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Effects of Dietary Sodium Selenite and Selenium Yeast on Antioxidant Enzyme Activities and Oxidative Stability of Chicken Breast Meat

Hussain Ahmad,[†] Jinke Tian,[†] Jianjun Wang,[†] Muhammad Ammar Khan,[‡] Yuanxiao Wang,[†] Lili Zhang,[†] and Tian Wang*[,†]

[†]College of Animal Science and Technology and [‡]National Laboratory for Meat Quality and Safety Control, Nanjing Agricultural University, Nanjing 210095, People's Republic of China

ABSTRACT: The effects of sodium selenite (SS) and selenium yeast (SY) alone and in combination (MS) on the selenium (Se) content, antioxidant enzyme activities (AEA), total antioxidant capacity (TAC), and oxidative stability of chicken breast meat were investigated. The results showed that the highest ($p < 0.05$) glutathione peroxidase (GSH-Px) activity was found in the SS-supplemented chicken breast meat; however, SY and MS treatments significantly increased ($p < 0.05$) the Se content and the activities of catalase (CAT), total superoxide dismutase (T-SOD), and TAC, but decreased ($p < 0.05$) the malondialdehyde (MDA) content at 42 days of age. Twelve days of storage at 4 °C decreased ($p < 0.05$) the activity of the GSH-Px, but CAT, T-SOD, and TAC remained stable. SY decreased the lipid oxidation more effectively in chicken breast meat. It was concluded that SY and MS are more effective than SS in increasing the AEA, TAC, and oxidative stability of chicken breast meat.

KEYWORDS: *selenium, broiler, antioxidant enzyme activities, oxidative stability, sensory test*

INTRODUCTION

Lipid oxidation (LO) is among the major reasons after microbial deterioration for decreased nutritional contents as well as sensory traits of meat. It decreases the shelf life of meat, which leads to economic losses in the meat industry.[1] Lipid oxidation also produces reactive free radicals, which lead to serious health problems.[2] Dietary antioxidants such as β-carotene, vitamin C (Vit C), and vitamin E (Vit E) have been reported to prevent LO in animal muscles and, thus, improved the meat quality, as well as stability.[3] Vit E is the chain-breaking antioxidant, the major protector against LO in living organisms.

Selenium (Se) is involved in cellular antioxidant defense mechanisms by the activity of glutathione peroxidase (GSH-Px), which is a Se-dependent enzyme that catalyzes the reduction of hydrogen peroxide and organic peroxides to water and the corresponding stable alcohol, thus inhibiting the formation of free radicals.[4] Se had a sparing effect on Vit E and increased its content of meat and egg yolk in chickens.[5] Another recent study has reported that the activity of α-tocopherol is improved by the addition of Se in the diets, thus resulting in a better quality of meat.[6] In the past, meat producers relied on Vit E to reduce LO and increase meat shelf life. Now, it is clear that efficient utilization of Vit E is dependent upon the Se-based antioxidant enzymes in the body, and an adequate Se intake is required to ensure the best utilization of this exclusive vitamin.[7]

There are two forms of Se in nature, inorganic sources (selenite, selenate, and selenide) and organic sources such as Se-methionine (Se-Met), Se-cystine (Se-Cys), and Se-cysteine. Sodium selenite (SS) is the most frequent source of Se, used in the animal feed industry. It is also well-known for showing signs of strong cytotoxicity and low bioavailability, thus resulting in the production of animal feedstuffs that contain low Se content. However, organic Se has comparatively higher bioavailability and thus produces Se-enriched meat.[8,9] Selenium yeast (SY) is an organic Se source, the Se-enriched *Saccharomyces cerevisiae* produced by aerobic fermentation. It has been reported that SY has a potential to improve antioxidant status superior to that of SS in chickens.[10]

Fresh meat and meat products are usually marketed at temperatures of 2−5 °C. At this temperature, many undesirable changes can occur during refrigeration due to microbes and LO, which decrease the quality and spoilage of meat and create economic losses in the meat industry. Our objectives were to examine the effects of different dietary sources of Se (SS and SY), alone and in combination on Se content, nutritive values, antioxidant enzyme activities (AEA), total antioxidant capacity (TAC), and LO in chicken breast meat after 42 days of feeding. Furthermore, the oxidative stability and sensory evaluation of chicken breast meat stored at 4 °C for 0, 3, 6, 9, and 12 days were assayed.

MATERIALS AND METHODS

Materials. Six hundred 1-day-old Arbor Acres broiler chickens of the same grade were procured from a local commercial hatchery (Hewei, Anhui, People's Republic of China) and randomly assigned to five treatments, consisting of six replicates of 20 birds.

The birds were fed corn−soybean basal diets (Table 1). Birds in the control group were fed the diet without any Se supplementation or the basal diets with SS at 0.3 mg/kg (SS group), SY at 0.2 mg/kg (SY-I group), SY at 0.3 mg/kg (SY-II group), and 0.3 mg of mixed Se sources (SS 0.15 mg/kg feed + SY 0.15 mg/kg) (MS group),

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Table 1. Ingredients and Nutrient Content of the Basal Diets

	1−21 days	22−42 days
ingredient		
corn, g	59.1	64.3
soybean meal, g	30.6	24.3
corn gluten meal, g	3.8	4.5
vegetable oil, g	1.7	2.5
limestone, g	1.31	1.23
dicalcium phosphate, g	1.77	1.58
sodium chloride, g	0.42	0.33
L-lysine, g	0.15	0.16
DL-methionine, g	0.15	0.1
premix,[a] g	1	1
calculation of nutrients		
metabolizable energy, MJ/kg	12.27	12.77
crude protein, %	21.2	19.3
calcium, %	1.0	0.91
available phosphorus, %	0.43	0.38
lysine, %,	1.08	0.95
methionine, %	0.50	0.43
methionine + cystine, %	0.82	0.73

[a]Provided per kg of diet: iron, 60 mg; copper, 7.5 mg; zinc, 65 mg; manganese, 110 mg; iodine, 1.1 mg; bacitracin zinc, 30 mg; vitamin A, 4500 IU; vitamin D_3, 1000 IU; vitamin E, 30 IU; vitamin K, 1.3 mg; vitamin B_1, 2.2 mg; vitamin B_2, 10 mg; vitamin B_3, 10 mg; choline, 400 mg; vitamin B_5, 50 mg; vitamin B_6, 4 mg; biotin, 0.04 mg; vitamin B_{11}, 1 mg; vitamin B_{12}, 1.013 mg.

respectively, for 42 days. The basal starter and grower diets contained 0.11 mg/kg Se. SS was purchased from Sigma-Aldrich Chemical Co., St. Louis, MO, USA, whereas SY was from Sunhy Biological Co. Ltd., Wuhan Hubei, People's Republic of China. All nutrients met or exceeded the nutrient requirements of broilers[11] and were analyzed by following the methods of the Association of Official Analytical Chemists (AOAC).[12]

