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Comparison of Different selenium Sources on Performance, Serum Attributes and Cellular Immunity in Broiler Chickens

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Abstract

The effects of organic and inorganic sources and concentration (0 and 0.3 mg per kg of diet) of Selenium (Se) on growth performance, blood biochemical and immune system were evaluated in broiler chickens. Chickens were fed corn-soy-based diets formulated to 8 dietary treatments containing no added Se (negative control), negative control plus yeast (positive control), and 6 diets had 0.3 mg/kg of diet supplemented with Se from Availa Se, Sel-plex, SeleMax, Se enriched yeast, sodium selenite and sodium selenate. Four hundred Ross 308 male chickens were randomly divided into 8 treatments and 5 replicates of 10 birds each. Feed intake, body weight gain, and feed conversion ratio were measured at starter (0-10 d), grower (11-24 d), and finisher (25-42 d) periods. On d 24 and 42, one bird from each replicate was killed by cervical dislocation and blood samples were collected to determine blood chemicals, glutathione peroxidase (GPx) activity and heterophile to lymphocyte ratio. Results showed that Se supplementation had no effect on feed intake, body weight gain, and feed conversion ratio of the chickens ($P < 0.05$). However, blood triglycerides, GPx activity and heterophile to lymphocyte ratio were significantly affected by organic and inorganic Se sources ($P < 0.05$). Results showed that selenium in organic and inorganic forms didn't have any effect on growth performance and blood parameters but they could improve immune system through increase in GPx activity.

Introduction

Selenium (Se) has been defined as an essential element for growth (Yoon *et al*., 2007; Wang and Xu, 2008), immune competence (Cai *et al*., 2012; Liao *et al*., 2012), antioxidant (Peng *et al*., 2007; Zhou and Wang, 2011) and reproductive functions, immunocompetence, and ageing (Sevescova *et al*., 2006; Leeson *et al*., 2008) of broilers. Selenium as an essential trace mineral is crucial in human health (Rayman, 2004), and improving performance and health of the birds (Haug *et al*., 2007; Yoon *et al*., 2007).

Commercial organic and inorganic forms of Se are available in the market. Organic forms are selenomethionine, Se enriched yeast, and Se enriched alga, while inorganic forms of Se are available as selenite, selenate, and selenide (Sevescova *et al*., 2006). The main used Se source in poultry diets is sodium selenite. However, research has shown Se yeast and other sources of Se, have been examined as alternatives to inorganic Se supplementation (Payne and

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Southern, 2005; Baylan *et al*., 2010). Organic Se has shown an enhancement in the tissue Se concentration, while has no other effects on plasma GPx activity, carcass characteristics and growth performance compared to inorganic Se (Sevescova *et al*., 2006; Yoon *et al*.,2007). Use of Se yeast as an organic Se in poultry diets was authorized by Food and Drug Administration (FDA, 2000), and then Se yeast extracted from various yeast species through different methods (Yoon *et al*., 2007). When yeast and alga cultivated in a media enriched by Se, they may convert Se to selenomethionine as a source of organic Se which is more efficiently absorbed and retained in tissues compared to inorganic Se salts such as sodium selenite (Yoon *et al*., 2007).

In biological systems, during normal metabolism reactive oxygen species (ROS) and free radicals are produced in the cells (Tappel and Tappel, 2004) while neutralized by innate antioxidant systems (Sies, 1991). However, the excessive production of free radicals and ROS under stress conditions and diseases can damage the phospholipid membranes of the cells and other macromolecules and destroy the oxidants and antioxidants balance (Wiseman and Halliwell, 1996). The antioxidant effect of Se has been shown in farm animals. For example, Se shows its physiological activities in the forms of selenoproteins, including superoxide dismutase (SOD), GPx, glutathione reductase, selenoprotein P, and selenoprotein in mammals (Kaushal and Bansal, 2007).

Various sources of Se have been added to poultry diets to evaluate its effect on health and production of birds. This study was designed to enrich specific yeast by selenium at the laboratory conditions. When the concentration of selenium inside of the yeast reached at the acceptable level, they dried and used at an appropriate level in the diet. In the current study, the effects of a produced organic Se enriched yeast compared with several commercial inorganic and organic Se sources and their efficacy on performance, immune system, GPx activity and blood biochemical indices of broiler chickens were evaluated.

