The Journal of Animal & Plant Sciences, 26(4): 2016, Page: 916-923
ISSN: 1018-7081

EFFECT OF DIFFERENT ORGANIC AND INORGANIC SELENIUM LEVELS ON PERFORMANCE, SELENIUM CONCENTRATIONS OF SOME TISSUES, GLUTATHIONE PEROXIDASE ENZYME ACTIVITY AND MEAT QUALITY IN BROILERS

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ABSTRACT

A total of 672 one-day-old male broiler chicks were randomly assigned to eight experiment groups each having four replicate under completely randomized design. The experimental diets were prepared by adding certain amounts of organic (Sel-Plex-50) and inorganic Selenium (Se) (sodium selenite) sources that provided 0, 0.15, 0.30 and 0.60 ppm Se in the basal ration. The experimental period was six weeks. The results revealed that none of the performance parameters were influenced significantly by the treatments. Plasma and liver Se concentration significantly increased with increasing Se levels in the diet. Breast and thigh Se concentration affected by the (source x level interaction). The main significant effect of Se level was on the plasma and liver glutathione peroxidase enzyme activity, which increased with increasing Se levels in the diets. The treatments did not significantly influence thigh and breast pH, hardness, color criteria (L, a, b) or cook loss parameters. Dietary Se levels and sources had a significant effect on the water holding capacity of the breast. Selenium supplementation of broiler diets at the level of 0.60 ppm had a positive effect on tissues Se concentration. Considering the quality of meat, the organic Se source (0.60 ppm) was more effective than the inorganic Se source.

Keywords: Broiler, glutathione peroxidase, meat quality, performance, selenium.

INTRODUCTION

Selenium (Se) has a number of important biological roles including regulation of glutathione peroxidase activity (GSH-Px), immune function, health, and productivity (Surai, 2002; Choct *et al.*, 2004). A concentration of 0.15 mg Se/kg in the diet is recommended for broiler chickens throughout the growth period. Natural feedstuffs often meet these requirements, but there is considerable variation in the Se content of natural feedstuffs. Therefore, it is common practice in the Turkish poultry industry to supplement the diet with some form of Se (NRC, 1994). The levels of Se in soils globally are decreasing because of the intensity of agricultural cropping. The official documentation of Turkey's Se status is relatively poor. Selenium concentrations in feed ingredients vary greatly depending on the plant species and in particular the Se status of the soil. Therefore, poultry diets require supplementary Se in order to provide a margin of safety against deficiency and to maintain productive performance (Deniz *et al*., 2005). Although the requirement for Se often is met by the natural feedstuffs in poultry diets, there are several detrimental conditions that can result in poultry being deficient in dietary Se. The dietary sources of Se for poultry can be divided into two groups: natural feedstuffs, such as corn or soybean meal, and supplemental sources. Supplemental Se sources are supplied as an inorganic complex, such as sodium selenite (Na_2SeO_3) or as part of organic molecules, such as selenomethionine from selenized yeast. Organic Se has a couple of advantages compared to inorganic Se sources. Firstly, organic Se sources have greater bio-availability and secondly, organic Se will not undergo pro-oxidation because it is already in the organic form (Mahan, 1995).

Animal and poultry feed therefore requires supplementation to ensure health, efficient performance, and good meat quality. The response to dietary Se supplementation has been observed to be somewhat variable. Several researchers have reported that Se supplementation increased growth performance while several others have reported no effect (Cantor *et al.*, 1982; Edens *et al*., 2001; Spears *et al.*, 2003; Deniz *et al*., 2005; Yoon *et al.*, 2007). Over the past few years, consumer demands regarding meat quality have substantially increased. Consumers regard a loss of water during handling and cooking as an indicator of poor meat quality. Therefore, the water-holding capacity of breast meat is considered to be one of the most important quality characteristics. Increased levels of oxidation can damage cell membranes, reducing their integrity and allowing seepage of intracellular fluids. This can result in pale, exudative meat, a problem exacerbated by the prooxidant effects of inorganic sodium selenite (Mahan *et al*., 1999).

Meat quality is thought to be influenced by antioxidants such as vitamin-E and Se-dependent enzymes, including glutathione peroxidase (GSP-Px) (Ahn *et al*., 1998). Surai (2002) reported that GSH-Px contributes significantly to the overall antioxidant defense of muscle in broilers. Moreover, organic selenium supplementation of the diet could reduce tissue susceptibility to lipid peroxidation and increase the oxidative stability of skeletal muscle. Meat producers have previously relied on vitamin-E to reduce these problems, but it is now known that efficient utilization of vitamin-E in the body is dependent on Se-based antioxidant enzymes, and adequate Se intake is necessary to ensure the best use of this expensive vitamin (Peric *et al*., 2009).