Husbandry. The birds were kept in wire cages in a three-level battery and housed in an environmentally controlled room (at 34−36 °C) during 1 to 14 days, and then the temperature was gradually decreased to 26 °C and kept constant until the end of experiment. The broilers were kept under 24 h constant lighting and also vaccinated against infectious bursal disease and Newcastle disease. Birds were allowed to take feed and water ad libitum. This project was approved and conducted under the supervision of the Animal Care and Use Committee, Nanjing Agriculture University, Nanjing, Poeple's Republic of China, which has adopted the Animal Care and Use Guidelines governing all animals used in experimental procedures. The average daily gain (ADG in g) was determined as the average daily change in body weight between two consecutive body weight measurements by using the following formula:

$$\frac{\text{final wt (g)} - \text{initial wt (g)}}{\text{age (days)}}$$

The feed conversion ratio (FCR) was calculated by using the formula

$$\frac{\text{total feed consumption (total feed offered} - \text{total feed residue) (g)}}{\text{total final wt (g)} - \text{total initial wt (g)} + \text{total mortality wt (g)}}$$

Sample Preparation. Following 42 days of exposure to experimental diets, 60 randomly selected broiler chickens (2 birds per replicate) were slaughtered. Individual carcasses were trimmed for breast meat by removing feathers, bones, and connective tissues. Following trimming, breast meat samples were individually sliced in different sections. One section was vacuumed packed and stored at −80 °C until further analysis. Other sections of breast meats were kept for oxidative stability studies.

Storage Procedure. To assess the effects of different dietary Se sources alone or in combination on antioxidant enzymes, antioxidant capacity, and lipid stability of raw chicken breast meat during refrigeration storage, the breast meat samples were wrapped in sealed plastic bags and placed at 4 °C. After 3, 6, 9, and 12 days of storage at 4 °C, the meat samples were collected and stored at −80 °C until further analysis.

Determination of Selenium Content of Feed and Chicken Breast Meat. To determine the Se content, the feed and chicken breast meat samples (1.0 g) of 0, 3, 6, 9, and 12 days of storage at 4 °C were digested in a mixture of nitric acid (HNO_3) and hydrogen peroxide (H_2O_2), purchased from Sigma-Aldrich Chemical Co., in Teflon high-pressure vessels in an MDS-2000 microwave oven (LabX, Midland, ON, Canada). After mineralization, the solution was diluted with ultrapure water, and Se was determined according to a fluorometric method as described in the AOAC.[12]

Determinations of Antioxidant Enzymes and Thiobarbituric Acid Reactive Substances of Raw Chicken Breast Meat. One gram of the raw chicken breast meat samples stored at 4 °C for 0, 3, 6, 9, and 12 days was homogenized in 9 mL of 0.9% sodium chloride buffer on ice by using an Ultra-Turrax homogenizer (Tekmar Co., Cincinnati, OH, USA) for 10 s at 8000 rpm and centrifuged at 4000 rpm for 15 min at 4 °C. The supernatant was used for further analysis. The activities of GSH-Px, catalase (CAT), and total superoxide dismutase (T-SOD) were measured.[13−15] The LO of the chicken breast meat was measured, and the results were expressed as thiobarbituric acid reactive substances (TBARS) in nanomoles per milligram of malondialdehyde (MDA).[16]

The GSH-Px activity is the amount of enzyme that will oxidize 1 μmol/L GSH in the reaction system at 37 °C per minute in 1 mg of meat. The CAT activity was measured by the rate of disappearance of H_2O_2 at 240 nm and expressed as micromoles of H_2O_2 decomposed per minute per gram of meat.[14] The T-SOD activity was measured as that which will inhibit the rate of oxidation of hydroxylamine by 50% in a coupled system, using xanthine and xanthine oxidase at 37 °C in 1.0 mg/mL protein concentration of meat homogenate. The TAC was measured as, in which the reaction mixture, ferric ion was reduced by antioxidant reducing agents and blue complex Fe^{2+} TPTZ (2,4,6-tri(2-pyridyl)-*s*-triazine) was produced, which reacted with phenanthroline to generate a stable complex. This stable complex was measured spectrophotometerically at 520 nm and expressed as milligrams of tissue protein that increased the optical density value 0.01 per minute at 37 °C. Data for GSH-Px, CAT, T-SOD, and TAC were expressed as specific activity units per milligram of protein (U/mg protein) in chicken breast meat. The assays were conducted using the assay kits procured from Nanjing Jiancheng Institute of Bioengineering (Nanjing, Jiangsu, People's Republic of China), according to the instructions of the manufacturer. All samples were measured in triplicate. Protein contents of supernatants were determined by a previously reported method.[17]

Sensory Evaluation. Sensory attributes such as color, odor, flavor, juiciness, and overall acceptability were determined according to a previously reported method.[18] Chicken breast meat was evaluated by a panel of 10 selected assessors. All were members of the Animal Science and Technology College and National Laboratory for meat quality and safety control of Nanjing Agriculture University, Nanjing, China. The chicken breast meat samples were cooked for 20 min at 85 °C. Water was used between two samples when the flavor of cooked chicken breast meat was evaluated. A nine-point scale was used for the assessment (1, like extremely; 2, like very much; 3, like moderately; 4, like slightly; 5, neither like nor dislike; 6, dislike slightly; 7, dislike moderately; 8, dislike very much; 9, dislike extremely).

Statistical Analysis. All data were analyzed by ANOVA using the General Linear Model procedures of SAS (SAS Institute Inc., Cary, NC, USA). Duncan's multiple-range test was used for significance of difference ($p < 0\ 0.05$) of two factors (Se source and storage days) and interaction between the two factors.

