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Full Length Research Paper

Effect of organic and inorganic selenium supplementation on growth performance, meat quality and antioxidant property of broilers

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Ninety-six thousand one-day-old AA broilers were randomly assigned to two groups, 5 replicates in each group, and 9,600 chickens for each replicate. In the control group, 0.3 part per million (ppm) inorganic selenium (Na_2SeO_3) was added to the diets; while in the experimental group, 0.3 ppm organic selenium (Se-enriched yeast) was added to the same basal diets. The feeding experimental period was 42 days. The results show that: (1) Organic selenium could increase daily weight gain and feed intake by 8.92 ($P<0.05$) and 3.99% ($P<0.05$), and decrease survival rate and feed conversion by 0.93 ($P<0.05$) and 4.84% ($P<0.05$), indicating that the effects of organic selenium on broiler growth performance were better than that of inorganic selenium, except for survival rate. (2) Compared with the control, meat red color degree of chest and thigh muscles were increased by 13.98 ($P<0.05$) and 20.83% ($P<0.05$); the drip losses of chest and thigh muscles were decreased by 13.57 ($P<0.05$) and 24.92% ($P<0.05$), respectively. (3) Serum glutathione peroxidase (GPX) activity in experimental group were 155.83% higher than that in the control ($P<0.05$). These results indicate that the effects of organic selenium on enhancing body oxidation resistance were superior to that of inorganic selenium.

Key words: Organic selenium, broilers, growth performance, meat quality, antioxidant property.

INTRODUCTION

Selenium (Se) is an essential trace element for human and animal health. Selenium could be supplemented in diets as inorganic mineral salts, typically as sodium selenite (SS) or in organic forms such as Se-enriched yeast (SY), selenocysteine (Se-Cys) and selenomethionine. Usually, the organic forms of Se have higher bioavailability and antioxidant properties than inorganic forms (Mahan et al., 1999; Mahmoud and Edens, 2003). In addition, organic forms of Se are less toxic and more environmental friendly than inorganic forms (Kim and Mahan, 2001; Kuricova et al., 2003).

The antioxidant systems in the body contain numerous antioxidant enzymes, such as superoxide dismutase (SOD), thioredoxin peroxidase (TPx) and glutathione peroxidase (GSH-Px), GPX while numerous non-enzymatic substances are also employed to protect the body from oxidative stress (Flohé, 2010). Drip loss and meat color are important indexes for evaluation of meat quality. Mahan et al. (1999) found that SY was more beneficial than SS in decreasing drip loss of loin muscle in pigs. Choct et al. (2004) reported that the broilers that received SS had a greater 24 h drip loss than those that received SY. And SY was found to be a highly bioavailable form of Se in comparison to SS (Rider et al., 2010). Cantor et al. (1982) reported an increase in breast Se concentration in poultry fed with DL-selenomethionine

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Abbreviations: PPM, Part per million; **GPX,** glutathione peroxidase.

Table 1. Compositions and nutrient levels of basal diets for broilers (%).

Ingredients	0 - 3 Week old	4 - 6 Week old
Corn	55.80	59.80
Extruded soybean	37.60	32.20
Soybean oil	2.30	3.36
Limestone	1.30	1.20
Calcium phosphate	1.54	1.42
Zeolite powder	-	0.65
Lysine	0.02	-
Methionine	0.14	0.07
Salt	0.30	0.30
Mineral and vitamin premix[a]	1.00	1.00
Total	100.00	100.00
Nutrient levels		
Crude protein	21.00	19.00
Metabolized energy (MJ/Kg)	12.13	12.55
Calcium	1.01	0.90
Available phosphorus	0.45	0.40
Lysine	1.10	1.00
Methionine	0.50	0.45

[a]The premix supplied per kilogram of feed: 6 mg of Cu , 75 mg of Fe , 75 mg of Zn , 80 mg of Mn, 0.4 mg of I , 1 mg of zeolite powder, 3 mg of choline , 6000 IU of vitamin A, 2000 IU of vitamin D_3, 12 IU of vitamin E, 2 mg of vitamin K_3, 0.05 mg of biotin, 0.4 mg of folic acid, 32 mg of niacin, 7 mg of pantothenic acid, 1 mg of vitamin B_1, 5 mg of vitamin B_2, 1 mg of vitamin B_6 and 10 mcg of of vitamin B_{12}.

when compared with those fed with SS diet. However, data regarding the effectiveness of SY supplementation in diets of broilers are limited.

The purpose of this study was to study the effect of inorganic and organic Se on growth performance, meat quality and antioxidant property of broilers.

