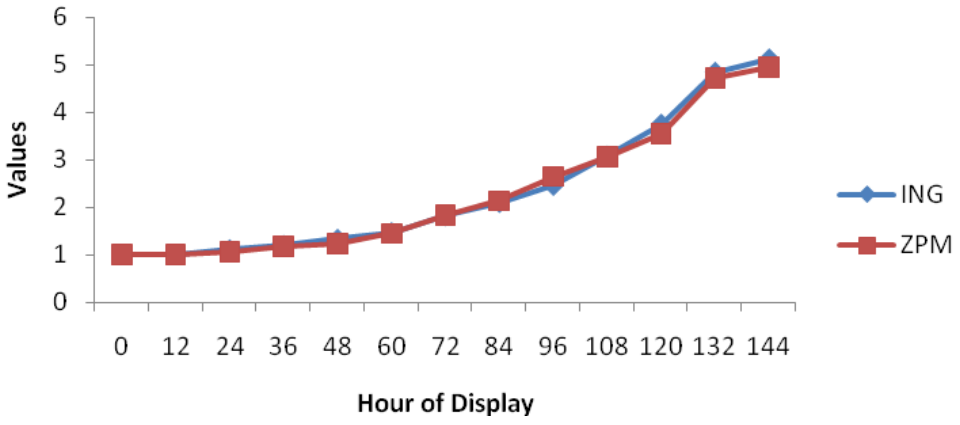
Muscle color scale: 8 = extremely bright cherry red, 1 = extremely dark red

Figure 4: The influence of trace mineral source on surface discoloration of steaks for the retail display period of harvest group 1



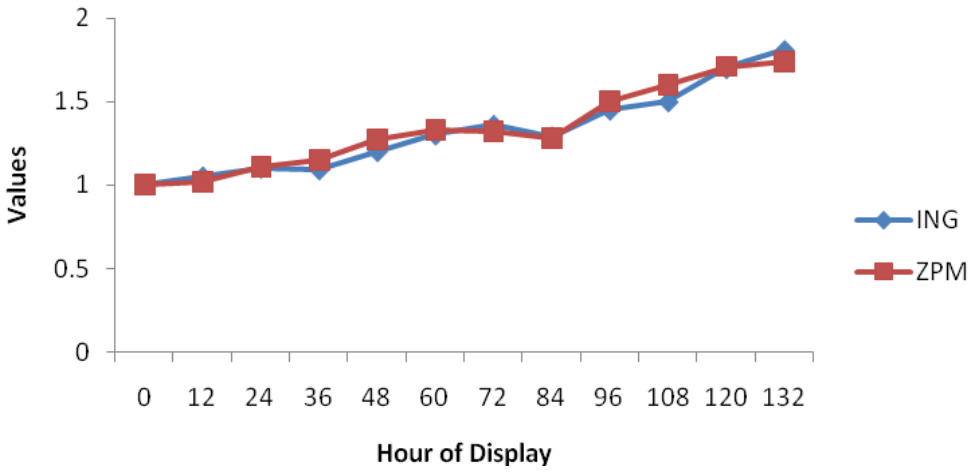
Surface discoloration scale: 1 = no discoloration, 7 = Total discoloration (100%)

Figure 5: The influence of trace mineral source on surface discoloration of steaks for the retail display period of harvest group 2



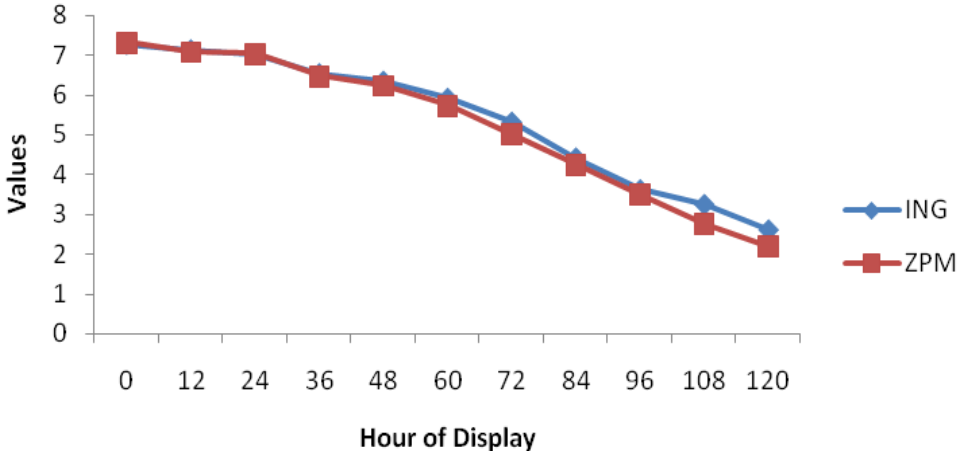
Surface discoloration scale: 1 = no discoloration, 7 = total discoloration (100%)