The aim of this work was to investigate the influence of different sources and levels of dietary Se on performance, plasma and liver GSH-Px activity and meat quality.

MATERIALS AND METHODS

A total of 672 1-day-old male broiler chicks (Ross 308) were randomly assigned to eight experimental groups each having four replicate. Each pen contained 21 chicks. The experimental diets were prepared by adding certain amounts of organic (Sel-Plex-50, Alltech) and inorganic (sodium selenite) Se sources that provided 0 (control), 0.15, 0.30 and 0.60 ppm Se in the basal ration. Starter and grower diets were formulated according to the recommendations in the Ross management manual and NRC (1994). The basal diet composition is show in Table 1. Broilers were fed with starter diets from 1 to 21 days of age and grower diets from 22 to 42 days. Water and feed were supplied *ad libitum* throughout the experiment.

Body weight (BW) and feed intake (FI) were recorded on a pen basis at weekly intervals. Feed conversion ratio (FCR) was calculated as FI/BWG. Mortality was recorded daily. On the last day of the trial, three broilers from each replicate were randomly selected and slaughtered and blood and tissue samples were taken for determination of breast, thigh and liver plasma Se concentration, plasma and liver GSH-Px activity and meat quality parameters.

Blood samples were taken in heparinized tubes centrifuged at 2500 x g at 4ºC for 15 minutes and the plasma samples stored at -20 ºC. The birds were then slaughtered and breast, thigh and liver samples were collected and stored at -20 ºC until analysis. The selenium content of the sample was determined using a microwave oven system (CEM Corp., USA, 3100 Smith Farm Road, Matthews, NC) and ICP-MS device (Inductively Coupled Plasma – Mass Spectrometer). Approximately 0.50 g of fresh sample was put into a burning cup, and 5ml nitric acid and 2ml hydrogen peroxide was added. The sample was incinerated in a MARS 5 Microwave at 1.207 kPa, and afterwards diluted with10ml of distilled water. Selenium concentrations were determined using an ICP-MS (Agilent 7500 series).

Plasma GSH-Px activity was determined after of glutathione peroxidase extraction. Red blood cells were removed from samples then homogenized and the supernatant separated by ultra-centrifugation. Plasma and liver GSH-Px activities were determined using Glutathione Peroxidase Activity Assay Kits (Paglia and Valentine, 1967; Forstrom *et al*., 1978; Ursini *et al*., 1986; Cayman Chemical Corp, Catalogue Number, 703102). Water holding capacity (Wardlaw *et. al.*, 1973), cook loss (Kondiah *et al*., 1985), pH (AOAC, 2000), penetrometer value (Anonymous, 1975) and color criteria (Hunt *et. al.*, 1991) were determined according to methods.

Table 1. Composition of basal diets

Ingredients (%)	Starter Diet (0-3 week)	Grower Diet (3-6 week)
Corn	54.0	54.78
Soybean meal	37.0	29.50
Sunflower meal	-	5.00
Alfalfa meal	-	1.50
Vegetable oil	5.0	6.00
Limestone	1.3	1.10
Dicalcium phosphate	1.9	1.50
Salt	0.35	0.30
Vitamin Premix[1]	0.15	0.15
Mineral Premix(Se-free)[2]	0.10	0.10
DL-Methionine	0.20	0.07
Calculated Nutrients		
Crude protein (%)	22.50	20.20
Metabolizable Energy (MJ/kg)	12.77	13.08
Calcium (%)	1.10	0.94
Available phosphorus (%)	0.46	0.37
Methionine (%)	0.55	0.41
Methionine + Cystine (%)	0.88	0.72
Lysine (%)	1.11	0.98
Selenium[3] (mg/kg)	0.09	0.09

[1]: Provided (per kilogram of diet): Retinol 3.03 mg; cholecalciferol$_3$ 0,10 mg; α-tocopheryl acetate 30 mg; menadione 5.0 mg; thiamine 3 mg; riboflavin 6 mg; pyridoxine hydrochloride 5 mg; cyanocobalamin 0.03 mg; niacin 30 mg; biotin 0.1 mg; calcium D-pantotenat 12.0 mg; folic acid 1.0 mg; colin chloride 400 mg.

