2019, Scienceline Publication
World's Veterinary Journal
World Vet J, 9(1): 16-25, March 25, 2019
ISSN 2322-4568

Effect of Dietary Organic Selenium Supplementation on Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits

Fawzia Amer Hassan, Noha Mahmoud Abdel-Azeem, Samah Mohamed Abdel-Rahman*, Hamdy Farouk Amin and Lamiaa Fathy Abdel-Mawla

Animal Production Research Institutes, Agriculture Research center, Dokki, Giza, Egypt

*Corresponding author`s Email: samah.abdelrahman@yahoo.com

ORGINAL ARTICLE
pii: S232245681900003-9
Received: 22 Jan 2019
Accepted: 27 Feb 2019

ABSTRACT

Total of 45 weaned male New Zealand White (NZW) rabbits about six weeks old with an average initial body weight 618.11±10.01g were randomly allotted to three dietary groups; the first group fed the basal diet without organic Se, the second fed basal diet +0.2 mg Se-yeast, the third fed basal diet +0.2 mg Se-algae. The obtained results showed that supplementation rabbit diets with Se-yeast and Se-algae have no impact on final body weight and average daily body weight gain. Se-algae supplementation tended to increase ($P<0.05$) average daily feed intake. Rabbits group fed diet supplemented with Se-yeast achieved better ($P<0.05$) FCR than that group fed Se-algae (5.06 g feed/g gain). Supplementation of Se-algae at 0.2 mg was the highest ($P<0.05$) in total protein, albumin, and globulin concentration (7.94, 4.16 and 3.78 g/dl). Diets supplemented with Se-yeast or Se-algae significantly reduced plasma creatinine levels compared to the control group. All recorded values of creatinine and urea concentrations were within the normal ranges. Dietary supplementation with 0.2 mg Se-yeast or Se-algae resulted in a significant ($P<0.05$) decrease in the activity of AST enzyme. Plasma total cholesterol and plasma LDL levels were significantly decreased ($P<0.05$) with dietary supplementation with Se-yeast or Se-algae. There was a significant ($p<0.05$) decrease in plasma MDA level in rabbits fed diets supplemented with Se-yeast or Se-algae. While Catalase activity was significantly ($P< 0.05$) increased. Rabbits fed diet supplemented with Se-algae was the lowest ($P<0.05$) group in ether extract meat content while dietary supplementation of Se-algae significantly increased ($P<0.05$) Se content of rabbits meat of hind leg. Conclusively, Se-yeast and Se-algae can be used as selenium sources in growing rabbit diets without causing any adverse effects on growth performance. Besides, their beneficial effects in improving the antioxidative status.

Key words: Anti-oxidative status, Carcass, Growth, Organic selenium, Rabbit

INTRODUCTION

Selenium (Se) supplements are commonly added to animal feedstuffs. Selenium is an important micronutrient in animals as well as human and its deficiency has various negative impacts (Kieliszek and BłaZejak, 2016). Diseases such as white muscle, liver degeneration, exudative diathesis, impaired reproduction, and poor immunity have been associated with selenium deficiency. Se is a constituent of the enzyme Glutathione (GSH) peroxidase which plays a role in the detoxification of peroxides formed during metabolic processes (Mateos et al., 2010). The H_2O_2 is the most toxic molecule to the cells, and it is detoxified by GSH and catalase. Thus, the inhibition of GSH causes the inhibition of the activities of its dependent enzymes (Safhi et al., 2018). It is also important for a number of physiological processes including regulation and function of the immune system through its incorporation into selenoproteins. Also, Se is involved in the regulation of oxidative stress, redox mechanisms, and other crucial cellular processes involved in innate and adaptive immune response (Dalgaard et al., 2018). Body weight gain, feed conversion efficiency and antioxidant capacity of growing rabbits were improved when offered supplementary dietary Se at a level of 0.24 mg Se/kg Dry Matter (DM) (Zhang et al., 2011). While, Syvyk et al., (2018) mentioned the best dose of selenium for rabbits is 0.2 mg/kg of DM. This dose of Se seemed to be optimal for young rabbits for fattening.

Feedstuffs are routinely supplemented with various Se sources, but organic forms of Se like as selenized yeast, selenomethionine and selenium enriched algae are better utilized due to higher bioavailability and less toxic than the inorganic forms as selenites and selenates which can be toxic at increased dietary concentration (Suraï, 2002; Dunshea and Uglietta, 2008; Douch et al., 2009; Hassan et al., 2015). Papadomichelakis et al. (2017) reported that dietary organic Se supplementation at 0.5mg/kg improves meat fatty acids composition and oxidative stability of growing rabbits, whereas at 2.5mg/kg may induce pro-oxidant effects. Se-enriched microalgae may benefit from the presence of specific bioactive compounds such as antioxidant, pigments, fatty acids, polysaccharides and immune active substances (Douch et al., 2009; Kouba et al., 2014). Dietary fortification with Spirulina platensis microalga seems promising in improving the oxidative stability of rabbit meat, besides, adding functional ingredients (Dalle Zotte et al., 2011). Chen and Wong

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

(2008) stated that Se with phycocyanin (Spirulina platensis) is a promising organic Se and antioxidant agent. Selenium enriched spirulina supplementation improved growth performance and anti-oxidative status of growing rabbits under hot conditions (Hassan et al., 2015). Yeast enriched with Se has recently become commercially available, and research suggests that it may be an efficacious source for the production of Se enriched animal products (Shini et al., 2015).

The objective of this study was to evaluate the effects of dietary supplementation of organic Se forms such as Se-yeast and Se-algae on growth performance, carcass characteristics, blood biochemical parameters and antioxidant status of growing rabbits.

MATERIALS AND METHODS

Experimental region

The present study was carried out in rabbit research unit at Sakha research station located in Alexsanderia governorate, Egypt, belongs to Animal Production Research Institute (APRI), Agricultural Research Center (ARC).

Ethical approval

This experiment was conducted after obtaining the ethical approval of the Animal Production Research Institute (APRI), Egypt.

Experimental design and application

Forty-five (six weeks of age) New Zealand white male rabbits were divided randomly into three homogeneous groups (n=15 each) with 618.11±10.01 g average live body weight. Each group has five replicates of which three rabbits. The treated groups were, control (basal diet without any supplementation), the second one was supplemented by selenium enriched yeast (Se-yeast) at 0.2 mg/kg diet and the third group was supplemented with selenium enriched algae Spirulina (Se-algae) at 0.2 mg (Figure, 1). Se enriched yeast (Se-yeast) is produced by growing strain of yeast (*Saccharomyces cervisiae*) in a Se-enriched media, (Sel-Plex®, was obtained from Alltech Inc, Nicholasville, KY, USA). Selenium enriched algae is produced by growing strain of Spirulina platensis (*Arthrospira platensis*), algae containing 1 mg Se/g algae. This algae strain was obtained from agricultural microbiology department, National Research Centre (NRC), Giza, Egypt.

