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Effects of Dietary Selenium Source, Storage Time, and Temperature on the Quality of Quail Eggs

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Abstract We report the effects of time of storage, temperature, and supplementation with sodium selenite- and selenium-enriched yeast on the quality of quail eggs. For this study, 90 10-week-old female Japanese quails (*Coturnix coturnix japonica*) with similar body size were caged individually and randomly divided into five groups of 18 quails each. One group was fed a normal diet and served as control. A second group was supplemented with 0.2 mg/kg sodium selenite (In-Se) and three groups supplemented with 0.1, 0.2, and 0.3 mg/kg of a commercially available selenium-enriched yeast (O-Se1, O-Se2, and O-Se3, respectively). The eggs were collected at third and fourth weeks of the experiment and were stored at 4°C and 20°C for 0, 15, 30, and 45 days. Extension of the storage time to 45 days at 20°C resulted in significant deterioration of egg quality. The albumen Haugh unit (HU), pH, albumen index, yolk index, and egg weight loss were the most important parameters influenced by the nature of the selenium sources, storage time, and temperature. Storage time and temperature were also significant for egg weight loss, HU, and albumen and yolk indexes. The results show that supplementation with selenium yeast significantly affected shell weight, shell thickness, HU, albumen index, yolk index, and pH. The HU decreased with increased storage time and temperature. Higher levels of Se-yeast administration resulted in greater HU compared to the selenite and control groups.

Keywords Selenium · Storage time · Temperature · Internal quality · Quail egg

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Introduction

Overall egg quality is important for both poultry breeders and for consumers. Poor quality results in substantial economic losses to the worldwide egg industry. For example, losses due to poor eggshell quality have been calculated to be in the order of 6–8% [1].

Selenium is an essential trace element to livestock. Apart from supplementation, farm animals receive selenium mainly in the form of selenoamino acids in vegetable feed ingredients [2]. In nature, selenium is found in inorganic and organic compounds. Inorganic selenium refers to different minerals such as selenite, selenate, and selenide, and organic selenium is bound to amino acids such as methionine and cysteine [3]. Selenomethionine (SeMet) is a naturally occurring amino acid that is incorporated into body proteins instead of methionine. It represents the major nutritional source of selenium for higher animals and humans. The ability of SeMet to become a part of body proteins provides a means of reversible Se storage in organs and tissues. This property is not shared by any other naturally occurring selenoamino acids and thus could be associated with a specific physiological function. Although higher animals cannot synthesize SeMet, so this essential amino acid, the optimal supplemental levels of SeMet for different animal species still need to be determined. Suitable levels of SeMet added to animal feed are more effective for supplementation than inorganic Se salts. [4, 5].

Since its approval as a feed supplement in 1970 in Europe and 1974 in the USA, sodium selenite has become the traditional source of Se for supplementation of poultry and livestock. Although the requirement for selenium could be met by a typical corn-soybean meal diet without added supplements, both the health and performance of birds can be improved by the addition of selenium to animal feed, now a routine procedure in the poultry industry [1].

In Europe and the United States, supplementation with inorganic forms of selenium is permitted to a maximum level of 0.5 mg Se/kg while that of organic forms is allowed up to 0.3 ppm [1]. Studies on selenium sources in poultry have revealed contradictory results. Payne et al. found that average hen-day production is not affected by Se-source, but Se-yeast increased the Se egg concentration more effectively than selenite [6]. Canogullari et al. reported that the Se levels in egg yolk and egg albumin were higher in Se-supplemented groups compared to unsupplemented controls ($p<0.05$) and established that organic Se forms were more effective than inorganic Se as supplements [7]. Yaroshenko et al. pointed out that supplementation of 0.4 ppm Se to hens resulted in production of Se-enriched eggs with a prolonged period of freshness [8]. Gajcevic et al. also stated that eggs with higher amounts of organic Se remain fresh for a longer period of storage [3]. Arpasova et al. [2] studied the effects of dietary Se sources on the quality of eggshells and found that adding selenium to the feed of laying hens did not significantly influenced the average eggshell thickness ($p>0.05$).