[2]: Provided (per kilogram of diet): Manganese 80 mg; Iron 35 mg; Zinc 50 mg; Copper 5.0 mg; Iodine 2 mg; Cobalt 0.04 mg.

[3]: Analyzed value.

The experiment was designed as a 2 (Se sources) x 4 (Se levels) factorial scheme within a completely randomized design. The data were subjected to ANOVA by using the General Linear Model procedure (GLM) in

Minitab (2000). Duncan's multiple range tests were applied to separate means (Mstat-C, 1995).

RESULTS AND DISCUSSION

The effects of dietary Se supplementation on broiler performance according to Se sources and levels are presented in Table 2. Dietary Se sources, levels and their interactions had no significant effect on the performance parameters body weight (BW), body weight gain (BWG), feed intake (FI) or feed conversion ratio (FCR) or on mortality of broilers at end of the experiment (P> 0.05).

Table 2. Influence of dietary selenium sources and levels on broiler performance ($\bar{X} \pm S_{\bar{x}}$).

Diets	Body weight (g/bird)	Body weight gain (g/bird)	Feed consumption (g/bird)	Feed conversion ratio (g feed/g gain)	Mortality (%)
Source					
Ing.Se	2576 ± 27.23	2534 ± 27.17	4318 ± 50.17	1.71 ± 0.01	1.79 ± 0.73
Org.Se	2618 ± 18.56	2576 ± 18.55	4333 ± 48.67	1.68 ± 0.01	2.08 ± 0.74
Level					
0	2566 ± 49.21	2524 ± 49.24	4351 ± 54.90	1.73 ± 0.02	0.60 ± 0.59
0.15	2585 ± 31.39	2543 ± 31.38	4256 ± 52.25	1.68 ± 0.02	2.38 ± 1.27
0.30	2600 ± 21.41	2559 ± 21.29	4333 ± 82.97	1.69 ± 0.02	1.79 ± 0.87
0.60	2636 ± 25.75	2594 ± 25.58	4363 ± 85.73	1.68 ± 0.03	2.98 ± 1.25
Source x Level					
Ing.Se-0	2557 ± 102.0	2515 ± 101.89	4351 ± 111.65	1.74 ± 0.04	1.19 ± 1.19
Ing.Se-0.15	2554 ± 29.01	2513 ± 40.83	4182 ± 52.50	1.67 ± 0.03	1.19 ± 1.19
Ing.Se-0.30	2571 ± 23.05	2529 ± 32.23	4313 ± 146.60	1.71 ± 0.04	2.38 ± 1.37
Ing.Se-0.60	2622 ± 26.24	2581 ± 25.82	4426 ± 56.70	1.72 ± 0.01	2.38 ± 2.38
Org.Se-0	2575 ± 29.05	2534 ± 29.57	4352 ± 40.05	1.72 ± 0.02	0.00 ± 0.00
Org.Se-0.15	2616 ± 47.78	2574 ± 47.95	4330 ± 79.55	1.68 ± 0.03	3.57 ± 2.27
Org.Se-0.30	2630 ± 22.28	2588 ± 22.16	4352 ± 101.85	1.68 ± 0.04	1.19 ± 1.19
Org.Se-0.60	2650 ± 47.75	2608 ± 47.58	4300 ± 168.70	1.65 ± 0.06	3.57 ± 1.19

Edens *et al.* (2001) reported no differences in BW or feed efficiency when broilers were fed diets containing 0.20 ppm Se from organic or inorganic Se. Spears *et al.* (2003) also reported no difference in gain or feed efficiency of broilers fed diets containing 0, 0.05, or 0.15 ppm Se from organic or inorganic sources. Yoon *et al.* (2007) reported that dietary supplemental Se did not influence the growth performance of broilers. Deniz *et al.* (2005) reported that FI and mortality were not significantly altered by Se supplementation using organic or inorganic Se forms. Ryu *et al.,* (2005) observed that feeding even higher concentrations (1 to 8 ppm) of dietary Se from an inorganic source did not affect the BW of broilers. We observed no difference in mortality due to Se supplementation, which is in agreement with the results of Edens *et al.* (2001). According to the results of this study, when dietary Se content was 0.09 mg/kg, deficiency symptoms can be prevented.

