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IMPACT OF SELENIUM SOURCES ON PRODUCTIVE AND PHYSIOLOGICAL PERFORMANCE OF BROILERS

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ABSTRACT:A total number of 210 unsexed (Arbor Acres) broiler chicks at 7 day of age were used to investigate the effects of different sources of Selenium *i.e.* inorganic (Sodium selenite (SS), organic (*Saccharomyces cerevisiae* with Se and Zn / Se-Methionine/Se-Glycine/ Se-Yeast and *Saccharomyces cerevisiae* with Se) on the productive performance, blood hematological and biochemical constituents and immune response of broiler chicks. Experimental chicks were randomly divided into seven dietary treatments with six replicate cages per treatment, five chicks each. The first group was fed the basal diet without supplementation (control); while the 2nd, 3rd, 4th, 5th, 6th and 7th groups were fed basal diet supplemented with 100 ppm/kg diet of the above mentioned Se sources, respectively. Results showed that chicks fed the basal diet supplemented with different sources of Se had significantly better BW, BWG and FCR compared with control group. Organic Se supplementation improved growth performance of broilers compared with the inorganic one. Supplementation of different Se sources decreased serum levels of cholesterol and LDL, whereas RBCs count, hemoglobin, PCV, glucose, globulin, thyroid hormones, immune response (IgA- IgM, IgG), and antioxidant enzymes activity were significantly increased compared with the control. In conclusion, Se supplementation improved the growth performance, immune response and physiological status of broiler chickens. Broilers fed organic Se-supplemented diets had better growth performance and immune response than those fed inorganic selenium.

Key words: Selenium source, Broiler, Performance, Blood parameters, Immune response.

INTRODUCTION

Poultry industry is facing many challenges in the developing world concerning the improvement in production and reproduction (Zia *et al.*, 2017b).

Selenium (Se) has been reported as an important essential dietary supplement for improving the bird's performance and health and improvement of meat quality (Haug *et al.,* 2007). Selenium has been recognized as an integral part of over thirty special selenoproteins, Such as glutathione peroxidase enzyme (Zia *et al.*, 2016). It is a constituent of a glutathione peroxidase (GPx), an antioxidant enzyme, which plays an important role for preventing the formation of free radicals. It has been found that there is a significant positive correlation between Se level and GPx activity in most tissues (Madkour *et al.*, 2015 and Zia, *et al.*, 2016). Zhang *et al.* (2012) found a decrease in GSH-Px activity using low level of Se in diet. Moreover, Se is necessary in the diets of poultry to protect them from pancreatic fibrosis and exudative diathesis. Therefore, poultry diets need to supplementary Se to provide a safety margin against deficiency and to maintain better productive performance, ensure health and good meat quality (Deniz *et al.,* 2005 and Göçmen *et al.*, 2016). There are 2 major types of Se in the diet, i.e., organic Se and inorganic. Both, have the positive impact on the performance of poultry, however, organic source (Se-yeast) has found more effective compared to the inorganic source of Se (Mikulski *et al.*, 2009). In this respect, studies showed that Seleno-amino acids are absorbed by the same active-transport mechanism used for protein absorption, and therefore more available to the body than inorganic Se sources. In addition, it promotes lower Se excretion in the environment (Pappas *et al.,* 2005 and Wang *et al.,* 2009). Yang *et al.* (2012) indicates that organic Se had increased growth performance when compared with the inorganic Se. In addition, dietary organic Se supplementation significantly improved daily gain compared with birds fed diets supplemented with inorganic Se (Bakhshalinejad *et al*., 2018). Choupani *et al.* (2014) and Zia *et al.* (2017a) found that Se-yeast of grower diets increased the weight of live chickens significantly ($p < 0.01$). Moreover, Zhou and Wang (2011) indicated an improvement of production performance by organic Se supplementation. Moreover, Ibrahim *et al*. (2019) found that the groups of broiler chicks supplemented with Se-meth showed an increase in growth performance when compared with sodium selenite (SS). Sundu *et al.* (2019) indicated that organic Se (Sel-plex) led to an increase in BWG of broiler chickens. Se-yeast has a higher bioavailability when compared with the inorganic Se (Wu *et al.*, 2011 and Ahmad *et al*., 2012). On the other hand, Zia *et al.* (2017b) and Meng *et al*.(2019) studied the mean values of different blood biochemical constituents and found that the increased level of serum total protein, glucose and (GSH-Px) was observed in Se-yeast and in SS fed groups than control.

The dietary prerequisite of poultry for Se regularly can be met by common feedstuffs in the diets, however these feedstuffs vary widely in Se level relying upon the region that they are grown. Consequently, it is a typical practice in poultry production to enhance diets with Se. One of the most widely recognized Se enhancements utilized is sodium selenite (SS), an inorganic source of Se. On the other hand, in 2000, the Food and Drug Administration (FDA) approved the utilization of an organic Se source in poultry diets (FDA, 2000). Therefore, the objectives of this research were to compare inorganic and organic Se sources to assess their effects on productive performance, nutrient digestibility, blood hematological and biochemical constituents, immune response and economic traits of broiler chicks

MATERIALS AND METHODS

The present study was carried out at the Animal and Poultry Research Centre of the Animal and Poultry Production Department, Faculty of Agriculture (El-Bostan Farm), Damanhour University, during the period from October to November 2018. The main objective of the study was to evaluate the effect of dietary supplementation of different sources of selenium (inorganic and organic) on productive performance, blood hematological and biochemical constituents, and immune response of broiler chicks.