Table 2. Treatment Effects on the Growth Performance and Concentration of Moisture, Crude Protein, Fat, Ash, and Se Content in the Breast Muscle of Chickens after 42 Days of Feeding[a]

	control	SS	SY-I	SY-II	MS
ADG (g/day)	53.7 ± 1.3	53.7 ± 0.9	52.5 ± 0.7	52.7 ± 0.4	52.8 ± 0.6
ADFI, g/day	95.3 ± 0.8 a	94.2 ± 0.7 ab	90.9 ± 0.9 c	91.0 ± 1.2 c	90.7 ± 0.7 c
FCR	1.78 ± 0.0	1.76 ± 0.0	1.73 ± 0.0	1.73 ± 0.0	1.72 ± 0.0
moisture, %	73.2 ± 0.2 a	71.8 ± 0.6 ab	72.2 ± 0.2 ab	71.1 ± 1.0 ab	70.9 ± 0.9 b
crude protein, %	86.9 ± 1.1	85.7 ± 1.3	88.3 ± 1.3	88.7 ± 0.2	87.6 ± 0.4
fat, %	1.29 ± 0.0 a	3.05 ± 0.5 c	3.17 ± 0.3 c	2.01 ± 0.5 ac	2.12 ± 0.0 ac
ash, %	6.15 ± 0.3 a	5.27 ± 0.1 c	5.53 ± 0.1 bc	5.53 ± 0.1 bc	6.20 ± 0.1 a
Se content, mg/kg	0.19 ± 0.0 c	0.20 ± 0.0 c	0.42 ± 0.0 b	0.54 ± 0.0 a	0.40 ± 0.0 b

[a]Values are the mean ± standard deviation, $n = 6$. Means in the same row with different letters differ significantly ($p < 0.05$). The concentrations of moisture and Se content were determined on a fresh basis of chicken breast meat, whereas crude protein, fat, and ash contents were measured on a dry matter basis.

RESULTS AND DISCUSSION

Growth Performance of Broiler Chickens. The growth performance of broiler chicken breast meat after 42 days of treatments with different sources and levels of Se is summarized in Table 2. During the experimental period, ADG or FCR was not influenced by treatments nor were there differences between Se levels or sources. The mean of ADG was 53.12 ± 0.82 g/day and FCR was 1.71 ± 0.02 and did not differ between treatments.

This was consistent with the findings of Payne and Southern,[9] who found that any Se source (SS or SY at 0.3 mg/kg diet) had no influence on ADG and FCR in broiler chickens. Similarly, Wang et al.[19] reported that ADG and FCR of chickens were not affected by supplementation of different dietary sources (SS or L-Met or D-Se-Met at 0.15 mg Se/kg), after 42 days of feeding diets. However, Hartley and Grant[20] and Wichtel et al.[21] found positive effects on growth performance after Se supplementation in livestock if the basal diets fed were extremely deficient in Se. Wang and Xu[22] also found that both Se sources (SS and SY at 0.20 mg/kg) had a positive effect on FCR in broiler chickens after 21 days of feeding. It has also been reported that Se-deficient chickens exhibited a significant improvement in FCR after receiving Se-supplemented diets.[9] These results clearly indicated that Se-supplemented diets can improve the growth performance if there is evidence of a Se deficiency. The differences in the results might be due to the fact that previous chickens were deficient in Se, whereas, in the present study, chickens were not deficient in Se.[9]

In most parts of China, the Se content of forages and grains used in poultry diets ranged from 0.02 to 0.12 mg/kg.[23] The diets deficient in Se resulted in poor growth, low feathering score, increased mortality, hepatic necrosis, pancreatic fibrosis, dystrophy of muscles, exudative diathesis, microangiopathy, immune deficiency, and lower hatchability in birds.[22] Our results showed that the control group fed a basal diet without any Se supplementation did not show symptoms of Se deficiency. These findings suggested that the 0.11 mg Se/kg diet was of an adequate level and met the NRC (1994) requirements to sustain growth and performance for broiler chickens.[11]

In this present study, ADFI of chickens, averaging 90.90 ± 0.97 g/day, was not different among SY-I (0.20 mg/kg), SY-II (0.30 mg/kg), and MS (0.30 mg/kg). However, when we compared the ADFI of chickens supplemented with 0.30 mg/kg of SS (94.27 ± 0.70 g/day) and unsupplemented control (95.35 ± 0.87 g/day) groups, it was higher than SY and MS treatments. This indicated that SY and mixed sources of Se decreased the feed cost by reducing feed intake without affecting the FCR. Our results are consistent with Choct et al.,[24] who found that SY (0.25 mg/kg) supplementation reduced the ADFI in broiler chickens after 37 days of feeding. However, in some other studies, dietary Se did not affect ADFI in the broiler chickens when diets were supplemented with different sources of Se.[9,19]

It is possible that SY has a higher bioavailability than the inorganic source of Se. SY supplementation increased the metabolism of thyroxine hormones, which are important for normal growth and development. SY supplementation also increased the triiodothyronine (T_3) hormone level and high feather scoring that might be responsible for the reduction of ADFI in chickens.[24] The inconsistencies between the responses on ADFI reported for different Se sources and levels might be attributable to differences in the composition of the Se sources under test, as manufacturing processes ultimately affect the Se content and the proportion and bioavailability of Se.

Influence of Se on Nutritive Values of Chicken Breast Meat. The compositional analyses of moisture, protein, fat, ash, and Se contents in the breast meat of chickens are shown in Table 2. Dietary sources of Se significantly influenced the nutritive values of chicken breast meat. The moisture content (%) was significantly ($p < 0.05$) lowest in the breast meat of chickens that had been fed diets supplemented with MS (70.91 ± 0.99), and it was highest in the unsupplemented control group (73.29 ± 0.20). However, there was no difference in moisture content (on average 71.75 ± 0.66) of chicken breast meat supplemented with SS and SY. In the present study, there was no significant difference in the protein content, on average 87.47 ± 0.91% of chicken breast meat among all treatments. In the present study, the breast meat of chickens that had been fed diets supplemented with SS, SY, and MS had significantly ($p < 0.05$) higher fat contents (%) than the unsupplemented control group. SS (3.05 ± 0.59) and SY-I (3.17 ± 0.35) were more effective than SY-II (2.01 ± 0.56) and MS (2.12 ± 0.09). The lowest fat content in chicken breast meat was observed in the unsupplemented Se control group (1.29 ± 0.09). It was also found that the control and MS groups had significantly ($p < 0.05$) higher ash content (on average 6.17 ± 0.23%) of chicken breast meat than SS and SY groups (on average 5.44 ± 0.13%).

The results of the present study are consistent with the findings of Dlouhá et al.[25] and Zhan et al.,[26] who did not find any significant change in protein content of meats in broiler chickens and in pigs after supplementation with different sources of Se. Mikulski et al.[27] reported that fat content was

increased in breast muscles of turkeys that had been fed diets supplemented with SY (0.3 mg/kg of diet) for 112 days. Conversely, Zhan et al.[26] reported that no change in the fat content of pig loin muscles was observed after supplementation with SS or Se-Met (0.3 mg/kg of feed). Moreover, Vignola et al.[28] found that the different sources of Se did not affect the chemical composition of lamb meat.

The results of the present study concluded that both Se sources showed inconsistent influences on the nutritional composition of chicken breast meat. The difference in the results with other studies might be due to different animals (monogastric vs compound stomach) and types of meat muscles used in different experiments. It is also possible that Se has interactions with other minerals and vitamins that are involved in different metabolic pathways in the living body. These metabolic pathways are often difficult to explain. These involved compounds have multiple biochemical activities that are responsible for these compositional changes in living organisms. Further studies at the molecular level are required to explore the exact mechanism behind the role of different Se sources in nutritional composition metabolic pathways in chicken breast meat.

