Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

Animal Nutrition
Received on: 15/08/2023
Accepted on: 04/12/2023

Egg quality and performance of Japanese quail supplemented with organic and inorganic selenium

Qualidade de ovos e desempenho de codornas japonesas suplementadas com selênio orgânico e inorgânico

TORGA, Anderson de Paula[1]
https://orcid.org/0000-0002-5340-774X

TEIXEIRA, Alexandre de Oliveira[1]*
https://orcid.org/0000-0001-8700-9611

REIS, Renata de Souza[1]
https://orcid.org/0000-0003-3443-7086

MOREIRA, Leonardo Marmo[1]
https://orcid.org/0000-0002-1792-1741

SOUSA, Júlio César Melo de[1]
https://orcid.org/0000-0003-3661-9772

MORAES, Monique Silva de[1]
https://orcid.org/0000-0002-2672-2824

LACERDA, Alicia Beatriz Ferreira de[1]
https://orcid.org/0000-0003-4873-9106

LYON, Juliana Pereira[2]
https://orcid.org/0000-0002-9016-8311

ROCHA JUNIOR, Carlos Magno da[3]
https://orcid.org/0000-0002-9043-6152

[1]Departamento de Zootecnia - DEZOO, Universidade Federal de São João Del Rei (UFSJ), Av. Visconde do Rio Preto, s/n, Colônia do Bengo, São João del-Rei - MG, 36301-360, Brasil
[2] Departamento de Ciências Naturais – DCNAT, Praça Dom Helvécio, 74 - Dom Bosco, São João del Rei - MG, 36301-160, Brasil
[3]Universidade Federal de Lavras - UFLA, Av. Sul UFLA - Aquenta Sol, Lavras - MG, 37200-000, Brasil
*Mail for correspondence: alexandre_teixeira@ufsj.edu.br

RESUMO

Objetivou-se avaliar a suplementação de selênio orgânico (Se org.) em diferentes concentrações e de selênio inorgânico (Se inorg.) nas rações de codornas sobre o desempenho; qualidade dos ovos; e tempo e condições de armazenamento. No ensaio de desempenho foram utilizadas 360 codornas com 27 semanas de idade, distribuídas em delineamento inteiramente casualizado (DIC) composto por seis tratamentos: Ração Basal; 0,15; 0,30; 0,45; e 0,60 ppm de Se org. e 0,60 ppm de Se inorg. suplementados *on top* à ração basal, com seis repetições e dez aves por unidade experimental. Para avaliar o tempo e condições de armazenamento foram utilizados 720 ovos de codornas distribuídos em DIC, com esquema fatorial 6x5x2 (sendo seis tratamentos provenientes do ensaio de desempenho; cinco tempos de estocagem (7, 14, 21, 28 e 35 dias); e duas formas de estocagem (refrigerada e não refrigerada), com doze repetições contendo um ovo cada. Não houve efeito na suplementação de Se org. e Se inorg. nas rações sobre desempenho e qualidade dos ovos. Houve aumento linear na concentração de Se nos ovos de codornas alimentadas com níveis crescentes deste nutriente. Houve efeito da

suplementação com selênio sobre o tempo de estocagem na qualidade de ovos mantidos sob refrigeração e em temperatura ambiente. Conclui-se que a suplementação, *on top*, de níveis entre 0,15 e 0,60 ppm de selênio nas formas orgânica ou inorgânica, não altera o desempenho das codornas, acentuando, contudo, a deposição desse mineral nos ovos, favorecendo a manutenção da qualidade ao longo do tempo de armazenamento.
Palavras-chave: Absorção de selênio, Antioxidante, Biodisponibilidade, Glutationa, Mineral

ABSTRACT

The objective of this study was to assess the impact of supplementing quail diets with organic selenium (Se) at various concentrations and inorganic Se on performance, egg quality, and storage time under different conditions. In the performance trial, 360 quail aged 27 weeks were included in a completely randomized design comprising six treatments: Basal Diet; 0.15, 0.30, 0.45, and 0.60 ppm of organic Se; and 0.60 ppm of inorganic Se, supplemented “on top” of the basal diet. Six replications were used, each with 10 birds per experimental unit. For the evaluation of storage time and conditions, 720 quail eggs were employed in a completely randomized design. The design featured a 6×5×2 factorial arrangement consisting of six treatments derived from the performance trial, five storage times (7, 14, 21, 28, and 35 days), and two storage forms (refrigerated and non-refrigerated). Each replication contained one egg, totaling 12 replications. Results indicated no significant effect of organic or inorganic Se supplementation in the diets on performance or egg quality. However, Se concentration increased linearly in eggs from quail fed increasing levels of this nutrient. Selenium supplementation affected storage time and egg quality under refrigerated and room-temperature conditions. In conclusion, on-top Se supplementation at concentrations ranging from 0.15 to 0.60 ppm, whether in organic or inorganic forms, does not impact quail performance. Nevertheless, it leads to increased Se deposition in eggs, contributing to the maintenance of egg quality throughout the storage period.

Keywords: Antioxidant, Bioavailability, Glutathione, Mineral, Selenium absorption.

Introduction

In the context of animal nutrition, minerals participate in all metabolic processes, serving as key components of cells and tissues, which renders them essential for animal health and performance. Selenium (Se) holds particular importance in the body, existing in varied concentrations across different biological tissues (Boiago et al., 2014).

Studies have demonstrated that the effects of Se supplementation depend on dose and source, and maintaining controlled Se inclusion levels is crucial. Both natural and artificially enriched foods with Se have been evaluated as primary supplementation sources, revealing diverse physiological functions *in vitro* and *in vivo*. These functions encompass antioxidant, anti-inflammatory, and anti-cancer actions (Chen et al., 2023). In its role as an antioxidant, Se typically collaborates with phenolic compounds, carotenoids, and vitamins C and E (Sun et al., 2020). Notably, Se contributes to the construction of the enzyme glutathione peroxidase (GPx), safeguarding cells against oxidation induced by free radicals (Skrivan et al., 2013; Nemati et al., 2020).