Figure 6: The influence of trace mineral source on surface discoloration of steaks for the retail display period of harvest group 3



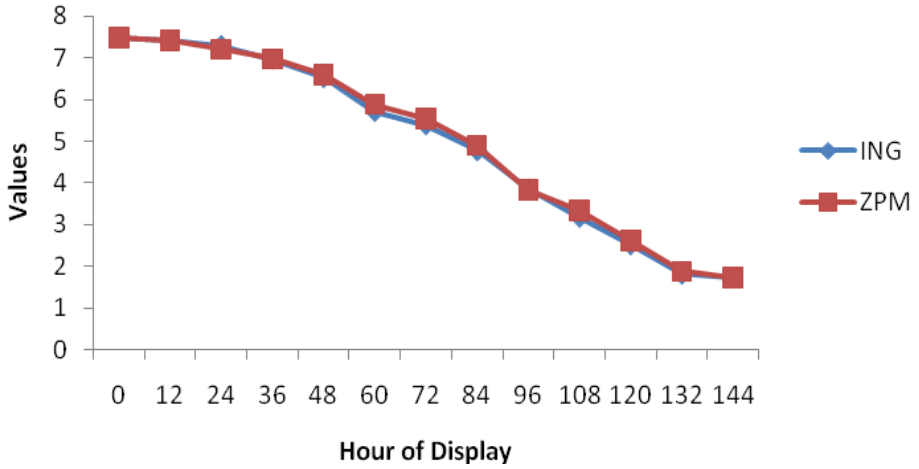
Surface discoloration scale: 1 = No discoloration, 7 = Total discoloration (100%)

Figure 7: The influence of trace mineral source on overall acceptability of steaks for the retail display period of harvest group 1



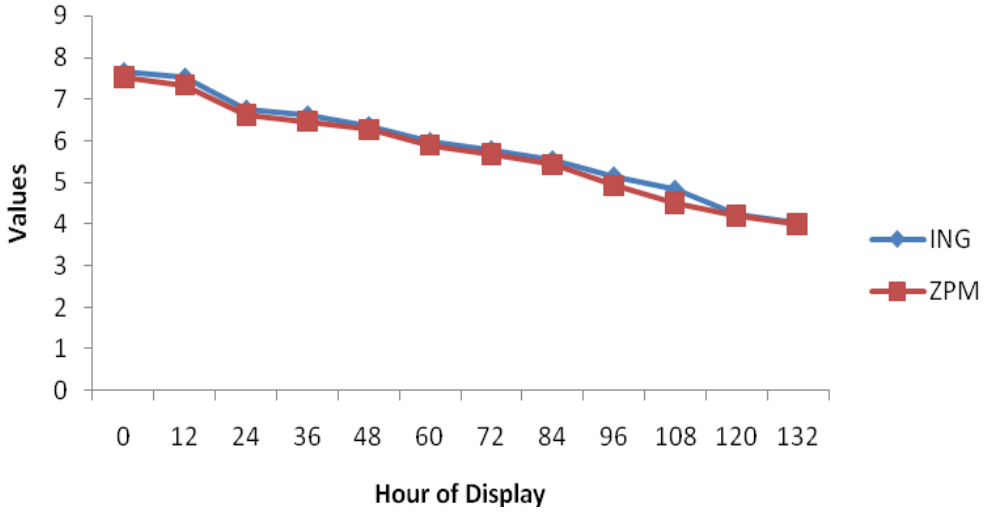
Overall acceptability scale: 8 = Extremely desirable, 1 = Extremely undesirable