Se Content in Chicken Breast Meat. In the present study, the diets supplemented with Se significantly increased the Se content of the chicken breast meat (Figure 1). SY- and MS-

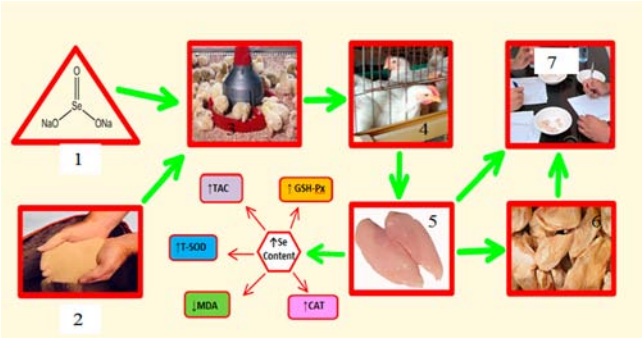

Figure 1. Schematic representation of the whole experimental setup: (1) sodium selenite; (2) selenium yeast; (3) chickens in the first week of experiment; (4) adult chickens after supplementation of different sources of Se; (5) chicken breast meat after 42 days of feeding; (6) Se-enriched diets increased oxidative stability and shelf life of chicken breast meat; (7) sensory evaluation of fresh and stored (at 4 °C for 12 days) breast meat of chicken.

supplemented diets showed significantly ($p < 0.05$) higher Se content (expressed in mg/kg on fresh meat basis) than control and SS groups in chicken breast meat (Table 2). Furthermore, the Se content was significantly ($p < 0.05$) higher in SY-II (0.54 ± 0.03) than in SY-I (0.42 ± 0.02) and MS (0.40 ± 0.02) groups than control and SS treatments in chicken breast meat. The Se content of chicken breast muscles in the SY-II group was >3-fold higher than the control and SS groups (0.54 vs 0.19/0.20 mg/kg of meat). We found that Se content in chicken breast meat was increased in SS (5.26%), SY-I (121.05%), SY-II (184.21%), and MS (110.52%) treatments as compared to the control group.

The results of the present study are in agreement with the reports of Payne and Southern,[9] Wang and Xu,[22] and Wang et al.,[29] who found that SY is more effective in deposition of Se content in broiler chickens meat. Vignola et al.[28] reported that the Se content of meat in lambs was reliant on different Se sources (SS or SY) and their levels (0.3 or 0.45 mg/kg) in the diets. Zhan et al.[26] also found that Se-Met (0.30 mg/kg) supplementation increased the Se content in loin meat muscle more than twice compared to the control (0.10 ± 0.02 μg/g) in pigs.

The present study also revealed no significant difference ($P < 0.05$) in Se contents of chicken breast meats of both control and SS (on average 0.19 ± 0.00) groups. Payne and Southern[9] found that there was no significant difference in breast meat Se contents of control (0.472 mg/kg on dry matter basis) and SS (0.545 mg/kg on dry matter basis) groups when chickens were fed diets without Se and supplemented with 0.3 mg/kg of SS, respectively. The variations of Se depositions in different types of muscles and in animals might be due to the difference in uptake, assimilation, and metabolism processes of different Se sources and animals used in experiments. It is also possible that the organic Se sources have higher bioavailability than inorganic Se source (SS) for tissue Se deposition. Inorganic Se is absorbed by passive diffusion from the intestine, whereas organic Se is actively absorbed through the sodium-dependent neutral amino acid transport mechanisms.[30,31] It is concluded that breast meat of broiler chickens is a good source of Se-enriched meat as Se-Met. Se-Met has a higher bioavailability and greater half-life than SS in humans.[28] It could be used to improve human Se status especially in Se-deficient areas of the world.

Influence of Se Supplementation on GSH-Px Activity of Breast Meat in Broiler Chickens. Free radicals can generate reactive oxygen species (ROS) in cells that can contribute to cell and tissue damage. The antioxidants may prevent these damages induced by oxidation. The antioxidant enzymes include GSH-Px, superoxide dismutase (SOD), and CAT. The principal form of Se-dependent enzyme is GSH-Px; thus, it is not astonishing that, in our present study and in several previous papers, the GSH-Px activity in different kinds of meat muscles was increased in animals that had been fed diets supplemented with Se. The highest ($p < 0.05$) GSH-Px activity (expressed in U/mg protein g of meat, 3.01 ± 0.04) was observed in breast meat of chickens that had been supplemented with SS (0.30 mg/kg), whereas MS (0.30 mg/kg) and SY-II (0.30 mg/kg) had no difference in GSH-Px activity (on average 2.91 ± 0.45). The lowest GSH-Px activity (2.60 ± 0.03) was found in unsupplemented breast meat of chickens (Table 3). The GSH-Px activity was increased in SS (15.76%), SY-I (9.23%), SY-II (11.53%), and MS (12.69%) as compared to control without Se-supplemented chicken breast meat at 42 days of age.

Our results are consistent with the findings of Wang et al.[29] and Dlouhá et al.[25] in broiler chickens. Similarly, Skrivanová et al.[32] found that the GSH-Px activity in meat of calves was increased by 56% as compared to the control when they had been fed with SY (0.50 mg/kg). Zhan et al.[26] reported that both SS and Se-Met sources of Se increased the GSH-Px activity in pig meat, but there were no significant differences among different Se sources. The difference in effect of dietary Se sources (SS or SY) on the GSH-Px activity in chicken breast meat is possibly due to the fact that Se, despite its form, must be converted to Se-Cys before incorporation into the GSH-Px. SS was metabolized into Se-Cys more efficiently than SY (in which the predominant form of Se is Se-Met). The other possibility might be that Se-Met can be incorporated into other body proteins in place of Met.[29]