Commonly employed in laying bird nutrition, inorganic Se forms include selenite and sodium selenate. However, their use should be judicious due to the high intoxication capacity of these chemical compounds, as they can lead to Se accumulation in the body. Conversely, organic Se has higher bioavailability and a broader safe concentration range (Chen et al., 2023). This increased bioavailability comes without negative impacts on bird performance, reducing mineral excretion (Nunes et al., 2013; Tomaszewska et al., 2014). Therefore, supplementing laying birds with organic Se holds the promise of enhancing production value, presenting high biological value without residual effects or toxicity risks, thereby potentially improving egg quality (Qiu et al., 2021; Rodriguez-Alfaro et al., 2019).

Scientific evidence supports the positive impact of refrigeration on the internal quality of eggs during storage (Pires et al., 2022). While various factors influence egg quality (e.g., age of laying birds, diet, health, housing system), the role of Se in preventing egg spoilage remains a subject of debate. Consequently, the study aims to evaluate the effects of organic and inorganic Se supplementation on bird performance, egg quality, shelf life, and Se deposition in quail eggs.

MATERIAL AND METHODS

The experiment was conducted at the Animal Experimentation and Metabolism Laboratory (LEMA) of the Department of Animal Science (DEZOO) at the Tancredo Neves campus (CTAN), Federal University of São João Del Rei (UFSJ), in São João del-Rei, Minas Gerais (MG), Brazil.

All experimental procedures adhered to ethical guidelines for animal research and received approval from the Ethics Committee on the Use of Animals (CEUA) of UFSJ (Approval no. 030/2020).

A total of 360 Japanese quail (*Coturnix coturnix* japonica), aged 27 weeks, were utilized in a completely randomized design with six treatments: T1 - Basal Diet (control); T2 - 0.15 ppm organic Se; T3 - 0.30 ppm organic Se; T4 - 0.45 ppm organic Se; T5 - 0.60 ppm organic Se; and T6 - 0.60 ppm inorganic Se. These treatments were added on top of the basal diet, with six replications of 10 birds per experimental unit. The experimental duration was 63 days, divided into three periods of 21 days each.

The basal diet, formulated according to Rostagno et al. (2017), had a selenium (Se) content of 0.44 ppm in the fresh matter (87% DM), as identified by analysis.

Birds were housed in galvanized wire cages measuring 37.5 × 35 × 23 cm (width × depth × height), resulting in a density of 131 cm²/bird.

Throughout the experimental period, feed and water were supplied *ad libitum* using a trough-type feeder that extended the entire length of the cages. The feeder was partitioned based on each treatment and replication. Water was dispensed through nipple drinkers, with one drinker allocated for each experimental unit.

The lighting program consisted of 16 h of light per day, maintained throughout the experiment by an automatic clock (timer).

Twice-daily monitoring of temperatures and relative humidity occurred at 8h00 and 15h00 using maximum and minimum thermohygrometers and dry and wet bulb thermometers positioned in the center of the shed.

Management activities included egg collection and counting (number of broken, cracked, soft-shelled, and unshelled eggs), supplying feed, and

CC BY

monitoring temperatures (maximum and minimum) and relative humidity.

The following parameters were evaluated in each period: feed intake, egg production per bird/day, egg production per housed bird, marketable-egg production, egg weight, egg mass, feed conversion per egg mass, production viability, weight of egg components (yolk, albumen, and shell), and specific gravity.

Specific weight was evaluated on the 16th, 17th, and 18th days of each 21-day period. In this process, all intact eggs collected in each replication were immersed in saline solutions (water + sodium chloride (NaCl)) with densities ranging from 1.055 to 1.100 g/cm³, with intervals of 0.005 g/cm³. The density of each solution was measured using a densimeter.

For the evaluation of egg components on the 19th, 20th, and 21st days of each 21-day period, four eggs with weights close to the average of their respective experimental units were selected. These eggs underwent individual weighing on a scale with an accuracy of 0.001 g. The yolk of each egg was weighed and recorded, and the corresponding shell was washed and air-dried for one day to determine the shell weight. The weight of the albumen was determined by subtracting the egg's weight from the combined weight of the yolk and shell.

To assess Se deposition in eggs during the last week of the experiment, 20 eggs were selected per replication. These eggs were broken into a specific package, and the yolks and whites were weighed together, homogenized, and cooked in a microwave oven for 5 min. Subsequently, the boiled eggs were dried in a ventilated oven at 55 ºC for 72 h to determine the air-dried sample weight. Finally, the samples were ground and stored in plastic bags for analysis.

The analysis procedures were conducted at the Food Analysis Laboratory of the Department of Animal Science (DEZOO) at UFSJ according to the methodologies described by Detman et al. (2021) in Methods for Food Analysis. The definitive dry matter (oven-dried weight) was determined. Subsequently, the organic matter of the samples underwent oxidation with 5 mL of a nitroperchloric mixture (three parts nitric acid (HNO_3) to one part perchloric acid ($HClO_4$)), heating on a hot plate coupled with an exhaust fan, at temperatures between 150 and 190 ºC. After the complete elimination of organic matter, when the solution was crystalline, transparent, and exuding white vapors, 5 mL of concentrated hydrochloric acid (HCl) were added. The solution was heated on the hot plate for 30 min at 70 ºC, brought to a volume of 25 mL using deionized water, and Se contents were quantified by inductively coupled plasma atomic emission spectrometry (ICP-OES) (Optical Emission Spectrometer 8300 Perkin Elmer).