The freshness of eggs is a quality factor influenced by storage time (expressed in days) and conditions (temperature and relative humidity). Egg age refers to the period from egg laying to its consumption. The most common indicators of egg freshness are air bubble height, pH of albumen, aging rate, oxidation intensity of yolk lipids, and Haugh units [3]. Kralik et al. stated that a higher concentration of organic selenium in eggs was a factor that positively affected the indicators of egg freshness [9].

This study was carried out to determine the effects of organic and inorganic selenium sources, storage time, and temperature on the overall quality of quail eggs.

Materials and Methods

Ninety 10-week-old female Japanese quails (*C. coturnix japonica*) with similar body weight and size were randomly divided to five groups of 18 quails in each. The birds were individually maintained in 16×26×25 cm cages in a well-ventilated room with artificial illumination for 16 h/day. Water and feed were available for ad libitum consumption.

The five study groups were treated as follows: (1) controls, receiving a standard diet (Table 1) without supplemental selenium; (2) the inorganic group (In-Se), supplemented with 0.2 mg/kg sodium selenite (Na_2SeO_3); (3) the group known as OSe-1, supplemented with 0.1 mg/kg Se-enriched yeast (Sel-Plex®, Alltech, Inc.); (4) group OSe-2 receiving 0.2 mg/kg Se-yeast; and (5) Group OSe-3, supplemented with 0.3 mg/kg Se-yeast.

In total, 800 eggs were collected (160 eggs per dietary group), all receiving identical treatment and length of storage. The eggs were collected on weeks 3 and 4 of the experiment and stored for 0, 15, 30, or 45 days refrigerated at 4°C and at 20°C. In both cases, humidity was maintained in the 60–65% range.

At the end of the storage period, the quality characteristics were evaluated. Fresh eggs (0 days of storage) were collected and analyzed within 2 h of being laid. Each egg was weighed, and its length and width were recorded before breaking it onto a flat surface where the height of the thickest part of the albumen and yolk were measured. Using a compass, the overall width and that of the yolk were also measured. The yolk was then separated and weighed, and the pH of the albumen was determined.

A calibrated micrometer was used for measuring the thickness of the eggshell, which is reported as the mean of three different sides, in millimeters.

Table 1 Composition of the standard diet

Ingredient	Percentage	Calculated nutrient content	
Barley	16.0	Crude protein,%	20.4
Maize	39.0	ME, kcal/kg	2917
Soybean meal	32.0	Ca, %	2.5
Meat–bone meal	3.0	P, %	0.9
Vegetable oil	4.6	Met+Cys, %	0.7
Limestone	1.6	Methionine	0.45
DCP	3.0	Available P, %	0.35
Salt	0.2	Sodium, %	0.15
DL-methionine	0.2	Potassium, %	0.74
Vitamin premix[a]	0.2		
Mineral premix[b]	0.2		

[a] Each kilogram of vitamin premix contained: vitamin A, 8,000 IU; vitamin D_3, 3,000 IU; vitamin E, 25 IU; menadione, 1.5 mg; vitamin B_{12}, 0.02 mg; biotin, 0.1 mg; folate, 1 mg; niacin, 50 mg; pantothenic acid, 15 mg; pyridoxine, 4 mg; riboflavin, 10 mg; and thiamin, 3 mg

[b] Each kilogram of mineral premix contained 60,000 mg of manganese, 120,000 mg of iron, 25,000 mg of zinc, 5,000 mg of copper, 300 mg of iodine, and 300,000 mg of magnesium. The mineral premix had no selenium. Sel-Plex and sodium selenite were added only in Se-supplemented diets

The yolk index (YI) was calculated as follows:

$$\mathrm{YI} = \frac{h}{w},$$

where h is the height and w the width, in millimeters.

The albumen index (AI) was calculated as follows:

$$\mathrm{AI} = 100x\frac{h}{l + 1/2w},$$

with h=height, l=length, and w=width (in millimeters).

The Haugh unit (HU) values [10] were calculated by the formula:

$$\mathrm{HU} = 100log\left(h + 7.57 - 1.7W^{0.37}\right),$$

where h=height of albumen (millimeters) and W=weight of egg (grams).