Figure 8: The influence of trace mineral source on overall acceptability of steaks for the retail display period of harvest group 2



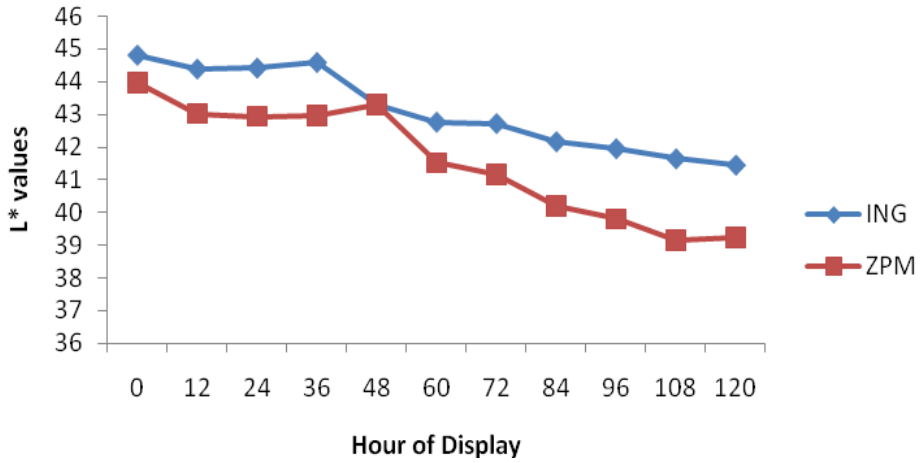
Overall acceptability scale: 8 = Extremely desirable, 1 = Extremely undesirable

Figure 9: The influence of trace mineral source on overall acceptability of steaks for the retail display period of harvest group 3



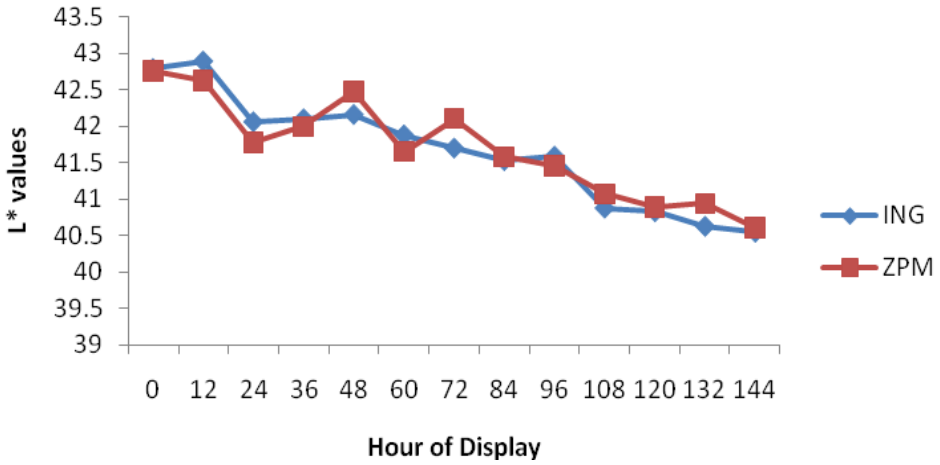
Overall acceptability scale: 8 = Extremely desirable, 1 = Extremely undesirable

Figure 10: The influence of trace mineral source on L* values for the retail display period of harvest group 1



