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Effect of Enrichment of Laying Quail Diets with Organic Selenium on Performance and Fresh and Stored Egg Quality

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ABSTRACT: Selenium, which is a good antioxidant, is an essential trace mineral and its organic forms are more available than inorganic. Dietary deficiency or excess of this trace mineral causes health problems in poultry, and, therefore, the amount of selenium in the diet is controversial. The current research was carried out to determine the effect of diets enriched with organic selenium on the performance, egg quality, and stored egg properties in laying quails. A total of 120 laying quails were arranged according to a completely randomized design into six treatment groups having five replicates of four birds each. Quails were fed for 70 days with experimental diet containing 0.12 mg/kg selenium based on corn-soybean meal enriched with the addition of organic selenium(Sel-Plex) at 0.0, 0.2, 0.4, 0.6, 0.8, or 1.0 mg/kg.Body weight change decreased linearly with the addition of 0.6 mg/kg and further levels of organic selenium (p=0.033). Feed intake quadratically increased with the supplementation of organic selenium up to 0.8 mg/kg, but it was minimum at 1.0 mg/kg (p=0.013). The eggshell quality parameters were not affected by the administration of organic selenium to the diet (p>0.05). Albumen pH linearly decreased with organic selenium supplementation up to the level of 0.60 mg/kg, but increased with the addition of higher levels of organic selenium (p=0.031). With the addition of organic selenium to the diet, yolk L* (p=0.001) and b* (p=0.008) values quadratically and linearly decreased respectively, while a* value increased linearly (p=0.007). Albumen pH value of stored eggs was linearly decreased by treatments (p<0.001), but other parameters was not affected (p>0.05). As a result, it was determined that laying quails can be fed with diets enriched with organic selenium up to 0.4 mg/kg and the eggs could maintain their freshness for a longer time in during storage.

Keywords: Egg quality, Quail, organic selenium, storage.

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INTRODUCTION

Selenium is an essential trace mineral involved in the antioxidant system, DNA repair, enzyme related to production, and the structure of hormones(Surai, 2002). At the same time, selenium is included in the thyroid gland and enzymes that provide the maintainability of production, along with its antioxidant properties against free radicals and immune-enhancing properties (Zia et al., 2018). In the animal nutrition, two sources of selenium are used as inorganic and organic.Compared to inorganic sources, organic selenium sources are known to have high absorption, low toxicity, and more effective in raising egg selenium levels (Pavlovic et al., 2009; Jlali et al., 2013). Zia et al. (2018) noted that organic selenium has greater bioavailability than inorganic source.

Freshness is one of the most important parameters that determine the consumer demand and preference, and egg freshness decreases with storage.Albumen pH and Haugh unit are among the key indicators of egg freshness (Gajcevic et al., 2009). The impairment in egg quality is mainly related to the loss of water and carbon dioxide as a result of storage (Leandro et al., 2005) and the decline of the albumen (Surai, 2002). As insufficiently storage conditions continue, albumen texture deteriorates and the continuous loss of carbon dioxide increases albumen pH, which negatively affects albumen pH, egg flavour, and Haugh unit (Surai,2002).

Another factor that preserves the freshness of eggs during storage is the egg selenium content, and the amount of egg selenium increases with increasing selenium in the diet (Surai and Fisinin, 2014).The supplementation of selenium to the diet ensures that the eggs remain fresh for a longer period during storage by preserving the structure of the perivitelline membrane (Surai, 2006) and reducing oxidation, which is important in the physical texture of albumen (Arpasova et al., 2009).Organic selenium positively affects egg quality in maintaining egg freshness during storage (Rutzet al., 2003).Kralik et al. (2009) stated that there is a positive correlation between the increased amount of selenium in stored eggs and the freshness indicators.Organic selenium (selenium yeast) is stored at a higher rate in eggs and tissues, although its inorganic (sodium selenite) and organic (selenium yeast) sources have almost the same antioxidant capacity (Han et al., 2017).

In Europe and the United States, supplementation with organic forms of selenium is permitted to a maximum level of 0.30 mg/kg. However, information on the effects of adding higher levels of organic selenium, especially on the storage of eggs, is very limited. Therefore, it is the hypothesis of this study that by enriching practical laying quail diets with organic selenium, both the performance of the birds would improve, and the egg freshness could be preserved for a long-time during storage.The aim of the research was to determine the effects of organic selenium (0-1.0 mg/kg) enriched diets on performance and fresh and stored egg quality in laying quails.