The general linear model (univariate) was chosen for statistical treatment of the data. The HU and pH were analyzed by one-way ANOVA. Duncan's multiple range test was used to establish significant differences between mean values of the main effects of treatment, storage time, and temperature. The SPSS for Windows v. 11.5 was used for all statistical procedures.

Results and Discussion

Table 2 shows how the source and concentration of Se supplementation influenced the Haugh unit values ($p<0.05$). Pooling data for all treatments and conditions, the HU score decreased significantly from 91.03 in the OSe-3 group compared to an average 88.14 for controls, In-Se.

Table 2 Effects of organic and inorganic selenium supplementation on the Haugh unit values in quail eggs

Treatment	4°C				20°C			Treatment means
	0	15	30	45	15	30	45	
Control, n=160	94.37	92.31b*	91.81b	92.24	85.58b	83.36b	82.05b	88.14b
In-Se, n=160	94.49	91.77b	91.74b	91.20	86.26b	83.57b	81.90b	88.14b
OSe-1, n=160	93.95	93.15ab	93.00ab	92.03	87.64ab	86.13ab	84.41ab	89.67a
OSe-2, n=160	93.02	93.37a	93.12ab	92.75	89.37a	87.70a	86.25a	90.56a
OSe-3, n=160	93.05	94.66a	93.88a	91.30	89.36a	87.04a	87.60a	91.03a
SEM	0.560	0.343	0.258	0.325	0.472	0.558	0.448	SEM 0.215
Storage time means	93.94a	93.05ab	92.72b	91.70c	87.64a	85.76b	84.44b	
SEM	0.178				0.290			
Storage temperature means	92.55a				85.95b			SEM 0.215

*Means within column with different letters differ significantly ($p<0.05$), *SEM* standard error means

Payne et al. found that eggs produced by hens fed a diet with 0.15, 0.30, 0.60, and 3.00 ppm organic Se had higher HU values than those of hens fed a standard diet [6]. Similarly, Arpasova et al. reported that the HU score was higher in all groups supplemented with selenium, but the difference was significant only in those given Se-yeast [11]. On the contrary, Paton et al. stated that supplementation with sodium selenite at 0.1, 0.2, or 0.3 ppm improved HU scores when compared to eggs from hens fed the same dietary levels of selenium yeast [12]. Gajcevic et al. analyzed the effects that selenium yeast supplementation had on the freshness of eggs stored for 0, 14, and 28 days at 4°C and found that the HU was better at the 0.4-ppm level than at 0.2 ppm [3].

The albumen HU score also decreased significantly with increasing storage time and temperature. The HU score decreased from 93.94 at 0 days to 91.70 (2.4%) after 45 days of storage at 4°C. At 20°C storage temperature, the decline was from 87.64 to 84.44 (3.6%). This result is in accordance with that of Wakebe, who reported that 0.3-ppm Se as Sel-Plex retarded the decline of HU of eggs stored for 7 days [13]. Similarly, Pappas et al. found that albumen HU decreased with increased storage, but supplemental selenium resulted in lower HU reductions [14]. Also, in agreement, Samlı et al. [15] reported that the HU decreased from 91.4 to 76.3 after 10 days of storage at 5°C, while at 21°C and 29°C the decline was further extended to 53.7 and 40.6, respectively.

Supplementation with Se-yeast resulted in lower pH of albumen, but the differences were not statistically significant (Table 3). This is in agreement with Pappas et al. who found that albumen pH was not significantly altered by dietary treatments [14]. Significant increases in pH of albumen were observed with increased storage time and temperature. Albumen became more alkaline with increasing storage temperature, from 8.69°C at 4°C to 9.47°C at 20°C. This result is in agreement with those of Avan and Alisarli [16], Silversides and Scott [17], and Akyurek and Okur Agma [18].