Materials and Methods

Birds and housing

A total of 400 male one-day-old Ross 308 broiler chickens were assigned into 8 dietary treatments with 5 replicates of 10 birds each. The birds with the initial weight of 42±0.9 g were used in a completely randomized design experiment. The brooding temperature was held at 33±0.5°C until d 7 and gradually decreased to 22°C by day 24 and kept constant thereafter. Birds were vaccinated against infectious bronchitis, infectious bursal disease and Newcastle disease according to the local veterinary officials. Birds received 23 hours of light per day. The birds were housed in an environmentally controlled poultry house with paper roll as litter at the research farm of Animal Science Research Institute of Karaj, Iran (ASRI).

Experimental diets

The current experiment was conducted with 8 treatments, four replicates of 10 birds each in a completely randomized design. The variable parameter in the diets was Se sources at the used level (0.3 mg/kg of diet). The birds had ad libitum access to feed and water.

This experimental was performed for 42 days with three phases of starter (1-10 d), grower (11-24 d), and finisher (25-42 d). Eight dietary treatments were as follow: 1) Negative control diet based on corn-soybean without Se or yeast supplementation (NC); 2) Positive control diet (NC with supplemental yeast; 3) NC with supplemental Availa®Se (zinc-L-selenomethionine, Zinpro Corporation, Eden Prairie, USA); 4) NC with supplemental SelMax® (Se yeast, Biorigin, Brazil); 5) NC with supplemental Sel-Plex® (Se yeast B, Alltech, Nicholasville, Kentucky), 6) NC with supplemental sodium selenite (99.9% purity, Merck, Germany); 7) NC with supplemental sodium selenate (99.9% purity, Merck, Germany); 8) NC with supplemental Se enriched yeast (SEY) (contained 3000 ppm organic Se derived from Saccharomyces cerevisiae and produced in the biotechnology laboratory of Iranian Research Organization for Science and Technology), that approved by intellectual property center of Iran (Patent No. 139550140003008880).

The amount of Se in SEY was determined by ICP-OES (Wu *et al*., 2007). All Se supplements

were added to the diets at the rate of 0.3 mg per kg of diet that is the optimum requirement of Se in poultry. The amount of yeast in positive control diet was the same as that of SEY. All diets were balanced to meet the chicken requirements based on Ross 308 Broiler Nutrition Requirements Specifications (2014) as shown in Table 1. The experimental protocols were reviewed and approved by the Animal Care Committee of the Ferdowsi University of Mashhad, Iran (No. 3/29728 dated March 4, 2014).

Table 1. Composition of the basal diet (as-fed basis)

Feed ingredients (g/kg)	Experimental Periods (days)		
	Starter (1-10)	Grower (11-24)	Finisher (25-42)
Corn	551.63	610.40	648.07
Soybean Meal (440 g/kg crude protein)	391.11	333.30	278.98
Soybean Oil	15.53	20.42	31.27
Dicalcium Phosphate	11.72	9.47	7.91
Limestone	14.20	10.87	10.32
DL-Methionine	3.26	2.94	2.74
L-Lysine	2.05	2.16	2.30
L-Threonine	1.13	1.03	0.97
Sodium Chloride	2.05	2.11	1.95
$NaHCO_3$	1.82	1.80	2.08
Phytase[1]	0.50	0.50	0.50
Na-Bentonite	---	---	7.91
Mineral Premix[2]	2.50	2.50	2.50
Vitamin Premix[3]	2.50	2.50	2.50
Nutrient composition (%, unless stated)			
Metabolizable Energy (Kcal/kg)	2900	3000	3100
Crude Protein	21.83	19.68	17.59
Calcium	0.93	0.84	0.77
Available phosphorus	0.46	0.42	0.38
Sodium	0.16	0.16	0.16
Chlorine	0.19	0.20	0.19
Digestible Methionine	0.62	0.57	0.52
Digestible Methionine + Cystine	0.92	0.84	0.78
Digestible Lysine	1.24	1.11	1.00
Digestible Threonine	0.83	0.75	0.67