MATERIALS AND METHODS

Ethics approval

Criteria specified by European policy for the protection of animals (European Union, 2010) were followed during experimental period.

Animals and Feed Materials

In the experiment, 120 female quails at the age of 10 weeks were fed as *ad-libitum* for 70 days with 6 treatment diets added organic selenium source (Sel-Plex) at 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0 mg/kg to the basal diet (0.12 mg/kg selenium) based on corn-soybean meal (Table 1).The chemical composition of basal diet was analysed according to AOAC (2006) proceedings. Table 1 shows the ingredients of basal diet and its chemical composition. The study was carried out in 6 experimental groups according to a completely randomized design, consisting of 5 subgroups, each with 4 female quails. The quails were housed in cages (45 cm × 30 cm) in an environmentally controlled coop (23-25 °C). A 16-hour lighting program was applied.

Method

Determination of performance parameters

The body weight change was calculated as g with the group weighing at the beginning and end in the experiment.Trial feeds were given by weighing to the subgroups and calculated as g/day/quail.The eggs obtained were recorded daily and the egg production was determined as %.In the last three days of the experiment, all eggs collected from each subgroup were weighed and the egg weight was determined as g.From these data obtained, egg mass was calculated as g/day/quail with formula *(egg production x egg weight) / 100,* and feed conversion ratiowas calculated as g feed/g egg with formula *feed intake / egg mass*.

Table 1. Basal diet and its nutrient contents

Ingredients	g/kg	Nutrient composition	g/kg
Corn	572.0	Metabolizable energy, kcal/kg[2]	2898
Soybean meal	320.0	Crude protein[3]	200.16
Sunflower oil	32.1	Crude fibre[3]	40.50
Limestone	56.0	Crude fat[3]	72.90
Dicalciumphosphate	11.8	Moisture[3]	123.00
Salt	3.5	Calcium[3]	25.02
Premix[1]	2.5	Available phosphorus[3]	3.51
DL-methionine	2.1	Lysine[2]	10.64
Total	1000.0	Methionine[2]	4.56
		Cystine[2]	3.72
		Methionine + cystine[2]	8.28
		Selenium, mg/kg[3]	0.12

[1]Premix is suppliedthatper kg of diet; Manganese: 80 mg, Iron: 60 mg, Copper: 5 mg, Iodine: 1 mg, Vitamin A: 8.800 IU, Vitamin D_3: 2.200 IU, Vitamin E: 11 mg, Nicotineacid: 44 mg, Cal-D-Pan: 8.8 mg, Riboflavin: 4.4 mg, Thiamine: 2.5 mg, Vitamin B_{12}: 6.6 mg, Folicacid: 1 mg, Biotin: 0.11 mg, Choline: 220 mg.
[2]Calculated value.
[3]Analyzed value.

Determination of egg quality

During the experiment, broken, cracked and damaged eggs were recorded and calculated as % of the number of eggs.A total of 120 eggs collected on the 65th and 66th days of the experiment were stored in the egg storage cabinet at +4°C and 75% relative humidity for 28 days. Egg external and internal quality parameters were determined from all eggs that were collected and stored in the last three days of the trial. Specific gravity was determined same day using graded salt solutions ranging from 1.060-1.100 with gradations of 0.005 (Holder and Bradford, 1979). Eggshell breaking strength was measured by applying supported systematic pressure to the blunt of the eggs (Egg Force Reader, Orka Food Technology, Israel).After the eggs were broken on a clean glass table, egg residues in the eggshell were cleaned, then the eggshells were dried for three days at room temperature, and eggshell weights were calculated as % of the egg weights. Eggshell thickness was calculated by taking the average of the values obtained by measuring from three points of the egg (equator, blunt and pointed parts) using a micrometer (Mitutoyo, 0.01 mm, Japan).In order to determine the egg internal quality, albumen and yolk height were measured with a height gauge, and length and width or diameter were measured with the help of digital calliper, and from these data, the albumen index with the formula *albumen height/ ((albumen length + albumen width) / 2) × 100*, the yolk index with the formula *(yolk height / yolk diameter)*× 100, and the Haugh unit with the formula *100 x log (albumen height + 7.57-1.7 x egg weight$^{0.37}$)*were calculated. Egg yolk colour and L*, a* and b* values were measured with colorimeter (MinoltaCo.,Osaka, Japan) (Romero et al., 2002). Albumen pH was measured using a Sentix 42 electrode pH meter (pH 315i/SET WTW, Weilheim, Germany).