MATERIALS AND METHODS

Chickens, diets and feeding protocol

Ninety-six thousand 1-day-old AA broilers with average body weight of 39.50 ± 0.13 g were randomly allotted to two treatments, each of which was replicated five times with 9,600 birds per replicate. In the organic selenium group (experimental group), the birds were fed with the basal diet that contained 0.3 ppm organic selenium (Se-enriched yeast, supplied by Beijing Alltech Biological Products Co. Ltd., Beijing, China). In the inorganic selenium group (control group), the birds were given the same basal diet supplemented with 0.3 ppm inorganic selenium (Na_2SeO_3, Sigma-Aldrich Chemical Co., St. Louis, MO, USA).

The basal diet was formulated to meet nutrient requirements of broilers according to NRC (National Research Council) (1994), except for selenium. A two-phase feeding system was used for all broilers for diet 1 from 0 to 3 weeks old, and diet 2 from 4 to 6 weeks old (Table 1). The experiment ended at the age of 42 days. Water and feed were given *ad libitum*.

Sampling

Feed intake and survival rate were recorded daily. Average daily gain (ADG) and feed conversion ratio (FCR) were calculated. Ten broilers (5 males and 5 females) from each replicate were randomly sampled at days 42, fasted for 12 h, and blood samples were taken from the neck vein and serum was separated. Serum samples were stored at -20°C for further analysis. The carcasses, eviscerated broiler, half-eviscerated broiler, breast meat, leg muscle and abdominal fat were weighted after slaughter for determining slaughter performance of broilers. The left fresh breast and leg muscles per bird were collected for meat quality analyses. The pH value was determined at 45 min and 24 h postmortem in the left pectoralis major and leg muscle with a pH meter (S40 SevenMulti™, Mettler-Toledo Inc., Columbus, USA).

Cook loss determination

Broiler breast meat or leg muscle were trimmed to 2 × 1 × 0.5 cm size or 1 × 1 × 0.5 cm size, blotted to remove the surface water, and the initial weight was determined.

Samples were placed in a plastic bag filled with air and fastened to avoid evaporation and left at 4°C, the final weight was determined at 24 and 48 h postmortem. Percentage of drip loss was calculated by 100 × (initial muscle weight - final muscle fillet weight)/initial muscle weight. Muscle fiber direction of the samples was horizontal to gravity, as described in the former method (Rasmussen et al., 1996).

Table 2. Effects of different forms of selenium on growth performance of broilers.

Parameter	Control group	Experimental group
Daily weight gain (g/d)	56.82±0.60^{B}	61.89±2.16^{A}
Feed consumption (g/d)	105.5±0.28^{B}	109.71±2.58^{A}
Feed conversion	1.86±0.02^{A}	1.77±0.03^{B}
Survival rate	97.73±0.12^{A}	96.83±0.49^{B}

Control group: The birds were given the basal diet containing 0.3 ppm inorganic selenium. Experimental group: The birds were given the basal diet containing 0.3 ppm organic selenium. Means with different superscript capital letters in the same rows indicate differences at P<0.05; means with the same superscript capital letters (or without marks) in the same rows indicate insignificant differences at P>0.05.

Shear force determination

Tenderness was assessed using an objective texture procedure described by Meek et al. (2000). Five adjacent 1 (width) × 1 (thickness) × 2 cm (length) strips were cut from the cooked breast, parallel to the direction of the muscle fibers. Each strip was sheared once, and the mean was calculated for each breast. Samples were sheared perpendicular to the muscle fibers by using a Texture Analyser (TMS-PRO, FTC, USA) with a 50 kg load transducer and a cross-head speed of 200 mm/min.

Color measurements

The breast and leg muscle colors were determined using Chroma meter (SP60 Series, X-Rite Incorporated, Michigan, USA) within 12 h natural exposure at 25°C room temperature (Pi et al., 2005). Color for each sample was expressed in terms of CIE values for lightness (L*), redness (a*) and yellowness (b*).

Serum biochemical index determination

The serum biochemical indexes were determined with 7600-020 Automatic Analyzer HITACHI in Biochemical Laboratory of Zhengzhou University, Zhengzhou, China.

Statistical analysis

Experimental data were analyzed by two-way ANOVA using the SAS 6.12 statistical program (SAS Institute Inc., Cary, NC, USA). The results were expressed as the means and standard errors. Differences due to diet treatment were considered significantly at P<0.05.