Table 3. GSH-Px, CAT, and T-SOD Activities and TAC and MDA Values in Raw Breast Meat Stored at 4 °C for 12 Days[a]

antioxidant capacity	control	SS	SY-I	SY-II	MS
GSH-Px					
0 days	2.60 ± 0.03 dA	3.01 ± 0.04 aA	2.84 ± 0.03 cA	2.90 ± 0.07 bA	2.93 ± 0.02 bA
3 days	2.45 ± 0.05 dB	2.86 ± 0.04 aB	2.72 ± 0.01 cB	2.82 ± 0.04 abB	2.79 ± 0.02 bB
6 days	2.39 ± 0.03 dC	2.79 ± 0.05 aC	2.65 ± 0.02 cC	2.74 ± 0.03 abC	2.70 ± 0.05 bC
9 days	2.28 ± 0.07 cD	2.72 ± 0.03 aD	2.57 ± 0.05 bD	2.66 ± 0.03 aD	2.58 ± 0.05 bD
12 days	2.20 ± 0.04 cE	2.62 ± 0.03 aE	2.48 ± 0.03 bE	2.62 ± 0.02 aD	2.49 ± 0.06 bE
CAT					
0 days	3.74 ± 0.06 d	3.85 ± 0.13 c	4.10 ± 0.07 b	4.26 ± 0.06 a	3.93 ± 0.05 c
3 days	3.74 ± 0.13 d	3.84 ± 0.06 c	4.09 ± 0.04 b	4.27 ± 0.05 a	3.91 ± 0.03 c
6 days	3.73 ± 0.04 d	3.83 ± 0.05 c	4.05 ± 0.04 b	4.26 ± 0.09 a	3.90 ± 0.06 c
9 days	3.74 ± 0.06 d	3.86 ± 0.08 c	4.08 ± 0.07 b	4.23 ± 0.04 a	3.91 ± 0.07 c
12 days	3.71 ± 0.08 d	3.84 ± 0.08 c	4.07 ± 0.08 b	4.20 ± 0.06 a	3.91 ± 0.09 c
T-SOD					
0 days	32.87 ± 0.85 d	36.60 ± 1.61 c	45.31 ± 1.91 a	46.04 ± 1.67 a	41.07 ± 1.05 b
3 days	33.31 ± 2.37 d	37.02 ± 1.28 c	45.14 ± 1.25 a	46.32 ± 1.57 a	41.50 ± 1.91 b
6 days	33.25 ± 3.48 d	36.82 ± 1.60 c	45.04 ± 1.72 a	46.19 ± 1.86 a	41.41 ± 3.48 b
9 days	33.80 ± 2.07 d	36.94 ± 1.86 c	45.47 ± 2.96 a	46.69 ± 2.16 a	41.55 ± 2.32 b
12 days	32.87 ± 2.80 c	35.85 ± 3.78 c	44.74 ± 3.15 ab	46.21 ± 3.12 a	41.13 ± 1.89 b
TAC					
0 days	0.31 ± 0.02 c	0.33 ± 0.00 bc	0.37 ± 0.03 a	0.38 ± 0.02 a	0.35 ± 0.01 ab
3 days	0.31 ± 0.01 d	0.33 ± 0.01 c	0.35 ± 0.01 b	0.38 ± 0.00 a	0.36 ± 0.01 ab
6 days	0.30 ± 0.02 b	0.32 ± 0.01 b	0.37 ± 0.01 a	0.36 ± 0.02 a	0.35 ± 0.02 a
9 days	0.30 ± 0.01 c	0.32 ± 0.02 b	0.36 ± 0.01 a	0.35 ± 0.02 a	0.34 ± 0.00 a
12 days	0.30 ± 0.02 b	0.31 ± 0.01 b	0.34 ± 0.01 a	0.36 ± 0.02 a	0.36 ± 0.02 a
MDA					
0 days	0.41 ± 0.01 aE	0.32 ± 0.00 bE	0.29 ± 0.00 dE	0.26 ± 0.01 eE	0.30 ± 0.00 cE
3 days	0.79 ± 0.01 aD	0.54 ± 0.00 bD	0.38 ± 0.00 dD	0.33 ± 0.01 eD	0.45 ± 0.01 cD
6 days	1.01 ± 0.00 aC	0.85 ± 0.00 bC	0.68 ± 0.00 dC	0.61 ± 0.01 eC	0.78 ± 0.04 cC
9 days	1.37 ± 0.01 aB	1.01 ± 0.01 bB	0.76 ± 0.01 dB	0.69 ± 0.00 eB	0.92 ± 0.01 cB
12 days	1.51 ± 0.04 aA	1.30 ± 0.00 bA	0.97 ± 0.00 dA	0.88 ± 0.01 eA	1.17 ± 0.02 cA

[a]Values are the mean ± standard deviation (n = 6). Values in a row belonging to different Se sources and levels with different letters (a−e) were significantly different ($p < 0.05$). Values in a column belonging to different storage days with different letters (A−E) were significantly different ($p < 0.05$). Data on GSH-Px, CAT, T-SOD, and TAC are expressed as U/mg protein g of meat; values of MDA are expressed in nmol malondialdehyde/mg.

However, Wang et al.[19] reported that the GSH-Px activity in breast meat of chickens was not affected by any Se source. Similarly, Vignola et al.[28] also found that the GSH-Px activity in lamb meat was not influenced by Se levels or sources. The inconsistencies between the responses reported for different Se sources might be attributable to differences in the manufacturing processes of different Se sources (inorganic vs organic) and SY strains used for fermentation that eventually affect both the Se content and the proportion of total Se. It is also possible that the GSH-Px activity also varies significantly among different animal species and types of muscles under test. The variation in dietary Se concentration alone could not explain differences in GSH-Px activity. In these studies, probably only a part of Se-Met from SY in tissues was converted to selenide and integrated as Se-cysteine into GSH-Px enzyme, whereas most was stored in muscle as a methionine substitution for the synthesis of other proteins.[29]

Influence of Se Supplementation on CAT and T-SOD Activities of Chicken Breast Meat. Endogenous antioxidant enzymes, especially CAT and SOD with GSH-Px, could potentially delay the oxidation in meat. The activities of CAT and T-SOD (expressed in U/mg protein g of meat) in chicken breast meat were significantly increased ($p < 0.05$) after supplementation of SY and MS compared with SS and Se unsupplemented control groups at 42 days (Table3). The activity of CAT (4.26 ± 0.06) was highest in SY-II (0.30 mg/kg). The CAT activity was increased in SS (2.94%), SY-I (9.62%), SY-II (13.90%), and MS (5.08%), compared to control without Se-supplemented chicken breast meat at 42 days of age. However, the activity of T-SOD was highest in the SY (0.30 and 0.20 mg/kg) on average (45.67 ± 1.79) in chicken breast meat. The activity of T-SOD was increased in SS (11.34%), SY-I (37.84%), SY-II (40.06%), and MS (24.94%), compared to control without Se-supplemented chicken breast meat at 42 days of age.

Jiang et al.[33] reported the similar findings that CAT and T-SOD activities were increased in breast meat of Lingnan yellow chickens after supplementation of dietary Se-Met at 0.225 mg/kg of diet for 21 days. Wang et al.[29] also found that Se-Met (0.15 mg/kg diet) was more effective in increasing the activities of CAT and T-SOD in chicken breast meat compared to SS (0.15 mg/kg) at 42 days of age.