Statistical analysis

Data were analysed in the SPSS Version 22.0 software package with model of one-way ANOVA, using the group mean as an experimental unit. A probability value of $p<0.05$ was considered statistically significant. Orthogonal polynomial contrasts were used to evaluate the significance of linear and quadratic models to determine the response of the dependent variable to an increasing organic seleniumlevel. The model $Y_{ij} = \mu + a_i + e_{ij}$was used, where Y_{ij}= the dependent variable, μ= the overall mean, a_i= the effect of increasing organic selenium, e_{ij}= the random residual error.

RESULTS

No mortality or illness symptoms were observed during the entire trial among all the diets, and all quails were alive at the end of the experiment.

Performance

Effect of enriching the diet with organic selenium on the performance parameters of laying quails was demonstrated in Table 2. Egg production, egg weight, egg mass, and feed conversion ratio were not affected by the addition of organic selenium to laying quail diets ($p>0.05$). Body weight change was linearly decreased by the supplementation of organic selenium to the diet (p=0.033).Feed intake, on the other hand, quadratically increased up to 0.8 mg/kg dietary addition of selenium, but decreased with high level of (1.0 mg/kg) organic selenium (p=0.013).

Egg external quality parameters

Effect of enriching the diet with organic selenium on the egg external quality of laying quails was presented in Table 3. Damaged egg rate, specific gravity, eggshell breaking strength, eggshell rate, and eggshell thickness were not statistically affected by the administration of organic selenium to the diet(p>0.05).

Egg internal quality parameters

In the end of study, effect of the treatments on albumen index, yolk index, Haugh unit, albumen pH, and yolk L*, a*, and b* values were given in Table 4. Dietary organic selenium addition to diet did not affect the final albumen index, yolk index, and Haugh unit, considerably (p>0.05). Albumen pH value linearly decreased with the supplementation of organic selenium to the diet up to 0.6 mg/kg (p=0.031), and it was minimum in the group with 0.4 mg/kg organic selenium.A quadratic decrease was observed in yolk L* value with the addition of organic selenium to laying quail diet (p=0.001). Yolk a* value increased (p=0.007), on the contrary, b* value decreased (p=0.008) with the dietary supplementation of organic selenium, linearly.

Stored egg quality parameters

In the end of 28-day storage period, egg quality parameters of eggs obtained from quails fed with or-

Table 2. Effect of enrichment of laying quail diets with organic selenium on performance parameters

Parameter	Organic selenium addition, mg/kg						S.E.M*	P-value of contrast		
	0.0	0.2	0.4	0.6	0.8	1.0		Combined	Linear	Quadratic
BWC, g	18.60	17.58	18.50	7.58	8.00	5.83	4.773	0.298	0.033	0.258
EP, %	88.79	83.69	86.19	85.96	83.49	90.48	4.072	0.870	0.846	0.351
EW, g	12.69	12.77	13.06	12.10	12.72	11.63	0.349	0.141	0.060	0.213
EM, g/d/quail	11.26	10.76	11.25	10.38	10.57	10.52	0.598	0.889	0.380	0.875
FI, g/d/quail	32.05	32.74	32.41	32.79	32.83	31.78	0.241	0.081	0.772	0.013
FCR, g feed/g egg	2.85	3.19	2.89	3.18	3.15	3.05	0.183	0.807	0.533	0.581

BWC: Body weight change, EP: Egg production, EW: Egg weight, EM: Egg mass, FI: Feed intake, FCR: Feed conversion ratio.
*Standard error means

Table 3. Effect of enrichment of laying quail diets with organic selenium on egg external quality

Parameter	Organic selenium addition, mg/kg						S.E.M*	P-value of contrast		
	0.0	0.2	0.4	0.6	0.8	1.0		Combined	Linear	Quadratic
Damaged egg rate, %	1.64	0.40	0.98	0.39	0.19	0.42	0.467	0.398	0.110	0.389
Specific gravity, g/cm^3	1.067	1.068	1.065	1.070	1.065	1.065	0.0022	0.632	0.760	0.563
Eggshell breaking strength, N	14.32	14.71	13.93	14.81	13.73	13.73	0.490	0.506	0.256	0.524
Eggshell rate, %EW	8.31	8.24	7.91	8.43	8.85	8.31	0.295	0.728	0.500	0.863
Eggshell thickness, mm	0.218	0.214	0.212	0.209	0.210	0.210	0.0032	0.447	0.074	0.276

