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Sire breed effect on beef longissimus mineral concentrations and their relationships with carcass and palatability traits[☆], [☆☆]

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ABSTRACT

The objective of this study was to evaluate sire breed effect on mineral concentration in beef longissimus thoracis (LT) and investigate the correlations between beef mineral concentrations and carcass and palatability traits. Steer progeny ($N = 246$) from the Germplasm Evaluation project—Cycle VIII were used in this study. In addition to carcass traits, LT was evaluated for mineral concentrations, Warner–Bratzler shear force, and palatability traits. A mixed linear model estimated breed effects on mineral concentrations. No significant sire breed ($P \geq 0.43$) or dam breed ($P \geq 0.20$) effects were identified for mineral concentrations. Pearson correlation coefficients were calculated among mineral concentrations, carcass, and sensory traits. Zinc concentration was positively correlated ($P \leq 0.05$) with total iron ($r = 0.14$), heme iron ($r = 0.13$), and magnesium ($r = 0.19$). Significant ($P < 0.05$) correlations were identified between non-heme or heme iron and most traits in this study. Magnesium concentration was correlated with all carcass and palatability traits.

1. Introduction

Total beef consumption in the U.S. decreased 15% between 1980 and 2000 and was followed by a decrease from 12.7 to 11.4 billion kg per year between 2002 and 2011 (USDA-ERS, 2014). One of the major contributing factors to this trend is health concerns about fat intake from red meat. However, beef is an excellent source of protein and dietary iron, zinc, and magnesium and should not be viewed only from the fat content perspective. Beef contains the highest amount of iron and zinc of meats commonly consumed in the U.S. (Carpenter & Clark, 1995; USDA-ARS, 2010). In addition, the porphyrin ring of heme iron and the protein in beef can promote the absorption of iron or zinc; therefore enhancing their bioavailability (Stipanuk, 2006).

Beef mineral concentrations vary among individuals and are affected by various physiological, environmental, and within breed additive genetic factors (Doyle, 1980; Duan et al., 2011; Mateescu et al., 2013; Mateescu et al., 2013; Zarkadas et al., 1987). Few studies have evaluated mineral concentrations across several sire and dam breeds of cattle. In one study (Doornenbal & Murray, 1981), the effect of sire breed, from a sampling of *Bos Taurus* breeds, on mineral concentrations was reported to be small. In addition, little information is available in regard to the relationships between beef mineral concentrations and carcass and palatability traits (Casas et al., 2014; Garmyn et al., 2011; Mateescu, Garmyn, et al., 2013). Understanding of the relationships between mineral concentrations and other traits in beef cattle could be valuable for selective breeding to improve the nutritional value of beef.

The primary objective of this study was to evaluate the effect of diverse *Bos Taurus* or *Bos Taurus* × *Bos Indicus* composite sire-breed (Hereford, Angus, Brangus, Beefmaster, Bonsmara, and Romosinuano) on total iron, non-heme iron, heme iron, zinc, and magnesium concentrations of beef longissimus thoracis (LT). Our second objective was to examine the correlations among these five measures of minerals with beef carcass and palatability traits.

2. Materials and methods

All animal procedures were reviewed and approved by the U.S. Meat Animal Research Center (USMARC) Animal Care and Use Committee.

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2.1. Animals and sample collection

Detailed information for animal management, sample collection, and processing can be found in Wheeler, Cundiff, Shackelford, and Koohmaraie (2010). Briefly summarized, steer progeny resulted from artificial insemination mating of Angus or MARC III (1/4 Hereford, 1/4 Angus, 1/4 Red Poll, and 1/4 Pinzgauer) dams with Hereford, Angus, Brangus, Beefmaster, Bonsmara, or Romosinuano sires (Table 1). Data from cattle in this study were obtained from 246 steers harvested in 2002 ($n = 116$) and 2003 ($n = 130$) in Cycle VIII of the Germplasm Evaluation program at USMARC. The male calves were castrated within 24 h of birth. All steers were fed a maize and maize silage based diet and harvested in a commercial facility when they were approximately 427 days of age. The wholesale rib was obtained and transferred to the meat laboratory at USMARC approximately 36 h postmortem. The rib was separated into ribeye roll, lean trim, fat trim, and bone. The ribeye roll was vacuum packed, aged at 2 °C until 14 days (2002) or 15 days (2003) postmortem and frozen at −30 °C. A rib steak from approximately the 8th rib was sent to Iowa State University and stored at −20 °C until mineral concentration analysis.