The effects that the selenium source has on some egg quality characteristics are presented in Table 4. The type of Se source did not affect the fresh egg weight, egg weight loss, or the shape and yolk indexes, but there were significant differences in albumen index, eggshell weight, and thickness. Pavlovic et al. found out no effects of Se on hen's eggs shape index, regardless of the type of supplement [1]. Arpasova et al. found that eggshell weight in the control, 0.4 mg/kg inorganic Se-, 0.4 mg/kg organic Se-, and 0.9 mg/kg

Table 3 Effects of organic and inorganic selenium supplementation on albumen pH in quail eggs

Treatment	4°C				20°C			Treatment (means)
	0	15	30	45	15	30	45	
Control, n=160	8.56	8.66	8.76	8.82	9.36	9.52	9.57	9.08
In-Se, n=160	8.56	8.66	8.75	8.84	9.35	9.49	9.56	9.08
OSe-1, n=160	8.52	8.65	8.74	8.79	9.37	9.54	9.55	9.07
OSe-2, n=160	8.53	8.61	8.72	8.81	9.36	9.51	9.55	9.06
OSe-3, n=160	8.54	8.60	8.74	8.82	9.32	9.51	9.53	9.05
SEM	0.011	0.005	0.004	0.015	0.007	0.009	0.006	SEM 0.016
Storage time means SEM	8.54d*	8.64c	8.75b	8.82a	9.35c	9.52b	9.55a	
	0.006				0.006			
Storage temperature means	8.69b				9.47a			SEM 0.016

*Means within rows with different letters are significantly different (p<0.05), *SEM* standard error means

Table 4 Effects of selenium sources, storage time, and temperature on the quality of quail eggs

Treatment[a]	Storage[a] temperature (°C)	Storage[a] time (days)	Egg weight		Shell		Albumen index	Yolk index	Shape index
			Fresh (g)	Loss (g)	Weight (g)	Thickness (mm)			
Control	4	0	13.61	–	1.46	0.48	14.85	45.34	75.09
		15	13.36	0.241	1.33	0.44	14.01	49.18	75.20
		30	13.24	0.317	1.33	0.44	13.23	48.21	76.77
		45	13.44	0.436	1.32	0.44	14.79	45.41	76.25
	20	15	13.79	0.430	1.28	0.42	9.96	38.38	75.99
		30	13.43	0.682	1.31	0.43	8.34	34.62	74.65
		45	13.26	0.945	1.26	0.42	7.86	32.37	75.12
In-Se	4	0	13.56	–	1.45	0.48	13.77	51.52	76.95
		15	13.38	0.225	1.29	0.43	13.13	49.35	75.21
		30	13.54	0.495	1.31	0.43	13.41	46.46	75.30
		45	13.60	0.403	1.40	0.46	13.45	44.71	75.10
	20	15	13.44	0.368	1.26	0.42	10.07	40.28	75.53
		30	13.38	0.654	1.31	0.43	7.98	35.36	75.96
		45	13.42	0.949	1.29	0.43	7.07	33.55	76.67
OSe-1	4	0	13.18	–	1.49	0.49	14.54	48.25	77.17
		15	13.90	0.197	1.42	0.47	14.30	48.58	76.84
		30	13.50	0.306	1.35	0.45	14.36	48.15	75.87
		45	13.78	0.305	1.35	0.45	14.16	45.63	75.67
	20	15	13.88	0.378	1.31	0.43	10.90	40.31	75.58
		30	13.69	0.637	1.33	0.44	9.29	35.95	76.28
		45	13.64	0.998	1.34	0.44	8.40	33.00	76.29
OSe-2	4	0	13.63	–	1.51	0.50	13.01	48.35	76.58
		15	13.87	0.224	1.44	0.48	14.72	50.87	75.74
		30	13.65	0.392	1.39	0.46	14.87	48.73	76.68
		45	13.72	0.332	1.42	0.47	14.82	45.78	75.38
	20	15	13.54	0.411	1.37	0.45	11.99	41.34	76.43
		30	13.67	0.587	1.36	0.45	9.55	35.71	75.54
		45	13.62	1.021	1.34	0.45	9.35	32.96	76.53
OSe-3	4	0	13.83	–	1.54	0.49	13.47	47.90	76.69
		15	13.59	0.158	1.42	0.46	15.15	50.73	76.96
		30	13.23	0.398	1.41	0.45	15.51	48.30	78.50
		45	13.64	0.390	1.44	0.46	13.40	44.17	75.46
	20	15	13.63	0.367	1.39	0.44	11.79	41.58	76.92
		30	13.44	0.621	1.38	0.44	10.05	37.53	75.80
		45	13.20	1.037	1.38	0.44	9.64	34.52	77.34
Control			13.43	0.470	1.31c	0.43c	11.53c	41.55	75.60
In-Se			13.46	0.478	1.32c	0.44c	10.98c	42.24	75.75
OSe-1			13.68	0.438	1.36b	0.45b	12.04ab	42.32	76.19
OSe-2			13.67	0.460	1.40a	0.46a	12.51a	42.92	76.11
OSe-3			13.48	0.459	1.41a	0.47a	12.63a	43.17	76.86
SEM[b]			0.038	0.014	0.005	0.001	0.134	0.283	0.145

