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Effects of Dietary Selenomethionine Supplementation on Growth Performance, Meat Quality and Antioxidant Property in Yellow Broilers

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This study was conducted to investigate the effects of dietary selenomethionine (Se-Met) supplementation on growth performance, meat quality and antioxidant property in male broilers. A total of 800 43-day-old Lingnan yellow male broilers were randomly allotted to 5 dietary treatments with four replicates of 40 birds for a period of 3 weeks *ad libitum*. Final BW and weight gain of birds significantly increased by Se-Met supplementation at the 0.225 mg/kg level ($P < 0.05$). The addition of Se-Met significantly decreased drip loss, lightness value, and elevated pH value of meat ($p < 0.05$). Adding sodium selenite (SS) only increased pH value of meat ($p < 0.05$). In plasma, supplemental Se-Met at 0.225 mg/kg level increased total antioxidant capability (T-AOC), glutathione peroxidase (GPX), total superoxide dismutase (T-SOD), catalase (CAT) activities, glutathione (GSH) concentration ($p < 0.05$), and decreased malondialdehyde production ($p < 0.05$), compared with the control and broilers fed SS diet. In breast muscle, the addition of Se-Met significantly elevated T-AOC, GPX, T-SOD, CAT activities, contents of metallothionein and GSH ($p < 0.05$), and reduced carbonyl protein content ($p < 0.05$). While compared with broilers fed SS diet, supplemental 0.225 mg/kg Se-Met increased T-AOC, GPX, CAT activities, and GSH content ($p < 0.05$). Therefore, dietary Se-Met supplementation could improve growth performance and meat quality by enhancing antioxidative capacity in broilers compared with SS.

KEYWORDS: Yellow broiler; selenomethionine; growth performance; meat quality; antioxidation

INTRODUCTION

Selenium (Se) is an essential trace element that plays a vital role in various physiologic processes. The Se supplement that primarily has been used in animal diets is the inorganic form, sodium selenite (SS). Recently, organic sources of Se, such as selenocysteine, selenomethionine (Se-Met), or Se-enriched yeast (SY), have been explored as an alternative to inorganic supplementation (*1*−*5*). Se-Met is the major selenocompound in cereal grains, grassland legumes and soybeans (*6*, *7*). Considerable differences exist between the metabolic pathways of organic and inorganic Se compounds in the body (*8*). The absorption of Se-Met is more efficient than that of sodium selenite (*9*, *10*). Most of the Se from selenite forms physiologically functional selenoproteins, whereas a substantial portion of the Se from Se-Met is also incorporated nonspecifically into nonfunctional or structural proteins (*11*). Zhou et al. (*5*) reported that supplemental dietary Se-Met increased relative gain rate and final weight of Crucian carp. Calamari et al. (*12*) reported that organic forms of Se are superior to selenite as glutathione peroxidase (GPX) activity is maintained during periods of Se inadequacy in mature horses. Data regarding the effectiveness of Se-Met supplementation to diets in broilers are limited. Therefore, The aim of our study was to evaluate the efficacy of different levels of dietary supplemental Se-Met on performance, meat quality, and antioxidant property in broiler chicks.

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MATERIALS AND METHODS

Chickens, Diet, and Management. Eight hundred Lingnan yellow male broilers, 43 days old, were weighed and allotted to five treatment groups, each of which included four replicates of 40 birds. Broilers were randomly placed in floor pens (1.3 m × 3.5 m). Over a period of three weeks the birds were offered the corn−soybean meal basal diet with no supplemental Se, or this diet supplemented with 0.075 mg/kg, 0.15 mg/kg, 0.225 mg/kg Se from Se-Met, or 0.15 mg/kg Se from SS, respectively. Appropriate amounts of DL-methionine were added to the diets to formulate the same methionine content. Nutrient levels of the diets were based on the National Research Council (*13*) recommended nutrient requirements of broiler chickens (**Table 1**). Feed consumption per pen was recorded daily during the 3-week experiment. At 63 days of age, birds were deprived of feed for 12 h and weighed just prior to slaughter per pen, and cumulative weight gain and feed intake were determined, whereas cumulative feed to gain ratios were calculated. Feed intake and feed to gain

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ratio were adjusted for mortalities when appropriate. Eight broilers per treatment group (two birds per replicate) were killed by cervical dislocation for meat analyses. The birds were bled via brachial vein for plasma sample and then slaughtered and dissected by a trained team. Plasma and breast muscle were collected and snap-frozen in liquid nitrogen. Frozen tissues were stored at −70 °C prior to analysis.

pH Measurements. The pH value was measured 45 min postmortem in the right pectoralis major with a portable pH meter (HI8424, Beijing Hanna Instruments Science & Technology Co., Ltd., Beijing, P. R. China) equipped with an insertion glass electrode calibrated in buffers at pH 4.01 and 7.007 at ambient temperature.