2.1 Chicks and Se supplements

A total number of 210 unsexed broiler chickens (Arbor Acres) at 7 days of age, obtained from a commercial hatchery were randomly distributed into seven groups, each of five replicates, six birds per replicate. They were reared in similar hygienic and managerial conditions. After the first week, chicks were submitted to seven dietary treatment groups. The first group was fed the basal diet without supplementation (control); while the 2nd, 3rd, 4th, 5th, 6th and 7th groups were fed basal diet supplemented with 100 ppm/kg diet of Se-inorganic (S.S), *Saccharomyces cerevisiae* with Se and Zn, Se-Meth, Se-Glycine, Se-Yeast and *Saccharomyces cerevisiae* with Se (S.C), respectively. The experimental diets were formulated according to the strain management guide as shown in Table 1.

2.2 Housing and husbandry

Chicks were housed in breeding pens in semi-opened house. They were fed, *ad libitum*, the experimental diets and given free access to water. A light schedule similar to commercial condition was 23 h light until 7th day followed by 20 h light from the 8th day until the end of the experimental period was provided. Average outdoor minimum and maximum temperature and relative humidity during the experimental period was 20C^{o} and 27 C^{o} and 55.7 % and 58.7%, respectively. The brooding temperature (indoor) was declined gradually, being 32, 30, 27 and 24-21 C^{o} during 1-7, 8-14, 15-20 and 21-35 days of age, respectively.

2.3. Data collection:

Performance parameters including individual live body weight (LBW, g) and feed intake (FI, g) were recorded weekly throughout the trial period (7-35 d of age). For each replicate within treatment groups, body weight gain (BWG, g) and feed conversion ratio (FCR) was estimated.

Apparent digestibility of dry matter, crude protein, ether extract and crude fiber were done using five birds per treatment housed individually in metabolic cages using total collection method as cited by Abou-Raya and Galal (1971). Nitrogen, ether extract, crude fiber and dry matter of the excreta as well as those of feed were determined according to AOAC (2004). Economical evaluation for all experimental treatment diets was made according to Zeweil, *(*1996). At 35 d of age, serum samples were collected from three birds per each treatment to determine some blood constituents in terms of glucose concentration (mg/dl) according to Trinder (1969), total protein (Henry *et al.*, 1974), albumin (Doumas, 1971), globulin and its fractions (α-globulin, β-globulin and γ-globulin) according to Bossuyt *et al.* (2003). In addition, serum samples were assigned for determination of creatinine and uric acid (Bartles *et al.*, 1972), total cholesterol (Stein, 1986), triglycerides (Fossati and Prencipe, 1982), while LDL was determined according to Friedewald *et al.(*1972) and HDL according to (Lopez-Virella, 1977). The activity of serum aspartate amino transferase, and serum alanine amino transferase, were estimated according to Reitman and Frankle (1957).

Besides, six blood samples were collected from each treatment in heparinized tubes to determine the number of red blood cells, white blood cells and different types of leukocytes. Packed cell volume (%), Hemoglobin concentration and red cell indices (MCH and MCHC) were determined according to the following equations:

Mean Corpuscular Hemoglobin (MCH, Pg) = HbX10/ Red blood cell

Mean Corpuscular Hemoglobin Concentration (MCHC, g/dl) = HbX100/ Packed cell volume.

Total antioxidant capacity was determined according to Koracevic *et al.* (2001), Superoxide dismutase activity (Misra and Fridovich, 1972), Glutathione peroxidase activity (Paglia and Valentine, 1967) and Glutathione concentration (Ellman, 1959).Phagocytic activity and index were determined according to Kawahara *et al.* (1991). Phagocytic activity (PA) = Percentage of phagocytic cells containing yeast cells. Phagocytic index (PI) = Number of yeast cell phagocytized/ Number of phagocytic cells.

Alkaline phosphatase (ALP) activity was determined according to the colorimetric method of Bauer *et al.*(1982). Serum immunoglobulins (IgY, IgM and IgA) were determined using commercial ELISA kits (Kamiya Biomedical Company, USA) according to Bianchi *et al.* (1995). Lymphocyte transformation test was determined following the method described by Balhaa *et al.* (1985). Serum bactericidal activity to *Aeromonas hydrophila* strain was determined according to Rainger and Rowley (1993). Serum lysozyme activity was measured with the turbidimetric method described by Engstad *et al.* (1992) and the results are expressed as one unit of lysozyme activity that defined as a reduction in absorbance at 0.001/min. Lysozyme activity = (A0 - A) / A.

All measurements were conducted according to the manufacturer's instructions.

2.4 Statistical analysis

Data were analyzed by the GLM procedure (Statistical Analysis System **(SAS),**2002) using one-way ANOVA with the following model: Yijk= μ+ Ti + eijk , Where :

Y is the dependent variable; μ is the general mean; T is the effect of experimental treatments; e is the experimental random error.

Noting that before analysis, all percentages were subjected to logarithmic transformation ($\log_{10}x+1$) to normalize data distribution. The differences among means were determined using Duncan's new multiple range test (Duncan,1955) at $P<0.05$.