Table 4 (continued)

Treatment[a]	Storage[a] temperature (°C)	Storage[a] time (days)	Egg weight		Shell		Albumen index	Yolk index	Shape index
			Fresh (g)	Loss (g)	Weight (g)	Thickness (mm)			
	4		13.56	0.317b	1.37a	0.45a	14.23a	47.80a	76.04
	20		13.53	0.672a	1.33b	0.44b	9.48b	36.48b	76.10
	SEM[b]		0.039	0.014	0.005	0.001	0.141	0.294	0.153
		0	13.56	–	1.49a	0.49a	13.93c	48.27a	76.50
		15	13.64	0.300c	1.35b	0.45b	12.60b	45.06b	76.04
		30	13.48	0.509b	1.35b	0.45b	11.65a	41.86c	76.14
		45	13.52	0.716a	1.35b	0.45b	10.98a	38.55d	76.03
		SEM[b]	0.038	0.014	0.005	0.001	0.134	0.283	0.145

Means with different letters differ significantly ($P<0.05$), *SEM* standard error means

[a] Significant interactions: egg weight loss=storage time×storage temperature; albumen index=storage time× storage temperature; yolk index=diet ×storage temperature, storage time×storage temperature

[b] Pooled SEM for main effects ($n=800$ eggs)

organic Se-supplemented groups were 60.45±3.87, 60.81±5.63, 62.41±3.72, and 62.15± 3.16 g ($P<0.05$), respectively [2].

The eggshell weight and thickness increased with inorganic or organic Se supplementation. The increase was statistically higher in Se-yeast-supplemented groups ($p<0.05$). According to Klecker et al., substituting 50% selenite by organic selenium in the diet of laying hens was associated with a significant increase in eggshell weight [19]. On the contrary, Arpasova et al. reported that eggshell weight was not significantly influenced by Se supplementation. Also, they found that average eggshell thickness was statistically higher in control group and 0.9 mg/kg Se-yeast-supplemented group [20]

Eggshell thickness was positively influenced by organic selenium [19, 21] and inorganic Se administered together with vitamin E [22]. Weight and thickness also decreased significantly with increasing storage time and temperature ($p<0.05$), in agreement with the findings of Samlı et al. [15] who reported that these parameters significantly decreased with increased storage time and temperature ($p<0.05$).

Egg weight loss decreased with Se-yeast supplementation, but this decrease was not significant. However, this value increased significantly with storage time and temperature ($P<0.05$). These results are in agreement with those of Walsh et al., who reported significant egg weight decreases of 0.36 and 0.57 g, respectively, after 7 and 14 days of storage [23]. Akyurek and Okur Agma also reported similar weight losses [18].

The albumen and yolk indexes increased with Se-yeast supplementation but only the AI increase was significant ($p<0.05$). Arpasova et al. reported similar increases of AI and YI [11]. On the contrary, both AI and YI decreased considerably with increasing storage time and temperature. The AI decreased with increasing storage time from 13.93 at 0 days to 10.98 after 45 days of storage. Higher temperature storage had the same effect on albumen and yolk indexes. These results are in good agreement with those of other studies [16, 18].

In conclusion, this experiment shows that the majority of indicators of quail egg quality are positively influenced by selenium yeast supplementation. These parameters were negatively influenced by the storage time and temperature. Selenium yeast supplementation may help ameliorating the decrease of quality during storage.

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