Biol Trace Elem Res (2018) 181:340–346
DOI 10.1007/s12011-017-1049-4

Effects of Different Selenium Sources on Growth Performance, Antioxidant Capacity and Meat Quality of Local Chinese Subei Chickens

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Received: 10 March 2017 / Accepted: 4 May 2017 / Published online: 17 May 2017

Abstract Despite increasing evidence indicating the essential involvement of selenium (Se) on growth performance, antioxidant capacity, and meat quality of commercial broilers, the effects of different Se sources on local Chinese Subei chickens is unclear. A total of 360 50-day-old male chickens were individually weighed and randomly allocated to four treatment groups. Chickens in each of the four groups were fed diets supplemented with 0.3 mg Se/kg as sodium Se (SS), Se-enriched yeast (SY), selenomethionine (Met-Se), or nano red element Se (Nano-Se) for 40 days. At the end of the experiment, one bird of approximately average weight from each cage was selected and slaughtered, and blood and breast muscles samples were collected. The results showed that there was no significant difference in feed intake, body weight gain, or feed to gain ratio among treatments ($P > 0.05$). Dietary SY, Met-Se, and Nano-Se supplementation increased the activity of glutathione peroxidase in serum and breast muscles and decreased the concentration of malondialdehyde in serum and carbonyl in breast muscles compared with the SS group ($P < 0.05$). Moreover, SY, Met-Se, and Nano-Se supplementation increased pH_{45min}, total protein solubility, and myofibrillar protein solubility, as well as decreased the shear force value compared with the SS group ($P < 0.05$). In addition, birds in the SY and Met-Se groups exhibited lower cooking loss compared with the SS group ($P < 0.05$). In conclusion, organic Se and Nano-Se supplementation resulted in an improvement of antioxidant capacity and meat quality in local Chinese Subei chickens relative to inorganic Se.

Keywords Selenium source · Growth performance · Antioxidant capacity · Meat quality · Local chicken

Introduction

Selenium (Se) is a basic trace element that influences the physiological function and growth performance of animals and humans [1, 2]. Se is essential for animal life, as it is required for various enzymes that are active in all cells. Dietary supplementation with Se could increase growth performance in broiler chickens [3, 4]. Se additives in the poultry diet could be divided into three main forms: inorganic Se, organic Se, and nano red element Se (Nano-Se). Inorganic Se is generally used as sodium Se (SS), while organic Se is usually in the form of Se-enriched yeast (SY) or selenomethionine (Met-Se). It is established that SY and Met-Se are preferable to SS as Se sources in animal nutrition, due to their excellent bioavailability and lower toxicity [5, 6], while Nano-Se has attracted widespread attention because of its high catalytic efficiency, strong adsorbing ability, and lower toxicity relative to SS [7].

Oxidation is a major factor associated with deterioration of numerous physiological functions important in poultry production, including health, growth, reproduction, and immunity. The selenoprotein glutathione peroxidase (GSH-Px), together with the non-Se-containing enzymes, such as superoxide dismutase (SOD) and catalase (CAT), are constituents of primary physiological antioxidant defense systems [8]. Se is an important component of GSH-Px, and supplementation

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with Se could increase the mRNA expression of GSH-Px1 in the livers of broiler chickens [9]. Moreover, dietary addition with Se could also increase the activities of SOD, CAT, and GSH-Px and reduce the levels of the biomarkers of oxidative stress, such as the malondialdehyde (MDA) and carbonyl, thus improving the antioxidant status in broilers [5, 10, 11]. Meanwhile, the effects of organic Se and Nano-Se supplementation on antioxidant status were more effective than the SS [12, 13].

Meat color and drip loss are important indices for evaluation of meat quality, and are closely related to the oxidation status in muscles. The color of meat is determined by the oxidation status of myoglobin [14]. Improved antioxidant capacity, induced by Se supplementation, could increase the content of myoglobin, thereby improving the color of meat [10, 15]. In addition, when the phospholipids in the cell membranes are oxidized, alterations in cell permeability occur, leading to decreased muscle water-holding capacity. Several researches also reported that dietary Se could decrease the drip loss of meat [16, 17]. Furthermore, the improvement of meat quality induced by organic Se and Nano-Se seemed more effective than the SS [10, 12].