3. Results and Discussion

3.1 The performance traits:

The growth performance of broilers that fed diets supplemented with different sources of Se during 7 to 35 d of age are shown in Table 2. Initial BW of broiler chicks was similar for all treatments. Chicks fed diets supplemented with either Se-organic or Se-inorganic significantly recorded higher BW compared to control diet (basal diet) at 35d of age. Moreover, broiler chicks fed diet with Se-Meth, Se-Glycine, Se-Yeast and SC with Se had significantly greater BWG during 7-35 d of age. In general, organic Se supplementation has improved BWG of broilers during the whole experiment period (7-35 d of age). Results indicated that organic-Se increased FI of broiler during period compared with inorganic-Se and control group. Therefore, chicks having either Se-organic or Se-inorganic had significantly better FCR compared to control diet (basal diet) all over the experimental period. Among the experimental groups, the diet with Se-Meth, Se-Yeast and SC with Se had significantly better FI followed by those fed diet with Se-Glycine, SC with Se-Zn and Se-inorganic compared to the control group. Therefore, chicks fed basal diet supplemented with different sources of Se had significantly better economic efficiency than the control group. Moreover, organic Se supplementation improved economic efficiency compared with inorganic Se and control. The positive effect of Se on BW of treated groups could be attributed to the role of Se in body metabolism and growth, since it has been shown to create an integral part of the deiodinases (Zhang *et al*.,2011), where the iodothyronine deiodinases enzymes convert the pro-hormone T4 to T3 being the active form (Chun *et al*.,2009) which is significant for normal growth and development in birds (Ankur and Baghel,2011). Also, T3 hormone is a main hormone which regulates growth by dominating the body's energy and protein anabolism (Preter,2000).

The obtained results are in agreement with those of Sevcikova *et al. (*2006) who found that organic Se supplementation improved growth performance of broiler chicken compared with the inorganic Se. Upton *et al.* (2008) indicated that BW of broilers significantly increased when they were given diets with 0.2 mg/kg of organic Se compared with those given diet with inorganic Se in addition to the control diet. Zhou and Wang (2011) indicated an improvement of production performance by organic Se supplementation. Also, Yang *et al.* (2012) indicates that organic Se had increased growth performance when compared with the inorganic Se. In addition, dietary organic Se supplementation significantly improved daily gain compared with birds fed diets supplemented with inorganic Se (Bakhshalinejad *et al*., 2018). In this respect, Sundu *et al.* (2019) indicated that organic Se (Sel-plex) led to an increase in BWG of broiler chickens. Moreover, it has been reported that BW improved in chicken reared under the heat stress by using diet supplemented with Se (Niu *et al*., 2009 and Ibrahim *et al*., 2011). Such improvement may be due to the fact that organic Se is more bioavailable than inorganic Se (Edens *et al.*, 2001) which obviously resulted in enhanced BW. Similarly, it is claimed that increased BW is linked to using organic Se in the diet of broilers (Salman *et al.*, 2007).

On the other hand, several researchers reported that Se supplementation did not influence ($P > 0.05$) the growth performance of broiler chickens during the experimental period (Wang *et al*., 2011; Ahmad *et al*., 2012; Chen *et al*., 2013; Rao *et al*., 2013; Li *et al*., 2017 and

Bakhshalinejad *et al*., 2019).The reason for the contradiction among the results might be due to the result of the difference in the species used, age of birds, duration and the amount of Se added to the diet.

3.2. Apparent digestibility of nutrients:

Data concerning the effects of Se source on the apparent digestibility of the nutrients of broilers are shown in Table 3. Basal diet supplemented with both of Se-organic and Se-inorganic significantly increased the digestibility of crude protein (CP) compared to control diet (basal diet). Basal diet supplemented with Se-organic significantly increased the ether extract compared to control diet (basal diet). However, there were no significant effects of different Se sources on crude fiber (CF) digestibility. Broiler fed diet with Se-Meth, Se-Glycine, Se-Yeast and SC with Se had significantly greater dry matter (DM) digestibility followed by those fed basal diet supplemented with SC-Se.Zn in addition to the Se-inorganic compared to the control . These results are in consistent with Edens (2001) who indicated that Sel-plex supplementation in the diet increased DM digestibility of the diets fed to broiler chickens. The authors also found that DM digestibility of the diets increased from 74.4 to 82.4%.On the other hand, Amer *et al.* (2018) showed insignificant differences on digestion coefficient for DM, OM, and CP between the Se treated groups and control group. Also, no significant differences in the digestion coefficient of DM, OM, and CP were observed between the organic and inorganic source of Se. In this connection, Sundu *et al.* (2019) reported that there was no increase in DM digestibility when the diets were supplemented with Se from different sources.

3.3. The blood hematological criteria:

The blood hematological criteria of broilers fed diet supplemented with different Se sources at 35 day of age are shown in Table 4 . Chicks fed basal diet supplemented with Se-organic and Se-inorganic had significantly better RBC's, Hb and PCV compared to the control group. The basal diet supplemented with either Se-organic or Se-inorganic significantly increased the percentage of lymphocytes compared to control diet. There were no significant differences in White blood cells WBC's differential leukocytes counts between different sources of Se , however, the differences were significant compared to the control. In this connection, El-Sheikh *et al.* (2010) showed that overall means of blood hemoglobin (Hb), RBC`s and WBC`s were increased in chicken fed diets with Se compared with those fed control diet. ElSebai (2000) and Abaza (2002) found that WBC's or RBC's counts increased by using Se supplementation to diets of chickens. Organic Se play important role for increasing number of lymphocytes therefore improve immune system (Fisinin *et al*., 2008). Moreover, Hanafy *et al.* (2009) found that Se supplementation increased values of Hb, RBC`s and WBC`s in Se groups compared with those in the control group. While, Boostani *et al*.,(2015) found that dietary Se supplementation (organic or Inorganic) had no significant effect on Hb, RBC's and WBC's in broiler chickens. The reason for the contradiction among the results might be due to the difference in the species used, age of animals, duration and the amount of Se addition to the diet.