RESULTS

Growth performance

Table 2 indicates that organic selenium had reduced feed conversion when compared with inorganic selenium (P<0.05). When compared with the inorganic selenium, organic selenium could decrease survival rate by 0.93% (P<0.05), the survival rate in inorganic selenium group was 97.73 ± 0.12, and in organic selenium group it was 96.83 ± 0.49.

Slaughter performance and meat quality

In Table 3, the respective carcass characteristics were displayed. The results show that different selenium forms did not affect slaughter performance of broilers (P>0.05).

Effects of selenium forms on meat quality and pH values

When compared with inorganic Se, organic Se significantly increased the meat red color degree, and decreased cooking loss (Table 4). The meat red color degree of breast meat and leg muscle were increased by 13.98 (P<0.05) and 20.83% (P<0.05), respectively. The drip loss of breast meat and leg muscle were decreased by 13.57 (P<0.05) and 24.92% (P<0.05), respectively. Different forms of dietary selenium did not affect pH values and shear force of meat significantly (P>0.05). The results indicate that the effects of organic selenium on decreasing myoglobin oxidation, stabilization of meat color and drip loss were better than that of inorganic selenium.

Antioxidant property

Organic Se increased the antioxidant status of broilers. Table 5 shows that organic Se could significantly increase serum GPX activity by 155.83% (P<0.05) when compared with inorganic Se. There were no significant difference for other serum biochemical indexes between the control and experimental groups (P>0.05).

DISCUSSION

It is known that selenium enhances the metabolism of thyroid hormones, which are important for normal growth and development (Arthur, 1991; Arthur and Beckett, 1994). Selenium has also shown an essential component of the Se-dependent glutathione peroxidase (Combs, 1981). Glutathione peroxidase protects cells against

Table 3. Effects of different selenium sources on slaughter performance of broilers (%).

Parameter	Gender	Control group	Experimental group
Percentage of carcass	Male	92.78±1.08	92.84±0.56
	Female	92.34±0.29	92.61±1.18
Percentage of half-eviscerated	Male	87.09±1.76	87.41±0.88
	Female	86.07±1.25	85.89±0.69
Percentage of eviscerated	Male	78.16±0.55	77.76±0.55
	Female	77.06±1.24	75.76±1.29
Percentage of breast meat	Male	24.20±1.83	24.47±1.02
	Female	24.49±1.56	23.87±0.57
Percentage of leg muscle	Male	8.50±0.65	8.53±1.01
	Female	8.24±0.54	8.14±0.44
Percentage of abdominal fat	Male	2.11±0.177	2.23±0.17
	Female	2.99±0.71	3.45±1.12

Control group: The birds were fed the basal diet containing 0.3 ppm inorganic selenium. Experimental group: The birds were fed the basal diet containing 0.3 ppm organic selenium.

Table 4. Effects of different selenium sources on meat quality and pH values.

Parameter	Control group	Experimental group	Control group	Experimental group
	breast meat	breast meat	leg muscle	leg muscle
CIE L* (lightness)	48.25±3.11	47.28±2.80	44.44±2.34	43.60±2.83
CIE a* (redness)	9.66±0.93^{B}	11.01±1.12^{A}	12.82±0.75^{B}	15.49±1.48^{A}
CIE b* (yellowness)	22.26±2.45	22.81±3.29	16.12±2.47	17.80±1.82
Cooking loss (%)	6.41±0.22^{A}	5.54±0.50^{B}	12.36±1.04^{A}	9.28±0.1.00^{B}
Shear Force^{2} (N)	78.56±18.58	84.64±28.92	28.09±8.72	30.05±9.23
pH (45 min)	6.10±0.21	6.28±0.16	6.34±0.27	6.06±0.48
pH (24 h)	6.01±0.19	6.13±0.10	6.23±0.23	6.01±0.31

Control group: The birds were given the basal diet containing 0.3 ppm inorganic selenium. Experimental group: The birds were given the basal diet containing 0.3 ppm organic selenium. Means with different superscript capital letters in the same row indicate differences at P<0.05; means with the same superscript capital letters (or without marks) in the same row indicate insignificant differences at P>0.05.

damage caused by free radicals (Flohé, 2010). Dietary Se could prevent lipid peroxidation of biological membranes. The results of increasing glutathione peroxidase activity in serum by organic Se in this experiment were in agreement with previous reports (Jiang et al., 2009). These findings suggested that Se-enriched yeast improved antioxidative status of broilers by elevating activities of antioxidant enzymes, and also implicated that Se-enriched yeast supplementation may have a beneficial effect on oxidative stability and extended shelf life of fresh meat than sodium selenite.