Plasma and liver Se concentrations significantly increased with increasing Se levels in the diets (P<0.01). The Se concentrations of breast and thigh were affected by the sources x levels interaction (P<0.05). Breast and thigh Se concentrations were greater in birds fed with diets containing the organic Se source than in those fed with inorganic Se (Table 3). The highest breast and thigh Se concentrations were in the Org.Se-0.60 group.

Dietary Se was absorbed efficiently; the retention of organic forms breast and thigh was higher than for inorganic forms in the present study. Our result are in the agreement with those of Echevarria *et al.*, (1988), Sevcikova *et al.*,*(*2006), Yoon *et al*., (2007), Payne and Southern (2005) and Wang and Xu (2007). Sevcikova *et al. (*2006) reported that the Se contents of breast, thigh and liver increased when birds were fed with 0.3 ppm Se-yeast and 0.3 ppm Se-chrolle compared to the control. Broiler chickens fed with a basal diet had lower Se content in muscle compared to the Se-supplemented group (Wang and Xu, 2007). Choct *et al.* (2004) also reported that an increasing supplementation of dietary Se from 0.1 to 0.25 mg/kg increased the Se concentration in breast muscle from 0.232 to 0.278 mg/kg.

Boiago *et al.* (2014) reported that a higher concentration of Se was observed in the meat of broilers fed diets supplemented with Se, supplementation being more effective with the organic Se source. Mahan and Parrett (1996) reported that inorganic Se was retained at a much lower concentration in muscle tissue, was less efficiently absorbed and was excreted at a higher rate than organic Se due to their different metabolic pathways. Inorganic Se is passively absorbed from the small intestine by simple diffusion, whereas organic Se is actively absorbed through the amino acid transport

mechanisms (Wolfram *et al.*, 1989 a, b). The reason is that muscle mass represents about 52-56 % of body weight. The practice of supplementing organic Se in poultry diets benefits human consumers. Human populations in many countries, especially the young and middle aged, face marginal to medium severe Se deficiencies with consequent health disorders such as decreased nonspecific immunity, disorders of thyroid metabolism heart and vascular diseases and cancer (Kvicala, 1996; Rayman, 2000).

The main effect of Se supplementation was on plasma and liver GSH-Px activity, which significantly increased with increasing Se levels in diet (P<0.05) (Table 4).

Table 3. Influence of dietary selenium sources and levels on plasma, liver, breast and thigh selenium concentrations ($\bar{x} \pm S_{\bar{x}}$).

Diets	Plasma	Liver	Breast	Thigh
	mg/100 ml			
Source				
Ing.Se	0.95 ± 0.08	5.57 ± 0.54	1.59 ± 0.20	1.40 ± 0.22
Org.Se	0.95 ± 0.11	6.08 ± 0.72	2.93 ± 0.36	2.24 ± 0.30
Level				
0	0.56 ± 0.03^{C}	4.31 ± 0.61^{B}	1.26 ± 0.10	0.99 ± 0.07
0.15	0.90 ± 0.07^{BC}	5.04 ± 0.46^{B}	1.91 ± 0.22	1.40 ± 0.11
0.30	1.02 ± 0.11^{AB}	5.77 ± 0.84^{AB}	2.31 ± 0.38	1.84 ± 0.27
0.60	1.34 ± 0.08^{A}	8.19 ± 0.92^{A}	3.56 ± 0.61	3.04 ± 0.52
Source x Level				
Ing.Se-0	0.61 ± 0.17	4.56 ± 1.43	1.19 ± 0.06^{d}	1.08 ± 0.07^{cd}
Ing.Se-0.15	0.96 ± 0.11	5.92 ± 0.67	1.37 ± 0.07^{d}	1.14 ± 0.05^{cd}
Ing.Se-0.30	1.02 ± 0.11	4.78 ± 0.79	1.70 ± 0.54^{cd}	1.29 ± 0.34^{cd}
Ing.Se-0.60	1.22 ± 0.12	7.03 ± 1.15	2.11 ± 0.56^{bcd}	2.08 ± 0.78^{bc}
Org.Se-0	0.50 ± 0.02	4.06 ± 0.43	1.33± 0.20^{d}	0.91 ± 0.11^{d}
Org.Se-0.15	0.81 ± 0.08	4.15 ± 0.16	2.46 ± 0.13^{bc}	1.65 ± 0.10^{bcd}
Org.Se-0.30	1.04 ± 0.21	6.75 ± 1.43	2.93 ± 0.35^{b}	2.40 ± 0.20^{b}
Org.Se-0.60	1.46 ± 0.09	9.34 ± 1.31	5.00 ± 0.12^{a}	4.00 ± 0.21^{a}

$^{A, B, C}$: Means with different majuscule in the same column are significantly different at P< 0.01.
$^{a, b, c, d}$: Means with different minuscule in the same column are significantly different at P< 0.05.