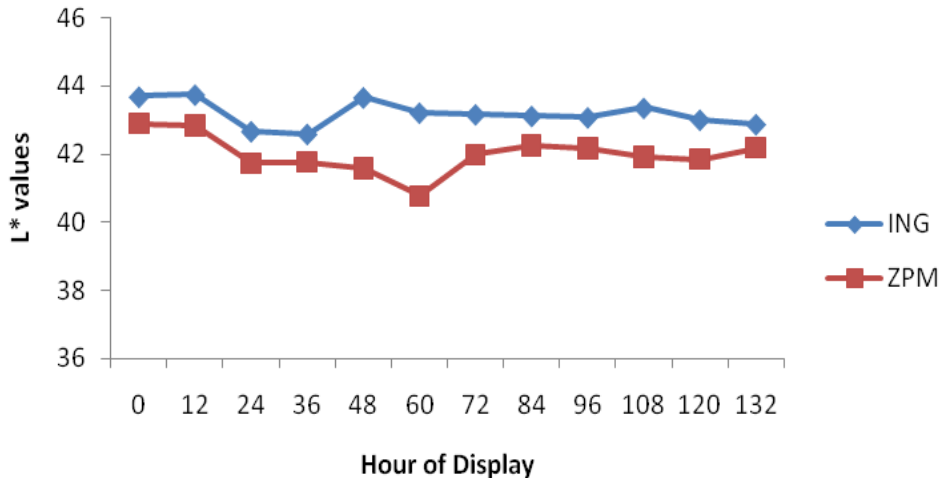
L* values measure brightness: 0 = Black, 100 = White

Figure 11: The influence of trace mineral source on L* values for the retail display period of harvest group 2



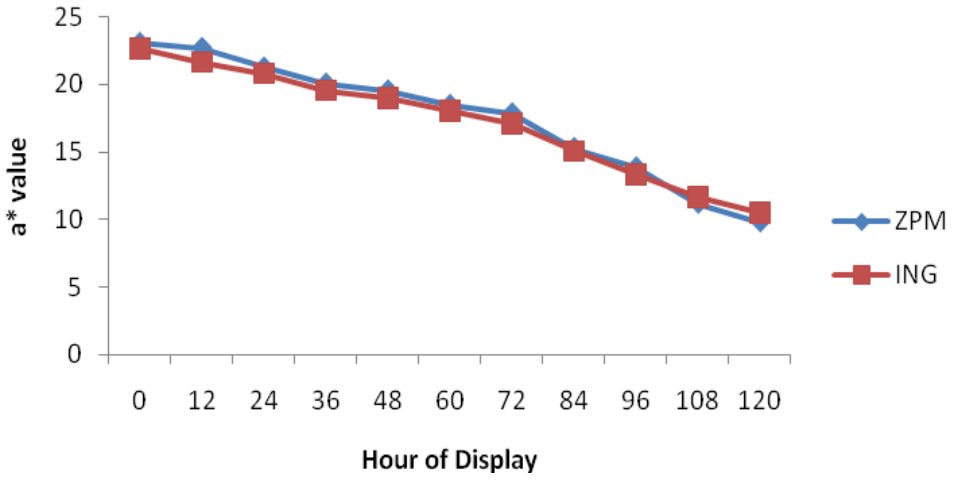
L* values measure brightness: 0 = Black, 100 = White

Figure 12: The influence of trace mineral source on L* values for the retail display period of harvest group 3



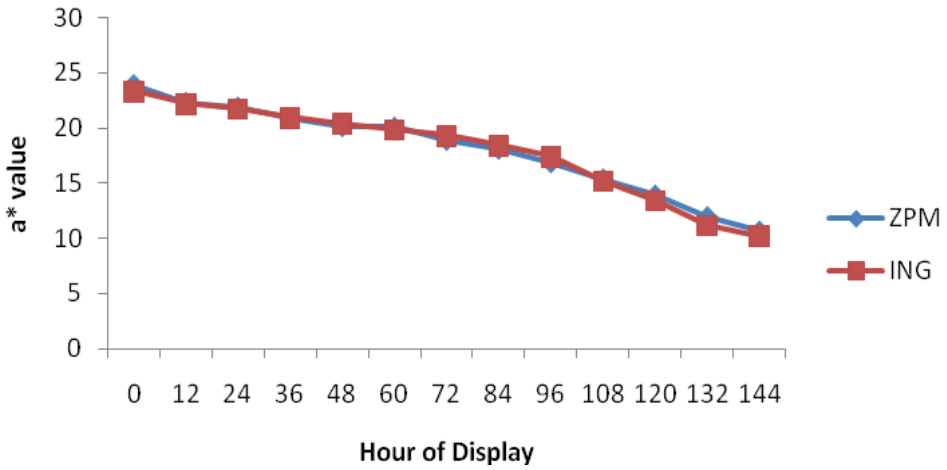
L* values measure brightness: 0 = Black, 100 = White