For the evaluation of storage time and methods, 720 Japanese quail eggs with an average weight of 11.48 g were used from treatments and replications of the performance trial. In the morning, the eggs were collected from industrial batteries and taken to the Animal Products Technology Laboratory at UFSJ, where the eggs were weighed using a digital scale with a precision of 0.001 g and identified individually.

After weighing and identification, the eggs were placed in trays for quail eggs. Subsequently, half were stored under refrigeration, and the other half were stored at room temperature, following the expected date of analysis according to each stipulated treatment.

The evaluation of storage time and conditions involved 720 Japanese quail eggs in a completely randomized design

CC BY

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

with a 6×5×2 factorial arrangement (six treatments corresponding to eggs from the performance trial; five storage times (7, 14, 21, 28, and 35 days); and two storage forms (refrigerated and non-refrigerated)), with 12 replications containing one egg each. After the designated period for each treatment, the analysis of quality parameters included weight loss of eggs (g), specific gravity of eggs (g/cm³), yolk weight (g), albumen weight (g), and shell weight (g). The parameters of performance, egg quality, Se deposition in eggs, and shelf life underwent analysis of variance utilizing the statistical analysis system – SAEG, developed at the Federal University of Viçosa - UFV (2007). The means of the positive control (inorganic Se) were compared with the means of treatments containing organic Se using Dunnett's test. Additionally, the means of the parameters, with quail subjected to different levels of inclusion of organic Se or shelf time, were subjected to regression analysis at a 5% probability.

RESULTS AND DISCUSSION

During the experiment, the maximum and minimum temperatures observed were 26.6 ± 2.36 ºC and 13.5 ± 3.63 ºC, respectively, with a relative humidity inside the shed of 67.5 ± 10.43%.

The recorded temperature values fall outside the thermal comfort range for adult quail. According to Rosa et al. (2011), the thermal comfort temperature for quail is between 18 and 22 ºC, with relative humidity around 60%. Although the climatic conditions theoretically did not compromise the birds' performance, the observed temperature values suggest that the quail may have been exposed to stressful situations, either due to heat or cold. However, it was noted that laying Japanese quail can exhibit a good productive response to temperatures in the range of 17 to 29 °C (Santos et al., 2016). On the other hand, feed supplementation with different sources of selenium (Se) can mitigate the damage caused by heat stress in birds (Wang et al., 2022; El-Deep et al., 2017).

Table 1 displays the performance results of Japanese quail supplemented with organic and inorganic Se.

Table 1. Performance parameters of Japanese quail fed diets supplemented with different levels of organic and inorganic selenium

Parameter	TREATMENT						Mean	p - value
	Control	Organic Se (%)				Inorganic Se		
	0%	0.15	0.3	0.45	0.6	0.6%		
Intake/bird/day (g)*	28.50	27.97	27.67	28.36	28.63	28.30	28.24	3.27
Laying rate/bird/day (%)*	92.12	94.62	92.41	94.04	93.50	92.37	93.17	5.21
Laying rate/bird housed (%)*	92.11	94.18	92.41	93.44	92.01	92.09	92.71	5.25
Percentage of marketable eggs*	97.33	98.83	99.00	99.33	98.83	99.00	98.72	1.90
Egg mass/bird/day (g)*	10.87	11.05	10.78	10.99	11.08	10.91	10.95	5.96
Feed conversion/egg mass*	2.63	2.53	2.57	2.59	2.59	2.60	2.58	5.60

* p-value - NS (not significant); CV – coefficient of variation (%)

CC BY

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

No significant effect was observed ($p>0.05$) for the parameters of laying rate/bird housed, eggs/bird/day, percentage of marketable eggs, egg mass/bird/day, feed conversion per egg mass, or feed intake/bird/day.

In the present study, no difference was observed in the use of organic sources compared to the positive control (inorganic Se) concerning the performance parameters of the quail. These findings align with Han et al. (2017), who found no significant differences in the supplementation of laying hen diets with inorganic and organic sources of Se. However, in contrast, Wang et al. (2022) concluded that the effect of organic Se is superior to that of inorganic Se in layers.

Regarding the evaluation of different levels of organic Se inclusion, there was no observed improvement in the performance parameters of the birds. This is consistent with findings by Wang et al. (2022) in their work with laying hens. Additionally, dietary supplementation of Japanese quail with varying levels of vitamin E and organic or inorganic Se did not significantly affect feed intake, feed conversion, or egg production (Nemati et al., 2020). Nonetheless, Radwan et al. (2015) and Skrivan et al. (2013) reported an improvement in performance parameters in laying hens when evaluating different sources of Se. The Se levels assessed in the present study exceeded nutritional requirements, making it challenging to obtain statistical differences. However, the excess Se did not impact performance or cause toxicity in the birds.

Table 2 presents results regarding the quality of eggs from Japanese quail supplemented with organic and inorganic Se. No significant effect ($p>0.05$) was found for the parameters of egg weight, specific weight, shell weight, yolk weight, albumen weight, shell percentage, yolk percentage, or albumen percentage.

In numerous studies, no significant differences in egg quality traits were found between the Se diet and the control group (Han et al., 2017; Lu et al., 2020; Liu et al., 2020). Conversely, Invernizzi et al. (2013) observed a positive effect on egg weight and eggshell weight when laying hens were supplemented with 0.4 mg kg^{-1} of organic and inorganic Se. The addition of organic Se to the diet had no effect on the total weight, egg white weight, shell weight, and shell thickness of eggs, but significantly increased the yolk weight (Januzi et al., 2017). Factors contributing to improved albumen quality include a more absorbable form of organic Se, positive effects of Se on oviduct health, and antioxidant enzyme activities, which could enhance metabolism and protein utilization. Limited information exists on the influence of organic Se on the quality of fresh egg albumen, as mentioned by Obianwuna et al. (2022).