3.4. Biochemical constituents of blood:

3.4.1. Protein profile, glucose and thyroid hormones:

The blood serum proteins of broiler fed diet supplemented with different sources of Se at 35 day of age are shown in Table 5. Organic Se supplementation group gave significantly higher total protein than the other groups. Moreover, Se–organic supplementation significantly decreased globulin. Also, broiler fed basal diet supplemented with Se Meth, Se-Glycine, Se-yeast and S.C with Se had significantly greater α–globulin, β– globulin, γ –Globulin followed by those fed diet with S.C, Se-Zn and Se-inorganic compared to the control group. In this connection, Ramezani *et al.* (2011) reported that increased total protein of blood ($P \leq 0.05$) was observed because using Se supplementation. Also, there was increase in the blood protein, globulin and albumin due to overall effect of 0.1 ppm Se and the values are 466g/dl, 1.66g/dl, 3.00g/dl and 0.56, respectively (Naik, 2012). Also, El-Deep *et al.* (2017) showed that total protein was increased by dietary all types of Se source. Attia *et al.* (2010) found that Se supplementation significantly decreased albumin and globulin on layer. On the other hand, Yang *et al.* (2012) found that the total protein, globulin and glucose concentration were observed to be insignificant when compared between Se supplemented and control group in chicks. Inorganic or organic Se supplementation increased serum glutathione peroxidase concentration ($P<0.05$) but, did not affect blood total protein and albumin, with respect to control (Invernizzi *et al.*, 2013).

Serum content of glucose and thyroid hormones of broiler fed diet with Se supplementation at 35 day of age are shown in Table 5. Organic Se supplementation increased glucose than the control group, while, T_3 and T_4 concentrations were significantly higher in all Se sources compared to the control. Also, Se-Meth, Se-Glycine and Se-Yeast and S.C with Se supplementation groups gave significantly higher T_3 concentrations than other treated groups and the control. Similarly, Zia *et al.* (2017b) demonstrates that the increased ($P \leq 0.05$) level of glucose was observed in Se-yeast and in SS fed groups than control. Also, Upton *et al.* (2008) found that serum T3 level was higher in chickens fed diet with Sel-Plex™ compared to those fed a basal diet. Also, Choct *et al.* (2004) and Upton *et al.* (2008) reported that serum T3 concentration was higher in broiler chickens supplemented with Sel-Plex™ compared to those in birds fed a basal diet. In addition, Srimongkol (2003) and Choupani *et al*., (2014) reported that Se supplementation increased T3 than in the unsupplemented control group. El-Sheikh *et al.* (2010) also showed that overall means of T3 were significantly increased in Se treated groups than the control group of chicken.

3.4.2. Renal and liver function tests:

Data concerning the effects of Se sources on renal and liver functional of broiler fed diet with different sources of Se at 35 day of age are shown in **Table 5** .Additions of organic and inorganic sources of Se to the feed had a significantly lower ALT in blood plasma compared with the control group. While, AST was significantly lower in Se-organic groups than the control group. Also, S.C with Se supplementation group gave significantly lower Uric acid concentrations in plasma than the other

Se supplementation group compared with the control group. However, there was no significant effect of the different sources of Se supplementation on ALT/AST, Creatinine, Uric acid and alkaline phosphatase in blood serum. The present results are in agreement with those obtained by Peric *et al.* (2009) demonstrating that the levels of ALT and AST were decreased with the supplementation of Se. Decreased level of ALT and AST and creatinine values were noted in the birds exposed to Se-yeast supplemented diet in contrast to SS treated or those fed control diet (Zia *et al*., 2017b). Also, Yang *et al.* (2012) found that the AST, alkaline phosphatase and urea concentrations were observed to be insignificant when compared between Se supplemented and control group in chicks. On the other hand, Selim *et al*. (2015) and Ibrahim *et al*. (2019) showed that the activity of liver enzymes of Ross broiler chickens including ALT and AST were not significantly affected by the interaction between different sources of Se. In addition, Yang *et al*. (2012) observed that Se (organic or inorganic) didn't affected liver enzymes. Moreover, Inorganic and organic Se supplementation did not affect ALT and AST activity or the serum antioxidant capacity of turkey (Mikulski *et al*., 2009).

3.4.3. Lipids profile:

Data concerning the effects of Se sources on the blood serum lipid profile of broiler at 35 day of age are shown in **Table 5**. Additions of organic and inorganic sources of Se to the feed had a significantly lowers , cholesterol and triglycerides in blood serum compared with the control group. In addition, chicks fed basal diet supplemented with Se-Glycine had significantly the lowest low-density lipoprotein (LDL). On the other hand, there was no significant effect of the different sources of Se supplementation on the high-density lipoprotein (HDL) in blood. Similarly, Yang *et al.* (2012) revealed that the HDL concentration were observed to be insignificant when compared between Se supplemented and control group in chicks. Data obtained herein confirmed those obtained by Ferit *et al.* (2003) that cholesterol levels reduced as a result of Se supplementation. In addition, Ljubic *et al.* (2006) found that the organic Se supplementation decreasing the total cholesterol level during the fattening period and increasing the free cholesterol level after 48 h feed deprivation. Also, decreased triglycerides levels has been observed as a result of Se addition (Ramezani *et al*., 2011). Also, it has been reported that Se addition lowered the total cholesterol in blood serum (Attia *et al*., 2010 and Bunglavan *et al*., 2014). However, Zia *et al.* (2017b) found that serum triglycerides level in the birds received Se-yeast added diet was enhanced compared to those got inorganic Se-treated or control diet. Moreover, Yang *et al.* (2012) and Invernizzi *et al.* (2013) revealed that total cholesterol and triglycerides concentrations were observed to be insignificant when compared between Se supplemented and control group in chicks.