Figure 13: The influence of trace mineral source on a* values for the retail display period of harvest group 1



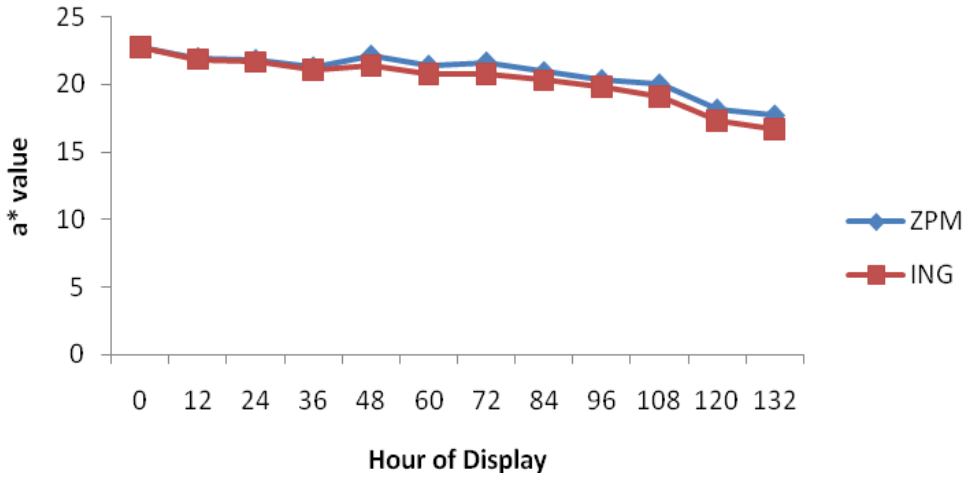
a * values measure redness/greenness: Positive values = Red, Negative values = Green

Figure 14: The influence of trace mineral source on a* values for the retail display period of harvest group 2



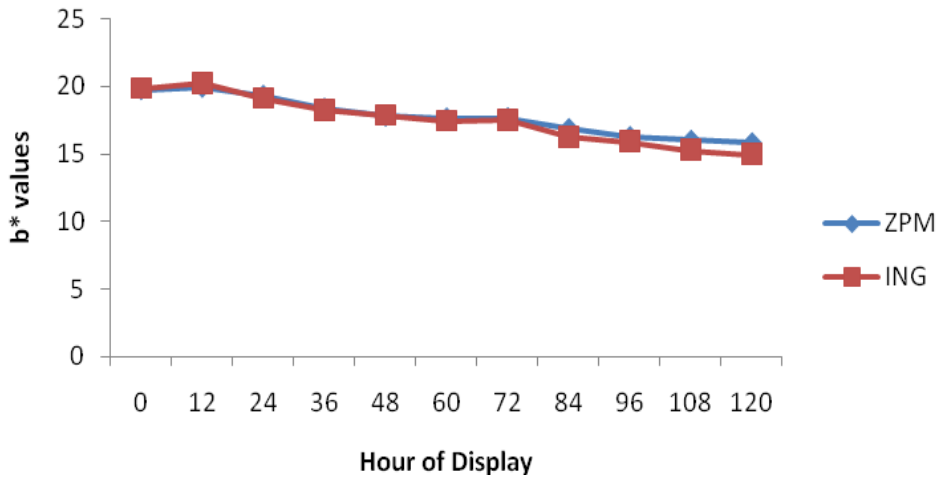
a* values measure redness/greenness: Positive values = Red, Negative values = Green

Figure 15: The influence of trace mineral source on a* values for the retail display period of harvest group 3