CC BY

Table 2. Internal and external quality parameters of eggs from Japanese quail fed diets supplemented with different levels of organic and inorganic selenium

Parameter	TREATMENT Control	Organic Se (%)				Inorganic Se	Mean	p - value
	0%	0.15	0.3	0.45	0.6	0.6%		
Egg weight (g)*	11.80	11.68	11.67	11.68	11.84	11.81	11.75	2.55
Yolk weight (g)*	3.51	3.49	3.48	3.50	3.54	3.57	3.52	3.26
Yolk percentage (%)*	29.79	29.93	29.84	29.95	29.85	30.25	29.94	2.44
Album weight (g)*	7.27	7.17	7.18	7.17	7.31	7.22	7.22	3.10
Album percentage (%)*	61.67	61.42	61.50	61.32	61.68	61.17	61.46	1.29
Shell weight (g)*	1.007	1.015	1.011	1.019	1.003	1.012	1.011	3.022
Shell percentage (%)*	8.54	8.69	8.66	8.73	8.47	8.57	8.61	2.714
Specific weight (g/cm^3)*	1.076	1.076	1.077	1.077	1.077	1.077	1.077	0.12

* p-value - NS (not significant); CV – coefficient of variation (%)

Table 3 shows the results regarding the deposition of Se in the eggs of Japanese quail supplemented with organic and inorganic Se.

Table 3. Selenium deposition parameters in eggs from Japanese quail fed diets supplemented with different levels of organic and inorganic selenium

Parameter	TREATMENT Control	Organic Se (%)				Inorganic Se	Mean	p - value	CV
	0%	0.15	0.3	0.45	0.6	0.6%			(%)
Egg dry matter (%)	24.1	25.3	25.2	24.7	24.2	24.3	24.6	-	-
Se deposition in the egg (mg kg^{-1}) ^{L}	0.357	0.384	0.409	0.464*	0.546*	0.488*	0.442	0.0005	15.78

Means followed by an asterisk (*) differ from the negative control treatment, without on-top inclusion of Se, based on the Dunnett test ($p<0.05$). L – linear regression ($p<0.05$) in treatments according to on-top inclusion levels of organic Se. CV – coefficient of variation (%)

Figure 1 highlights the deposition trend of Se obtained only from organic sources. There was a significant effect ($p<0.05$) on Se deposition in eggs, with quail supplemented on-top with 0.45 and 0.6% of organic Se and 0.6% of inorganic Se showing greater deposition compared to the negative control (without on-top inclusion of Se). A linear effect ($p < 0.05$) on Se deposition in eggs was observed in groups that received treatments containing on-top inclusion levels of organic Se.

CC BY

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

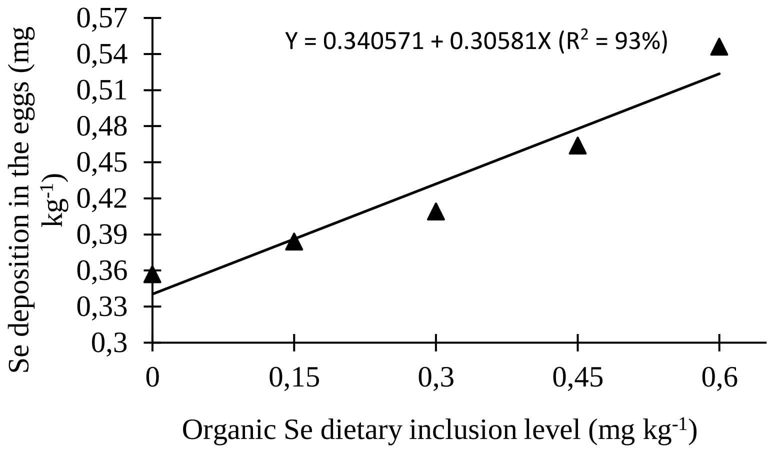

Figure 1 – Selenium (Se) deposition in quail eggs (in mg kg^{-1}) according to the level of on-top inclusion of organic Se in the feed.

As observed in our experiment, enhancing the nutritional content of eggs in terms of Se through dietary supplementation of quail with varying levels of vitamin E and organic or inorganic sources resulted in improved quality of both fresh and stored eggs (Nemati et al., 2020). Payne et al. (2005), on the other hand, supplemented laying hens with 0.15, 0.30, and 0.60 ppm of organic and inorganic Se and found a linear increase in Se deposition in eggs. However, the deposition of organic Se in the form of SeMet was greater when compared to its inorganic form (sodium selenite). Gjorgovska et al. (2012) investigated organic Se in feed for laying hens and observed an increase in the levels of Se deposited in both albumen and yolk. Since the Japanese quail in the present study were of the same age and kept under identical conditions, it is assumed that the concentration of Se supplemented in the diets was the sole reason for the increased Se deposition in the eggs. Thus, positive effects were identified from Se enrichment in the quail diet, corroborating the findings of Qiu et al. (2021ab).

The average ambient temperature and relative humidity in the areas where the eggs were stored under refrigeration were 2.6±0.9 ºC and 36.1±5.3%, respectively. In environments where eggs were stored at room temperature, the ambient temperature and relative humidity were 25.6±1.7 ºC and 62.3±10.7%, respectively.

Concerning eggs stored under refrigeration (Table 4), there was an interaction between the levels and sources of Se used in the feed and the egg storage time ($p<0.05$), but only for specific gravity. In a simple effect analysis, Se supplementation in the Japanese quail diet did not influence egg weight, yolk weight, shell weight, or albumen weight, impacting ($p<0.05$) weight loss and specific gravity. Egg storage time influenced ($p<0.05$) all variables related to egg quality.