† [1]Microbial phytase AVEMIX® P10000 from AVEVE® (AVEVE Biochem NV, Belgium)
[2] Each kg of Mineral Premix contained: Mn, 48 g; Fe, 8 g; Zn, 44 g; Cu, 6.4 g; I, 0.5 g; Se, 0.12 g.
[3]Each kg of Vitamin Premix contained: vitamin A (retinol), 3000000 IU; vitamin D_3 (cholecalciferol), 2000000 IU; vitamin E (tocopheryl acetate), 32000 IU; vitamin K3, 1.28 g; vitamin B1, 1.28 g; vitamin B2, 3.44 g; Niacin, 26 g; Pantothenic Acid, 8 g; B6, 1.72 g; B9, 0.88 g; Biotin, 0.08 g; vitamin B12, 0.0068 g; Choline chloride 100 g; Folic acid 0.88 g; H2; 0.088 g.

Performance

Body weight gain (BWG) and feed intake (FI) were measured weekly for each pen, and daily mortality was recorded. FCR were calculated based on Body weight gain and FI.

Blood biochemical measurements

At 24 and 42 days of age, 2 mL of blood was taken from wing vein of one bird from each replicate; 1 mL of blood was collected in anticoagulant EDTA (1 mg/mL) tube and centrifuged at 1,734 × g at 0°C for 20 min and the plasma was collected to measure GPx activity. The other 1 mL of blood was collected in glass tube and the supernatant was centrifuged at 1,734 × g at 0°C for 20 min to have clear serum sample. This sample was used to measure albumin, globulin, glucose, triglyceride, cholesterol, low density lipoprotein-cholesterol (LDL-c), high density lipoprotein-cholesterol (HDL-c), total protein, and urea nitrogen using commercial test kits supplied by Pars Azmoun (Tehran, Iran) using autoanalyzer (Bio Systems S. A – Costa Brava 30, 08030 Barcelona Spain).

The whole blood sample was used to measure heterophile to lymphocyte ratio (H/L). For

measuring H/L ratio, blood smears were made and stained with May-Grünwald-Giemsa stain. From 100 white blood cells, heterophiles and lymphocytes were counted to calculate their ratio (H/L).

Statistical analysis

Analysis of variance was examined using SAS software (SAS, 1987). Treatment effects were analyzed using the General Linear Models procedure (GLM) of SAS along with Tukey's range test to compare means. Differences due to experimental treatments were considered significant at $P < 0.05$. Orthogonal contrasts were made for presence or absence of Se, Se sources, and SEY vs other Se sources for the measured indices.

Results

Growth performance

Feed intake was not affected by dietary treatments (Table, 2). Body weight gain of broilers at each period (Table, 3) showed no significant difference among treatments. No significant difference was observed among treatments for FCR over the entire trial periods (Table, 4). No significant orthogonal contrasts in FI, BWG, and FCR was attributable to dietary Se. In other words, supplemental organic Se, inorganic Se and SEY at the rate of 0.3 mg/kg diet had no significant impact on performance.

Table 2. Effect of supplemental dietary selenium sources on feed intake of broilers (g)

Treatments	Se dose (mg/kg diet)	1-10 d	11-24 d	25-42 d	1-42 d
Negative control†	0.0	271.00	1072.00	2698.20	4041.20
Positive control†	0.0	275.00	1066.00	2720.80	4061.80
Availa Se	0.3	265.00	1087.00	2715.40	4067.40
SelMax	0.3	268.00	1078.00	2718.20	4064.20
Sel-Plex	0.3	268.00	1078.00	2742.60	4088.60
Sodium Selenite	0.3	272.00	1075.00	2699.60	4046.60
Sodium Selenate	0.3	272.00	1078.00	2724.20	4074.20
Selenium enriched yeast	0.3	270.00	1082.00	2713.80	4065.80
*SEM**	---	1.096	2.427	6.424	6.305
P-values	---	0.454	0.582	0.787	0.709
Orthogonal contrasts					
Presence or absence of Se	---	0.948	0.908	0.898	0.939
Se sources	---	0.712	0.595	0.475	0.320
Selenium enriched yeast *vs* other sources	---	0.854	0.540	0.706	0.852

† Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source but added yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.
*Standard error of means ((n = 10) per treatment).