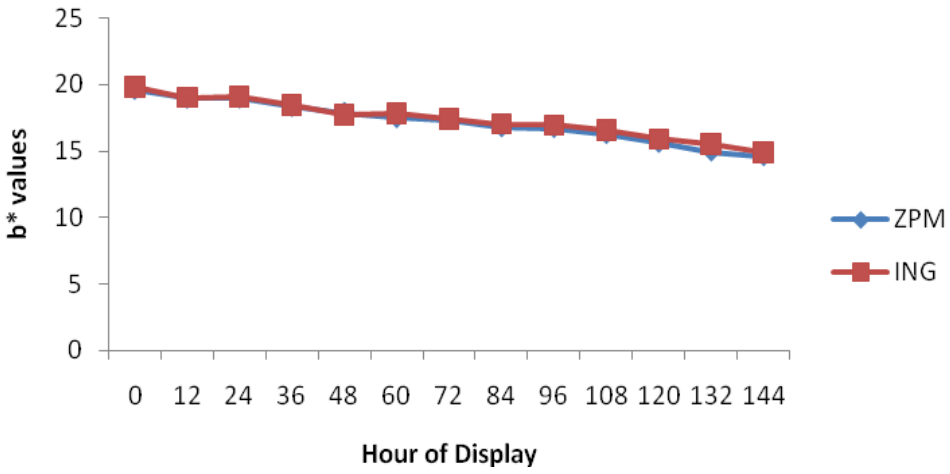
a* values measure redness/greenness: Positive values = Red, Negative values = Green

Figure 16: The influence of trace mineral source on b* values for the retail display period of harvest group 1



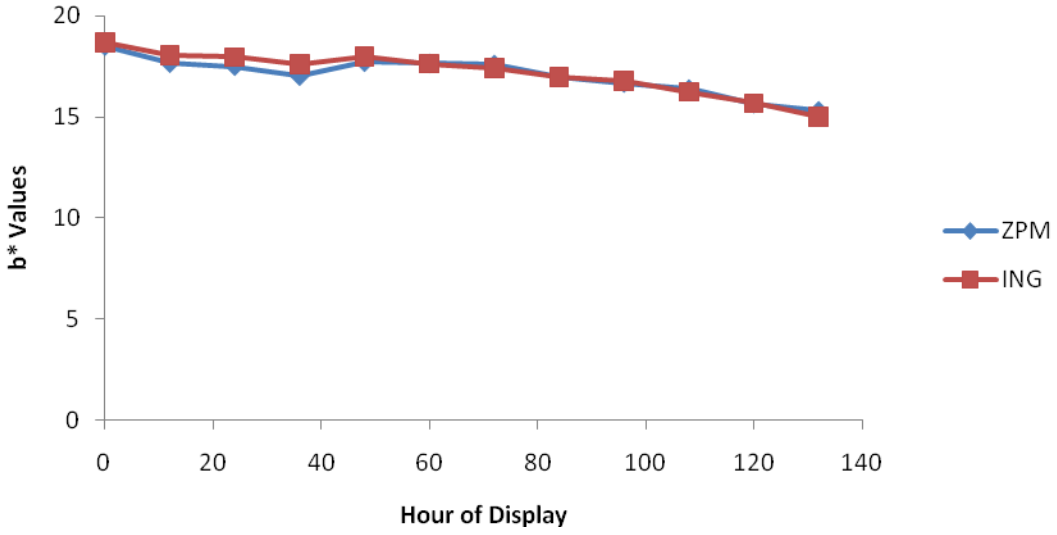
b* values measure yellowness/blueness: Positive values = Yellow, Negative values = blue

Figure 17: The influence of trace mineral source on b* values for the retail display period of harvest group 2



b* values measure yellowness/blueness: Positive values = Yellow, Negative values = Blue

Figure 18: The influence of trace mineral source on b* values for the retail display period of harvest group 3



b* values measure yellowness/blueness: Positive values = Yellow, Negative values = Blue

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APPENDICES

OSU Meat Color Score Sheet

Evaluator: _____ **Project:** Cow subprimals **Date:** _____ **AM / PM**

Sub: Ribeye **Age:** 21d

Muscle Color (MC)

8 Extremely bright cherry red
7 Bright cherry red
6 Moderately bright cherry red
5 Slightly bright cherry red
4 Slightly dark cherry red
3 Moderately dark cherry red
2 Dark red
1 Extremely dark red

Surface Discoloration (SD)