*Standard error means

Table 4. Effect of enrichment of laying quail diets with organic selenium on egg internal quality

Parameter	Organic selenium addition, mg/kg						S.E.M*	P-value of contrast		
	0.0	0.2	0.4	0.6	0.8	1.0		Combined	Linear	Quadratic
Albumen index	8.55	9.19	8.75	7.78	8.34	8.71	0.521	0.673	0.586	0.634
Yolk index	47.10	47.25	46.83	46.53	47.97	48.24	1.051	0.881	0.434	0.450
Haugh unit	85.39	86.27	85.12	84.02	84.73	85.48	1.176	0.915	0.661	0.608
Albumen pH	8.65^{a}	8.56^{bc}	8.51^{c}	8.61^{ab}	8.66^{a}	8.66^{a}	0.023	0.002	0.031	0.002
L*	52.18^{a}	50.08^{ab}	48.98^{bc}	47.45^{c}	49.95^{ab}	50.74^{ab}	0.701	0.011	0.182	0.001
a*	-0.06^{c}	0.06^{bc}	0.34^{abc}	0.79^{a}	0.42^{abc}	0.55^{ab}	0.110	0.036	0.007	0.135
b*	29.77^{a}	24.40^{b}	24.69^{b}	25.73^{b}	26.15^{b}	24.51^{b}	0.741	0.001	0.008	0.018

*Standard error means

Table 5. Effect of enrichment of laying quail diets with organic selenium on stored egg quality

Parameter	Organic selenium addition, mg/kg						S.E.M*	P-value of contrast		
	0.0	0.2	0.4	0.6	0.8	1.0		Combined	Linear	Quadratic
Egg weight loss, %	2.76	2.29	2.48	2.25	2.83	1.92	0.559	0.113	0.185	0.802
Eggshell breaking strength, N	15.49	14.81	14.02	14.51	14.22	14.12	1.157	0.523	0.885	0.864
Eggshell rate, %EW	8.70	8.57	8.25	8.71	8.45	8.66	0.293	0.123	0.939	0.113
Albumen index	7.41	8.36	7.51	6.84	7.19	7.25	0.822	0.108	0.116	0.923
Yolk index	44.22	45.20	43.51	43.67	42.66	43.19	1.885	0.383	0.080	0.953
Haugh unit	80.55	83.63	81.08	79.70	80.57	80.78	1.927	0.075	0.237	0.964
Albumen pH	8.77[a]	8.76[a]	8.71[b]	8.72[b]	8.70[b]	8.71[b]	0.027	<0.001	<0.001	0.068
L*	49.71	50.59	51.46	48.84	50.01	50.20	1.235	0.059	0.689	0.662
a*	2.05	0.76	0.91	1.23	0.99	1.07	0.660	0.091	0.160	0.081
b*	30.92	30.20	30.44	27.79	29.68	29.86	1.805	0.136	0.172	0.146

*Standard error means

ganic selenium-supplemented diets are shown in Table 5. Effect of enriching the laying quail diets with organic selenium on loss of egg weight, eggshell breaking strength, eggshell rate, albumen index, yolk index, Haugh unit, and yolk L*, a*, and b* values in the eggs stored for 28 days was found to be statistically insignificant (p>0.05). Albumen pH value of stored eggs was affected by the administration of organic selenium to the diet, and it decreased with the treatments, linearly (p<0.001).