Blood biochemical indices

The mean blood serum albumin, globulin, total protein, cholesterol, triglyceride, HDL-c, LDL-c, serum urea nitrogen, and glucose on 24 and 42 d of age are presented in Tables 5 and 6, respectively. None of the serum indices on days 24 and 42 except triglyceride showed any significant effect among dietary treatments. On day 42, the mean values of serum triglyceride in negative control group was significantly higher than those of other treatments ($P < 0.05$).

The GPx activity and H/L on days 24 and 42 are shown in Table 7. Plasma GPx activity was significantly increased by supplementation of 0.3 mg/kg Se when compared to those of other experimental groups on 24 and 42 days of age ($P < 0.05$). H/L ratio significantly decreased in positive control group when compared to those of other experimental groups ($P < 0.05$). Supplementation of the diets by Se sources either organic or inorganic forms increased GPx activity when they orthogonally compared to negative control group.

Table 3. Effect of supplemental dietary selenium on body weight gain of broilers (g)

Treatments	Se dose (mg/kg diet)	1-10 d	11-24 d	25-42 d	1-42 d
Negative control†	0.0	193.00	700.00	1338.00	2231.00
Positive control†	0.0	193.60	695.00	1347.00	2235.60
Availa Se	0.3	189.80	710.00	1331.80	2231.60
SelMax	0.3	193.80	700.00	1348.00	2241.80
Sel-Plex	0.3	191.80	711.00	1339.20	2242.00
Sodium Selenite	0.3	193.00	705.00	1343.00	2241.00
Sodium Selenate	0.3	194.20	703.00	1341.00	2238.20
Selenium enriched yeast	0.3	195.60	705.00	1333.60	2234.20
*SEM**	---	1.022	1.730	2.290	2.930
P-values	---	0.943	0.305	0.615	0.967
Orthogonal contrasts					
Presence or absence of Se	---	0.465	0.703	0.844	0.546
Se sources	---	0.926	0.157	0.511	0.753
Selenium enriched yeast vs other sources	---	0.471	0.811	0.335	0.551

†Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source + yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.
*Standard error of means ((n = 10) per treatment).

Table 4. Effect of supplemental dietary selenium on broiler feed conversion ratio of broilers

Treatments	Se dose (mg/kg diet)	1-10 d	11-24 d	25-42 d	1-42 d
Negative control†	0.0	1.40	1.53	2.02	1.81
Positive control†	0.0	1.42	1.53	2.02	1.82
Availa Se	0.3	1.40	1.53	2.04	1.82
SelMax	0.3	1.38	1.54	2.02	1.81
Sel-Plex	0.3	1.40	1.52	2.05	1.82
Sodium Selenite	0.3	1.41	1.52	2.01	1.81
Sodium Selenate	0.3	1.40	1.53	2.03	1.82
Selenium enriched yeast	0.3	1.38	1.53	2.03	1.82
*SEM**	---	0.004	0.003	0.005	0.003
P-values	---	0.255	0.674	0.670	0.838
Orthogonal contrasts					
Present or absence of Se	---	0.180	0.753	0.826	0.582
Se sources	---	0.746	0.272	0.289	0.496
Selenium enriched yeast *vs* other sources	---	0.102	0.333	0.770	0.748

†Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source + yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.
*Standard error of means ((n = 10) per treatment).

Table 5. Effect of supplemental dietary selenium on blood biochemical parameters of broilers at 24 day of age