Throughout the experimental period, body weight was determined every four weeks (at 6, 10 and 14 weeks of age) and average body weight gain was calculated. During the whole experimental period, the feed intake was determined precisely and is given as grams per rabbit per week. From each cage, feed residuals were collected daily, weighed and taken into consideration for the calculation of feed intake and feed conversion ratio (FCR) was calculated as a ratio of gram of feed per gram of gain.

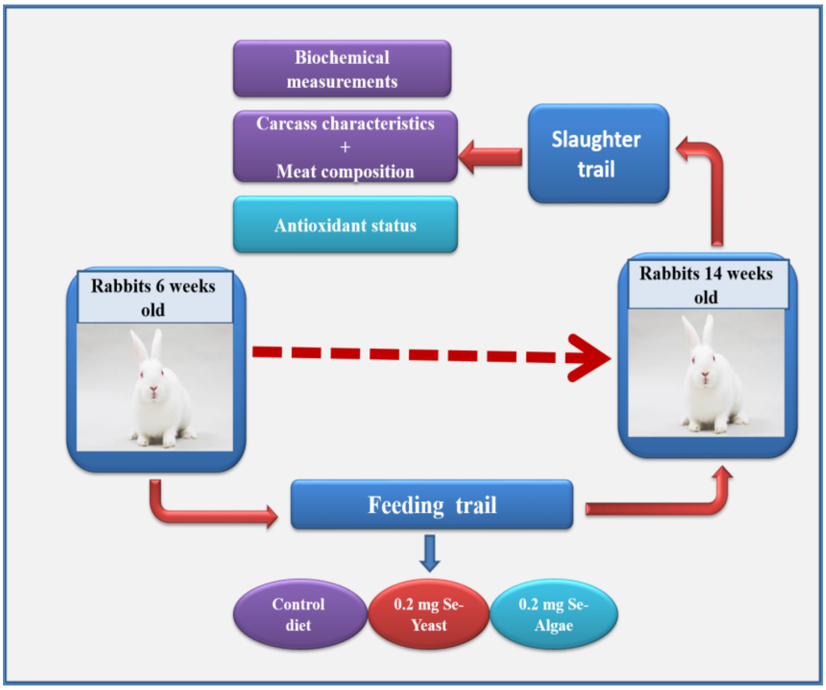

Figure 1. Experimental design and feeding trail of New Zealand white rabbit (6-14 weeks old) under Egyptian conditions

Experimental diets and housing

The experimental diets were pelleted and formulated to meet recommended nutrient requirements of growing rabbits according to Lebas (2013). Ingredient and chemical composition of the basal diet is presented in table 1. The control diet, thus containing only the endogenous Se contained in the ingredients of the diet (0.08mg Se/kg diet). Rabbits were housed individually in stainless steel cages (35 ×35 ×60 cm^3) provided with feeders and automatic nipple drinkers. Diet and water were offered *ad libitum*. All rabbits were kept under the same management, hygienic and environmental conditions.

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

Table 1. Feed ingredients and chemical analysis of the basal diet on the dry matter basis for New Zealand white rabbit (6-14 weeks old) during January 2018

Feed Ingredient	(%)	Chemical analysis (% dry matter basis)	(%)
Soybean meal (44% CP[a])	19.60	Dry matter (DM)	89.87
Barley	17.10	Organic matter (OM)	90.70
Yellow corn	7.00	Crude protein (CP)	17.86
Wheat bran	25.08	Crude fiber (CF)	13.33
Clover hay	24.50	Ether extract (EE)	2.350
Molasses	3.00	Nitrogen free extract (NFE)	58.44
Limestone	1.08	Ash	8.020
Di- calcium phosphate	1.71	Methionine[b]	0.670
DL-Methionine	0.08	Methionine+cysteine[c]	0.760
Sodium chloride	0.35	Lysine[d]	0.980
Vit.-Min. premix[b]	0.30	Calcium[e]	1.290
Anti-coccidiosis	0.10	Available Phosphours[f]	0.510
Anti-Fungi	0.10	Digestible energy (Kcal/Kg DM) [g]	2708.14
Total	100	Selenium (mg/kg DM) [h]	0.08

[a] CP: Crude Protein, [b]Vit.-Min. premix: Mineral and vitamin mixture supplied per kg of diet: Vitamin A 10000 IU, Vitamin D3; 1800 UI, Vitamin E; 15 mg, vitamin K3; 4.5 mg, Vitamin B1; 0.5 mg, Vitamin B2; 4 mg, Vitamin B12; 0.001 mg, Folic acid; 0.1 mg, Pantothenic acid; 7 mg, Nicotinic acid; 20 mgm I; 1 mg, Mn; 60 mg, Cu; 5.5 mg, Zn; 75 mg, Fe; 40 mg, Co; 0.3 mg, Robenidine; 52.8 mg, (b,c,d,e,f,h) Calculated on the basis of the ingredients composition. (g) Digestible energy (DE) was calculated according to Lebas (2013).

Carcass traits

At the end of the experimental period (14 weeks old), five rabbits from each treatment were randomly kept off feed for 12h, weighed and slaughtered for carcass characteristics and meat analysis. Carcass characteristics were measured according to Blasco and Ouhayoun et al. (1996). After complete bleeding, the skin, viscera, and tail were removed and the hot carcasses and its components were weighed as edible parts (liver, kidneys and heart) and the non-edible parts including lung, spleen, stomach, large intestine, small intestine were also weighed. Dressing percentage was calculated by dividing the hot dressed carcass weight by pre-slaughter weight and expressed as a percentage according to Blasco and Ouhayoun et al. (1996).

Biochemical measurements and antioxidant parameters

Blood samples (5ml from each rabbit) were collected during slaughtering to determine blood plasma components. Plasma was separated by centrifugation at 3000 rpm for 10 min and stored at −20°C until analyzed. Plasma total protein, albumin, total cholesterol, Low Density Lipoprotein (LDL-cholesterol), creatinine, urea, Aspartate Transaminases (AST), Alanin Transaminases (ALT), Malondialdehyde (MDA) and Catalase (CAT) were colorimetrically determined using commercial kits (purchased from Bio-Diagnostic, Cairo, Egypt, according to the manufacturers' instructions). The concentration of globulin (g/dl) was calculated by subtracting albumin values from total protein values, thereby we calculated Albumin/ Globulin ratio (A/G ratio).