3.4.4. Antioxidative defense indicators:

The blood serum antioxidant enzymes of broiler fed diet supplemented with different sources of Se at 35 day of age are shown in **Table 6** .Chicks fed basal diet supplemented organic Se groups significantly increased superoxide dismutase (SOD) activity and GSH concentration compared with those fed inorganic Se and control group.

However, there were no significant effects among inorganic Se and organic Se groups in GPX activity. Moreover, broilers fed basal diet supplemented with either Se-organic or Se-inorganic sources had significantly higher TAOC activity and lower Malondialdehyde (MDA) values compared with those fed the control diet. Our findings on GSH-Px are in agreement with Yoon *et al*. (2007); Wang and Xu (2008) and Ebeid *et al*. (2013) who showed that dietary Se supplementation improves antioxidant status by activating GSH-Px. Also. Se supplementation could significantly improve blood glutathione peroxidase activity and enhance oxidation resistance of broilers (Cai *et al*., 2012; Oliveira *et al*., 2014). In this respect, Gajčević *et a*l. (2009), Dalto *et al*. (2015) indicated that GPX activity increased by using the Se-supplements. Also, the serum GSH-Px activity was significantly increased when Se was supplemented to the control diet (Invernizzi *et al*., 2013). Okunlola *et al*. (2015) also noted that GPx activity increased with both organic and inorganic supplements of Se. It has been found by Chen *et al*. (2013) that supplementation with 0.3 mg/kg Se-yeast led to increased GSH-Px and SOD activities in serum relative to 0.3 mg/kg SS supplementation. Moreover, Bakhshalinejad *et al*., (2018) showed that the GSH-Px and TAC were improved by using supplementation with organic Se sources. In addition, Moslehi *et al*. (2019) observed that glutathione peroxidase activity was increased by supplementation of Se (organic and inorganic). Also Birds fed Se-yeast had increased TAOC compared with birds that had not received supplemental Se ($P<0.01$). In contrast to the results obtained, there were no significant differences among Se sources or levels in GPX3 activity (Payne and Southern, 2005a,b) and SOD activity (Moslehi *et al*., 2019). Moreover, D-Se-meth supplementation was more effective ($p<0.01$) in increasing blood GSH level and decreasing breast muscle malondialdehyde (MDA) level than SS. The GSH-Px were improved by using supplementation of organic Se sources (Bakhshalinejad *et al*., 2018).

3.4.5 Immune response indices:

The blood serum Immune indices of broiler fed diets supplemented with different sources of Se at 35 day of age are shown in **Table 7**.

Feeding broiler basal diet supplemented with Se-organic and Se-inorganic significantly increased P.A, B.A, and IgM compared with those fed the control diet. Chicks fed basal diet supplemented with Se-organic groups significantly increased P.I, L.T.T, L.A and IgG in blood compared with those fed the control diet. In addition, the highest IgA was in broiler fed Se-Meth and Se-Glycine followed by those fed basal diet supplemented with SC with Se, SC with Se-Zn, Se-Yeast and Se-inorganic compared to the control group. In this study, IgM and IgG concentrations in response to anti-sheep red blood cell (SRBC) were significantly higher in groups with organic Se than those having the inorganic Se as well as the control diet. In this respect, dietary organic Se supplementation increased total anti-SRBC and IgG titres (Cai *et al*., 2012 and Zamani Moghaddam *et al*., 2017). Moslehi *et al*., (2019) showed that IgM was greater in hens fed diets containing SS and Se-yeast than those fed control diet ($P<0.05$). Madron and Vrzgulova (1988) found that Se supplementation improved the immune system and raised the natural resistant of animals by increasing response of the organism to antigenic stimuli. Also, Hegazy and Adachi (2000), Schrauzer (2000) and DengHua *et al.* (2001) reported an increase in humoral antibody titers by using Se in feed, the perceptible reason for improved antibody production is the increase in number of lymphocytes with increased Se supplementation. Moreover, Boostani *et al*. (2015) found that the highest serum IgM levels were observed for unstressed birds which given organic Se. Besides, organic Se supplementation led to better production performance and immune response than the inorganic one (Bakhshalinejad *et al*., 2018).

Table (1): Composition and calculated analysis of experimental diets fed to broiler chicks from 7 to 35 days of age.