Treatments	Se dose (mg /kg diet)	Albumin (g/dL)	Globulin (g/dL)	Total Protein (mg/dL)	Total Cholesterol (mg/dL)	Total Triglyceride (mg/dL)	HDL‡ (mg/dL)	LDL‡ (mg/dL)	Serum urea nitrogen (mg/dL)	Glucose (mg/dL)
Negative control†	0.0	2.81	156.31	4.33	160.57	169.58	44.11	82.54	6.21	1.42
Positive control†	0.0	2.77	162.60	4.24	155.46	151.70	43.22	81.89	5.78	1.31
AvailaSe	0.3	2.80	174.32	4.48	166.08	151.70	46.67	89.08	6.26	1.51
SelMax	0.3	2.77	166.59	4.38	165.72	156.09	48.19	86.31	6.15	1.41
Sel-Plex	0.3	2.77	169.20	4.62	162.65	153.37	49.25	82.72	6.43	1.65
Selenite sodium	0.3	2.77	157.16	4.53	158.07	145.15	46.64	82.40	6.02	1.60
Selenate sodium	0.3	2.77	163.39	4.37	165.87	165.75	46.79	85.93	6.23	1.35
Selenium enriched yeast	0.3	2.77	160.20	4.49	165.72	160.32	46.08	80.72	6.13	1.51
*SEM**	---	0.005	1.86	0.060	1.45	2.31	0.59	1.26	0.068	0.060
P-values	---	0.549	0.211	0.853	0.478	0.138	0.212	0.753	0.449	0.858
Orthogonal contrasts										
Presence or absence of Se	---	0.020	0.609	0.811	0.516	0.303	0.331	0.416	0.473	0.276
Se sources	---	1.000	0.632	0.224	0.832	0.675	0.299	0.719	0.163	0.276
Selenium enriched yeast *vs* other sources	---	1.000	0.603	0.913	0.490	0.439	0.433	0.491	0.656	0.898

†Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source + yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.
‡LDL: Low Density Lipoprotein, HDL: High Density Lipoprotein.
‡Standard error of means ((n = 10) per treatment).

Table 6. Effect of supplemental dietary selenium on blood biochemical parameters of broilers at 42 day of age

Treatments	Se dose (mg /kg diet)	Albumin (g/dL)	Globulin (g/dL)	Total Protein (mg/dL)	Total Cholesterol (mg/dL)	Total Triglyceride (mg/dL)	HDL‡ (mg/dL)	LDL‡ (mg/dL)	Serum urea nitrogen (mg/dL)	Glucose (mg/dL)
Negative Control†	0.0	2.85	165.21	4.71	165.44	185.63^{a}	45.70	84.73	6.03	1.90
Positive control†	0.0	2.96	162.25	4.75	165.44	164.87^{ab}	43.58	86.12	6.01	1.75
AvailaSe	0.3	2.88	160.98	4.95	163.36	168.86^{ab}	47.45	82.14	6.32	2.07
SelMax	0.3	2.82	154.91	4.77	158.93	175.57^{abc}	43.65	80.17	6.21	1.94
Sel-Plex	0.3	2.76	158.92	4.89	155.56	155.85^{b}	43.05	81.34	5.71	2.12
Sodium Selenite	0.3	2.85	159.18	4.90	164.08	179.88^{ab}	44.86	83.24	5.98	2.05
Sodium Selenate	0.3	2.87	173.65	4.44	169.87	163.03^{ab}	44.52	92.75	6.13	1.57
Selenium enriched yeast	0.3	2.78	164.24	4.81	159.50	164.07^{ab}	42.34	84.35	5.60	2.03
*SEM**	---	0.021	1.730	0.051	1.775	2.515	0.528	1.500	0.086	0.052
P-values	---	0.317	0.179	0.297	0.619	0.041	0.313	0.576	0.464	0.095
Orthogonal contrasts										
Presence or absence of Se	--	0.930	0.249	0.343	0.626	0.526	0.208	0.233	0.083	0.340
Se sources	--	0.206	0.081	0.420	0.314	0.026	0.666	0.501	0.771	0.170
Selenium enriched yeast vs other sources	--	0.057	0.527	0.979	0.873	0.030	0.850	0.682	0.718	0.392

$^{a-c}$ Means value within the same column sharing a common superscript letter are not statistically at P< 0.05.

†Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source + yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.

‡LDL: Low Density Lipoprotein, HDL: High Density Lipoprotein;

*Standard error of means ((n = 10) per treatment).