Chemical analysis

Chemical analyses of the experimental diets, hind leg meat was carried out according to AOAC (2000) for Crude Protein (CP), Ether Extract (EE), Crude Fiber (CF) and ash. Total selenium of meat determination according to Shaltout et al. (2013), the analytical procedure was performed using an inductively coupled plasma mass spectrometry (ICP-MS) (Perkin Elmer-SCIEX, Thornhill, Canada), the concentration of total selenium was read from the calibration curve.

Statistical analysis

The differences among experimental groups were statistically analyzed using the general linear model procedures of SAS (2001), applying a One-Way Analysis of Variance (ANOVA). The significant differences among treatments means of treatments were compared using Duncan's multiple range test ($P< 0.05$) (Duncan 1955). All results were analyzed using the statistical model was: $Yij= \mu+ Ti+ eij$, Where: Yij= the observation of ij; μ = Overall mean; Ti= Effects of i (treatments) and eij= Experimental random error.

RESULTS

Growth performance

The effect of dietary of Se-yeast and Se-algae on growth performance of growing rabbits is presented as shown in table 2. The obtained results showed that supplying rabbits diets with Se-yeast and Se-algae had no significant effect on the average of both final body weight and daily body weight gain during the different experimental periods compared to the control group. However, rabbits group fed diet supplemented with Se-algae was the highest group in final body weight (1918.66g) followed by rabbits group fed diet supplemented with Se-yeast (1888.66g) while, the lowest one was with that rabbits group fed the control diet (1880.66g). On the other hand, Se-algae supplementation tended to increase ($P<0.05$) average daily feed intake during the first, second and the whole periods compared to the rabbits group fed the control diet and the rabbits fed diet supplemented with Se-yeast, while, the supplementation of Se-yeast recorded the lowest ($P<0.05$) average daily feed intake during all the experimental periods.

The results also revealed that FCR values were not significantly (P>0.05) influenced by dietary treatment during the first period. It is worthy to notice that rabbits group fed diet supplemented with Se-yeast achieved better (P<0.05) FCR (4.33 g feed/g gain) than that group fed Se-algae (5.06 g feed/g gain) while the control group recorded better FCR than Se-algae group during both the second and the whole periods.

Table 2. Effect of dietary supplementation of Se-yeast and Se-algae on growth performance of New Zealand white rabbit (6-14 weeks old) during February 2018 in Egypt

Item / Experimental diets	Control	Se-yeast	Se-algae	±SEM	P value
Average body weight (g/rabbits)					
Initial body weight (g)	618.33	617.66	618.33	17.75	0.999
Final body weight (g)	1880.66	1888.66	1918.66	36.36	0.739
Average daily weight gain (g/day/rabbit)					
Weeks 6-10	27.33	25.97	27.59	0.99	0.475
Weeks 10-14	17.75	19.42	18.84	0.93	0.439
Weeks 6-14	22.54	22.69	23.22	0.59	0.702
Average daily feed intake (g/day/rabbit)					
Weeks 6-10	77.25[b]	74.55[c]	83.06[a]	0.65	0.0001
Weeks 10-14	82.47[b]	79.43[b]	94.16[a]	1.41	0.0001
Weeks 6-14	79.85[b]	76.99[c]	88.62[a]	0.92	0.0001
Feed Conversion Ratio (g feed/g gain)					
Weeks 6-10	2.89	2.92	3.07	0.12	0.520
Weeks 10-14	4.78[ab]	4.33[b]	5.06 [a]	0.24	0.106
Weeks 6-14	3.58[ab]	3.42[b]	3.84[a]	0.10	0.016

Se-yeast 0.2 mg selenium yeast/kg diet; Se-algae, 0.2 mg selenium algae/kg diet;SEM: Strandard Error Mean, [a,b,c] Means values with the same letter within the same row did not differ significantly (P>0.05)

Carcass characteristics

Effects of Se-yeast and Se-algae supplementation on carcass characteristics are summarized in table 3. The results indicated that dietary supplementation of Se-yeast and Se-algae did not significantly (P>0.05) affect the pre-slaughter weight, carcass weight, heart, and dressing percentages. However, there were significant differences (P<0.05) between rabbits group fed diets supplemented with Se-yeast and rabbits group fed diet supplemented with Se-algae in liver%, edible giblet%, and spleen%. While, there were significant (P<0.05) differences between the control group and rabbits group fed Se-algae diet in liver% and edible giblets. Moreover, Se-yeast supplementation increased (P<0.05) spleen% compared to the control group. The obtained results also showed that feeding rabbits on the tested experimental diets including the control had no effect on cecum weight, length and intestine length.

Chemical composition of meat

Data concerning the effects of Se-yeast and Se-algae on the chemical compositions of rabbit meat are shown in table 4. It could be noticed that supplementation of dietary Se-yeast and Se-algae significantly decreased (P<0.05) DM and EE content compared to the control group. Rabbits fed diet supplemented with Se-algae was the lowest (P<0.05) group in EE content. On the other hand, it could be observed that there was a significant (P<0.05) increase in CP and ash meat content with supplementing Se-yeast and Se-algae compared to the control group. Regarding Se content, the dietary supplementation of Se-algae significantly increased (P<0.05) Se content of rabbit's meat of hind leg compared to the other tested rabbits' groups.

Plasma constituents and antioxidative status

Data of plasma biochemical constituents are shown in table 5. Dietary supplementation of Se-yeast and Se-algae significantly (P<0.05) increased plasma total protein concentration. It is worthy to note that rabbits group fed diets supplemented with Se-algae at 0.2 mg was the highest (P<0.05) group in total protein, albumin and globulin concentration (7.94, 4.16 and 3.78 g/dl, respectively). While no significant (P>0.05) differences in albumin and globulin levels were observed between the rabbits group fed Se-yeast diet and rabbits group fed the control diet. The albumin/ globulin (A/G ratio) was not affected significantly (P>0.05) by the dietary treatments.

To assess the condition of the kidneys, the following parameters were taken into account creatinine and urea. Feeding diets supplemented with 0.2 mg Se-yeast or Se-algae significantly (P<0.05) reduced plasma creatinine levels when compared to the control group. As well as there were significant (P<0.05) differences in urea concentrations between the control group and rabbits fed diets supplemented with Se-yeast and Se-algae. Dietary supplementation with 0.2 mg Se-yeast or Se-algae resulted in a significant (P<0.05) decrease in the activity of AST enzyme while, the activity of ALT was not affected significantly (P<0.05) by the supplemental feeding of Se-yeast but it was lower (P<0.05) for the rabbits group given Se-algae diet compared to the rabbits fed the control diet.