Table 4. Influence of dietary selenium sources and levels on plasma and liver GSH-Px activity ($\bar{x} \pm S_{\bar{x}}$).

Diets	Plasma	Liver
	nmol/min/ml	
Source		
Ing.Se	0.350 ± 0.0039	1.289 ± 0.0697
Org.Se	0.350 ± 0.0055	1.327 ± 0.0751
Level		
0	0.340 ± 0.0045^{B}	0.999 ± 0.0529^{C}
0.15	0.342 ± 0.0051^{B}	1.210 ± 0.0562^{BC}
0.30	0.346 ± 0.0057^{B}	1.381 ± 0.0475^{B}
0.60	0.370 ± 0.0060^{A}	1.640 ± 0.0738^{A}
Source x Level		
Ing.Se-0	0.347 ± 0.0043	1.004 ± 0.1102
Ing.Se-0.15	0.345 ± 0.0100	1.204 ± 0.0794
Ing.Se-0.30	0.348 ± 0.0107	1.354 ± 0.0660
Ing.Se-0.60	0.360 ± 0.0052	1.593 ± 0.1125
Org.Se-0	0.334 ± 0.0683	0.994 ± 0.0304
Org.Se-0.15	0.339 ± 0.0037	1.217 ± 0.0917
Org.Se-0.30	0.344 ± 0.0057	1.408 ± 0.0754
Org.Se-0.60	0.381 ± 0.0082	1.687 ± 0.1062

$^{A, B, C}$: Means with different majuscule in the same column are significantly different at P< 0.01.

The highest plasma and liver GSH-Px activity were observed in the group fed with the Org. Se-0.60 treatment. The GSH-Px activities in plasma and liver were higher in 0.60 ppm Se supplementation of group compared with other groups. Yoon *et al*. (2007) reported that the GSH-Px activity was higher for all Se-supplemented groups compared with the negative control, whereas the efficiency (GSH-Px activity/Se intake) determined at 0.3 ppm of Se decreased with supplemental Se. GSH-Px activities in the Se supplemented groups were higher than in the control groups (Wang and Xu, 2007). However, these data did not agree with Payne and Southern (2005) who reported the GSH-Px activity was not affected by Se source or concentration.

Spears *et al*. (2003) indicated that plasma GSH-Px activity was higher in broilers fed selenomethionine compared with sodium selenate in one experiment but not in another. This discrepancy in the results is probably due to the concentration of Se in the basal diet. Selenium regardless of its form has to be converted to selenocysteine before incorporation in to the plasma GSH-Px enzyme. Sunde and Hoekstra (1980) reported that inorganic Se was effectively metabolized into selenocysteine, whereas Henry and Ammerman (1995)

indicated that selenomethionine was converted to selenocysteine at a lower rate of efficiency.

The effects of dietary Se supplementation on broiler breast and thigh meat quality according to Se source and level are presented in Tables 5 and 6. Dietary supplementary Se sources and levels had no significant effect on pH, color criteria (L, a, b), cook loss (CL) or penetrometer values (PM) for breast and thigh meat in broilers. The main significant effects of dietary Se levels and sources were on the water holding capacity (WHC) of breast meat ($P<0.01$; $P<0.05$). However, the WHC of thigh meat was affected only by the dietary Se levels ($P<0.01$). These results are consistent with Boiago *et al*. (2014), who reported that there was no effect of Se supplementation on the WHC. There was also a positive effect of dietary levels of Se from different sources on the breast meat quality of broilers. A linear effect of dietary Se levels on the amount of Se deposited in the muscle was observed, and the organic source (selenomethionine) was more effective than inorganic Se (sodium selenite) for broiler meat conservation.

