Effects of Dietary Mineral Element Reduction on Growth Performance, Meat Quality, Serum Biochemical Indices, and Skeletal Muscle Mineral Element Content in Finishing Pigs: Postprint

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Abstract

This experiment aimed to investigate the effects of reducing the dietary supplementation levels of five mineral elements (iron, manganese, zinc, magnesium, and copper) on growth performance, meat quality, serum biochemical indices, and mineral element content in skeletal muscle of finishing pigs during the late fattening period. A total of 300 healthy three-way crossbred (Duroc × Landrace × Yorkshire) finishing pigs with similar body condition and initial body weight [(76.17$±$1.58) kg] were randomly allocated into 3 groups, with 10 replicates per group and 10 pigs per replicate, half barrows and half gilts. The control group was fed a basal diet, while the experimental groups were fed the basal diet with 30% and 60% reductions in mineral elements, respectively. The preliminary period lasted 3 days, followed by a formal trial period of 30 days. The results showed that, compared with the control group: 1) reducing dietary mineral elements by 30% and 60% had no significant effects on growth performance and meat quality of finishing pigs ($P>0.05$); 2) reducing dietary mineral elements by 30% and 60% significantly increased serum ammonia content ($P<0.05$); reducing mineral elements by 60% significantly decreased serum total cholesterol content ($P<0.05$), while showing a tendency to decrease serum total protein content ($P=0.09$); 3) reducing dietary mineral elements by 30% had no significant effect on the content of various mineral elements in skeletal muscle of finishing pigs ($P>0.05$), whereas reducing by 60% significantly decreased the contents of copper, iron, and manganese in skeletal muscle ($P<0.05$). It can be concluded that the contents of iron, manganese, zinc, magnesium, and copper in finishing pig diets can be reduced by 30% of the NRC (2012) recommended levels without affecting the growth performance and meat quality of finishing pigs during the late fattening period.

Full Text

Effects of Reducing Dietary Trace Mineral Elements on Growth Performance, Meat Quality, Serum Biochemical Indices and Mineral Content in Skeletal Muscle of Finishing Pigs

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Abstract

This experiment was conducted to investigate the effects of reducing dietary levels of five trace mineral elements—iron (Fe), manganese (Mn), zinc (Zn), magnesium (Mg), and copper (Cu)—on growth performance, meat quality, serum biochemical indices, and skeletal muscle mineral content in finishing pigs during the late fattening period. A total of 300 healthy crossbred (Duroc × Landrace × Large White) finishing pigs with similar body weight [(76.17 ± 1.58) kg] were randomly allocated to three groups, each consisting of 10 replicates with 10 pigs per replicate (half barrows and half gilts). The control group received a basal diet, while the experimental groups received diets with 30% and 60% reductions in trace mineral elements relative to the basal diet. The experiment included a 3-day adaptation period followed by a 30-day formal feeding trial. The results showed that: (1) Reducing dietary trace minerals by 30% or 60% had no significant effects on growth performance or meat quality of finishing pigs ($P > 0.05$); (2) Both 30% and 60% reductions significantly elevated serum ammonia levels ($P < 0.05$), while the 60% reduction significantly decreased serum total cholesterol ($P < 0.05$) and tended to reduce serum total protein ($P = 0.09$); (3) The 30% reduction did not significantly affect mineral content in skeletal muscle ($P > 0.05$), whereas the 60% reduction significantly decreased copper, iron, and manganese concentrations in skeletal muscle ($P < 0.05$). These findings indicate that dietary levels of Fe, Mn, Zn, Mg, and Cu can be reduced by 30% below NRC (2012) recommendations without compromising growth performance or meat quality in finishing pigs during the late fattening period.

Keywords: trace mineral elements; growth performance; meat quality; serum biochemical indices; finishing pigs

1. Materials and Methods

1.1 Experimental Equipment

The study utilized a BS-190 automatic biochemical analyzer (Mindray, Shenzhen), a Matthaus pH Star pH meter, and a Minolta CR-410 colorimeter for data collection.

1.2 Experimental Animals and Design

Three hundred crossbred (Duroc × Landrace × Large White) finishing pigs with good health status and similar initial body weight [(76.17 ± 1.58) kg] were selected for the experiment. Using a single-factor design and following the principle of consistent body weight and genetic background, the pigs were randomly divided into three groups with 10 replicates per group and 10 pigs per replicate, with equal numbers of barrows and gilts in each replicate.