Chinese Subei chicken is an important commercial native breed in China and is known to possess desirable characteristics, including resistance to some diseases, outstanding meat flavor and taste. There are extensive reports of the effects of different Se sources on commercial broilers; however, there is limited information regarding their effects on local Chinese Subei chickens. The objective of the current study was to evaluate the effects of different Se sources on the growth performance, antioxidant capacity, and meat quality of local Chinese Subei chickens, and verify whether the organic Se and Nano-Se are more effective than the inorganic Se.

Materials and Methods

Bird Management

All birds were provided and managed by Xincao Farm, Dongtai, China. A total of 360 50-day-old male chickens were individually weighed and randomly allocated to four treatment groups, each with ten replicates (cages) of nine birds (nine birds per cage). Chickens in four groups were fed diets supplemented with 0.3 mg Se/kg as sodium Se (SS), SY, Met-Se, or Nano-Se for 40 days. The Se contents of SS, SY, Met-Se, and Nano-Se were 4550, 2000, 1500, and 5000 mg/kg, respectively. SS, Met-Se, and Nano-Se were obtained from Jiahe Feed Technology Co. Ltd. (Hangzhou, China), and SY was obtained from Angel Yeast Co. Ltd. (Wuhan, China). The composition and nutrient levels of the basal diet are presented in Table 1. Feed and water were available ad libitum during the experiment. To determine growth performance, body weight and feed intake (FI) were recorded for each replicate as a unit at the beginning and the end of the experiment and were used to calculate body weight gain (BWG) and feed to gain ratio (F/G). The experimental design and procedures were approved by the Animal Care and Use Committee of Nanjing Agricultural University.

Table 1 The composition and nutrient levels of the basal diet

Ingredients	Percent	Nutrients levels[b]	Percent
Maize	66.0	Metabolizable energy (MJ/kg)	11.85
Soybean meal	29.0	Crude protein	17.50
Premix[a]	5.0	Available phosphorus	0.35
		Calcium	1.00
		Lysine	0.85
		Methionine	0.35
		Methionine+cysteine	0.68

[a] Premix provided per kg of diet: retinyl acetate for vitamin A, 10,000 IU; cholecalciferol for vitamin D_3, 3000 IU; DL-α-tocopheryl acetate for vitamin E, 30 mg; menadione sodium bisulphate for vitamin K, 2 mg; thiamin mononitrate for vitamin B_1, 2 mg; pyridoxine hydrochloride for vitamin B_6, 4 mg; calcium pantothenate, 10 mg; nicotinamide, 50 mg; biotin, 0.04 mg; choline chloride, 500 mg; folic acid, 0.5 mg; cobalamine, 0.01 mg; calcium (from limestone), 9000 mg; phosphorus (from dicalcium phosphate), 2100 mg; sodium (from salt), 3700 mg; iron (from calcium iodate), 110 mg; copper (from copper sulfate), 10 mg; manganese (from manganese sulfate), 120 mg; zinc (from zinc sulfate), 100 mg; iodine (from calcium iodate), 1.1 mg; methionine (from DL-methionine), 800 mg; lysine (from L-lysine-HCL), 100 mg

[b] Calculated value

Sample Collection

At the end of the 40 days of dietary treatment, one bird of approximately average weight was selected from each cage and slaughtered after an 8-h fast. Blood samples were collected in heparinized tubes from wing punctures, and serum was separated by centrifugation at 2700×*g* for 10 min at 4 °C, and serum samples were stored at −20 °C for further analysis. Broilers were euthanized by cervical dislocation after bleeding. The entire right breast muscles were dissected and placed at 4 °C to measure meat quality traits. At the same location of left breast muscles, the samples were obtained and immediately frozen in liquid nitrogen, then stored at −80 °C for further analysis.