Ingredients (%)	**Starter diet (7 to 21 d of age)**	**Growing diet (22 to 35 d of age)**
Yellow Corn	57.60	61.00
Soybean Meal (48%)	29.50	26.00
Corn gluten meal (60%)	5.20	6.00
Soy oil	1.10	2.70
Full fat soya bean	2.00	0.00
Mono calcium Phosphate	1.50	1.65
Lime stone	1.90	1.50
Choline chloride	0.10	0.10
Sodium Bicarbonate	0.20	0.20
Salt (Na Cl)	0.20	0.20
DL –methionine	0.10	0.10
L-lysine HCl	0.30	0.25
Broiler Premix *	0.30	0.30
Total	100	100
Calculated analysis (on DM basis)* **		
Crude Protein, %	22.9	21.4
ME (kcal/kg) **	3042	3147
Ether extract, %	4.10	4.40
Calcium, %	1.05	0.90
Available phosphorus, %	0.51	0.43
Methionine, %	0.50	0.46
Lysine, %	1.40	1.23
Methionine + Cystine, %	0.98	0.89

* Each kg premix contains: vit. A (12 I.U.), vit. D3 (5 I.U.), vit. E (75 I.U.), vit. K menadione (2 mg), vit. B1 (2 mg), vit. B2 (6 mg), vit. B6 (4 mg), vit. B12 (0.016 mg), Pantathenic acid (13 mg), Nicotinic acid (55 mg), Folic acid (2 mg), Biotin (0.2 mg), Copper (16 mg), Iodine (1.25 mg), Iron (40 mg), Manganese (120 mg), Zinc (100 mg), Selenium (0.3 mg).

** ME=Metabolizable Energy *** According to NRC(1994)

Table (2): Effect of different selenium sources on the performance and economical efficiency of broiler chicks.

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-Yeast	SC	SEM	*P* value
B.W 7d	173	171	162	166	168	173	171	3.95	NS
B.W 35d	1666[b]	1789[ab]	1867[ab]	2000[a]	1994[a]	1940[a]	1950[a]	46.01	0.001
B.W.G 7- 35 d	1493[c]	1620[b]	1706[b]	1834[a]	1826[a]	1830[a]	1830[a]	467	0.001
FI 7-35	3267[a]	2996[b]	2888[c]	2775[c]	2784[c]	2811[c]	2874[c]	18.25	0. 002
FCR7-35	2.17[a]	1.85[b]	1.69[bc]	1.51[c]	1.52[c]	1.53[c]	1.57[c]	0.053	0.001
Total cost (L.E)	16.3[a]	14.93[b]	14.45[b]	13.90[c]	13.1[c]	14.1[b]	14.4[b]	0.449	0.001
Total revenue (L.E)	31.7	33.9	35.5	38.2	38.1	39.2	37.3	0.784	0.062
EE	0.945[c]	1.20[b]	1.34[a]	1.37[a]	1.37[a]	1.38[a]	1.36[a]	4.43	0.002
REE (%)	100[c]	139[b]	141[a]	144[a]	144[a]	146[a]	143[a]	--	--

[a,b,c] Means in the same row followed by different letters are significantly different at $p \leq 0.05$.SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite; B.W= Body weight,.B.W.G= Body weight gain, FI =Feed intake, FCR = feed conversion ratio.
EE = Economical efficiency ; REE = Relative economical efficiency
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Table (3): Effect of different selenium sources on the apparent digestibility of the nutrients(%)

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-yeast	SC	SEM	*P* value
Crude protein	66.11[b]	70.1[a]	73.4[a]	75.1[a]	79.9[a]	80.9[a]	81.0[a]	2.18	0.005
Ether extract	69.5[b]	63.4[b]	70.1[a]	75.9[a]	80.3[a]	81.3[a]	83.1[a]	9.19	0.001
Crude fiber	17.1	18.6	19. 3	17.9	19.8	18.6	20.1	1.09	0.098
Dry matter	66.9[c]	72.2[b]	70.8[b]	76.5[a]	75.9[a]	78.9[a]	76.5[a]	8.77	0.002

a,b,c Means in the same row followed by different letters are significantly different at $p \leq 0.05$ SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite.

Table (4): Effect of different Selenium sources on hematological criteria of broiler chicks fed different sources of Se.

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-yeast	SC	SEM	*P* value
RBC's(10^6/cmm3)	3.13^b	3.99^{ab}	4.53^a	4.46^a	4.36^a	4.31^a	4.23^a	0.501	0. 001
Hb (g/100ml)	9.33^b	11.6^{ab}	12.6^a	12.3^a	13.0^a	12.3^a	12.0^a	0.602	0. 002
PCV %	23.6^b	30.3^{ab}	36.3^a	35.0^a	37.0^a	36.6^a	34.3^a	2.22	0. 01
WBC's(10^3/mm^3)	24.6	28.3	28.3	26.0	27.0	26.3	27.6	0.671	NS
Lymphocytes (%)	40.6^b	45.3^a	45.3^a	43.0^a	45.0^a	46.0^a	44.3^a	0.791	0.002
Monocytes (%)	16.6	16.0	16.0	16.3	16.0	16.33	16.00	0.482	NS
Eosinophils, (%)	0.660	0.330	0.330	0.330	0.660	1.00	0.990	0.273	NS
Heterophils, (%)	13.6	12.6	12.6	13.3	14.0	13.0	11.6	0.715	NS
Basophils, (%)	23.6	24.0	24.0	23.6	24.0	22.6	22.3	0.667	NS

a,b,c Means in the same row followed by different letters are significantly different at $p \leq 0.05$.SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite; RBC's, red blood cell; PCV, packed cell volume; MCH, mean corpuscular hemoglobin; MCV, Mean cell volume, MCHC, Mean Corpuscular Hemoglobin Concentration

Tble (5): Effect of different selenium sources on blood biochemical criteria of broiler chicks.