Drip Loss. The drip loss of breast muscle was estimated 45 min postmortem using the method described by Rasmussen and Andersson (*14*) as follows. Broiler musculus pectoralis major was taken from the carcass, and samples were cut using a 25 mm cork borer at a right angle to the muscle fiber direction. Samples were placed in a plastic bag filled with air and fastened to avoid evaporation and left at 4 to 6 °C for 24 h, and drip loss was determined by weighing. Muscle fiber direction of the samples was horizontal to gravity, not vertical, as described in the original method (*14*).

Color Measurements. Meat color was measured 45 min postmortem with a Chroma Meter (CR-410, Minolta Co., Ltd., Suita-shi, Osaka, Japan) to measure CIE lab values (L^* measures relative lightness, a^* relative redness, and b^* relative yellowness). A reading was made from the surface of sample, representing the whole surface of the muscle. A white tile (L^* 92.30, a^* 0.32, and b^*0.33) was used as standard.

Measurement of Shear Force. The breast muscles were refrigerated overnight at 4 °C and then brought to room temperature before cooking. The breast muscle from each bird was cooked to an internal temperature of 70 °C on a digital thermostat water bath (HH-4, Jiangbo instrument, Jiangsu, P. R. China). End point internal temperature was monitored with a thermometer. Cooked muscle was cooled to room temperature. Slices of 1 cm × 1 cm were cut perpendicular to the fiber orientation of the muscle. Ten 1 cm × 1 cm cores about 3 cm thick were removed parallel to the fiber orientation through the thickest portion of the cooked muscle. Warner−Bratzler shear force was determined by using an Instron Universal Mechanical Machine (Instron model 4411, Instron corp., Canton, MA). A Warner−Bratzler apparatus was attached to a 50 kg load cell, and tests were performed at a cross head speed of 127 mm/min. Signals were processed with the Instron Series ninth software package.

Biochemical Determinations. The activities of total SOD (T-SOD), GPX, catalase (CAT), total antioxidant capability (T-AOC), the contents of malondialdehyde (MDA), a lipid oxidation product and reduced glutathione (GSH) in plasma were assayed using colorimetric methods with a spectrophotometer (Biomate 5, Thermo Electron Corporation, Rochester, NY). The assays were conducted with the assay kits purchased from Nanjing Jiancheng Insititute of Bioengineering (Nanjing, Jiangsu, P. R. China) and the procedures accordingly.

Forty milligrams of frozen tissue in 4 mL of homogenization buffer (0.05 M Tris-HCl, pH 7.4, 1 mM EDTA, 0.25 M sucrose) was homogenized on ice with an Ultra-Turrax (T8, IKA-Labortechnik, Staufen, Germany) for 5 s at 13,500 rpm. The homogenate was centrifuged at 3,000 rpm for 10 min at 4 °C, and the supernatant was stored at −70 °C until analysis. The activities of T-SOD, GPX, CAT, T-AOC, the contents of MDA, GSH and lactic acid (LD) were assayed using colorimetric methods with a spectrophotometer (Biomate 5, Thermo Electron Corporation, Rochester, NY). The assays were conducted with the assay kits purchased from Nanjing Jiancheng Insititute of Bioengineering (Nanjing, Jiangsu, P. R. China) and the procedures accordingly. The concentration of metallothionein (MT) was determined by ^{109}Cd-hemoglobin affinity assay (*15*) with a gamma spectrometer (model 4000, Beckman Instruments, Palo Alto, CA). The concentration of MT was calculated using a ^{109}Cd-MT binding stoichiometry of 7:1. As a hallmark of protein oxidation, the content of carbonyl protein was determined by a spectrophotometric method (*16*) and expressed as nanomoles of protein carbonyl per milligram of protein.

All samples were measured in triplicate, at appropriate dilutions, to give activities of the enzymes in the linear range of standard curves constructed with pure enzymes. Protein content of supernatants was determined using the Coommasie Brilliant Blue G250 (Sigma Chemical, St.Louis, MO) assay with bovine serum albumin.