Table 7. Effect of supplemental dietary selenium on GPx[1] activity and H/L of broilers at 24 and 42 day of age

Treatments[2]	Se dose (mg /kg diet)	24 d		42 d	
		GPx‡ activity (U/mg protein)	H/L	GPx‡ activity (U/mg protein)	H/L
Negative control†	0.0	190.11[b]	0.842[a]	681.37	0.806
Positive control†	0.0	196.63[b]	0. 419[b]	681.37	0.442[b]
Availa Se	0.3	651.09[a]	0.352[b]	653.61	0.361[b]
SelMax	0.3	672.12[a]	0.303[b]	631.74	0.341[b]
Sel-Plex	0.3	746.99[a]	0.323[b]	689.78	0.382[b]
Sodium Selenite	0.3	676.32[a]	0.346[b]	674.64	0.354[b]
Sodium Selenate	0.3	730.16[a]	0.333[b]	699.88	0.323[b]
Selenium enriched yeast	0.3	682.21[a]	0.312[b]	668.75	0.330[b]
*SEM**	---	37.10	0.030	9.590	0.030
P-values	---	<0.0001	<0.0001	0.764	<0.0001
Orthogonal contrasts					
Presence or absence of Se	---	<0.0001	0.492	0.092	0.441
Se sources	---	<0.0001	<0.0001	0.858	<0.0001
Selenium enriched yeast *vs* other sources	---	0.432	0.667	0.993	0.534

[a-b] Means value within the same column sharing a common superscript letter are not statistically at P< 0.05.

[1]GPx, glutathione peroxidase; H/L, heterophile to lymphocyte ratio.

†Treatment groups: The negative control group without added selenium source; The positive control group without added selenium source + yeast without selenium. Except for positive and negative control groups, in other treatments the only difference is the type of selenium sources used.

‡Glutathione peroxidase

*Standard error of means ((n = 10) per treatment).

Discussion

The results of the present study in both ANOVA and orthogonal contrasts showed that dietary supplementation of Se had no effect on the growth performance of broilers, which was in agreement with those of others (Spears *et al*., 2003; Yoon *et al*., 2007; Peric *et al*., 2009; Oliveira *et al*., 2014). In other words, Se supplementation either with organic or inorganic forms did not have any significant effect on BWG, FI, and FCR. However, in another study, FCR and BWG improved in broiler chickens fed diets supplemented with Se enriched yeast (Krstic *et al*., 2012). No significant difference observed in the present study regarding BWG and FCR might be due to feeding the balanced diet including adequate nutrients (Lesson and Summers, 2001). The non-effect of Se on performance of the chickens might also be due to the fact that Se has no direct role on BWG and FCR, especially when birds reared under normal conditions without stress. The growth response of birds to Se supplementation can be influenced by the birds' stress level, and the stressed birds are more responsive (Surai, 2006; Seven *et al*., 2009). The variation in the results could contribute to the differences in the chicken strains used in various experiments, the concentration of Se in the basal diet, analytical techniques, composition of diets, seasons, maintenance, and weather conditions during the rearing periods.

Serum samples did not show any significant effect on the measured indices. However, the content of triglycerides at day 42, showed significant difference among treatments ($P < 0.05$). The highest and the lowest content of total triglycerides were seen in positive and Sel-Plex fed birds, respectively. Yang *et al*. (2012) showed that chickens fed diet containing 0.3 mg/kg organic Se had no significant effect on their total cholesterol when the serum samples were compared to those fed diet without Se supplementation.

Brewer's yeast is a rich source of Se. This yeast when cultivated in a medium containing Se, converts Se to selenomethionine, which is efficiently absorbed and retained in the rat body as compared to inorganic Se salts such as sodium selenite (Amany and Badawy, 2010).

Se supplementation decreased serum total cholesterol and triglyceride levels in rabbits

(Kang *et al*., 2000). Yang *et al*. (2012) observed that addition of 0.3 mg/kg organic Se added to the diet of broilers showed no insignificant effect on serum globulin, glucose, total cholesterol, LDL-c, HDL-c, serum urea nitrogen, and total protein levels when compared to that of control group.

No effect of ingredients on blood glucose is already described by others (Collin *et al*., 2003; Swennen *et al*., 2005, 2006). They suggested that the lack of diet ingredients effect on blood glucose levels is probably due to the strict adjustment of carbohydrate metabolism in broilers. The blood glucose levels retain constant, even when broilers are submitted to fasting (Swennen *et al.*, 2007).