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-Yeast	SC	SEM	*P* value
Total Protein(mg/dl)	3.40^b	4.17^b	5.27^a	4.97^a	4.87^a	4.75^a	4.96^a	0.191	0. 001
Albumin(mg/dl)	1.50	1.34	1.76	1.44	1.43	1.35	1.51	0.092	0. 002
Globulin(mg/dl)	1.90^b	2.81^b	3.51^a	3.53^a	3.44^a	3.40^a	3.45^a	0.165	0. 001
α–globulin (g/dl)	0.830^c	1.13^b	1.19^b	1.39^a	1.29^a	1.31^a	1.28^a	0.021	0.003
β–globulin (g/dl)	0.867^c	1.11^b	1.16^b	1.29^a	1.30^a	1.26^a	1.31^a	0.041	0.002
γ-Globulin (g/dl)	0.349^c	0.565^b	0.691^b	0.855^a	0.844^a	0.837^a	0.860^a	0.066	0.001
Glucose(mg/dl)	180^b	188^{ab}	227^a	200^a	193^a	199^a	228^a	12.8	0. 001
T3(ng/dl)	0.900^c	1.17^b	1. 02^b	1.48^a	1.50^a	1.48^a	1.20^{ab}	0.081	0. 001
T4(ng/dl)	10.6^c	13.3^b	15.3^a	15.6^a	14.9^a	14.0^{ab}	15.0^a	0. 041	0. 001
ALT(U/L)	41.9^a	35.9^b	38.1^b	35.5^b	33.5^b	31.5^b	32.0^b	1.77	0. 002
AST (U/L)	62.3^a	62.3^a	56.8^b	56.5^b	58.0^b	57.5^b	59.5^b	10.0	0. 001
Uric acid, (mg/dl)	2.87^a	2.14^b	2.03^b	1.99^b	2.11^b	2.09^b	1.98^c	0.970	0. 002
Creatine (mg/dl)	0.880^a	0.571^b	0.712^b	0.663^b	0.576^b	0.747^b	0.692^b	0.091	**0. 001**
Alkaline phosphatase (U/100ml)	12.6	11.3	11.6	13.6	11.3	13.0	12.0	1.59	0. 09
Cholesterol (mg/dl)	133^a	106^b	112^b	103^b	100^b	101^b	117^b	6.96	0. 004
Triglycerides (mg/dl)	80.4^a	68.3^b	65.6^b	54.6^b	68.6^b	62.3^b	66.0^b	9.82	0. 002
HDL (mg/dl)	54.3	54.0	57.7	56.6	66.9	48.9	59.1	4.72	0. 086
LDL (mg/dl)	63.5^a	38.2^b	42.5^b	36.5^b	21.0^c	30.9^b	45.0^b	4.30	0. 003

a,b,c Means in the same column followed by different letters are significantly different at $p \leq 0.05$.SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite; HDL=high-density lipoprotein; LDL=low-density lipoprotein ; T3= triiodothyronine; T4=thyroxine.

Table (6): Effect of different Selenium sources on plasma antioxidants enzymes of broiler chicks.

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-Yeast	SC	SEM	*P* value
SOD(U/dl)	201[c]	221[b]	251[a]	247[a]	251[a]	250[a]	251[a]	1.39	0. 001
GSH(mg/dl)	957[b]	969[b]	984[a]	985[a]	988[a]	989[a]	983[a]	1.28	0.002
GPX(U/dl)	40.3[b]	47.0[a]	47.0[a]	44.0[a]	45.6[a]	47.3[a]	46.6[a]	0.871	0. 03
TAOC(mMol/dl /dl)	1.52[b]	2.07[a]	1.64[ab]	1.78[a]	1.82[a]	2.07[a]	1.87[a]	0.121	0.001
MDA(nmol/dl)	69.5[a]	52.9[b]	40.3[c]	19.6[d]	14.9[d]	19.0[d]	40.8[c]	2.56	0. 004

a,b,c,d Means in the same row followed by different letters are significantly different at $p \leq 0.05$.SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite; SOD =superoxide dismutase; GSH = glutathione; GPX =glutathione peroxidase; TAOC = total antioxidant capacity ;MDA= Malondialdehyde.

Table (7): Effect of different Selenium sources on blood plasma immune indices of broiler chicks.

Treatment	Control	S.S	SC-Se.Zn	Se-Meth	Se-Glycine	Se-Yeast	SC	SEM	*P* value
PA (%)	18.0[b]	23.3[a]	23.3[a]	21.0[a]	22.3[a]	22.6[a]	22.6[a]	0.863	0. 006
PI (%)	18.3[c]	21.0[b]	23. 0[a]	24.6[a]	22.3[a]	22.6[a]	23.3[a]	0.642	0. 007
LTT (%)	21.3[c]	23.2[b]	26.7[a]	26.9[a]	24.6[ab]	25.3[a]	26.3[a]	0.45	0. 001
BA (%)	30.6[b]	41.0[a]	41.0[a]	37.6[a]	38.6[a]	38.6[a]	37.6[a]	1.07	0. 008
LA (IU%)	10.6[c]	11.0[b]	12.3[a]	12.8[a]	13.0[a]	12.0[a]	12.6[a]	0.512	0. 001
IgG(mg/100ml)	65.3[c]	72.7[b]	76.7[b]	81.3[a]	85.4[a]	71.9[b]	78.3[b]	0.796	0.003
IgA(mg/100ml)	33.4[c]	53.7[b]	81.3[a]	60.6[a]	69.6[a]	79.3[a]	80.6[a]	4.45	0. 008
IgM(mg/100ml)	18.4[b]	54.1[a]	53.0[a]	31.6[a]	30.0[a]	35.5[a]	53.6[a]	2.71	0. 001

a,b,c Means in the same row followed by different letters are significantly different at $p \leq 0.05$.SEM=Standard error of mean's. S .C = *Saccharomyces cerevisiae* with Se; S .S =Sodium Selenite; PA= Phagocytic activity; PI= Phagocytic index; LA= lysozyme activity; BA= Bactericidal activity; LTT= Lymphocyte transformation test; IgA= Immunoglobulin A; IgG= Immunoglobulin G; IgM= Immunoglobulin M.