Statistical Analysis. All statistical analyses were computed using the GLM procedures of SAS software(*17*). A software program using Duncan's multiple range test to compare treatment means was applied. A $P < 0.05$ was considered statistically significant. Replicate was considered as the experimental unit for performance determined. The experimental unit was a bird for the other parameters. Numbers (n) used for statistics are noted in the tables. All data were expressed as means ± SE.

Table 1. Ingredients and Composition of the Basal Diets for the Finishing Broilers (as Fed Basis)

ingredients	%	chemical composition	%
maize (corn)	66.30	metabolizable energy (MJ/kg)	12.75
soybean meal	24.80	crude protein	17.00
soybean oil	3.00	calcium	0.80
limestone	1.09	nonphytate phosphorus	0.35
dicalcium phosphate	1.32	lysine	0.90
L-lysine·HCl	0.10	methionine + cysteine	0.64
DL-methionine	0.09		
salt	0.30		
vitamin−mineral premix[a]	1.00		
total	100		

[a] Supplied per kilogram of diet: vitamin A (*trans*-retinyl acetate), 1500 IU; vitamin D_3, 200 IU; vitamin E (DL-α-tocopherol acetate), 10 IU; vitamin K_3, 0.5 mg; riboflavin, 3.6 mg; niacin, 30 mg; pantothenic acid, 10 mg; 50% cholinechloride, 800 mg; cobalamin, 10 μg; biotin, 0.15 mg; folic acid, 0.55 mg; $FeSO_4 \cdot 7H_2O$, 300 mg; MnO, 100 mg; $CuSO_4 \cdot 5H_2O$, 20 mg; $ZnSO_4 \cdot H_2O$, 150 mg; $NaSeO_3$, 0.15 mg; KI, 0.5 mg; ethoxyquin, 100 mg; avoparcin, 15 mg. The carrier was zeolite.

RESULTS AND DISCUSSION

Growth Performance. The effects of organic Se on growth performance in animals are somewhat variable. Miller et al. (*18*) reported no difference in gain or feed intake of broilers fed various concentrations (0 to 0.5 ppm) of Se from SS or Se-Met, whereas Edens et al. (*19*) and Spears et al.(*20*) also reported no differences in BW or feed efficiency when broilers were fed diets containing Se from SS or SY. Payne et al. (*21*) showed that daily gain, feed intake and gain to feed ratio of broilers were not affected by SS or Se-yeast supplementation. In the present study, final BW and weight gain of birds significantly increased by supplementation of Se-Met at 0.225 mg/kg level ($P < 0.05$). Final BW of birds fed 0.225 mg/kg Se as Se-Met was significantly more than those of SS and 0.075 mg/kg Se as Se-Met supplemented groups($P < 0.05$) (**Table 2**). The differences in previous results and ours may be due to the fact that their chicks were not deficient

Table 2. Effect of Selenomethionine on Growth Performance of Male Broilers from 43 to 63 Days of Age[a]

		Se-Met[b]			
items	control, 0 mg/kg	0.075 mg/kg	0.15 mg/kg	0.225 mg/kg	SS,[c] 0.15 mg/kg
final BW (kg)	1.96 ± 0.01 b	1.97 ± 0.017 b	1.99 ± 0.009 ab	2.02 ± 0.012 a	1.96 ± 0.02 b
wt gain (g/bird per day)	38.27 ± 0.34 b	38.68 ± 0.73 ab	39.12 ± 0.50 ab	40.70 ± 0.29 a	38.75 ± 1.39 ab
feed intake (g/bird per day)	110.34 ± 0.83	112.27 ± 1.63	114.20 ± 1.14	114.2 ± 3.19	113.22 ± 2.39
feed to gain ratio (g/g)	2.91 ± 0.02	2.87 ± 0.01	2.90 ± 0.034	2.80 ± 0.04	2.86 ± 0.04

[a] Values are means ± SE, n = 4. a,b: Entries within a row without a common letter differ ($p < 0.05$). [b] Selenomethionine. [c] Sodium selenite.