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

Table 4. Internal and external quality parameters of cold-stored eggs from Japanese quail fed diets with different levels of on-top inclusion of organic and inorganic selenium

Selenium inclusion (mg kg^{-1})	EW (g)	YW (g)	SW (g)	AW (g)	WL (g)	SE (g/cm³)
0.00, organic	11.474	3.699	0.971	6.804	0.382a	1,053
0.15, organic	11.627	3.695	0.998	6.937	0.317ab	1,054
0.30, organic	11.512	3.678	0.984	6.849	0.298ab	1,053
0.45, organic	11.561	3.644	0.998	7.102	0.244b	1,057
0.60, organic	11.674	3.706	0.989	6.977	0.241b	1,055
0.60, inorganic	11.676	3.680	1.008	6.987	0.280b	1,057
Storage time (days)						
7	11.893a	3.666ab	1.012a	7.368a	0.154c	1,060
14	11.811ab	3.663ab	1.017a	7.133ab	0.178bc	1,060
21	11.493bc	3.644b	0.970b	6.878bc	0.253b	1,055
28	11.309c	3.627b	0.970b	6.711c	0.445a	1,050
35	11.430c	3.818a	0.987ab	6.624c	0.438a	1,050
Se	0.6305	0.9573	0.159	0.4862	<0.001 (L)	<0.001 (L)
Days	<0.001 (L)	0.0192 (L)	<0.001 (Q)	<0.001 (L)	<0.001 (L)	<0.001 (L)
Se*Days	0.7402	0.8145	0.495	0.4122	0.1668	0.0318
CV (%)	6.82	10.21	8.02	12.56	58.78	0.42

Egg weight (EW), yolk weight (YW), shell weight (SW), albumen weight (AW), weight loss (WL), specific gravity (SG), L - Linear

Egg yolk weight exhibited a linear increase ($p<0.05$) during the storage period when stored under refrigeration. The beneficial effects of refrigeration on eggs were noted by Jones et al. (2018), who observed a positive impact on yolk quality in refrigerated eggs. During storage, chemical and physical reactions may occur, leading to the degradation of the protein structure in thick albumin. The reaction product, water linked to large protein molecules, passes into the yolk by osmosis, consequently increasing its weight (Pissinati et al., 2014).

No effect was observed ($p>0.05$) regarding the Se levels evaluated for yolk weight in eggs kept under refrigeration. Thus, increased Se intake had no influence on this variable. These findings align with Gjorgovska et al. (2012), who observed no effect on the percentages of yolk, albumen, and shell in Japanese quail eggs, irrespective of Se levels or sources.

Shell weight decreased ($p<0.05$) with storage time. The external quality of eggs can be influenced by factors related to bird age, environment, management, and nutrition. Research indicates that eggs with thicker shells are more resistant to physical damage, reducing economic losses from cracks and actual breaks. Selenium supplementation did not affect albumen weight ($p>0.05$), consistent with the results of Gjorgovska et al. (2012), who found no effect on the

CC BY

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

percentage of albumen in Japanese quail eggs, regardless of Se levels or sources.

Albumen weight decreased significantly ($p<0.05$) with storage time for both analyzed storage methods. The high coefficient of determination demonstrates the considerable impact of storage time on the quality of the specific parameter, albumen weight. Indeed, changes in the albumen can be attributed to the porosity of the shell. This phenomenon arises because the shell is permeable, allowing water to be lost from the albumen to the external environment, resulting in a reduced proportion of albumen in the overall weight of stored eggs (Pissinati et al., 2014). The implementation of refrigeration mitigates the rate of carbon dioxide (CO_2) loss from the interior of the eggs to the environment through the eggshell pores. This mitigation tends to elevate the pH of the albumen, reducing its viscosity (Pires et al., 2019). In this context, refrigeration serves to delay the deterioration of albumen quality.

Figure 2 illustrates the decomposition of the interaction effect between Se levels and refrigerated-storage time of eggs for specific gravity. Eggs from quail fed with 0.45 and 0.60 ppm of organic Se took longer to decrease in specific gravity depending on the storage time. The density was higher on days 7, 14, and 21, being the same on the other days. Since density is the ratio between mass and volume, with mass being a quantity directly proportional to density, a decrease in mass leads to a simultaneous decrease in density. Consequently, the greater loss of egg mass throughout the storage period resulted in lower specific gravity.

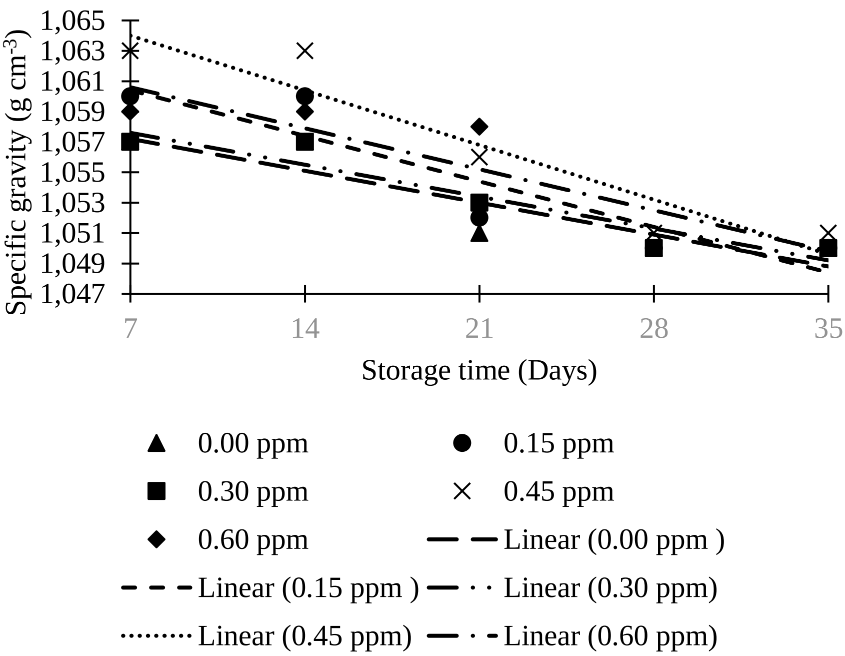

Figure 02. Decomposition of the interaction effect between selenium inclusion levels and storage time on specific gravity of quail eggs stored under refrigeration.