7 Total Discoloration (100%)
6 Extensive discoloration (80-99%)
5 Moderate discoloration (60-79%)
4 Modest discoloration (40-59%)
3 Small discoloration (20-39%)
2 Slight discoloration (1-19%)
1 No discoloration (0%)

Overall Appearance (OA)

8 Extremely desirable
7 Very desirable
6 Moderately desirable
5 Slightly desirable
4 Slightly undesirable
3 Moderately undesirable
2 Very undesirable
1 Extremely undesirable

ID	MC	SD	OA	ID	MC	SD	OA	ID	MC	SD	OA
1				21				41			
2				22				42			
3				23				43			
4				24				44			
5				25				45			
6				26				46			
7				27				47			
8				28				48			
9				29				49			
10				30				50			
11				31				51			
12				32				52			
13				33				53			
14				34				54			
15				35				55			
16				36				56			
17				37				57			
18				38				58			
19				39				59			
20				40				60			

VITA

Cheyanne Lee Coggins

Candidate for the Degree of

Master of Science

Thesis: EVALUATING EFFECTS OF ZINPRO PERFORMANCE MINERALS® ON PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS FED FINISHING DIETS DESIGNED FOR NATURAL BEEF PRODUCTION

Major Field: Animal Science

Biographical:

Personal Data: Born in Atlanta, Georgia on June 5, 1985 to Thomas and Elisabeth Coggins.

Education: Graduated from Central High School in Carrollton, Georgia in May 2003; received Bachelor of Science degree in Animal Science from Oklahoma State University, Stillwater, Oklahoma in December 2006; Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in December, 2009.

Experience:

Professional Memberships: American Meat Science Association

Name: Cheyanne Coggins Date of Degree: December, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EVALUATING EFFECTS OF ZINPRO PERFORMANCE MINERALS® ON PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS FED FINISHING DIETS DESIGNED FOR NATURAL BEEF PRODUCTION

Pages in Study: 72 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: One hundred sixteen steers, (harvest 1, n = 42 and harvest 2, n = 38, and harvest 3, n = 36, respectively) were used to evaluate the effect of organic Zinpro Performance Minerals® on performance, carcass characteristics, tenderness and retail-case life of longissimus steaks. Steers were blocked by initial weight and assigned one of two treatment groups, inorganic (ING) or Zinpro (ZPM) trace mineral supplements, at weaning. Each group was fed to a compositional endpoint and harvested at a commercial facility. Strip loins (IMPS #180) were collected upon harvest and aged for 14 d. Carcass characteristics, retail-case life, Warner-Bratzler shear force (WBS), and trace mineral content were evaluated.

Findings and Conclusions: In group one, carcass adjusted average daily gain (ADG) and dry matter intake (DMI) were greater ($P < 0.05$) for ING steers and gain to feed (G:F) tended to be greater ($P = 0.06$) for the entire trial period compared to ZPM steers. In harvest group two, body weight (BW), ADG, DMI and G:F were similar among treatments; however, ING steers tended to gain more efficiently ($P = 0.07$) than ZPM steers. Only DMI tended to be greater ($P = 0.09$) in ING steers for the entire trial period with all other measurements being similar ($P > 0.05$). No differences ($P > 0.05$) were observed between treatment groups for strip loin steak WBS and cooking loss percentage. In harvest group one, ING had significantly ($P < 0.05$) greater hot carcass weights (HCW) and tended to have more 12^{th} rib fat ($P = 0.07$) than ZPM. Kidney, pelvic and heart fat percentage (KPH) tended to be lower ($P = 0.07$) in ING compared to ZPM. All carcass traits were similar in harvest group three. No differences ($P > 0.05$) were found for the subjective color evaluation or a* and b* values between treatments. Steers in ING initial harvest group had higher ($P < 0.05$) L* values than the organic contemporaries. Trace mineral analysis revealed no differences ($P > 0.05$) between treatments for Ca, Na, Fe, Cu, or Mn content. In harvest group one, Zn content tended to be greater ($P = 0.07$) and Ni was greater ($P < 0.05$) in ING. For harvest group two, S, Mg, K and P were greater ($P < 0.05$) for ING compared with ZPM.

ADVISER'S APPROVAL: Dr. J. Brad Morgan

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