Table 3. Effect of Selenomethionine on Meat Quality Attributes of Breast Fillets of Male Broilers[a]

		Se-Met[b]			
items	control 0 mg/kg	0.075 mg/kg	0.15 mg/kg	0.225 mg/kg	SS,[c] 0.15 mg/kg
shear force (kgf)	2.25 ± 0.17	2.08 ± 0.08	2.23 ± 0.14	2.31 ± 0.15	2.01 ± 0.16
drip loss (%)	4.25 ± 0.31 a	3.16 ± 0.18 b	3.07 ± 0.22 b	2.27 ± 0.27 b	3.58 ± 0.38 ab
a^* [d]	13.63 ± 0.21	14.43 ± 0.47	14.44 ± 0.47	14.65 ± 0.22	14.18 ± 0.38
b^* [e]	24.43 ± 0.66	23.90 ± 0.72	23.27 ± 0.57	22.58 ± 0.86	24.40 ± 0.43
L^* [f]	55.21 ± 0.58 a	54.36 ± 0.39 ab	54.51 ± 0.53 ab	53.66 ± 0.51 b	54.71 ± 0.0.68 ab
pH value	6.01 ± 0.05 b	6.26 ± 0.09 a	6.30 ± 0.09 a	6.16 ± 0.06 ab	6.27 ± 0.08 a

[a] Values are means ± SE, n = 8. a,b: Entries within a row without a common letter differ ($p < 0.05$). [b] Selenomethionine. [c] Sodium selenite. [d] Redness. [e] Yellowness. [f] Lightness.

Table 4. Biochemical Indices in Plasma, Breast Muscle of Male Broilers[a]

		Se-Met[b]			
items	control, 0 mg/kg	0.075 mg/kg	0.15 mg/kg	0.225 mg/kg	SS,[c] 0.15 mg/kg
		Plasma			
T-AOC[d](U/mL)	13.01 ± 0.37 d	14.38 ± 0.47 cd	16.17 ± 0.65 b	17.61 ± 0.37 a	15.37 ± 0.78 bc
T-SOD[e] (U/mL)	210.60 ± 5.29 c	238.81 ± 6.23 ab	242.98 ± 4.00 ab	253.08 ± 7.20 a	232.29 ± 6.44 b
GPX[f] (IU)	705.47 ± 32.91 c	1066.20 ± 63.00 b	1237.50 ± 72.35 b	1719.05 ± 88.49 a	1209.38 ± 73.95 b
CAT[g] (U/mL)	1.11 ± 0.16 c	1. 84 ± 0.14 b	2.13 ± 0.10 ab	2.33 ± 0.07 a	1.88 ± 0.12 b
MDA[h](nmol/mL)	2.16 ± 0.15 a	1.65 ± 0.10 b	1.35 ± 0.12 bc	1.21 ± 0.12 c	1.70 ± 0.08 b
GSH[i](mg/L)	257.35 ± 8.82 c	295.12 ± 8.53 ab	305.75 ± 8.25 ab	312.73 ± 7.89 a	279.89 ± 12.36 bc
		Breast Fillets			
T-AOC (U/mL)	0.60 ± 0.03 c	0.68 ± 0.05 abc	0.78 ± 0.04 ab	0.82 ± 0.06 a	0.65 ± 0.02 bc
GPX (IU)	2.76 ± 0.23 c	3.69 ± 0.28 b	4.49 ± 0.26 ab	4.63 ± 0.31 a	3.22 ± 0.19 bc
T-SOD (U/mL)	26.48 ± 0.68 b	30.53 ± 1.86 ab	34.86 ± 1.67 a	38.71 ± 1.37 a	27.64 ± 0.41 b
CAT (U/mL)	0.47 ± 0.02 c	0.62 ± 0.05 bc	0.73 ± 0.04 ab	0.78 ± 0.08 a	0.61 ± 0.02 bc
MDA (nmol/mL)	0.30 ± 0.02 a	0.23 ± 0.02 b	0.20 ± 0.01 b	0.19 ± 0.01 b	0.21 ± 0.01 b
GSH (mg/L)	33.08 ± 1.53 d	41.24 ± 1.86 c	51.78 ± 2.05 ab	57.36 ± 2.89 a	38.23 ± 0.93 dc
MT[j] (nmol/gprot)	2.67 ± 0.20 c	2.95 ± 0.10 bc	3.41 ± 0.22 ab	3.55 ± 0.17 a	3.28 ± 0.15 ab
carbonyl protein (nmol/mgprot)	0.36 ± 0.03 a	0.27 ± 0.04 ab	0.24 ± 0.03 b	0.22 ± 0.03 b	0.25 ± 0.02 b
LD[k](mmol/gprot)	1.59 ± 0.12 a	1.44 ± 0.06 ab	1.39 ± 0.03 ab	1.33 ± 0.06 b	1.41 ± 0.04 ab

[a] Values are means ± SE, n = 8. a,b,c,d: Entries within a row without a common letter differ ($p < 0.05$). [b] Selenomethionine. [c] Sodium selenite. [d] Total antioxidant capability. [e] Total superoxide dismutase. [f] Glutathione peroxidase. [g] Catalase. [h] Malondialdehyde. [i] Reduced glutathione. [j] Metallothionein. [k] Lactic acid.

in nutrients of Se and vitamin E before the study, whereas our broilers were fed low Se and vitamin E diets from 1 day to 42 days of age.