A very few studies have reported the influence of dietary SY supplementation on the activities of CAT and T-SOD in chicken breast meat. In our study, it was found that SY supplementation profoundly increased CAT and T-SOD activities in chicken breast meat compared with inorganic Se source (SS). It is possible that SY contains >90% Se, 94% of which is as Se-Met that increased the CAT and SOD activities.[29,33−35] In contrast, Marounek et al.[36] found that

dietary SY did not influence the CAT activity in the longissimus thoracis et lumborum muscle of calves.

Both the CAT and SOD enzymes are not Se dependent for their activities. CAT is a heme-containing enzyme that catalyzes the decomposition of H_2O_2 to give water and oxygen molecules,[14] and SOD catalyzes the dismutation of the superoxide radical anion.[37] SOD has two distinct types in eukaryotic cells: one cytosolic copper, zinc superoxide dismutase and the other mitochondrial manganese superoxide dismutase. Superoxide can be converted by mitochondrial Mn-SOD into H_2O_2.[38] The inconsistencies between the responses reported for effectiveness of SY on the activities of CAT and T-SOD might be due to Se's being an important mineral for the proper functioning of many selenoproteins such as type 1, type 2, and type 3 iodothyronine deiodinases, which are responsible for the regulation of thyroxine hormones. These thyroid hormones are involved in the regulation of numerous body functions including oxygen consumption and lipid and carbohydrate metabolism. There are several physiological functions such as development, reproduction, and growth that are based on these Se-dependent hormones and selenoproteins. It is also possible that thyroid dysfunction due to high production of thyroxin hormones is closely related to production of ROS that might be also responsible for increases in the activities of CAT and T-SOD.

Influence of Se Supplementation on TAC of Breast Meat in Broiler Chickens. The accurate measurement of oxidative stress in biological systems is not simple. The TAC of the Se supplemented breast meat in chickens is summarized in Table 3. The TAC (expressed in U/mg protein g of meat) was significantly ($P < 0.05$) higher in Se-supplemented chicken breast meat than in the unsupplemented control group. The SY-supplemented (0.30 and 0.20 mg/kg) and MS-supplemented (0.30 mg/kg) chicken breast meat showed higher TAC (on average 0.36 ± 0.02) than SS (0.33 ± 0.00) and unsupplemented (0.31 ± 0.02) groups. The TAC was increased in SS (6.45%), SY-I (19.35%), SY-II (22.58%), and MS (12.90%) compared to control without Se supplementation chicken breast meats at 42 days of age. Our results are consistent with the findings of Wang et al.[29] and Jiang et al.,[33] who reported that Se-Met significantly increased the TAC of chicken breast meat as compared to SS and control groups.

The TAC reflects the total antioxidant capacity of the body. Low TAC could be an indication of oxidative stress or higher susceptibility to oxidative damage. A reliable estimation of the TAC of meat can be useful to describe the capacity of meat to resist against oxidation processes. The TAC mainly measures the chain-breaking antioxidants including ascorbate, bilirubin, urate, and thiols (in the aqueous phase) and α-tocopherol, carotenoids, and flavonoids (in the lipid phase) that have low molecular weight (excluding the antioxidant enzymes and metal-binding proteins). The combined activities of all chain-breaking antioxidants can be assessed in a single TAC assay.[39] In our present study, we found that SY (0.20 and 0.30 mg/kg) and MS (0.30 mg/kg) significantly increased the TAC of chicken breast meat. It is probable that the increased TAC in SY-supplemented chicken breast meat is due to high content of Se as Se-Met in SY. Se has interaction with different minerals and vitamins such as Vit E and Vit C that might be the responsible for this increase in TAC.

Influence of Se Supplementation on Lipid Oxidation in Chicken Breast Meat. In Se deficiency, the ability to synthesize antioxidant enzymes, mainly GSH-Px, was decreased in animals, which led to the increase of LO. In our present study, both Se sources (SS or SY) significantly decreased ($p < 0.05$) the MDA content (expressed as nmol malondialdehyde/mg of protein) of chicken breast meat (Table 3). SY-II had lower MDA content (0.26 ± 0.01) than the SS (0.32 ± 0.00) and control (0.41 ± 0.01) groups in chicken breast meat at 42 days of age. The MDA content was lower in SS (21.95%), SY-I (29.26%), SY-II (36.58%), and MS (26.82%) compared to control without Se-supplemented chicken breast meat at 42 days of age.

Our results were consistent with the findings of Wang et al.,[19] who found that chicken breast meat had lower MDA content with diets supplemented with the organic Se sources L-Se-Met at 0.15 mg Se/kg (0.44 ± 0.03 nmol/mg) or D-Se-Met at 0.15 mg Se/kg (0.50 ± 0.02 nmol/mg) than SS at 0.15 mg Se/kg (0.78 ± 0.03 nmol/mg). Zhan et al. also found that supplementation with SY (0.3 mg/kg) had lower MDA content (51 ± 8.3 nmol/mg) as compared with SS (617 ± 11.7 nmol/mg) in pig loin meat.[26] Conversely, Vignola et al. reported that dietary Se sources (SS or SY) did not influence the TBARS content in the meat of lambs.[28]

The LO is a quite complex process, in which unsaturated fatty acids react with molecular oxygen via a free radical chain mechanism and form fatty acyl hydroperoxides.[40] The primary autoxidation is followed by a series of secondary reactions that lead to the degradation of the lipid and the development of oxidative rancidity. The problems associated with LO have gained much interest as it is related to flavor deterioration, loss of nutritional value and safety, biological damage, aging, and environmental pollution.[41] MDA is one of the metabolic products of lipid peroxides. The level of LO in different kinds of meats can be monitored by MDA content. The MDA level is well correlated with the GSH-Px activity. Both the lower MDA level and the higher GSH-Px activity of meat indicated that Se improved its ability to protect against oxidation and extended the shelf life of fresh meat.[28]

Poultry meat is relatively more susceptible to oxidative deterioration due to its high polyunsaturated fatty acid content. One approach to enhance the oxidative stability of meat is to add antioxidants either into the diet of the animal or directly during meat processing. In the present study, SY and MS were more effective than SS in lowering the MDA content of chicken breast meat after 42 days of feeding (Table 3). Although SS treatment had higher GSH-Px activity in chicken breast meat, it showed higher MDA content (0.32 ± 0.00 nmol/mg) as compared to SY-II (0.26 ± 0.01 nmol/mg), SY-I (0.29 ± 0.00 nmol/mg), and MS (0.30 ± 0.00 nmol/mg) groups. It is possible that the difference in the responses of different Se sources might be due to the difference of Se sources (inorganic vs organic), as organic sources significantly maintained the muscle membrane integrity and lower protein carbonyl content in meat, which are related to the LO and protein oxidation and oxidative stability of meat.[42]

Influence of Se Supplementation on Oxidative Stability in Refrigerated Chicken Breast Meat. The oxidative stability of meat depends upon the balance between anti- and pro-oxidants.[42] The results obtained in the present study showed that different Se sources and levels significantly ($p < 0.05$) influenced the AEA in chicken breast meat during 12 days of storage at 4 °C, which could lead to a significant decrease in LO during meat storage and increase its shelf life (Table 3).