Plasma total cholesterol and plasma LDL levels were significantly decreased (P<0.05) with dietary supplementation with Se-yeast or Se-algae. Regarding blood antioxidative status as shown in table 5. A significant (P<0.05) decrease of plasma MDA level was observed in rabbits fed diets supplemented with Se-yeast or Se-algae. An opposite effect was noticed in CAT activity whereas the values were significantly (P< 0.05) increased.

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

Table 4. Effect of dietary Se-yeast and Se-algae supplementation on the chemical composition of New Zealand white rabbit's meat (6-14 weeks old) during April 2018 in Egypt

Item \ Experimental diets	Control	Se-yeast	Se-algae	±SEM	P value
Moisture	71.57[c]	72.68[b]	73.17[a]	0.103	0.0001
DM	27.38[a]	27.35[b]	27.02[c]	0.102	0.0001
CP	22.09[c]	22.55[b]	22.91[a]	0.086	0.0017
EE	3.73[a]	3.56[a]	3.16[b]	0.048	0.0004
Ash	1.20[c]	1.24[b]	1.31[a]	0.004	0.0001
Se (μg/g) content of hind leg	0.091[b]	0.098[b]	0.12[a]	0.003	0.0018

Se-yeast, 0.2 mg selenium yeast/kg diet; Se-algae, 0.2 mg selenium algae/kg diet; SEM: Strandard Error Mean, [a,b,c] Means values with the same letter within the same row did not differ significantly (P>0.05)

Table 5. Effect of dietary supplementation of Se-yeast and Se-algae on plasma constituents and blood antioxidative status of New Zealand white rabbit (6-14 weeks old) during April 2018 in Egypt

Item \ Experimental diets	Control	Se-yeast	Se-algae	±SEM	P value
Plasma proteins					
Total Protein (g/dl)	6.25[c]	6.78[b]	7.94[a]	0.11	0.0001
Albumin (g/dl)	3.23[b]	3.54[b]	4.16[a]	0.12	0.0050
Globulin (g/dl)	3.02[b]	3.25[b]	3.78[a]	0.12	0.0133
A/G ratio	1.07	1.09	1.11	0.07	0.0926
Kidneys functions					
Creatinine (mg/dl)	1.09[a]	0.90[b]	0.72[c]	0.04	0.0039
Urea (mg/dl)	25.74[c]	28.51[b]	31.36[a]	0.50	0.0008
Liver functions					
AST (IU/l)	49.94[a]	40.61[b]	37.77[c]	0.80	0.0001
ALT (IU/l)	56.72[a]	43.13[ab]	31.73[b]	4.15	0.0154
Plasma lipids					
Cholesterol (mg/dl)	200.5[a]	182.97[b]	169.27[c]	3.90	0.0038
LDL (mg/dl)	64.98[a]	57.43[b]	50.21[c]	1.60	0.0018
Antioxidative status					
MDA (mmol/ml)	3.85[a]	3.23[b]	2.62[c]	0.10	0.0006
Catalase (U/L)	129.87[c]	162.20[b]	201.47[a]	7.40	0.0015

Se-yeast, 0.2 mg selenium yeast/kg diet; Se-algae, 0.2 mg selenium algae/kg diet; SEM: Strandard Error Mean, [a,b,c] Means values with the same letter within the same row did not differ significantly (P>0.05), MDA: Malondialdehyde

DISCUSSION

Growth performance

The present study revealed that supplementation of rabbit diets with 0.2 mg Se-yeast and 0.2 mg Se-algae have no impact on final body weight and average daily body weight gain. The results agreed herein with Amer et al. (2018) who demonstrated that feeding rabbits diets supplemented with 0.3 or 0.6 mg Se-yeast did not have an improving effect on body weight and body weight gain. Besides, Hassan et al. (2015) showed that incorporation of 0.2 mg Se-algae in rabbit diet had no significant effect on average final body weight at 14 weeks old and daily body weight gain at the whole period. Moreover, Syvyk et al. (2018) noted that rabbits fed diets contained Se at levels of 0.1, 0.2, 0.3 and 0.4 mg/kg DM showed similar productivity and conversion of feed and found that a level of 0.2 mg Se/kg of DM was the best dose of selenium for fattening young rabbits.

Supplementation rabbit diet with 0.2 Se-algae increased (P<0.05) feed intake. This increase may be due to the significant impact on the nutrient status of the rabbit because of the profile of nutrient composition of Spirulina which considered as a source of essential bioactive compounds for organisms. They provide nearly all essential vitamins such as A, B6, B12, C, E, nicotinamide, biotin, folic acid, and pantothenic acid, polyunsaturated fatty acids and β-carotene (Spolaore et al., 2006; Dufosse et al., 2005). While rabbits fed diet contained 0.2 mg Se-yeast significantly (P<0.05) reduces feed intake. These findings are in accordance with the results of Saleh et al. (2013) reported that 0.3 ppm organic selenium reduced significantly feed intake of rabbits. Besides, Hassan et al. (2015) suggested that rabbits fed diet contained 0.2 mg Se-algae recorded the lowest feed intake (64.06 g/d) compared to rabbits fed the control diet (72.31 g/d).

Se-yeast supplementation at 0.2 mg/kg diet recorded the best (P<0.05) FCR. This result is consistent with findings of Hassan et al. (2015) who reported that rabbit fed diets included Se-algae at 0.05, 0.1, 0.2, 0.4 and 0.5 mg Se-algae/kg diet recorded better FCR than the control group and the best FCR (2.28 g feed/g gain) was achieved by 0.2 mg Se-algae. Furthermore, body weight gain, feed conversion efficiency and antioxidant capacity of growing rabbits was improved when offered supplementary dietary Se at a rate of 0.24 mg Se/kg DM (Zhang et al., 2011). A possible reason for this

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

could be attributed to nutritional yeasts as selenium yeast which has unique effects on metabolism, improving growth performance and health status of animals due to its content of high protein, amino acids, energy and B vitamins (Shurson, 2018; Mahan, 1999). Conversely, Amer et al. (2018) in rabbits, where feed conversion ratio not significantly (P>0.05) different with 0.6 mg Se-yeast /kg diet compared to the other groups. Also, Ebeid et al. (2013) who found that addition of organic Se in the form of yeast at 0.3 mg/kg diet reduced FCR in growing rabbits. In addition, Marounek et al. (2009) did not show a significant (P>0.05) effect of Se supplementation at 0.4 mg/kg on feed conversion of rabbit diet.