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Selenium source, Broiler, Performance, Blood parameters, Immune response

الملخص العربي

تأثير مصادر السيلينيوم علي الأداء الإنتاجي والفسيولوجي لدجاج اللحم

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أجريت هذه الدراسة في وحدة بحوث الدواجن بمزرعة البستان ، قسم الإنتاج الحيواني والداجني، كلية الزراعة جامعة دمنهور، في الفترة من أكتوبر حتى نوفمبر 2018. كان الهدف من الدراسة هو دراسة تأثير مصادر السيلينيوم علي الآداء الإنتاجي والفسيولوجي لدجاج اللحم حتى عمر 35 يوم . إستخدم فى الدراسة عدد 210 من كتاكيت اللحم (غير مجنسة) من سلالة تجارية (الأربورإيكرز) عمر سبعة ايام وزعت بشكل عشوائي في أقفاص سلكية إلي سبعة معاملات فى 6 مكررات وغذيت الطيور علي عليقة أساسية مضافا إليها المعاملات المختلفة على النحو التالى:

تم تغذية المجموعة الاولى على العليقة الاساسية بدون إضافات واستخدمت كمجموعة كنترول، في حين أن باقي المجموعات غذيت على العليقة الأساسية مع إضافة 100 جزء في المليون لكل كجم عليقة من السيلينيوم غير العضوى (سيلينوم سلينات) وكذلك صور مختلفة من السيلينيوم العضوي (سيلينيوم زنك مع الخميرة – سيلينيوم الميثيونين - سيلينيوم الجليسين وسيلينيوم الخميرة)على التوالي.أوضحت النتائج ان اضافة السيلينيوم العضوي والسيلينيوم غير العضوى في العلف ادي الي تحسن في وزن الجسم ومعدل الزيادة في وزن الجسم مقارنة مع مجموعة الكنترول. كما أدت التغذية علي سيلينيوم الميثيونين وسيلينيوم الجليسين و سيلينيوم الخميرة الي الحصول على أعلي زيادة في وزن الجسم يليه التغذية على سيلينيوم زنك والسيلينيوم غير العضوى مقارنةً مع مجموعة الكنترول. كما أدت التغذية علي السيلينيوم العضوي الي الحصول علي افضل معدل تحويل غذائي مقارنة مع مجموعة الكنترول.أدت اضافة السيلينيوم العضوي والسيلينيوم غير العضوى في العلف الي زيادة معامل هضم البروتين الخام مقارنة بالتغذية على العليقة الكنترول .أدت اضافة السيلينيوم بمصادره المختلفه في العلف الي الحصول على أعلى عدد لكرات الدم الحمراء وتركيز الهيموجلوبين وحجم كرات الدم الحمراء مقارنة مع مجموعة الكنترول.كما أدت اضافة السيلينيوم العضوى في العلف الي زيادة في البروتين الكلي والجلوبيولين يليه السيلينيوم غير العضوى مقارنة مع مجموعة المقارنة. أدت التغذية علي سيلينيوم الميثيونين وسيلينيوم الجليسين و سيلينيوم الخميرة الي الحصول علي أعلي مستوي من ألفا وبيتا وجاما جلوبيولين يليه التغذية على سيلينيوم زنك والسيلينيوم غير العضوى مقارنةً مع مجموعة الكنترول .أدت اضافة السيلينيوم العضوي والسيلينيوم غير العضوى في العلف الي زيادة مستوي جلوكوز الدم مقارنة مع مجموعة المقارنة.

أدت التغذية علي سيلينيوم الميثيونين وسيلينيوم الجليسين و سيلينيوم الخميرة الي الحصول علي أعلي تركيز من هرمون T3 يليه التغذية على سيلينيوم زنك مع الخميرة والسيلينيوم غير العضوى مقارنةً مع مجموعة المقارنة.أدت اضافة السيلينيوم العضوى والسيلينيوم غير العضوى إلى إنخفاض الدهون الكلية و الكوليسترول والجليسريدات الثلاثية في الدم عن مجموعة المقارنة وأدى سيلينيوم الجليسين في العلف الي انخفاض البروتين الدهني منخفض الكثافة (LDL) في بلازما الدم عن مجموعة المقارنة. أدت اضافة السيلينيوم العضوى في العلف الي زيادة في سوبر أكسيد ديسميوتاز (SOD) وتركيز الجلوتاثيون (GSH) مقارنة مع مجموعة المقارنة ، ومع ذلك ، زاد نشاط مضادات الأكسدة الكلية والجلوتاتيون بيروكسيداز(GPX) بإضافة السيلينيوم العضوى والسيلينيوم غير العضوى.أدت اضافة السيلينيوم العضوى والسيلينيوم غير العضوى الي زيادة في PA ,BA, IgM مقارنة مع مجموعة المقارنة.

وقد خلصت نتائج الدراسة إلي أن إضافة السيلينيوم بمصادره المختلفة كان لها تأثير على الأداء الإنتاجي والصفات الفسيولوجية والمناعية لدجاج اللحم ، بينما سجلت أفضل النتائج بإستخدام السيلينيوم العضوي مقارنة بالسلينيوم غير العضوى.