Meat Quality. The results of meat quality of breast muscles are presented in **Table 3**. The data clearly showed that the difference in shear force of breast muscles was not significant between groups ($p > 0.05$). The drip loss was significantly decreased by the addition of Se-Met ($p < 0.05$). The L^* value of meat color was significantly decreased by supplemental 0.225 mg/kg Se as Se-Met ($p < 0.05$). Meanwhile, adding SS or Se-Met at 0.075 mg/kg, 0.15 mg/kg level to the diet significantly increased the pH value of meat ($p < 0.05$).

Se is required in poultry for the maintenance of optimal health and meat quality. Zhan et al. (*4*) indicated that, compared to SS, Se-Met is more effective in decreasing the volume of drip loss and stabilizing the meat color of pigs. Choct et al. (*22*) reported that birds receiving organic Se in their diets had reduced drip loss.The present study showed that the addition of Se-Met decreased drip loss and L^* value and raised the pH value of meat. This result may be attributed to a decreased LD production in muscles postmortem (*23*). The inability of muscle cells to rid themselves of metabolic byproduct such as LD causes a decrease in pH (*24*). This decrease in pH can decrease water holding capacity (*25*). The present results showed that Se-Met addition at 0.225 mg/kg level reduced the concentration of LD in breast muscles. In this study, SS supplementation only increased meat pH value. This finding suggested that Se-Met supplementation in broilers would be expected to improve meat quality, and Se-Met was more effective than SS in reducing percent drip loss and improving meat color.

Biochemical Analyses. As shown in **Table 4**, the addition of 0.15 mg/kg or 0.225 mg/kg Se-Met significantly elevated T-AOC, GPX, CAT, T-SOD activities ($p < 0.05$), content of GSH ($p < 0.05$), decreased content of MDA ($p < 0.05$) in plasma and breast muscle, and increased MT content and reduced carbonyl protein content ($p < 0.05$) in breast muscle. The LD production of breast muscle was significantly decreased by 0.225 mg/kg Se-Met treatment ($p < 0.05$). Supplementation with SS significantly increased T-AOC, GPX, CAT, T-SOD activities ($p < 0.05$) in plasma, and decreased MDA production ($p < 0.05$) in plasma and breast muscle. When compared with 0.15 mg/kg SS treatment, the use of 0.225 mg/kg Se-Met significantly improved T-AOC ($p < 0.05$), the activities of GPX and CAT ($p < 0.05$), and content of GSH ($p < 0.05$) in plasma and breast muscle, significantly increased T-SOD activity and decreased the concentration of MDA ($p < 0.05$) in plasma.

Poultry meat is quite sensitive to oxidative deterioration due to its high content of polyunsaturated fatty acids. Se is an essential trace element that upregulates a major component of the antioxidant defense mechanism by controlling the body's GSH pool and its major Se-containing antioxidant enzyme, GPX. It is necessary in preventing free radical damage to phospholipid membranes, enzymes and other important molecules. Moskovitz and Stadtman (*26*) observed that the Se-deficient diet led to substantial accumulations of of protein carbonyl derivatives in

the liver, kidney, cerebrum, and cerebellum of mouse. Mahmoud and Edens (*27*) observed an enhanced GSH−GPX antioxidant system in organic Se-fed chickens than inorganic Se groups. Cantor et al. (*28*) and Spears et al. (*20*) reported that Se supplementation increased pGPX3 activity over that of birds fed unsupplemented diets. In the study presented here, dietary supplementation with Se-Met raised activities of antioxidant enzymes and concentrations of antioxidant and reduced the production of protein and lipid peroxidation products in plasma and breast muscle. And Se-Met is more effective in improving the antioxidant status than SS in broilers. The results were consistent with those of Spears et al. (*20*) (2003), Wang and Xu (*29*), Zhan et al. (*4*) and Skřivan et al. (*30*). These findings suggested that Se-Met improved antioxidative status of male broilers by elevating activity of antioxidant enzymes and reducing peroxidation products, and also implicated that Se-Met supplementation may have a beneficial effect on oxidative stability and shelf life of chick meat.

Summarily, Se-Met was superior to SS for growth performance, meat quality and antioxidative property. We concluded that Se-Met might act as an efficient Se source in broilers.

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