It could be observed that there was no depression found after supplementing diets with Se-yeast and Se-algae, a reason for this may be that organic selenium sources could cross through the intestine and enter into the blood by active transport so organic Se has high absorption efficiency (Schrauzer, 2001). Moreover, organic Se build Se reserves in the body in the form of selenomethionine which can be used to help additional Se-protein production (Surai and Fisinin, 2014). It has been shown that selenium contributes to normal cell growth and has an important role in modulating the action of transcription factors and cell signaling systems (Kieliszek and BłaZejak, 2016). Furthermore, it was known that Se enhances the metabolism of the thyroid hormones, which is important for normal growth and metabolism because of selenoenzymes may modulate or control many aspects of thyroid hormone metabolism (Parchami and Fatahian, 2012; Mehdi and Dufrasne, 2016). Therefore, in this research, a combination of better absorption efficiency and thyroid hormone activation by Se-yeast and Se-algae availability may explain the improved feed efficiency of the rabbits. Thus, it is necessary to include selenium in rabbit diets.

Further confirmation of no indication of adverse effects on rabbits health associated with the use of Se-algae has been obtained from spirulina which can enhance the productive performance as well as lowering the problems of different animal diseases. These properties could be attributed to some natural constituents such as phycocyanin, beta-carotene, tocopherols, linolenic acid, minerals, vitamins and phenolic compounds that had been shown to have strong antioxidant properties which promote growth and maintain health (Alvarenga et al., 2011; Farag et al., 2016).

Carcass characteristics

In present experiment, the results of carcass characteristics are in agreement with other results indicated no significant (P>0.05) effect of Se-algae supplementation on carcass yield of rabbits (Dokoupilovà et al., 2007). Also, Marounek et al. (2009) reported that no significant (P>0.05) difference in hot carcass weight, chilled carcass weight, and dressing percentage were observed with Se-selenite, Se-yeast and Se-algae supplementation in rabbit diets. Moreover, Payne and Southern (2005) found that carcass traits were not affected by Se sources or levels supplementations for chickens fed sodium selenite or Se-enriched yeast. Besides, Downs et al. (2000) stated that carcass and deboned meat yield of broiler were not influenced by the addition of 0.3 mg/kg Se to diets in the form of selenite and Se-enriched yeast. Dietary supplementation with 0.3 mg/kg inorganic and organic selenium had no significant (P>0.05) effect on carcass traits of turkeys (Mikulski et al., 2009). Recently, Amer et al. (2018) found that carcass traits were not affected by organic Se supplementation in rabbit diets at 0.6 mg /kg diet. In contrast, Hassan et al. (2015) found that supplying rabbit diets with Se-algae at 0.05, 0.1, 0.2, 0.4 and 0.5 mg/kg increased hot carcass, dressing%, and total edible parts% compared to the control group, and rabbits fed diet contained 0.4 mg Se-algae achieved the best hot carcass, dressing, edible giblets, and total edible parts. Shourrap et al. (2018) reported that dressing % was increased when chicks received 0.3 and 0.4 ppm/kg selenium enriched yeast.

The chemical composition of meat

The effect of dietary treatments on meat chemical analysis as well as Se contractions is summarized in table 6. . Dietary supplementation of Se-yeast or Se-algae decreased (P<0.05) EE content of meat. Rabbits fed diets supplemented with Se-algae was the lowest (P<0.05) group in EE content. Similar results were reported by Dalle Zotte et al., (2012) who stated that 5% spirulina supplementation seems promising in reducing the cholesterol content of fattening rabbit meat. In addition, Hassan et al. (2015) indicated that the content of EE of growing rabbit meat significantly (P<0.05) decreased when rabbit fed diet supplemented with 0.05, 0.1, 0.2, 0.4 and 0.5 mg Se-algae/kg DM. In this connection, Marounek et al. (2009) revealed that the hind leg meat of rabbits fed Se-algae (Chlrella) at 0.40 mg/kg diet contained less fat than that of control rabbits. While no effect observed on fat concentration of loin meat of rabbits.

Present results regarding DM, CP and EE content of rabbit meat, are in contrast to the findings reported by Dokoupilová et al. (2007), who indicated that the content of DM and fat in rabbit meat was not significantly (P>0.05) affected by dietary Se-enriched yeast supplementation. Also, Ebeid et al. (2013) who found that dietary Se-yeast supplementation at 0.3 mg/ kg diet had no significant (P>0.05) effect on meat composition of rabbits. Marounek et al. (2009) revealed that Se supplements had no effect on the DM and protein content of rabbits.

The present study was revealed that dietary Se-algae supplementation increased (P<0.05) Se content and ash content in the hind leg. Present findings are in agreement with Amer et al. (2018) who evaluated the inclusion of selenium yeast at 0.3 and 0.6 mg in the NWZ rabbit diets and found that selenium can be deposited in the meat and other tissue of rabbits and improved meat quality, which positively reflects on human acceptance. Similar results were reported by Dokoupilová et al. (2007), who found that lion and hind leg meat of rabbits fed diet supplemented with Se- enriched yeast contained four times more Se than the meat of rabbits fed the basal diet. Additionally, Marounek et al. (2009) reported that, Se concentration increased in meat of rabbits fed diets supplemented by Se-algae in which the Se concentration in the meat was doubled. Also, Boiago et al. (2014) observed highest Se concentration in muscles of broilers fed diets enriched with organic Se. Additionally, the organic selenium (Se-algae) is more deposited into the muscle tissue and animal organs than inorganic one (Behne et al., 2009). Papadomichelakis et al. (2017) concluded that

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

dietary selenium yeast supplementation at 0.5 mg/kg level improved rabbits meat fatty acids composition and oxidative stability, whereas at 2.5 mg/kg may induce pro-oxidant effects.

Most research conducted in recent years on rabbit meat quality has focused on incorporating bioactive compounds in meat for the benefit of human health. Moreover, rabbit meat consumption could become a good way to provide bioactive compounds to human consumers (Hernández, 2008), since manipulation of rabbit diet is very effective in increasing the levels of selenium is also responsive to dietary supplementation (Lynch and Kerry, 2000). Shini et al. (2015) reported that tissue enrichment with Se may enhance an animal's resilience to stress and disease challenge. Organic Se, in the form of yeast enriched with selenomethionine, has obvious implications for the production of Se enriched animal products.

Therefore, it would be premature to conclude that the organic selenium sources used in present study have beneficial effects on carcass composition due to their positive effects on reducing the fat of content meat and a noticeable increase in meat protein content.