1.3 Diets and Management

The experimental diets were corn-soybean meal based and formulated according to NRC (2012) guidelines, incorporating the ideal amino acid pattern and standardized ileal digestible amino acid system. The basal diet served as the control, while experimental diets were formulated with 30% and 60% reductions in Fe, Mn, Zn, Mg, and Cu. Diet composition and nutrient levels are presented in Table 1 .

Pigs were housed in pens with slatted plastic flooring, equipped with stainless steel adjustable feeders and nipple drinkers. Pens and floors were cleaned daily, and the pig house was disinfected by spraying once weekly. Animal health status was observed and recorded daily. All diets were provided as pellets with ad libitum access to feed and water throughout the experiment. The trial consisted of a 3-day adaptation period followed by a 30-day formal experimental period.

1.4 Sample Collection and Processing

At the conclusion of the experiment, 10 pigs were randomly selected from each group for blood collection and subsequently transported to a local abattoir (Shandong Yinbao) for slaughter and tissue sampling.

1.5 Measurement Indices

1.5.1 Growth Performance Pigs were weighed at 08:00 on the first and last day of the formal trial period after overnight feed deprivation starting at 20:00 the previous evening. Residual feed was collected to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G).

1.5.2 Meat Quality Post-slaughter, average backfat thickness was measured, and the longissimus dorsi muscle at the 6th–7th rib of the right carcass side was collected for meat quality analysis. Measurements included muscle pH at 45 min (pH_{45}) and 24 h (pH_{24}) postmortem, meat color parameters [lightness (L*), redness (a*), and yellowness (b*)], and cooking loss. For cooking loss determination, muscle samples were first weighed (W_0), placed in ceramic containers, and steamed for 45 minutes after the water reached boiling. Samples were then hung in a draft-free, shaded area at room temperature for 30 minutes before being reweighed (W_1). Cooking loss was calculated as:

$$\text{Cooking loss (\%)} = 100 \times \frac{W_1}{W_0}$$

1.5.3 Serum Biochemical Indices On the final day of the experiment, six pigs per group were randomly selected and fasted overnight. Blood samples (5 mL) were collected from the anterior vena cava at 08:00, allowed to clot at room temperature, and then centrifuged at 3,000 rpm for 15 minutes. Serum was harvested, aliquoted into EP tubes, and stored at -20°C until analysis. Serum biochemical indices were measured using a Mindray BS-190 automatic biochemical analyzer with assay kits purchased from Nanjing Jiancheng Bioengineering Institute.

1.5.4 Skeletal Muscle Mineral Content Approximately 5 g of dorsal muscle tissue was dried and ashed in a muffle furnace at 550°C for 5 hours. The ash was dissolved in dilute acid, diluted to volume with double-distilled water, and analyzed for Fe, Mn, Zn, Mg, and Cu content using inductively coupled plasma optical emission spectrometry (ICP-OES).

1.6 Statistical Analysis

All experimental data were analyzed using SAS 9.1 software. One-way ANOVA and Duncan' s multiple range test were employed to determine treatment differences. Significance was declared at $P < 0.05$, and trends were noted at $P < 0.10$.

2. Results

2.1 Effects of Dietary Mineral Reduction on Growth Performance and Meat Quality

As shown in Tables 2 and 3 , reducing dietary Fe, Mn, Zn, Mg, and Cu by 30% or 60% had no significant effects on growth performance or meat quality of finishing pigs ($P > 0.05$).

2.2 Effects of Dietary Mineral Reduction on Serum Biochemical Indices

Table 4 shows that compared with the control group, reducing dietary trace minerals by 30% or 60% significantly increased serum ammonia content ($P < 0.05$). The 60% reduction also significantly decreased serum total cholesterol ($P < 0.05$) and tended to reduce serum total protein ($P = 0.09$). As presented in Table 5 , the 60% mineral reduction tended to decrease serum total antioxidant capacity (T-AOC) compared with other groups ($P = 0.07$). No significant effects were observed on other serum biochemical indices ($P > 0.05$).

2.3 Effects of Dietary Mineral Reduction on Skeletal Muscle Mineral Content

Table 6 demonstrates that the 30% mineral reduction did not significantly affect mineral content in skeletal muscle ($P > 0.05$). However, the 60% reduction significantly decreased copper, iron, and manganese concentrations in skeletal muscle ($P < 0.05$).