2.2. Evaluation of carcass and palatability traits

Assessment of carcass and palatability traits was described in Wheeler et al. (2010). Briefly summarized, frozen steaks were thawed at 5 °C for 24 h and then cooked on a conveyorized electric belt grill to a final internal temperature of 71 °C. Separate cooked steaks were used to evaluate Warner–Bratzler shear force or trained sensory panel assessed tenderness, juiciness, and beef flavor intensity for palatability. After cooling for 24 h at 4 °C, Warner–Bratzler shear force was measured on six round cores (1.27 cm diameter) removed parallel to the orientation of the muscle fibers within each steak. The sensory traits were evaluated on a descriptive 8-point scale (8 = extremely tender, juicy, or intense to 1 = extremely tough, dry, or bland) by a trained panel of eight members. Retail product was predicted from lean trim, fat trim, and short ribs as described by Shackelford, Cundiff, Gregory, and Koohmaraie (1995).

2.3. Total iron, zinc, and magnesium analysis

At Iowa State University, steak samples were thawed over a 24-hour period in a 4 °C walk-in cooler. All glassware used was washed in 1 M hydrochloric acid and rinsed with deionized water prior to use. Analytical samples were collected from the center portion of each steak, weighed (~1 g, recorded to 0.001 g), and placed into a 50 ml centrifuge tube to which 10 ml of deionized water was added. This mixture was homogenized for 20 s with a Kinematica Polytron. Mineral concentrations in beef samples were determined according to the method modified from the AOAC official method 999.10 (Jorhem & Engman, 2000). Wet digestion was performed on 5 ml of homogenized sample to which 5 ml concentrated nitric acid and 2 ml deionized water were added. This solution was heated on a heating block at 60–70 °C until clear. After cooling, the digested solution was diluted to a volume of 25 ml with deionized water. Total iron, zinc, and magnesium concentrations were determined with an atomic absorption spectrometer (Perkin Elmer, Waltham, MA). A separate ~1 g sample from the same steak was used to measure non-heme iron with a spectrophotometric assay according to procedures of Rebouche, Wilcox, and Widness (2004). Heme iron concentration was calculated by difference between total iron concentration and non-heme iron concentration.

2.4. Statistical analysis

Statistical analysis was carried out with SAS (SAS Inst., Inc., Cary, NC). The descriptive statistics were generated using PROC MEANS. Extreme mineral concentrations were removed from the dataset (iron > 8.0 mg/100 g, $n = 3$; zinc > 8.0 mg/100 g, $n = 24$; magnesium > 20.0 mg/100 g, $n = 2$; non-heme iron > total iron, $n = 1$). The mineral concentration least squares estimate of the mean for each breed was calculated using a mixed linear model (PROC MIXED in SAS) that included sire and dam breeds as fixed effects; lipid percentage (2.09 to 11.78%), final weight (428.2 to 689.5 kg), and animal age (range 389 to 462 days) as covariates; and year as a random effect. Additionally, linear relationships between mineral concentrations and other traits were evaluated using PROC CORR in SAS to calculate Pearson correlation coefficients.

3. Results and discussion

3.1. Carcass characteristics and palatability

The descriptive statistics for carcass traits, palatability traits, and LT mineral concentrations are presented in Table 2. Sire breed effects on carcass, yield, and palatability traits were reported by Wheeler et al. (2010).

3.2. Breed effect on mineral concentration

The means for LM total iron, non-heme iron, heme iron, zinc, and magnesium concentrations were 3.44 mg/100 g, 0.86 mg/100 g, 2.59 mg/100 g, 4.10 mg/100 g, and 16.42 mg/100 g, respectively, which were consistent with values reported previously (Gerber et al., 2009; USDA-ARS, 2010). Our finding of 69.3% of the total iron being heme iron is consistent with previous reports of heme iron comprising more than 60% of total iron in beef (Valenzuela, Lopez de Romana, Olivares, Morales, & Pizarro, 2009). No significant sire breed ($P \geq 0.43$) or dam breed ($P \geq 0.20$) effect was observed for the concentration of total iron, non-heme iron, heme iron, zinc, or magnesium after adjusting for animal age, intramuscular fat, and final body weight (Table 3).

Similar results for breed effect on mineral concentrations of beef were reported in a previous study. Doornenbal and Murray (1981) evaluated the effect of Charolais, Simmental, Limousin and Chianina sire breeds on the concentration of iron, zinc, magnesium, copper, calcium, sodium, and potassium in three muscles. They reported that the breed of sire differences were small and not significant, except for calcium and sodium (which were not evaluated in this study). They also found a significant interaction between muscle and breed of sire. For example, the LT from Chianina sired cattle had significantly ($P < 0.05$) higher calcium concentration than the LT from Charolais sired cattle. Similarly, sodium was significantly lower in the LT of Limousin sired cattle than the LT of the other sire breeds. In contrast, sire breed differences for sodium

Table 1
Distribution of steers by sire and dam breed.

	Sire breed						
Dam breed	Hereford	Angus	Brangus	Beefmaster	Bonsmara	Romosinuano	Total
Angus	23	0	23	24	24	21	115
MARC III	21	24	22	19	22	23	131
Total	44	24	45	43	46	44	246