Table 4. Mean Scores for Color, Odor, Flavor, Juiciness, and Overall Acceptability of Cooked Breast Meat of Chickens Stored at 4 °C for 12 Days[a]

sensory trait	control	SS	SY-I	SY-II	MS
color					
0 days	3.78 ± 0.17 B	3.80 ± 0.18 A	3.76 ± 0.25 A	3.76 ± 0.15 A	3.76 ± 0.12 A
3 days	3.83 ± 0.08 AB	3.81 ± 0.17 A	3.78 ± 0.15 A	3.79 ± 0.09 A	3.78 ± 0.14 A
6 days	3.91 ± 0.16 AB	3.86 ± 0.19 A	3.80 ± 0.12 A	3.79 ± 0.19 A	3.83 ± 0.13 A
9 days	3.95 ± 0.18 AB	3.97 ± 0.12 A	3.81 ± 0.21 A	3.80 ± 0.14 A	3.88 ± 0.14 A
12 days	4.00 ± 0.14 A	3.99 ± 0.17 A	3.86 ± 0.08 A	3.83 ± 0.19 A	3.88 ± 0.09 A
odor					
0 days	3.20 ± 0.15	3.21 ± 0.11	3.20 ± 0.10	3.20 ± 0.20	3.21 ± 0.09
3 days	3.21 ± 0.24	3.21 ± 0.15	3.22 ± 0.18	3.23 ± 0.10	3.20 ± 0.26
6 days	3.25 ± 0.12	3.29 ± 0.27	3.21 ± 0.17	3.23 ± 0.06	3.21 ± 0.10
9 days	3.23 ± 0.16	3.25 ± 0.03	3.24 ± 0.04	3.24 ± 0.13	3.23 ± 0.23
12 days	3.24 ± 0.17	3.24 ± 0.08	3.28 ± 0.06	3.26 ± 0.08	3.24 ± 0.05
flavor					
0 days	3.54 ± 0.17	3.51 ± 0.11	3.50 ± 0.20	3.46 ± 0.14	3.50 ± 0.12
3 days	3.41 ± 0.30	3.52 ± 0.23	3.52 ± 0.14	3.53 ± 0.16	3.52 ± 0.17
6 days	3.45 ± 0.17	3.54 ± 0.16	3.51 ± 0.17	3.55 ± 0.18	3.56 ± 0.12
9 days	3.49 ± 0.09	3.55 ± 0.17	3.58 ± 0.16	3.57 ± 0.16	3.60 ± 0.12
12 days	3.54 ± 0.10	3.58 ± 0.17	3.59 ± 0.14	3.60 ± 0.17	3.61 ± 0.18
juiciness					
0 days	3.52 ± 0.09 B	3.49 ± 0.14 A	3.45 ± 0.19 A	3.45 ± 0.13 A	3.46 ± 0.13 A
3 days	3.58 ± 0.07 AB	3.56 ± 0.13 A	3.45 ± 0.10 A	3.45 ± 0.20 A	3.46 ± 0.15 A
6 days	3.60 ± 0.20 AB	3.60 ± 0.10 A	3.50 ± 0.19 A	3.49 ± 0.13 A	3.52 ± 0.14 A
9 days	3.70 ± 0.14 AB	3.66 ± 0.21 A	3.51 ± 0.14 A	3.52 ± 0.16 A	3.53 ± 0.16 A
12 days	3.73 ± 0.13 A	3.68 ± 0.20 A	3.55 ± 0.08 A	3.56 ± 0.13 A	3.58 ± 0.14 A
overall acceptability					
0 days	3.53 ± 0.16	3.51 ± 0.18	3.53 ± 0.10	3.50 ± 0.20	3.51 ± 0.24
3 days	3.51 ± 0.19	3.50 ± 0.08	3.50 ± 0.30	3.50 ± 0.15	3.55 ± 0.10
6 days	3.55 ± 0.20	3.51 ± 0.11	3.53 ± 0.13	3.53 ± 0.18	3.54 ± 0.11
9 days	3.56 ± 0.10	3.53 ± 0.25	3.55 ± 0.13	3.51 ± 0.11	3.55 ± 0.08
12 days	3.58 ± 0.23	3.53 ± 0.12	3.55 ± 0.24	3.56 ± 0.22	3.53 ± 0.18

[a]Values (mean ± standard deviation, $n = 6$) in the same column with different letters differ significantly ($p < 0.05$). A nine-point scale was used for the assessment (1, like extremely; 2, like very much; 3, like moderately; 4, like slightly; 5, neither like nor dislike; 6, dislike slightly; 7, dislike moderately; 8, dislike very much; 9, dislike extremely).

The GSH-Px activity was significantly ($p < 0.05$) higher in SS (3.01 ± 0.04), followed by MS-supplemented (2.84 ± 0.03), SY-II-supplemented (2.90 ± 0.07), and SY-I-supplemented (2.93 ± 0.02) chicken breast meat at 0 days of storage. However, GSH-Px activity decreased significantly in all treatments during 12 days of storage. This decrease was higher in control, SS, and MS groups than in the SY treatments. Decreases in GSH-Px activity during 12 days of storage at 4 °C in chicken breast meat were found in control (15.38%), SS (12.95%), SY-I (12.67%), SY-II, (9.65%) and MS (15.01%). The results showed that SY-II had more influence on the stability of GSH-Px activity in chicken breast meat during 12 days of storage at 4 °C.

Nothing has been reported regarding the effects of SY supplementation on antioxidant enzyme stability and TAC during 12 days of storage at 4 °C in chicken breast meat. However, some previous studies reported the stability of GSH-Px activity without Se supplementation during different storage days and temperatures in different animals. Gheisari et al.[43] found that the activity of GSH-Px decreased in cattle meat after 2 days and in chicken meat after 4 days of storage at 4 °C. Contrary to this, Renerre et al.[44] reported that the activity of GSH-Px was stable in beef psoas major (PM), longissimus lumborum (LL), and tensor fasciae latae (TFL) muscles over 8 days of storage at 2 °C. Daun et al.[45] also found that GSH-Px activity was stable in beef PM and L. dorsi (LD) for 14 days and in pork LD muscles for 4 days of cold storage.