3. Discussion

High dietary supplementation of trace minerals, particularly copper and zinc, has been shown to significantly improve average daily gain and feed intake in pigs [1], but 80–95% of these minerals are excreted, leading to soil accumulation and potential toxicity to plants and microorganisms [2]. This contamination poses risks to human health through the food chain and represents a major technical barrier in animal product trade. However, research on reducing trace mineral supplementation in finishing pig diets remains limited in China. Therefore, this study evaluated the effects of 30% and 60% reductions in Fe, Mn, Zn, Mg, and Cu on growth performance, meat quality, serum biochemical indices, and skeletal muscle mineral content to explore mineral reduction strategies and provide data supporting waste management, cost reduction, and sustainable development of China' s swine industry.

3.1 Effects on Growth Performance and Meat Quality

Long-term feeding of commercially recommended trace mineral levels can impair liver structure and metabolic function [10]. Previous studies have shown that omitting trace mineral premixes from corn-soybean meal diets during the final 30 days before slaughter does not significantly affect pig growth performance [6,7], consistent with our findings. Similar results have been reported with sorghum-soybean meal diets [11]. However, prolonged mineral omission may tend to reduce ADG [12] and significantly increase ADFI [8]. The effects of trace mineral omission on backfat thickness have been inconsistent across studies, with some reporting no effect [7-9,13] and others showing increased backfat thickness [5], possibly due to differences in initial body weight among experimental animals. Our results align with previous research indicating that reducing or omitting trace minerals does not affect longissimus dorsi muscle color [9] or loin eye area [9,13]. These findings suggest that trace mineral supplementation can be reduced during the late finishing phase to reduce feed costs and environmental pollution from excreta without compromising performance or carcass quality.

3.2 Effects on Serum Biochemical Indices

Iron, manganese, zinc, magnesium, and copper function as enzyme components or activators in various metabolic pathways [14]. Studies have shown that dietary zinc levels (0, 40, 80, 120 mg/kg) do not significantly affect serum T-AOC in finishing pigs [15], suggesting zinc may not be a critical factor for serum antioxidant capacity. In contrast, low copper supplementation adversely affects serum T-AOC [16], while reduced iron levels significantly decrease serum T-AOC in an age-dependent manner [17]. Manganese supplementation influences superoxide dismutase (SOD) activity [18,19], and magnesium serves as an essential cofactor for glutathione (GSH) synthesis and ATP production in erythrocytes, significantly affecting SOD, catalase activities, and GSH content [20]. Our observation that serum T-AOC tended to decrease with mineral reduction aligns with these findings, indicating that trace minerals interact synergistically and are closely associated with serum biochemical indices.

Research has demonstrated that reduced copper supplementation significantly increases serum total cholesterol [21], whereas decreased manganese tends to lower cholesterol [22], suggesting antagonistic effects between these minerals in cholesterol regulation. Arginase, which contains four manganese ions per molecule, participates in urea formation, and manganese deficiency can reduce arginase activity, leading to elevated blood ammonia [23]. Our results showing significantly increased serum ammonia and decreased total protein with 60% mineral reduction suggest impaired protein synthesis, likely due to reduced activity of key metabolic enzymes. Therefore, the feasibility of 60% mineral reduction in late finishing diets requires further investigation.

3.3 Effects on Skeletal Muscle Mineral Content

Omitting trace mineral supplementation tends to reduce zinc accumulation in muscle [6] while increasing hepatic concentrations of Fe, Cu, Mn, and Zn [14], possibly due to protective homeostatic mechanisms. Our finding that the 30% reduction did not affect muscle zinc content may reflect differences in the magnitude of reduction. Previous studies have shown that reduced copper supplementation decreases tissue copper retention [21] and that prolonged mineral omission reduces copper content in thigh muscle [12] and significantly decreases fecal excretion of Cu, Zn, Mn, and Fe [24,25]. These observations suggest that fecal mineral content may reflect skeletal muscle mineral status, consistent with our results.

4. Conclusion

Reducing dietary Fe, Mn, Zn, Mg, and Cu by 30% of recommended levels during the late finishing period does not adversely affect growth performance, meat quality, or serum biochemical indices in finishing pigs. While a 60% reduction also does not impair growth performance or meat quality, it significantly affects serum biochemical parameters and reduces skeletal muscle mineral content. The absence of negative effects at reduced supplementation levels may be attributed to improved intestinal absorption efficiency and mobilization of hepatic mineral stores. Further research is needed to optimize trace mineral supplementation strategies for efficient utilization and reduced environmental excretion.

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Note: Figure translations are in progress. See original paper for figures.