Plasma constituents and blood antioxidative status

The results of present study showed an increase in plasma total protein level which may be due to Se-yeast and S-alga supplementation. In this connection, Kovàcs et al. (2016) stated that increase of plasma total protein probably could be attributed to the synthesis of proteins related to immune response, and found that 5% Spirulina supplementation in rabbit diets increased plasma total protein by 13% as compared to the control group. Selenium is assumed to be built into the protein structure similarly as it is into Se-enriched yeast (Machat et al., 2005). Furthermore, Selenium is present in two biologically active forms, Se-containing enzymes and Se-containing proteins in animals (Zhang et al., 2011). Additionally, higher plasma albumin and globulin levels were achieved by dietary of Se-algae. These results were in line with Hassan et al. (2015) who observed that rabbit fed diets contained Se-algae caused a significant increase ($P<0.05$) in total protein and globulin. Also, Ebeid et al. (2013) postulated that Se-yeast supplementation at 0.3 mg/kg rabbit diet increased globulin concentration. It is clear to know that globulins are carrier proteins for steroid and thyroid hormones and play a vital role in natural and acquired immunity to infection (Ganong, 2005). Moreover, the reduction observed in creatinine concentrations depending on the protein content of the experimental diets. Creatinine content has been shown to depend on the quantity and quality of dietary protein (Esonu et al., 2001). The urea concentration was ranged normally with the dietary supplementation of Se-yeast and Se-algae. In addition, all recorded values of creatinin and urea were within the normal physiological ranges according to Brown (2002).

As previously mentioned, the activity of hepatic enzymes ALT and AST decreased, the enzymes levels remained within the physiological ranges as was reported by Harcourt-Brown (2002). The decline in total plasma cholesterol ($P<0.05$) and LDL-cholesterol may be related to the effect of selenium as it has an anabolic role on fat deposition. Also, the supplementation of Se as organic forms in yeast or algae could modulate the fatty acids composition in the whole body. Previous studies have demonstrated that dietary Se supplementation increased LDL receptor activity but decreased 3-hydroxy 3-methylglutaryl coenzyme A (HMG-CoA) reductase expression in rat, which can lead to decrease in serum LDL and cholesterol levels (Dhingra and Bansal 2006; Yang et al., 2010).

In agreement with present study, Amer et al. (2018) reported that rabbits fed diets contained organic Se in form of yeast decreased significantly ($P<0.05$) serum total cholesterol and LDL-cholesterol and showed hypolipidemic effect organic selenium. In addition, Hassan et al. (2015) found that dietary treatments with Se-algae significantly reduced total cholesterol and LDL-cholesterol in rabbits. In contrast, Ebeid et al. (2013) stated that supplementation rabbits' diet with 0.3 mg Se-yeast did not influence serum total cholesterol and LDL-cholesterol.

A serum concentration of MDA is an index of lipid peroxidation and oxidative stress, and its levels depend upon the antioxidants (Saffari et al., 2018). In present findigs regarding antioxidant status, plasma MDA decreased with the supplementation of Se-yeast and Se-algae. A reduction in oxidation level by the dietary supplementation of organic Se was associated with the higher ($P<0.05$) activity of catalase enzyme. The antioxidant enzymes play a key role in cellular defense against oxygen free radicals and oxidative stress (Bernabucci et al., 2002). Das (2011) found that CAT enzyme detoxified hydrogen peroxide H_2O_2 to H_2O and O_2 which increased in production by the increase dismutation of O_2 by superoxide dismutase. Selenium is an essential element necessary for the function of several identified selenoproteins, including glutathione peroxidases, reductases, and deiodinases, as several essential enzyme functions with regard to normal immune function (Hall, 2018). In this connection, Zhang et al. (2011) found that that rabbit fed diet contained 0.24 mg/kg Se has greatest serum CAT activity. Also, reducing the lipid peroxidation expressed as serum MDA was with the inclusion of 0.15 and 0.3 ppm Se for growing rabbits diets (Ebeid et al., 2012). It could be concluded that organic Se in form of yeast and algae enhanced the antioxidative status of rabbits by minimizing lipid peroxidation and increase the activity of catalase as an antioxidant enzyme.

CONCLUSION

Present findings demonstrated that organic selenium sources based on yeast or algae have the potential to be used as selenium sources for growing rabbits without causing any adverse effects on growth through their effect on improving antioxidant status of rabbits. It can be concluded that selenium does not play a direct role in promoting growth in rabbits. However, it helps to remove all constraints that may delay or inhibit growth performance. Moreover, feeding on Se-yeast or Se-algae resulted in the valuable deposition of Se in rabbit meat.

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

DECLARATIONS

Consent to publish

All the authors approved and agreed to publish the manuscript.

Author's contributions

Dr. Fawzia Amer Hassan designed the study and drafted the manuscript, Dr. Noha Mahmoud Abdel-Azeem performed the statistical analysis and tabulation of the experimental data, Dr. Samah Mohamed Abdel-Rahman participated the chemical analysis and reviewed the manuscript, and Dr. Hamdy Farouk Amin participated the chemical analysis and practical part of the study and Dr. Lamiaa Fathy Abdel-Mawla performed the practical part of the experiment. All the authors approved the final manuscript

Competing interests

The authors clarify that, they have no competing interest, and with respect to this search, all the authors are in agreement with each other and have no conflict with authorship or article publication, all authors approved the publishing of paper.

REFERENCES

Alvarenga RR, Rondrigues PB, Cantarelli VS, Zangeronimo G, Da Silva JW and Da Silva R (2011). Energy values and chemical composition of Spirulina (*Spirulina platensis*) evaluated with broiler. Revista Brasileira de Zootecnia, 40: 992–996.

Amer SA, Omar AE and Abd El-Hack ME (2018). Effects of selenium- and chromium-enriched diets on growth performance, lipid profile, and mineral concentration in different tissues of growing rabbits. Biological Trace Element Research, Pp. 1-8. DOI: https://doi.org/10.1007/s12011-018-1356-4.

AOAC (2007). Association of Official Analytical Chemists. Official methods of analysis. 18th ed.

Baker DH and Ammerman CB (1995). Copper bioavailability. In: Ammerman CB, Baker DH, Lewis AJ (eds) Bioavailability of nutrients for animals: amino acids, minerals, vitamins. Academic, London, Pp. 127–156.

Behne D, Alber D and Kyriakopoulos A (2009). Effects of long-term selenium yeast supplementation on selenium status studied in the rat. Journal of Trace Elements in Medicine and Biology, 23: 258-264. DOI: 10.1016/j.jtemb.2009.05.001

Bernabucci U, Ronchi B, Lacetera N and Nardone A (2002). Markers of oxidative status in plasma and erythrocytes of transition dairy cows during hot season. Journal of Dairy Science, 85: 2173-2179. DOI:10.3168/jds.S0022-0302(02)74296-3

Blasco A and Ouhayoun J (1996). Harmonization of criteria and terminology in rabbit meat research. World Rabbit Science, 4:93–99.