In the current study, CAT and T-SOD activities and TAC were higher ($p < 0.05$) at 0 days of storage in SY-supplemented chicken breast meat. The activities of CAT, T-SOD, and TAC were stable over 12 days of storage at 4 °C in breast meat of chickens fed either diets supplemented with Se or diets without Se supplementation (Table 3). Our results were consistent with the findings of Gheisari et al.,[43] who found that CAT activity was stable in refrigerated meats of chicken, camel, and beef muscles during 4 days of storage at 4 °C. Similarly, Pradhan et al.[46] reported that CAT activity in ground beef SM and LD, pork LD, and chicken breast and thigh muscles was stable over 2 months of storage at −20 °C. However, Renerre et al.[44] found that SOD activity significantly decreased in different PM, LL, and TFL muscles of beef during 8 days of storage without any Se supplementation. It is possible that the higher antioxidant capacity, lower concentration of myoglobin, and iron-chelating ability are mainly responsible for chicken breast meat oxidative stability.[47]

The differences in results of GSH-Px and T-SOD activity stability might be due to the difference in animal species and kind of muscles tested in the experiments. It is also possible that different rearing conditions of the tested animals, changes in refrigerated temperature, and different storage durations

might be other factors responsible for these variations in the results.

For GSH-Px activity and MDA values, correlation between Se sources, levels, and storage days studied were significant ($p < 0.05$). In the present study, the SY and MS treatments significantly decreased MDA content as compared to SS and control groups (Table 3). SY-II (0.30 mg/kg) was more effective in inhibiting LO and increasing oxidative stability than other Se sources and levels in chicken breast meat over 12 days of storage at 4 °C. It was also found that SS had higher GSH-Px activity, but it showed lower oxidative stability as compared to SY and MS treatments. The results of the present study indicated that there is no correlation between GSH-Px activity and MDA content in chicken breast meat. We also found that MDA content in chicken breast meat was increased in control (268.29%), SS (306.25%), SY-I (234.48%), SY-II (238.46%), and MS (290.0%) treatments over 12 days of storage at 4 °C.

Vignola et al.[28] found that no significant differences in TBARS values were observed after 9 days of storage in the LD muscles of lambs that has been fed diets supplemented with SS (0.30 mg/kg) or SY (0.30 or 0.45 mg/kg) for 63 days. Similarly, Mikulski et al.[27] also did not find significant difference in TBARS content between SS and SY sources of Se; however, when compared to the control, both SS and SY groups had low TBARS values in turkey breast meat after 70 days of storage at −20 °C. However, Dlouhá et al. reported that the MDA value was lower in chicken breast meat over 5 days of storage at 3−5 °C after supplementation with Se-enriched *Chlorella* as compared to SS supplementation.[25]

In the present study, it was also found that SY and MS supplementations showed lower ($p < 0.05$) MDA contents than SS-supplemented chicken breast meat during the 12 days of storage at 4 °C (Table 3). It is suggested that the rise in GSH-Px was not accompanied by an increase in the oxidative stability of meat. Skrivanová et al.[32] also reported that the rise in GSH-Px was not accompanied by an increase in the oxidative stability in veal meat. The differences in MDA content in different animals during refrigerated storage might be due to differences in the types of meat muscles, animals, and storage conditions. Dietary SY has limited potential for improving nutritive values, but it is superior to SS for improving the antioxidant enzymes activities, TAC, and oxidative stability of chicken breast meat over 12 days of storage at 4 °C, which has positive consequences for human food because chicken meat and meat products are widely consumed in the world. It also has a positive influence on meat storage at the retail level.

Effect of Different Se Sources on the Sensory Characteristics of Chicken Breast Meat. The effect of Se in animal nutrition is associated with maintaining the antioxidant system of the cells. The results obtained in the present study indicated that the odor, flavor, and overall acceptability were not changed due to different Se sources, levels, and storage days in chicken breast meat but showed significant influence on color and juiciness during the 12 days of storage (Table 4). Meat discoloration was believed to be related to the effectiveness of the oxidation processes. Changes associated with oxidation include discoloration and unpleasant tastes and odors. Lipid and protein oxidation reduced the shelf life of meat and decreased nutritive values and the sensory quality of meat.[48−50]

Poultry is the only species known to have muscles with marked differences in color, and the meat has been classified as either white or dark. Changes in color of chicken meat are of great concern in the poultry industry. The chicken breast muscle is more susceptible than the thigh muscles to variations in color because it comprises a high percentage of the carcass, and its natural light color makes any alterations in color more apparent. Meat color is very important because consumers relate it with freshness and the overall quality of meat and meat products. Difference in color between meat slices displayed in a retail package is very noticeable to consumers, leading to the rejection of an entire package. Chicken breast muscles have a small capacity to form oxymyoglobin after air exposure and have higher oxygen consumption rates as compared to pork and beef meat, which encourage the formation of metmyoglobin at the surface of the meat.[51]

The results of present study showed that both Se sources (SS and SY) and MS supplementation had significant effects on the color and juiciness of chicken breast meat over 12 days of storage at 4 °C. Ahadi et al. found that dietary SY with Vit E supplementation had higher scores of sensory characteristics in chicken meat after 7 days and 1 month of storage.[52] Conversely, Miezeliene et al. reported that different Se sources and levels in the diet did not influence the sensory properties and acceptability of chicken meat.[53] It is probable that SY increased the deposition of Vit E of meat, which is a key vitamin for the maintenance and integrity of cell membrane that delays the LO in chicken breast meat. The other possible reasons in variation of sensory score results are different methods used for sensory evaluation and the age and sex of judges. The results of this sensory evaluation suggested that different Se sources and levels had limited influence on the sensory characteristics of chicken breast meat.

AUTHOR INFORMATION

Corresponding Author

*E-mail: tianwangnjau@163.com. Phone: 0086-25-84395156. Fax: 0086-25-84395156.

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Notes

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ABBREVIATIONS USED

LO, lipid oxidation; β-carotene, beta-carotene; Vit E, vitamin E; Se, selenium; GSH-Px, glutathione peroxidase; α-tocopherol, alpha-tocopherol; Se-Met, selenium methionine; Se-Cys, selenium cystine; SS, sodium selenite; SY, selenium yeast; AOAC, Official Methods of Analysis of AOAC International; ADG, average daily gain; ADFI, average daily feed intake; FCR, feed conversion ratio; CAT, catalase; T-SOD, total superoxide dismutase; TAC, total antioxidant capacity; TBARS, thiobarbituric acid reactive substances; MDA, malondialdehyde; U/mg protein, units per milligram of protein; nmol/mg of protein, nanomoles per milligram of protein; SS, sodium selenite; SY-I, Se-yeast 0.2 mg/kg feed; SY-II, Se-yeast 0.3 mg/kg feed; MS, 0.3 mg combined Se sources (sodium selenite 0.15 mg/kg feed + Se-yeast 0.15 mg/kg feed)/kg feed; LD, longissimus dorsi; Met, methionine; PM, psoas major; LL, longissimus lumborum; TFL, tensor fasciae latae.

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