Meat Quality Measurement

The pH values of breast muscles were measured in triplicate at 45 min ($pH_{45\ min}$) and 24 h (pH_u) postmortem using a HI9125 portable digital pH meter (HANNA Instrument, Italy), and the average values were used.

Meat color parameters were registered as lightness (L*), redness (a*), and yellowness (b*). At 24 h postmortem, color

was measured using a CR410 Chroma Meter (Konica Minolta Sensing Inc., Japan). Measurements were performed in triplicate for each breast meat sample, and the values were averaged.

Within 1 h postmortem, dissected breast muscles were trimmed to a size of 5 × 2 × 1 cm, and the surface water was removed, and the samples were weighed as initial weight. Samples were then placed in a plastic bag filled with air, hung in a refrigerator at 4 °C for 24 h, and reweighed as final weight. Drip loss percentage was calculated as (initial weight − final weight)/initial weight × 100.

At 24 h postmortem, breast muscles samples of approximately 20 g were dissected to determine cooking loss and shear force. Samples were weighed accurately as initial weight, placed in a plastic bag, and then cooked in a water bath at 75 °C until the internal temperature reached 70 °C. After cooling ambient temperature in running water and removal of surface water, samples were reweighed as final weight. Cooking loss percentage was calculated as (initial weight − final weight)/initial weight × 100. Cooked samples were trimmed to a size of 3 × 1 × 1 cm parallel to the longitudinal orientation of the myofibers to measure the Warner–Bratzler shear force using a Digital Meat Tenderness Meter (C-LM3B, Northeast Agricultural University, Harbin, China). Measurements were performed in triplicate for each sample, and the values were averaged.

Total protein solubility (TPS) and sarcoplasmic protein solubility (SPS) in breast muscles were analyzed using the method of Niu et al. [18]. The TPS was extracted from 0.5 g breast meat using 10 mL of ice-cold 1.1 M potassium iodide in 0.1 M phosphate buffer (pH 7.2), while the SPS was extracted from 0.5 g breast meat using 5 mL of ice-cold 0.025 M potassium phosphate buffer (pH 7.2). Samples were homogenized for 30 s on ice and placed on a shaker at 4 °C overnight. Then, homogenates were centrifuged for 20 min at 1500×*g* at 4 °C and protein concentrations in the supernatants were determined spectrophotometrically using commercial kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China). Myofibrillar protein solubility (MPS) content was obtained by calculating the difference between TPS and SPS.

Determination of Antioxidant Capacity in Serum and Muscles and Phospholipase A2 in Muscles

Frozen muscle samples (about 0.5 g) were homogenized in centrifuge tubes containing 4.5 mL of 0.75% ice-cold saline, and then centrifuged at 3000×*g* for 10 min at 4 °C. The activities of T-SOD, CAT, and GSH-Px; total antioxidant capacity (T-AOC); and the concentrations of MDA, carbonyl, and phospholipase A2 in the supernatants and serum were determined spectrophotometrically using commercial kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China).

Statistical Analyses

All data were analyzed by one-way analysis of variance (ANOVA) with SPSS statistical software (version 20.0 for Windows; SPSS Institute Inc., Chicago, USA), and Tukey's test was performed. Data were reported as mean values and standard error of the means (SEM), and the result with $P < 0.05$ was considered statistically significant.

Results

The growth performance indices of local Chinese Subei chickens fed with different Se sources are shown in Table 2. There were no significant differences in FI, BWG, or F/G among treatment groups ($P > 0.05$).

Compared with the SS group, dietary SY, Met-Se, and Nano-Se supplementation increased the activity of GSH-Px, whereas decreased the concentration of MDA in serum ($P < 0.05$). No significant effects were observed among different treatment groups on the activities of T-SOD, CAT, and T-AOC ($P > 0.05$, Table 3). Similarly in serum, the activity of GSH-Px was higher and the concentration of carbonyl was lower in the SY, Met-Se, and Nano-Se groups than those in the SS group in the breast muscles ($P < 0.05$). However, dietary addition of SY, Met-Se, and Nano-Se did not affect the activities of T-SOD or T-AOC, or the concentration of MDA in the breast muscles ($P > 0.05$).