In contrast to the results of this study, it is reported that the addition of SeF as nanoparticles at 0.3 mg/kg level in layer chicks up to 8 week of post hatch significantly elevated serum glucose, albumin, globulin, urea nitrogen, and total protein and decreased cholesterol and triglycerides levels when compared to that of control treatment (Mohapatra *et al*., 2014). Sodium selenite supplementation as nanoparticles to male Wistar rat diet at the level of 150 ng/kg Se increased serum globulin levels and decreased albumin/globulin ratio, which are sign of stimulatory effect on the immune status in the animals (Bunglavan *et al*., 2014).

The results showed that diet supplementation with Se increased the GPx activity. The highest GPx activity was related to the birds received Se and the lowest GPx activity was related to the positive and negative control treatments. Addition of Se in either organic or inorganic sources to diet significantly affected GPx activity compared to those of the birds fed diet without Se.

This result is in agreement with those of others (Spears *et al*., 2003). They indicated that Se supplementation improved GPx activity in comparison to those of birds fed diet without Se. Sodium selenite elevates GPx activity and could play a critical role in controlling free radical damage in poultry (Choct *et al*., 2004). Some researchers showed that the addition of organic Se source in diet of broilers significantly elevated plasma GPx activity and hence improved antioxidant activity (Khajali *et al*., 2010; Markovic *et al*., 2018). Methionine moiety can also be changed to cysteine which in turn, changes to glutathione (GSH). Both GSH and cysteine can operate as direct scavengers of reactive oxygen species (ROS) and maintain proteins from oxidative damage (Mallis *et al*., 2002). Antioxidant defense systems remove ROS to prevent the oxidative stress. GPx catalyze the decrement of hydrogen peroxide and organic hydroperoxides, thus preserve cells from oxidative damage (Papp *et al*., 2007). Jun *et al*. (2011) reported a more mortality, less serum GPx activity, and histopathological changes in the mice fed a Se deficient diet.

In orthogonal comparisons, addition of SEY had no significant impact on GPx activity when compared with those of other Se sources. According to the proposed metabolic pathways for Se (Sunde, 1997), no significant effect for GPx activity from SEY group in comparison with inorganic Se sources was observed. Apart from Se sources, it needs to be converted to selenocysteine before incorporated into the GPx enzyme (Forstrom *et al*., 1978). Supplementation of diets by sodium selenite significantly improved GPx activity in red blood cells of the chickens and this effect was higher than that of organic Se (Choct *et al*., 2004). Payne & Southern (2005) noticed that organic and inorganic sources of Se did not have any effects on performance, carcass traits and GPx activity in broilers.

Supplementation of the diets with Se sources decreased H/L. Tayeb and Qader (2012) showed that addition of 0.45mg Se along with 100mg vitamin E/kg diet of broiler significantly increased lymphocytes, when compared to that of control group received no Se and vitamin E. Boiago (2006) described that these results might be due to a stronger immune system, higher leukocytosis and finally, better humeral and cell-mediated responses against pathogens. Basmacioglu *et al* (2009) reported that Se improves immune responses possibly through higher GPx activity which may protect organelles and maintain the membranes and organelles of the lymphocytes from the harmful effects of pro-oxidants and/or changing of Arachidonic acid metabolism to prostaglandin precursors or related compounds which cause

more immune responses by reducing the endogenous production of prostaglandin.

In the present study, addition of 0.3 mg Se from yeast/kg diet improved immune response when compared with that of negative group. Unicellular eukaryotes, yeast fungi and also Saccharomyces, have been used as models for many researches in various fields of biotechnology and medicine. Saccharomyces specious of Saccharomyces cerevisiae and Saccharomyces Boulardii are accepted and believed as probiotics. The result of many studies showed that orally ingestion of a component of yeast cell wall, such as yeast beta glucan, stimulates the immune system (macrophages) and help to inhibit bacterial infections.

Conclusion

Under the conditions of this study, it was concluded that supplementation of corn-soy diet with either organic or inorganic Se at the rate of 0.3 mg/kg diet had no significant effects on performance and blood biochemical indices of broiler chickens. All organic and inorganic Se sources improved GPx activity and H/L ratio. This study proved that the locally produced SEY is comparable to those commonly used Se sources in the market. SEY did not show any negative effect on the parameters evaluated in this study. Therefore, locally produced SEY can effectively be used in broiler diets.

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