ISSN 1519 9940

Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

In reference to eggs stored at room temperature, on a shelf (Table 5), an interaction between the levels and sources of Se used in the feed and egg storage time ($p < 0.05$) was observed, specifically in relation to egg weight loss.

Table 5 - Internal and external quality parameters of room temperature-stored eggs from Japanese quail fed diets with different levels of on-top inclusion of organic and inorganic selenium

Selenium inclusion (mg kg^{-1})	EW (g)	YW (g)	SW (g)	AW (g)	WL (g)	SG (g/cm³)
0.00 Org.	11.644a	3.882	0.996	6.765	0.422	1.052
0.15 Org.	11.612ab	3.855	0.974	6.806	0.365	1.051
0.30 Org.	11.643a	3.815	0.997	6.830	0.332	1.052
0.45 Org.	11.215b	3.736	0.981	6.497	0.498	1.052
0.60 Org.	11.548ab	3.826	1.006	6.712	0.529	1.053
0.60 Ino.	11.573ab	3.864	1.012	6.696	0.345	1.052
Storage time (Days)						
7	11.831a	3.713b	1.008	7.125a	0.124	1.056a
14	11.437b	3.669b	0.984	6.783b	0.208	1.056a
21	11.624ab	3.885a	1.007	6.731b	0.399	1.050b
28	11.514ab	3.964a	0.976	6.573bc	0.688	1.050b
35	11.291b	3.916a	0.998	6.376c	0.658	1.050b
Se	0.0284 (L)	0.3212	0.1479	0.0657	<0.001 (L)	0.0965
Days	0.0011 (L)	<0.001 (L)	0.1246	<0.001 (L)	<0.001 (L)	<0.001 (L)
Se*Days	0.5802	0.5568	0.7882	0.5721	<0.001	0.8776
CV (%)	6.88	9.71	8.95	9.56	67.09	0.36

Egg weight (EW), yolk weight (YW), shell weight (SW), albumen weight (AW), weight loss (WL), specific gravity (SG), L - linear.

In the case of eggs stored at room temperature, Se supplementation to Japanese quail feed did not affect yolk weight, shell weight, albumen weight, or specific gravity. However, it did have a significant impact ($p < 0.05$) on egg weight and weight loss. Previous studies have indicated that Se supplementation in Japanese quail diets can extend the shelf life of eggs by reducing yolk fat peroxidation (Ahmadian et al., 2019).

Egg storage time had a significant influence ($p < 0.05$) on all variables related to egg quality, except shell weight. In eggs stored at room temperature on shelves, there was a linear reduction ($p<0.05$) in egg weight based on the level of Se inclusion in the diet. However, only 15% of the variation in egg weight is explained by the change in Se levels. According to Oliveira & Santos (2018), egg weight is considered an important factor when assessing its quality.

In the two experiments conducted in this study, egg weight was affected by storage time, even in environments with controlled temperature and humidity. Over time, there was a linear reduction in the weight of eggs stored in both the refrigerator and at room temperature. This reduction is attributed to the loss of

CC BY

RBSPA
Rev. Bras. Saúde Prod. Anim., Salvador, v.25, 01 - 15, 20230027, 2024
http://dx.doi.org/10.1590/S1519-994020230027

water in the egg white through the pores in the shell (Santos et al., 2016).

Figure 3 illustrates the decomposition of egg weight loss as a function of the interaction between Se levels and storage time for cold-stored eggs. The weight loss in eggs from quail fed 0.45 and 0.60 ppm of organic Se was more pronounced after 21 days of storage at room temperature. This process is considered a crucial criterion for evaluating the decrease in egg freshness during packaging under experimental conditions (Pires et al., 2020).

Supplementing 0.15 and 0.30 ppm of organic Se resulted in less weight loss in eggs at the end of the storage period. A similar phenomenon was observed with 0.60 ppm of inorganic Se. Therefore, it can be inferred that organic Se is a more bioavailable source than inorganic sources, which is attributed to its ability to bind to tissues, associated with lower inclusion values that were sufficient to obtain statistical differences between the treatments. In contrast, the inorganic form, being eliminated in large quantities in excreta, required a higher level of inclusion to achieve statistical significance.

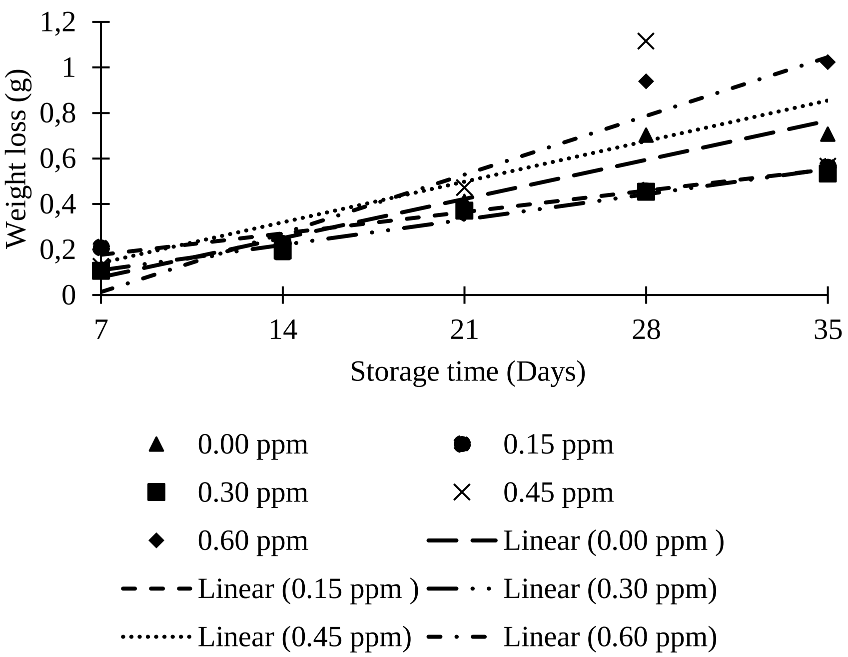

Figure 03- Decomposition of the interaction between selenium inclusion levels and storage time on weight loss in quail eggs stored at room temperature.