Boiago MM, Borba H, Leonel FR, Giampietro-Ganeco A, Ferrari FB, Stefani LM and Souza PAD (2014). Sources and levels of selenium on breast meat quality of broilers. Ciência Rural, 44: 1692-1698.

Butler JA, Beilstein MA and Whanger PD (1989). Influence of dietary methionine on the metabolism of selenomethionine in rats. Journal of Nutrition, 119: 1001-1009. DOI: https://doi.org/10.1093/jn/119.7.1001

Chen T and Wong YS (2008). In vitro antioxidant and antiproliferative activities of selenium-containing phycocyanin from selenium-enriched *Spirulina platensis*. Journal of Agricultural and Food Chemistry, 56(12): 4352-4358. DOI: 10.1111/j.1744-7909.2007. 00600.x

Dalgaard T S, Briens M, Engberg RM and Lauridsen C (2018). The influence of selenium and selenoproteins on immune responses of poultry and pigs. Animal Feed Science and Technology, 238:73-83. DOI: https://doi.org/10.1016/j.anifeedsci.2018.01.020

Das A (2011). Heat stress-induced hepatotoxicity and its prevention by resveratrol in rats. Toxicology Mechanisms and Methods, 2(5): 393-399. DOI: https://doi.org/10.3109/15376516.2010.550016

Dalle Zotte A and Szendrő ZS (2011). The role of rabbit meat as functional food, a review. Meat Science, 88: 319–331. DOI:10.1016/j.meatsci.2011.02.017

Dalle Zotte A1, Sartori A, Cullere M, Gerencsér Zs, Matics Zs, Dal Bosco A Kovàcs M and Szendrő ZS (2012). Dietary supplementation of Spirulina (*Arthrospira platensis*) and thyme (*Thymus vulgaris*). Part 4: effect on rabbit carcass and meat quality. World Rabbit Science Association, Proceedings 10th World Rabbit Congress – September 3 - 6, Sharm El- Sheikh – Egypt, pp. 949-953.

Dhingra S and Bansal MP (2006). Attenuation of LDL receptor gene expression by selenium deficiency during hypercholesterol-emia. Molecular and Cellular Biochemistry, 282:75–82. DOI:10.1007/s11010-006-1266-1

Dokoupilová A, Marounek M, Skřivanová V and Březina P (2007). Selenium content in tissues and meat quality in rabbits fed selenium yeast. Czech Journal Animal Science, 52 (6): 165-169.

Doucha J, Lívansk´y K, Kotrbácek V and Zachleder V (2009). Production of Chlorella biomass enriched by selenium and its use in animal nutrition: A review. Applied Microbiology and Biotechnology, 83: 1001–1008. DOI:10.1007/s00253-009-2058-9

Downs KM, Hess JB and Sacit Bilgili SF (2000). Selenium source effect on broiler carcass characteristics, meat quality and drip loss. Journal of Applied Animal Research, 18 (1): 61-72. https://doi.org/10.1080/09712119.2000.9706324

Dufosse L, Galaup P, Yaron A, Arad SM, Blanc P, Murthy KNC and Ravishankar GA (2005). Microorganisms and microalgae as sources of pigments for food use: a scientific oddity or an industrialreality. Trends Food Science Technology, 16:389–406.

Duncan DB (1955). Multiple range and multiple F-tests. Biometrics, 11: 1-42.

Dunshea FR and Uglietta R (2008). Selenium in Animal production. Asia Pacific Journal of Clinical Nutrition, 17(3): S25.

Ebeid T, Zeweil H, Basyony M and Badry H (2012). The impact of incorporation of organic selenium into meat on growth performance, antioxidative status, and immune response in growing rabbits. World Rabbit Science Association Proceedings 10th World Rabbit Congress- September 3-6, Sharm El- Sheikh –Egypt, pp. 861- 864.

Ebeid T, Zeweil H, Basyony M, Dosoky W and Badry H (2013). Fortification of rabbit diets with vitamin E or selenium affects growth performance, lipid peroxidation, oxidative status and immune response in growing rabbits. Livestock Science, 155: 323–331.

Esonu BO, Emenalom OO, Udedibie ABI, Herbert U, Ekpor CF, Okoli IC and Ihukwumere FC (2001). Performance and blood chemistry of weaner pigs fed raw Mucuna beans (Velvet bean) meal. Tropical Animal Production Investigations, 4: 49-54.

Farag MR, Alagawany M, Abd El-Hack ME and Dhama K (2016). Nutritional and healthical aspects of Spirulina (*arthrospira*) for poultry, animals and human. International Journal of Pharmacology, 12 (1): 36-51. DOI: 10.3923/ijp.2016.36.51

Ganong WF (2005). Review of Medical Physiology. McGrow-Hill Education, 22nd edition. pp.727.

Hall JO (2018). Veterinary Toxicology (third Eduction). Basic and Clinical Principles, pp. 469-477.

Harcourt-Brown F (2002). Biochemistry, in: Textbook of rabbit medicine. Oxford, UK, Elsevier, pp.148.

Hassan FA, Hoballah EM, Basyony MM and El-Medany A (2015). Effect of dietary selenium enriched micro-algae supplementation on growth performance and anti-oxidative status of rabbits under high ambient temperature in summer season. Egyptian Journal Nutrition and Feeds, 18 (2): 229-244.

Hernández P (2008). Enhancement of nutritional quality and safety in rabbit meat. 9th World Rabbit Congress – June 10-13, 2008 – Verona – Italy. Pp. 1287-1299.

Kieliszek M and Błazejak S (2016). Current Knowledge on the Importance of Selenium in Food for Living Organisms: A Review. Molecules, (21): 609-624. DOI:10.3390/molecules21050609

Kouba A, Velíšek J, Stará A, Masojídek J and Kozák P (2014). Supplementation with sodium selenite and selenium-enriched microalgae biomass show varying effects on blood enzymes activities, antioxidant response, and accumulation in common Barbel (Barbus barbus). BioMed Research International, 2014: p 1-8. DOI:http://dx.doi.org/10.1155/2014/408270.

Kovács M, Dal Bosco A, Szendrő Z, Tornyos G, Hafner D, Milisits G, Tuboly T, Mézes M, Balogh K, Gerencsér Z et al. (2016). Effect of dietary supplementation of spirulina (*ArthrospirA platensis*) and thyme (*thymus vulgaris*) on serum biochemistry, immune response and antioxidant status of rabbits. Annals of Animal Science, 16 (1): 181–195. DOI: 10.1515/aoas-2015-0059

Lebas F (2013). Feeding strategy for small and medium scale rabbit. 3rd Conference of Asian Rabbit Production Association – Bali Indonesia - 27-29 August 2013. Pp. 1-15.