The different treatments caused no significant differences in the pH of the breast or thigh meat in our study (Table 5 and 6). These results are consistent with Boiago *et al*. (2014) and Peric *et al*. (2009), who also observed that different sources and levels of Se caused no significant differences in the pH of breast meat. A significant decrease in brightness was noted when organic source of Se was used. Mahan *et al.* (1999) reported a reduction in pig meat brightness in response to dietary organic Se compared to inorganic dietary Se. These authors attributed this result to the relation between muscle light and WHC, as the inorganic source causes greater water loss and consequently, better muscle brightness. Brightness (L) and redness (a) intensity in breast meat of broilers were not affected ($P>0.05$) by dietary different Se sources and levels, but yellow intensity (b) was increased with the inorganic Se source compared with the organic Se source (Table 5). Brightness (L) and red (a) and yellow (b) intensities in broiler thigh meat were not affected ($P>0.05$) by different dietary Se sources and levels (Table 6). These results are consistent with Cao (2001), who found significant differences in these parameters with decreasing yellow (b) intensity of broiler breasts fed diets containing an organic Se source.

Table 5. Influence of dietary selenium sources and levels on broiler breast meat pH, color criteria (L, a, b), water holding capacity (WHC), cooking loss (CL), and penetrometer value (PM) ($\bar{x}$ ± S $\bar{x}$).

			Color criteria			WHC	CL
	pH	PM	L	a	b	%	%
Source							
Ing.Se	5.87 ± 0.03	370.2 ± 5.81	50.11 ± 0.64	3.84 ± 0.17	4.48 ± 0.40^{a}	31.64 ± 1.21^{b}	19.16 ± 0.76
Org.Se	5.90 ± 0.04	383.8 ± 7.83	48.67 ± 0.81	4.06 ± 0.25	3.38 ± 0.27^{b}	34.38 ± 1.28^{a}	19.11 ± 0.52
Level							
0	5.80 ± 0.02	375.7 ±12.68	50.52 ± 1.00	3.84 ± 0.25	3.31 ± 0.29	28.13 ± 1.18^{C}	20.25 ± 0.69
0.15	5.88 ± 0.05	378.7 ±11.78	48.64 ± 1.13	4.26 ± 0.28	4.04 ± 0.68	31.25±1.67^{BC}	19.31 ± 0.82
0.30	5.89 ± 0.05	373.5 ± 9.55	49.50 ± 0.56	4.10 ± 0.16	4.07 ± 0.30	35.16±1.14^{AB}	19.04 ± 0.56
0.60	5.97 ± 0.07	380.1 ± 6,22	48.90 ± 1.41	3.60 ± 0.44	4.33 ± 0.43	37.50 ± 1.18^{A}	17.93 ± 1.34
Source x Level							
Ing.Se-0	5.79 ± 0.04	366.4 ± 16.98	49.97 ± 0.61	3.70 ± 0.32	3.40 ± 0.34	28.13 ± 1.80	20.10 ± 1.11
Ing.Se-0.15	5.86 ± 0.04	371.8 ± 11.13	50.31 ± 1.57	3.77 ± 0.19	5.42 ± 0.63	28.13 ± 1.80	19.44 ± 0.89
Ing.Se-0.30	5.89 ± 0.07	365.7 ± 8.82	50.33 ± 1.00	4.04 ± 0.18	4.49 ± 0.78	34.38 ± 1.80	19.05 ± 0.89
Ing.Se-0.60	5.95 ± 0.08	376.9 ± 12.55	49.83 ± 2.08	3.86 ± 0.62	4.63 ± 1.23	35.94 ± 1.56	18.05 ± 2.86
Org.Se-0	5.82 ± 0.02	385.1 ± 20.12	51.07 ± 2.03	3.98 ± 0.43	3.22 ± 0.52	28.13 ± 1.80	20.40 ± 1.00
Org.Se-0.15	5.89 ± 0.10	385.6 ± 22.19	46.97 ± 1.30	4.74 ± 0.44	2.65 ± 0.72	34.38 ± 1.80	19.19 ± 1.53
Org.Se-0.30	5.90 ± 0.10	381.2 ± 17.56	48.66 ± 0.16	4.16 ± 0.30	3.64 ± 0.38	35.94 ± 1.56	19.04 ± 0.90
Org.Se-0.60	5.98 ± 0.12	383.3 ± 4.05	47.97 ± 2.10	3.34 ± 0.69	4.01 ± 0.41	39.06 ± 1.56	17.81 ± 0.53

$^{A, B, C}$: Means with different majuscule in the same column are significantly different at $P< 0.01$.

$^{a, b}$: Means with different minuscule in the same column are significantly different at $P< 0.05$.