According to the results of feed conversion and survival rate, the economic effectiveness of organic Se was better than inorganic Se. The results of improving broiler growth and feed efficiency by organic Se in this experiment were in agreement with the report of Choct et al. (2004). The reason may be that organic selenium could cross through intestine and enter into blood by active transport, while inorganic selenium was absorbed by passive diffusion (Arthur and Beckett, 1994). The Selenomethionine from selenised yeast was well absorbed and was incorporated into body proteins in place of methionine (Butler et al., 1989). The extent of selenomethionine incorporation into proteins depends on the dosage and methionine status (Butler et al., 1989; Salbe and Levander, 1990). Selenomethionine was incorporated primarily into the proteins of

Table 5. Effects of different selenium forms on antioxidant enzyme activity in serum of broilers.

Index	Control group	Experimental group
Superoxide dismutase (SOD)/(U/ml)	124.90±8.04	131.62±6.35
Glutathione peroxidase (GPX)/(U/ml)	2075.64±228.26^{B}	5310.03±265.27^{A}
Aspartate amino transferase (AST)/(U/L)	373±51.27	350.00±67.63
Alkaline phosphatase (ALP)/(U/L)	1068±208.50	1103.33±198.20
Total protein (TP)/(g/L)	41.10±8.18	38.66±8.23
Globulin (GLO)/(g/L)	24.68±5.79	23.04±5.75
Total bilirubin (T-BLL)/(μmol/L)	21.10±5.06	22.22±4.26
Glucose (GLU)/(mmol/L)	12.66±1.47	12.07±3.37
Urea (mmol/L)	0.57±0.18	0.58±0.31
Total cholesterol (CHO)/(mmol/L)	4.04±0.51	3.87±0.82
Triglyceride (TG)/(mmol/L)	0.61±0.16	0.57±0.26
High density lipoprotein (HDL)/(mmol/L)	2.58±0.31	2.54±0.46

Control group: The birds were fed the basal diet containing 0.3 ppm inorganic selenium. Experimental group: The birds were fed the basal diet containing 0.3 ppm organic selenium. Means with different superscript capital letters in the same row indicate differences at P<0.05; means with the same superscript capital letters (or without marks) in the same row indicate insignificant differences at P>0.05.

the skeletal muscles, erythrocytes, pancreas, liver, stomach, kidneys and gastrointestinal mucosa, its released from body proteins was linked to protein turnover and occurs continuously (Hansson and Jacobsson, 1966). Current evidence favors organic selenium over the other forms of selenium in absorption efficiency (Schrauzer, 2001). Further, it was known that selenium enhances the metabolism of thyroid hormones, which was important for normal growth and development (Arthur et al., 1992). Therefore, a combination of better absorption efficiency and thyroid hormone activation by organic selenium availability may explain the improved feed efficiency.

The adverse effect of organic Se on decreasing survival rate was found in this research. It might be the fast growth in organic Se group that cause heart overload or failure, which reduced the survival rate. Nain (2007) found that over-supplementation of vitamin D increases the risk of sudden death syndrome (SDS) in broilers, and that the most likely mechanism was associated with increased susceptibility of the ventricular myocardium to arrhythmia. The incidence of SDS in broilers was associated with good-nourishment, and the hearts of broilers are considerably more susceptible to arrhythmias and stress. Although, selenium deficiency has been implicated in the cardiomyopathy, the therapeutic benefit of selenium administration in preventing and curing cardiovascular diseases still remains insufficiently documented, and selenium is a risk factor for cardio-vascular diseases (Alissa et al., 2003). Selenium was an essential trace element with a narrow margin between beneficial and toxic effects (Zhang et al., 2008), so the study on optimal concentration of organic Se in animal feed needs more researches.

As a result of the involvement of selenium in membrane integrity and cell viability, the supplementation of selenium might improve meat quality and shelf life by reducing drip loss from meat. Meat color and quality analysis in this study showed that birds fed with diets containing 0.3 ppm of organic Se could have decrease in cooking loss and myoglobin oxidation, and increase in meat red color degree. The stabilization of meat color and drip loss recorded for the birds fed organic Se agree with the former researches (Choct et al., 2004; Edens et al., 1996).

Even though organic Se was found to increase body weight, feed conversion, meat quality and anti-oxidation for broilers in this study, there are some opposite reports (Ryu et al., 2005; Wang et al., 2011; Edens et al., 2001). So, the application of organic Se in animal feed should be considered in more researches, especially in the study of side effect of organic Se.

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