Kralik et al. (2009) observed less pronounced values of metabolic processes in eggs from laying hens fed diets supplemented with SeMet throughout the storage period. However, they also noted a decline in the internal quality of eggs over time, irrespective of the selenium source, indicating a correlation with the aging of eggs during shelf life.

Moreover, it can be asserted that the storage period negatively impacts the quality characteristics of eggs. Eggs stored at refrigerated temperatures exhibit superior quality parameters compared to those stored at room

cc BY

temperature (Pires et al., 2022; Pires et al., 2021).

On-top supplementation of selenium at levels ranging from 0.15 to 0.60 ppm, whether in organic or inorganic forms, does not alter the performance of Japanese quail. However, it accentuates the deposition of this mineral in the eggs, thereby promoting the maintenance of their quality throughout the storage period.

Acknowledgments

This study was developed with support from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG).

References

AHMADIAN, H., NEMATI, Z., KARIMI, A., & SAFARI, R. (2019). Effect of different dietary selenium sources and storage temperature on enhancing the shelf life of quail eggs. *Animal Production Research, 8*, 23–33.

Boiago, M. M., Borba, H., Leonel, F. R., Giampietro-ganeco, A., Ferrari, F. B., Stefani, L. M., & Souza, P. A. (2014). Sources and levels of selenium on breast meat quality of broilers. *Ciência Rural*, *44*(9), 1692-1698.

Chen, Z., Lu, Y., Dun, X., Wang, X., & Wang, H. (2023). Research Progress of Selenium-Enriched Foods. *Nutrients*, 15(19), 4189.

DETMANN, E., COSTA E SILVA, L. F., ROCHA, G. C., PALMA, M. N. N., & Rodrigues, J. P. P. (2021). *Métodos para análise de alimentos-INCT-Ciência Animal*, 2ª ed. Visconde do Rio Branco, Minas Gerais: Suprema, 2021, 350p.

EL-DEEP, M. H., SHABAAN, M., ASSAR, M., ATTIA, K., & SAYED, M. (2017). Comparative Effects of Different Dietary Selenium Sources on Productive Performance, Antioxidative Properties and Immunity in Local Laying Hens Exposed to High Ambient Temperature. *Journal of Animal and Poultry Production*, *8*(9), 335-343.

GJORGOVSKA, N., KIRIL, F., VESNA, L., & TOSHO, K. (2012). The effect of different levels of selenium in feed on egg production, egg quality and selenium content in yolk. *Lucrari Stiintifice Seria Zootehnie*, *57*, 270-274.

HAN, X. J., QIN, P., Li, W. X., Ma, Q. G., Ji, C., ZHANG, J. Y., & ZHAO, L. H. (2017). Effect of sodium selenite and selenium yeast on performance, egg quality, antioxidant capacity, and selenium deposition of laying hens. *Poultry Science*, *96*(11), 3973–3980.

INVERNIZZI, G., AGAZZI, A., FERRONI, M., REBUCCI, R., FANELLI, A., BALDI, A., DELL´ORTO, V., & SAVOINI, G. (2013). Effects of inclusion of selenium-enriched yeast in the diet of laying hens on performance, eggshell quality, and selenium tissue deposition**.** *Italian Journal of Animal Science*, *12*(1), 1-8.

JANUZI, V., SENA, L., & ELEZI, X. (2017). The influence of layers feed supplementation with organic selenium on the eggs quality and selenium content in the egg. *Albanian Journal of Agricultural Sciences*, 329–333.

JONES, D. R., WARD, G. E., REGMI, P., & KARCHER, D. M. (2018). Impact of Egg Handling and Conditions during Extended Storage on Egg Quality. *Poultry Science*, *97(2)*, 716–723.

Kralik, G., Gajčević, Z., Suchý, P., Straková, E., & Hanžek, D. (2009). Effects of Dietary Selenium Source and Storage on Internal Quality of Eggs. *Acta Veterinaria Brno*, *78*(2), 219–222.

LIU, H., YU, Q., FANG, C., CHEN, S., TANG, X., & AJUWON, K. M., (2020). Effect of selenium source and level on performance, egg quality, egg selenium content, and serum biochemical parameters in laying hens. *Foods*, *9*:68.

LU, J., QU, L., MA, M., LI, Y., WANG, X., & YANG, Z. (2020). Efficacy evaluation of selenium-enriched yeast in laying hens: effects on performance, egg quality, organ development, and selenium deposition. *Poultry Science*. *99*, 6267–77.

NEMATI, Z., AHMADIAN, H., BESHARATI, M., LESSON, S., ALIREZALU, K., DOMÍNGUEZ, R., & LORENZO, J. M. (2020). Assessment of Dietary Selenium and Vitamin E on Laying Performance and Quality Parameters of Fresh and Stored Eggs in Japanese Quails. *Foods*, 9, 1324.

NUNES, J. K., SANTOS, V. L., ROSSI, P., ANCIUTTI, M. A., RUTZ, F., MAIER, J. C., & SILVA, J. G. C. (2003). Qualidade de ovos e resistência óssea de poedeiras alimentadas com minerais orgânicos. *Arquivo Brasileiro de Medicina Veterinária e Zootecnica*, *65*(2), 610-618.