Table 6. Influence of dietary selenium sources and levels on broiler thigh meat pH, penetrometer value (PM), color criteria (L, a, b), water holding capacity (WHC), and cooking loss (CL) ($\bar{x} \pm S_{\bar{x}}$).

			Color criteria			WHC	CL
	pH	PM	L	a	b	%	%
Source							
Ing.Se	6.38 ± 0.03	351.2 ± 4.69	49.18 ± 0.52	5.39 ± 0.20	2.95 ± 0.36	38.28 ± 1.12	21.15 ± 0.68
Org.Se	6.40 ± 0.03	359.3 ± 3.81	49.44 ± 0.40	5.42 ± 0.21	2.38 ± 0.24	39.84 ± 1.38	20.75 ± 0.78
Level							
0	6.34 ± 0.03	346.9 ± 5.99	49.66 ± 0.80	5.25 ± 0.26	2.11 ± 0.40	34.38 ± 1.18^{C}	22.50 ± 0.79
0.15	6.38 ± 0.03	359.3 ± 6.80	48.47 ± 0.41	5.36 ± 0.16	3.51 ± 0.56	36.72 ± 1.42^{BC}	21.07 ± 1.36
0.30	6.41 ± 0.05	354.3 ± 5.56	49.44 ± 0.52	5.50 ± 0.26	2.38 ± 0.39	41.41 ± 1.14^{AB}	20.30 ± 0.96
0.60	6.43 ± 0.05	360.6 ± 6.01	49.69 ± 0.79	5.51 ± 0.43	2.68 ± 0.27	43.75 ± 1.67^{A}	19.93 ± 0.80
Source x Level							
Ing.Se-0	6.34 ± 0.04	341.9 ± 10.51	50.08 ± 1.58	5.58 ± 0.32	2.38 ± 0.77	34.38 ± 1.80	22.44 ± 1.24
Ing.Se-0.15	6.35 ± 0.03	356.1 ± 12.44	48.32 ± 0.40	5.06 ± 0.19	4.47 ± 0.72	35.94 ± 1.56	21.38 ± 1.80
Ing.Se-0.30	6.42 ± 0.08	345.5 ± 7.59	49.32 ± 0.77	5.76 ± 0.42	2.29 ± 0.56	40.63 ± 1.80	20.46 ± 1.29
Ing.Se-0.60	6.40 ± 0.10	361.3 ± 5.94	49.02 ± 1.29	5.17 ± 0.60	2.68 ± 0.39	42.19 ± 1.56	20.33 ± 1.36
Org.Se-0	6.34 ± 0.06	351.9 ± 6.35	49.24 ± 0.62	4.92 ± 0.38	1.85 ± 0.34	34.38 ± 1.80	22.56 ± 1.17
Org.Se-0.15	6.41 ± 0.05	362.4 ± 7.40	48.61 ± 0.77	5.65 ± 0.15	2.54 ± 0.58	37.50 ± 2.55	20.76 ± 2.32
Org.Se-0.30	6.41 ± 0.06	363.1 ± 5.96	49.56 ± 0.82	5.24 ± 0.38	2.47 ± 0.62	42.19 ± 1.56	20.14 ± 1.62
Org.Se-0.60	6.46 ± 0.06	359.8 ± 11.55	50.36 ± 1.00	5.86 ± 0.61	2.68 ± 0.45	45.31 ± 1.56	19.54 ± 1.01

$^{A, B, C}$: Means with different majuscule in the same column are significantly different at P< 0.01.

Boiago *et al*. (2014) reported that red and yellow intensities in broiler meat were not affected by different dietary Se sources. According to the results of the present study Se concentrations of plasma, liver, breast and thigh meat, and water holding capacity were significantly increased by increasing dietary Se levels. Breast and thigh meat Se concentrations were higher when birds were fed with an organic Se source than with an inorganic Se source. The highest breast and thigh muscle Se concentration were in the group fed with the Org.Se-0.60 treatment. Plasma and liver GSH-Px activity increased with increasing dietary Se levels.

In conclusion, the source or levels of Se in the diets did not affect growth performance. Se supplementation of broiler diets at the level of 0.60 ppm showed a positive effect on tissues Se concentration. Considering the meat quality organic Se (0.60 ppm) was more effective than inorganic Se. Selenium supplementation might be recommended in broiler rations to enhance broiler meat Se concentration.

Acknowledgements: This project was supported by a grant from the Scientific Research Projects (BAP) (Project number: 09101015) Coordinating Office of Selçuk University, Turkey.

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