The effects of diets supplemented with different Se sources on meat quality of breast muscles in chickens are presented in Table 4. Compared with the SS group, breast muscles from chickens receiving SY, Met-Se, and Nano-Se supplementation exhibited increased $pH_{45\ min}$ and decreased shear force values ($P < 0.05$). In addition, birds in the SY and Met-Se group had a lower cooking loss compared to those in the SS group ($P < 0.05$). However, no significant difference in pH_u, L*, a*, b*, or drip loss was observed in all treatment groups ($P > 0.05$). Moreover, as shown in Table 5, there was no difference in SSP among treatment groups ($P > 0.05$). However, chickens fed diets supplemented with SY, Met-Se, and Nano-Se had higher TPS and MPS compared with those in the SS group ($P < 0.05$). The effects of diets supplemented with different Se sources on the activity of phospholipase A2 in muscles are showed in Fig. 1, and no significant difference was found among treatment groups ($P > 0.05$).

Discussion

Se is an essential trace element with vital functions in animals, including its role as an integral component of selenoproteins. Many studies have indicated that Se is required for the expression of the selenoenzymes type I iodothyronine deiodinase

Table 2 Effects of different selenium sources on the growth performance in chickens

Items	SS	SY	Met-Se	Nano-Se	SEM	*P* value
FI (g/bird)	2339	2344	2259	2277	29.34	0.586
BWG (g/bird)	524	543	535	525	9.60	0.892
F/G (g/g)	4.46	4.32	4.22	4.34	0.06	0.405

$n = 10$

SS sodium selenite, *SY* selenium-enriched yeast, *Met-Se* selenomethionine, *Nano-Se nano* red element selenium, *SEM* standard error of the means, *FI* feed intake, *BWG* body weight gain, *F/G* feed to gain ratio

and selenoprotein P, which have crucial roles in the generation of the thyroid hormones and Se transport, respectively [19, 20]. Supplementation with Se resulted in increased growth performance in chickens [3, 4, 21], possibly due to increased protein digestibility and energy utilization [17]. In the present study, compared with 0.3 g/kg SS supplementation, dietary addition of the same amount of SY, Met-Se, or Nano-Se did not affect the FI, BWG, or F/G growth parameters of chickens. These findings were in agreement with those of Yoon et al. [22], where no differences in FI and BWG were observed among broilers fed diets supplemented with 0.1, 0.2, or 0.3 g/kg Se from SY or 0.3 g/kg of Se from SS. Couloigner et al. [23] and Wang [24] also reported that 0.2 g/kg Met-Se and 0.2 g/kg Nano-Se supplementation resulted in similar growth performance of broiler chickens to supplementation with 0.2 g/kg SS. These results indicated that supplementation with organic Se and Nano-Se probably did not influence the growth performance of broiler chickens compared with inorganic Se. In contrast, Skřivan et al. [3] found a significant improvement in body weight at 42 days in broilers fed with Met-Se compared with SS (both at 0.3 g/kg). Hu et al. [21] also reported that dietary Nano-Se supplementation at 0.6 g/kg raised the BWG of broilers. The discrepancies among the results of these different studies might result from the differences in the sources and dosages of Se and/or the chicken breeds used.