OBIANWUNA, U. E., OLEFORUH-OKOLEH, V. U., WANG, J., ZHANG, H. J., Qi, G. H., Qiu, K., & Wu, S. G. (2022). Natural products of plants and animal origin improve albumen quality of chicken eggs. *Frontiers in Nutrition*, 9, 875270.

OLIVEIRA, G. S., & SANTOS, V. M. (2018). Manejo de ovos férteis: revisão de literatura. *Nutritime Revista Eletrônica*, *15*(6), 8337-8351.

PAYNE, R. L., LAVERGNE, T. K., & SOUTHEM, L. L. (2005). Effect of inorganic versus organic selenium on hen production and egg selenium concentration. *Poultry Science*, *84*, 232–237.

PIRES, P. G. S., BAVARESCO, C. & MORAES, P. O. (2022). Cem anos de conhecimento em refrigeração de ovos de mesa. *World's Poultry Science Journal, 78*(4), 1007-1019.

PIRES, P. G. S., BAVARESCO, C., PIRES, P. D. S., CARDINAL, K. M., LEUVEN, A. L. R., & ANDRETTA, I. (2021). Development of an Innovative Green Coating to Reduce Egg Losses. *Cleaner Engineering and Technology*, *2*, 100065.

PIRES, P. G. S., MACHADO, G. S., FRANCESCHI, C. H., KINDLEIN, L. & I. ANDRETTA (2019). Rice Protein Coating in Extending the Shelf-Life of Conventional Eggs. *Poultry Science*, *98*(4), 1918–1924.

PIRES, P. G. S., PIRES, P. D. S., CARDINAL, K. M., & BAVARESCO, C. (2020). The Use of Coatings in Eggs: A Systematic Review. *Trends in Food Science & Technology 106*(August), 312–321.

PISSINATI, A., OBA, A., YAMASHITA, F., SILVA, C.A., PINHEIRO, J.W., & ROMAN, J.M.M. (2014). Internal quality of eggs subjected to different types of coating and stored for 35 days at 25°C. *Semina: Ciências Agrárias*, *35*(1), 531-540.

QIU, K., MA, Y., OBIANWUNA, U. E., WANG, J., ZHANG, H., Qi, G., & Wu, S. (2021b). Application of selenium conjugated to animal protein in laying hens' diet for the production of selenium-enriched eggs. *Foods*, *10*(6), 1224-14.

QIU, K., ZHENG, J. J., OBIANWUNA, U. E., WANG, J., ZHANG, H. J., Qi, G. H., & Wu, S. G. (2021a). Effects of Dietary Selenium Sources on Physiological Status of Laying Hens and Production of Selenium-Enriched Eggs. *Frontriers in Nutrition*, *8*, 726770.

RADWAN, N. L., SALAHELDIN, T. A., EL-ZAIAT, A. A., & MOSTAFA, M. A. S. A. (2015). Effect of dietary nano-selenium supplementation on selenium content and oxidative stability in table eggs and productive performance of laying hens. *International Journal of Poultry Science*, *14*(3), 161-176.

RODRIGUEZ-ALFARO, M., SALAS-DURAN, C., & OROZCO-VIDAORRETA, C. (2019). Suplementação de galinas ponedoras com selênio orgânico e sua transferência al huevo. *Agronomia. Mesoamericana*, *30*(1), 239-253.

ROSA, G. A., SORBELLO, L. A., DITTRICH, R. L., MORAES, M. T. T., & OLIVEIRA, E. G. (2011). G. Perfil hematológico de codornas japonesas (*Coturnix cotunix japonica*) sob estresse térmico. *Ciência Rural*, *41*(9), 1605-1610.

ROSTAGNO, H. S., ALBINO, L. F. T., HANNAS, M. I., DONZELE, J. L., SAKOMURA, N. K., PERAZZO, F. G., SARAIVA, A., ABREU, M. L. T., RODRIGUES, P. B., OLIVEIRA, R. F., BARRETO, S. L. T., & BRITO, C. O. (2017). *Tabelas Brasileiras Para Aves e Suínos – Composição de Alimentos e Exigências Nutricionais.* 4ª ed. Viçosa-MG: UFV. 488p.

SANTOS, J. S., MACIEL, L. G., SEIXA, V. N. C., & ARAÚJO, J. A. (2016). Parâmetros avaliativos da qualidade física de ovos de codornas (*coturnix coturnix japonica*) em função das características de armazenamento. *Revista Desafios*, *03*(01), 1-15.

SKRIVAN, M., M., MAROUNEK, M. ENGLMAIEROVÁ, & V. SKŘIVANOVÁ. (2013), Influence of dietary vitamin C and selenium, alone and in combination, on the performance of laying hens and quality of eggs. *Czech Journal of Animal Science*, *58*(2), 91-97.

SUN, X., YUE, S., QIAO, Y., SUN, Z., WANG, C., & LI, H. (2020). Dietary supplementation with selenium-enriched earthworm powder improves antioxidative ability and immunity of laying hens. *Poultry Science*, *2*–6.

TOMASZEWSKA, E., DOBROWOLSKI, P., KWIECIEŃ, M., BURMAŃCZUK, N., BADZIAN, B., SZYMAŃCZYK, S., & KURLAK., P. (2014). Alterations of liver histomorphology in relation to copper supplementation in inorganic and organic form in growing rats. *Bulletin of the Veterinary Institute in Pulawy*. *58*(3), 479–486.

WANG, W., KANG, R., LIU, M., WANG, Z., ZHAO, L., ZHANG, J., HUANG, S., & MA, Q. (2022). Effects of Different Selenium Sources on the Laying Performance, Egg Quality, Antioxidant, and Immune Responses of Laying Hens under Normal and Cyclic High Temperatures. *Animals*, 12, 1006.