DISCUSSION

In the present study, with the addition of organic selenium to the diet, the body weight gain decreased,especially at selenium levels of 0.6 mg/kg and above, and it was minimum at the level of 1.0 mg/kg.Maldarasanu et al. (2013) reported that the dietary addition of 0.4 mg/kg organic selenium increased the body weight of quails. Similar results were also stated by Lu et al. (2020) and Muhammad et al. (2021) with the supplementation of organic selenium at the levels of 0.1-0.4 mg/kg to the laying hen diets. Feed intake of laying quails increased with the administration of organic selenium (up to 0.8 mg/kg level) to the diet, but decreased at 1.0 mg/kg level. It is known that the reduced feed intake one of the symptoms of toxicity (Payne et al., 2005). Attia et al. (2010) and Liu et al. (2020) indicated that dietary supplementation of organic selenium at a lower level (0.1-0.5 mg/kg) in laying hens, feed intake was reduced.Results mentioned disagree with researches reported that feed intake was not affected by the addition of selenium to the diet (Maldarasanu et al., 2013; Han et al., 2017; Muhammad et al., 2021). In the literature, a low level (up to 0.5 mg/kg, approximately) of organic selenium was added to the diet, generally. However, it was also demonstrated that feed intake was not affected by the administration of selenium at high doses (1.5 and 3.0 mg/kg) (Lu et al., 2019). Differences between studies can be due to the selenium source, raw material, and animal material used. In addition, selenium is included in the diets as an anti-stress factor (Olgun et al., 2021). Therefore, stress factors such as diet, environmental temperature, housing conditions, and presence of pathogens could be the reason of distinctness between studies.Additionally, it can be said that selenium at the level of 0.6 mg/kg for body weight is toxic, but the toxic level is higher (1.0 mg/kg) for feed intake.In other words, body weight gain (ie body weight) at 0.6 mg/kg level of organic selenium and feed intake at 1.0 mg/kg level of organic selenium were significantly reduced compared to the lower organic selenium enriched groups.

In the current research, yolk brightness (L* value) and yellowness (b* value) decreased with the organic selenium supplementation to the diet, but redness (a* value) increased. The antioxidant property of selenium could also have affected yolk colour pigmentation. Yolk colour pigmentation occurs through fat-soluble xanthophyll and carotenoid compounds stored in the organism and ingested with diet (Nemati et al., 2020; Muhammad et al., 2021). The pigmentation characteristics of these compounds can also have changed during oxidation. Especially, the increase in a* value, which is an indicator of redness, could be a sign that selenium in the diet inhibits the oxidation of pigments. Additionally, the increase in egg yolk a* value may be due to better preservation of carotenoid compounds by enriching the diet with organic selenium. Besides selenium could have affected yolk colour values with its feature that affects the transfer and storage of carotenoid compounds from the digestive system to the yolk via the blood. Muhammad et al. (2021) reported that the addition of organic selenium (selenium yeast) to laying hen diets at the level of 0.3 mg/kg decreased the yolk L* value, on the contrary, increased the b* value and it did not affect a* value, similar to the current study. However, the level and bioavailability of the factors affecting the L*, a*, and b* values in the diets used in the experiment can be the reason for the difference between the studies.

Egg external quality is notable in terms of presenting in the best status while the internal quality is an important parameter in terms of consumer preference. In addition to other egg internal quality parameters revealing both the freshness of the egg and the difference during laying, albumin pH is the primary criteria of freshness of egg. Before the consumption, storage of eggs is inevitable. During storage, the pH rapidly increasesas a result of the loss of carbon dioxide in the egg (Decuypere et al., 2001; Samli et al., 2005). Fresh albumen pH value decreased with dietary addition of organic selenium up to 0.6 mg/kg, and this decrease was continuous in stored eggs.The decrease in pH value of albumin of fresh and stored eggs by enriching the diet with selenium may be due to the antioxidant property of selenium. According to Muhammad et al. (2021), on the other hand, albumen pH was not affected by the supplementation of 0.3 mg/kg organic selenium to the diet.Scheideler et al. (2010) who examined the effects of selenium levels and sources on some egg internal quality parameters stated that the albumen pH in organic source was lower than inorganic source. The researchers also noted that as the egg ages and air enter through its pores, the oxidation of the albumen and yolk could increase, causing the pH to rise. Scott and Silversides (2000) reported that the albumen pH significantly increased with storage. Mohiti-Asli et al. (2008) observed that the albumen pH considerably increased with storage, and the administration of selenium to the diet (0.4 mg/kg) did not prevent this increase caused by storage. In the study, among the eggs stored for 28 days, the albumen pH was found to be significantly lower in the groups that added organic selenium to the diet. However, Baylan et al. (2011) reported that the albumen pH of stored quail eggs was not affected by the supplementation of organic selenium to the diet.

CONCLUSION

In conclusion, feed intake, live weight, L* and b* values of yolk and albumin pH decreased in quails fed diets enriched with organic selenium, especially in stored egg albumin. According to these results, it can be said that laying quails can be fed with feeds enriched with organic selenium up to 0.4 mg/kg.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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