Antioxidant capacity is an important factor for maintenance of animal health. Physiological antioxidant systems include antioxidant enzymes [25], such as SOD, CAT, and GSH-Px, and non-enzymatic substances, such as glutathione (GSH) [26]. Notably, GSH-Px is composed of four identical subunits, with the activity center of each subunit containing a selenocysteine residue. Hence, Se has an important role in the synthesis and activity of GSH-Px, and GSH-Px activity is positively correlated with the Se concentration in various tissues [27]. Generally, organic Se has higher bioavailability and rates of tissue retention than inorganic Se. Briens et al. [6] demonstrated that organic Se supplementation at 0.3 g/kg, exhibited higher apparent Se digestibility compared with inorganic Se in broiler chickens. Tissue accumulation is considered to be a sensitive criterion for mineral utilization, and dietary organic Se and Nano-Se treatment could increase the Se concentrations in serum, liver, and breast muscles than inorganic Se in broiler chickens [10, 19, 28], likely resulting in a higher GSH-Px activity. In addition, MDA and carbonyl are the metabolic products of lipid and protein peroxides, and commonly used as biomarkers of oxidative stress. Se deficiency could increase the content of MDA in chicken immune organs [29].

As a type of antioxidant additives, Se supplementation increased the antioxidant capacity in chickens by elevating the activity of antioxidant enzymes and reducing the generation of oxidation products [5, 10, 11]. In the present study, 0.3 g/kg

Table 3 Effects of different selenium sources on serum and breast antioxidant index in chickens

Items	SS	SY	Met-Se	Nano-Se	SEM	*P* value
Serum						
T-SOD (U/mL)	168.99	183.44	180.13	184.23	4.27	0.610
CAT (U/mL)	1.94	2.71	2.47	2.48	0.15	0.318
T-AOC (U/mL)	14.24	15.41	15.74	15.56	0.56	0.865
GSH-Px (U/mL)	233.22^{b}	325.77^{a}	293.58^{a}	303.75^{a}	8.11	<0.001
MDA (nmol/mL)	6.20^{a}	4.91^{b}	4.35^{b}	4.42^{b}	0.17	0.044
Breast muscles						
T-SOD (U/mg protein)	32.37	34.70	36.48	32.85	0.95	0.464
T-AOC (U/mg protein)	1.97	2.20	2.39	2.19	0.11	0.662
GSH-Px (U/mg protein)	13.11^{b}	20.87^{a}	22.68^{a}	20.43^{a}	0.42	0.004
MDA (nmol/mg protein)	0.44	0.38	0.38	0.40	0.01	0.179
Carbonyl (nmol/mg protein)	2.15^{a}	1.65^{b}	1.52^{b}	1.52^{b}	0.11	0.041

Means in the same row with different letters are significantly different ($P < 0.05$). $n = 10$

SS sodium selenite, *SY* selenium-enriched yeast, *Met-Se* selenomethionine, *Nano-Se nano* red element selenium, *SEM* standard error of the means, *T-SOD* total superoxide dismutase, *CAT* catalase, *T-AOC* total antioxidant capacity, *GSH-Px* glutathione peroxidase, *MDA* malondialdehyde

Table 4 Effects of different selenium sources on the meat quality of breast muscles in chickens

Items	SS	SY	Met-Se	Nano-Se	SEM	*P* value
$pH_{45\ min}$	6.07[b]	6.17[a]	6.19[a]	6.17[a]	0.02	0.043
pH_u	5.79	5.85	5.84	5.85	0.01	0.595
L*	52.20	51.31	51.19	52.09	0.42	0.785
a*	2.68	3.21	3.35	3.43	0.19	0.436
b*	1.50	1.91	1.59	1.60	0.14	0.603
Drip loss (%)	1.61	1.53	1.55	1.56	0.05	0.620
Cooking loss (%)	14.80[a]	13.05[b]	13.06[b]	14.17[ab]	0.16	0.042
Shear force (N)	20.38[a]	15.89[b]	14.71[b]	15.17[b]	0.77	0.010

Means in the same row with different letters are significantly different ($P < 0.05$). $n = 10$

SS sodium selenite, *SY* selenium-enriched yeast, *Met-Se* selenomethionine, *Nano-Se nano* red element selenium, *SEM* standard error of the means, pH_{45min} pH at 45 min postmortem, pH_u pH at 24 h postmortem