Lynch PB and Kerry JP (2000). Utilizing diet to incorporate bioactive compounds and improve the nutritional quality of muscle foods. In: Decker E., Faustman F., López-Bote C. (Eds). Antioxidants in muscle foods. John Wiley and Sons Publication, New York, USA, 455-480.

Machat J, Ĉmelík J, Doucha J and Otruba V (2005). Selenium obohacené řasy Chlorella – frakcionace forem selenu. In: Mikroelementy 2005. 2THETA, Ĉeský Těšín, 71–75.

Mahan DC (1999). Organic selenium: using nature's model to redefine selenium supplementation for animals. In: Lyons, T.P., Jacques, K.A. (Eds.), Biotechnology in the Feed Industry. Nottingham University Press, Nottingham, UK, pp. 523–535.

Marounek M, Dokoupilová A, Volek Z and Hoza I (2009). Quality of meat and selenium content in tissues of rabbits fed diets supplemented with sodium selenite, selenized yeast and selenized algae. World Rabbit Science, 17: 207–212.

Mateos GG Rebollar PG and De Blas C (2010). Minerals, Vitamins and Additives. 128, In: De Blas, C. and Wiseman, J. (Ed.) The Nutrition of the Rabbit, 2nd Edition 2010, pp.128. CAB international publishing, London, U.K.

Mehdi Y and Dufrasne I (2016). Selenium in Cattle: A Review. Molecules, 21, 545-559.

Mikulski D, Jankowski V, Zduńczyk Z, Wróblewska M, Sartowska K and Majewska T (2009). The effect of selenium source on performance, carcass traits, oxidative status of the organism, and meat quality of turkeys. Journal of Animal and Feed Sciences, 18: 518–530.

Papadomichelakis G, Zoidis E, Pappas AC, Mount- zouris KC and Fegeros K (2017). Effects of increasing dietary organic Selenium levels on meat fatty acid composition and oxidative stability in growing rabbits. Meat Science, 131: 132-138. DOI: 10.1016/j.meatsci.2017.05.006

Parchami A and Fatahian RF (2012). Sex differences in thyroid gland structure of rabbits. International Journal of Animal and Veterinary Sciences, 6(5): 278-281. DOI: scholar.waset.org/1307-6892/1193

Payne RL and Southern LL (2005). Comparison of inorganic and organic selenium sources for broilers. Poultry Science, 84: 898-902. DOI:10.1093/ps/84.6.898

Saffari S, Keyvanshokooh S, Zakeri M, Johari AS, Pasha-Zanoosi H and Mozanzadeh MT (2018). Effects of dietary organic, inorganic, and nanoparticulate selenium sources on growth, hemato-immunological, and serum biochemical parameters of common carp (Cyprinus carpio) Fish Physiology and Biochemistry, 44:1087–1097. DOI:10.1007/s10695-018-0496-y

Safhi MM, Alam FM, Khuwaja G, Ashafaq M, Khan A, Islam F, Anwer T, Khan G, Sivakumar SM and Islam F (2018). Selenium in combination with tellurium protects the toxicity of tellurium in the liver mitochondria of rats. Bulletin of Environment, Pharmacology and Life Sciences, 7(4): 90-95.

Saleh AA, Ebeid TA and Eid YZ (2013). The effect of dietary linseed oil and organic selenium on growth performance and muscle fatty acids in growing rabbits. Pakistan Veterinary Journal, 33(4):450–454.

SAS (2001). User's Guide: Statistics. Version 8.2, Cary, NC, USA.

Schrauzer GN (2001). Nutritional selenium supplements: product types, quality, and safety. Journal of the American College Nutrition, 20(1):1-4. https://doi.org/10.1080/07315724.2001.10719007

Shaltout AA, Khoder, AA, El-Abssawy SK Hassan and Borges DL (2013). Determination of rare earth elements in dust deposited on tree leaves from Greater Cairo using inductively coupled plasma mass spectrometry. Environmental Pollution, 178: 197-201. DOI:10.1016/j.envpol.2013.03.044

Shini S, Sultan A and Bryden WL (2015). Selenium Biochemistry and Bioavailability: Implications for Animal Agriculture. Agriculture, 5: 1277-1288. DOI: https://doi.org/10.3390/agriculture5041277

To cite this paper: Hassan FA, Abdel-Azeem NM, Abdel-Rahman SM, Amin HF and Abdel-Mawla LF (2019). Effect of Dietary Organic Selenium Supplementation yfon Growth Performance, Carcass Characteristics and Antioxidative Status of Growing Rabbits. *World Vet. J.* 9(1): 16-25. www.wvj.science-line.com

Shourrap MI, Marwa Sh, Abdo HA and Abdelaziz MA (2018). Antioxidant activity, se deposition and growth performance of broilers as affected by selenium-enriched yeast. Egyptian Poultry Science Journal, 38:35-50.

Shurson GC (2018). Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. Animal Feed Science and Technology, 235: 60–76. DOI: https://doi.org/10.1016/j.anifeedsci.2017.11.010

Spolaore P, Joannis-Cassan C, Duran E and Isambert A (2006). Commercial applications of microalgae. Journal of Bioscience Bioengineering, 101:87–96. DOI: https://doi.org/10.1263/jbb.101.87

Suraï PF (2002). Selenium in poultry nutrition 1. Antioxidant properties, deficiency and toxicity. World's Poultry Science Journal, 58:333–347. DOI:10.1079/WPS20020032

Suraï PF and Fisinin VI (2014). Review Selenium in poultry breeder nutrition: An update. Animal Feed Science and Technology, 191: 1–15.

Syvyk TL, Dyachenko LS, Tytariova OM, Shulko OP, Osipenko OP, Pirova LV and Bilkevych VV (2018). Productivity of rabbits and balance of selenium in their body by feeding different doses of selenium. Bulgarian Journal Agricultural Science, 24 (3): 480–483.

Yang KC, Lee T, Huang HY, Chen CY and Huang KC (2010). Serum selenium concentration is associated with metabolic factors in the elderly: a cross-sectional study. Nutrition and Metabolism, 7:38-44. DOI: https://doi.org/10.1186/1743-7075-7-38

Zhang Y, Zhu S, Wang X, Wang C and Li F (2011). The effect of dietary selenium levels on growth performance, antioxidant capacity and glutathione peroxidase 1 (GSHPx1) mRNA expression in growing meat rabbits. Animal Feed Science and Technology, 169: 259– 264.