SY, Met-Se, and Nano-Se supplementation increased the activity of GSH-Px in serum and breast muscles, and decreased the concentration of MDA in serum and the concentration of carbonyl in the breast muscles of chickens compared with the SS supplementation, which were consistent with the results of previous studies. Chen et al. [12] found that supplementation with 0.3 mg/kg SY resulted in increased activities of GSH-Px and SOD in serum and breast muscles and decreased content of MDA in breast muscles, relative to 0.3 mg/kg SS supplementation. Wang et al. [10] reported that broilers fed diets formulated to contain 0.15 mg/kg of supplemental Se from Met-Se had higher activities of GSH-Px, T-SOD, and T-AOC, and higher GSH and lower MDA content in breast muscles than those receiving SS. Moreover, Mohapatra et al. [13] found a significant improvement in activities of GSH-Px, T-SOD, and CAT in the serum of layer chicks fed with Nano-Se at 0.3 g/kg relative to those receiving SS. GSH-Px was increased by organic Se supplementation because of the higher bioavailability, which was a limiting factor for the stability of GSH-Px1 mRNA expression. It has been reported that GSH-Px1 mRNA levels were significantly increased in the livers of chicks when broilers were fed a basal diet supplemented with SY or Met-Se [9]. Physiological oxidative stress is primarily caused by excessive reactive oxygen species (ROS), and dietary addition with Met-Se resulted in lower ROS content, and decreased the concentrations of MDA and carbonyl [30]. Together with the present study, these results demonstrate that antioxidant capacity is greater in chickens receiving organic Se or supplemented with Nano-Se, compared with those receiving inorganic Se.

In previous studies, the water-holding capacity and color of chicken muscles were improved by Se supplementation [10, 31]. In the present study, 0.3 g/kg SY, Met-Se, and Nano-Se supplementation increased $pH_{45\ min}$, as well as decreasing the shear force value of breast muscles. In addition, birds in the SY and Met-Se groups had a reduced cooking loss compared with those in the SS group, which was consistent with reports by other investigators. Chen et al. [12] found that 0.3 mg/kg Met-Se supplementation resulted in an increase in the pH of the breast meat of broilers compared with 0.3 mg/kg SS supplementation. After slaughter, the cessation of blood circulation leads to a large accumulation of lactic acid in the muscles, resulting in a decreased pH value. The increased pH value observed after Met-Se supplementation indicated a delay in the metabolic conversion of glucose to lactic acid in postmortem muscle. Delayed pH decline leads to reduced protein denaturation and consequently reduced drip loss and cooking loss [32], thus improving the water-holding capacity of meat. This is in agreement with the studies of Wang et al. [10], Oliveira et al. [16], and Saleh [17], who reported that dietary SY, Met-Se, and Nano-Se treatment increased the water-holding capacity of meat. The color of meat is closely related to muscle myoglobin oxidation; therefore, prevention of muscle oxidation is an important factor in

Table 5 Effects of different selenium sources on the protein solubility of breast muscles in chickens

Items	SS	SY	Met-Se	Nano-Se	SEM	*P* value
TPS (mg/g)	225.20[b]	286.62[a]	286.62[a]	300.27[a]	10.66	0.033
SPS (mg/g)	94.03	96.12	102.22	95.03	1.64	0.542
MPS (mg/g)	131.17[b]	190.49[a]	184.40[a]	205.24[a]	10.84	0.048

Means in the same row with different letters are significantly different ($P < 0.05$). $n = 10$

SS sodium selenite, *SY* selenium-enriched yeast, *Met-Se* selenomethionine, *Nano-Se nano* red element selenium, *SEM* standard error of the means, *TPS* total protein solubility, *SPS* sarcoplasmic protein solubility, *MPS* myofibrillar protein solubility

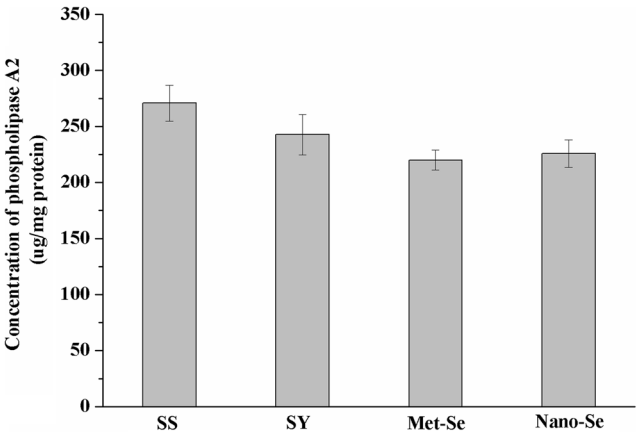

Fig. 1 Effects of different selenium sources on the concentration of phospholipase A2 of breast muscles in chickens. *SS* sodium selenite, *SY* selenium-enriched yeast, *Met-Se* selenomethionine, *Nano-Se nano* red element selenium. Data are represented as mean ± SD. $n = 10$

maintenance of meat color [14]. As demonstrated in the present study, dietary SY, Met-Se, and Nano-Se supplementation could increase the antioxidant capacity of chickens. However, no differences were identified in the color of breast muscles, similar to previous reports [10, 12]. In consistent with these findings, Boiago et al. [33] found that broilers fed with diets supplemented with Se from Met-Se decreased L* values of breast muscles, probably due to reduced moisture on the surface of meat as a result of its augmented water-holding capacity [34]. Tenderness, described as shear force, is an important indicator of consumer acceptability and is determined by the structural properties of various proteins and fats in muscle [35]. Yoon et al. [20] found a significant improvement in the intramuscular fat content in the breast muscles of broilers receiving SY treatment, which could result in a reduced shear force value. In addition, Baowei et al. [15] reported that 0.3 g/kg dietary SS supplementation reduced the hardness of breast muscles in goose. These results indicate that supplementation of chickens feed with organic Se or Nano-Se leads to improved meat quality, relative to addition of inorganic Se.

Muscle proteins comprise myofibrillar, sarcoplasmic, and connective tissue molecules [36]. During the ageing of muscle, protein denaturation occurs and this is reflected as protein solubility. Muscle protein denaturation is related to antioxidant capacity [37]. When cysteine, tryptophan, and other amino acids in the muscle protein are oxidized, disulfide bond and carbonyl are formed. Then, the advanced structure of protein is destroyed and accumulated, which would decrease the protein solubility [38]. In the current study, 0.3 g/kg SY, Met-Se, and Nano-Se supplementation led to increased TSP and SMP in the breast muscles of chickens compared with the SS supplementation, which could be a consequence of improved antioxidant capacity. Phospholipase, present in the cell membrane, could degrade phospholipids, in which phospholipase A2 plays a major role. Lambert et al. [39] reported that the cessation of blood circulation after slaughter induced the cellular hypoxia, which would cause the phospholipase A2 activation, leading to alter cell membrane permeability, and decrease the water-holding capacity. As demonstrated in the present study, organic Se and Nano-Se supplementation increased the water-holding capacity of breast muscles in broilers. However, no differences were found in the concentration of phospholipase A2 in muscles.

In conclusion, in local Chinese Subei chickens, dietary SY, Met-Se, and Nano-Se supplementation increased the $pH_{45\ min}$, protein solubility, and activity of GSH-Px, and decreased the cooking loss, shear force, and the carbonyl content of breast muscles, resulting in improved meat quality and antioxidant capacity compared with the SS supplementation. Hence, organic Se and Nano-Se supplementation exhibited superior function to inorganic Se in the improvement of chicken meat quality.

Acknowledgements The financial support provided by the National Key Research and Development Program of China (No. 2016YFD0500501), National Natural Science Foundation of China (No. 31572425 and No. 31402094), and Jiangsu Planned Projects for Postdoctoral Research Funds (No. 1601030A).

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