SEMINA
Ciências Agrárias

DOI: 10.5433/1679-0359.2026v47n2p415

Oxidative status and lipid peroxidation benefits in Japanese quail breeder supplemented with selenium-enriched yeast and antioxidant blend

Estado oxidativo e benefícios sobre a peroxidação lipídica em codornas japonesas reprodutoras suplementadas com levedura enriquecida com selênio e blend antioxidante

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Highlights

No performance impacts of dietary supplementation with SeY and AB.
Lower serum cholesterol and triglycerides in both male and female birds with SeY.
Greater antioxidant capacity and lower lipid peroxidation with SeY.

Abstract

The micronutrient selenium (Se) is essential in poultry nutrition and is primarily supplied through diet. Studies have shown that organic Se sources, such as selenomethionine, selenocysteine, and selenium-enriched yeast, have higher bioavailability than inorganic sources such as selenite. This study aimed to evaluate the productive performance and antioxidative status of quail breeders supplemented with selenium-enriched yeast (SeY) alone or as part of an antioxidant blend and their progeny. A total of 420 quails were assigned to five treatments: a basal diet (BD) with 0.25 mg/kg mg kg^{-1} Se from sodium selenite (SS); BD + 0.3 mg kg^{-1} SeY (0.3 SeY); BD + 0.6 mg kg^{-1} SeY (0.6 SeY); BD + 0.3 mg kg^{-1} SeY + 6.37 mg kg^{-1} antioxidant blend (0.3 SeY+AB); and BD + 0.6 mg kg^{-1} SeY + 13.08 mg kg^{-1} antioxidant blend (0.6 SeY+AB), with 12 replicates of two males and five females per treatment. Breeder parameters evaluated included productive performance, egg quality, serum biochemistry, antioxidant activity, and lipid peroxidation. The performance of the progeny was assessed from days 1 to 35, with 4 replicates of 25 chicks hatched from eggs of each breeder treatment. Data were analyzed by ANOVA, and means

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Received: Ago. 28, 2025 Approved: Jul. 28, 2026

were compared using Tukey's test with SAS v.9.0. No differences in breeder productive performance or egg quality were observed among treatments. In the first 15 days of life progeny from SeY treatments had lower body weight (P < 0.05). With the addition of AB, body weights were like those observed in the BD group. From days 15 to 35, progeny from the 0.3 SeY treatment showed lower body weight compared to the BD and both AB-supplemented groups. Breeders fed diets containing SeY, either alone or as part of antioxidant blend, had lower serum cholesterol and triglyceride concentrations than those fed the basal diet. In quail breeders, antioxidant capacity (DPPH%) was higher and lipid peroxidation was lower in the serum, liver, and egg yolk in all groups supplemented with SeY, regardless of AB inclusion. It was concluded that SeY supplementation, with or without AB, is recommended to produce fertile eggs in Japanese quails due to its beneficial effects on antioxidant status and blood lipid profile.
Key words: Ascorbic acid. Malonaldehyde. Organic minerals.

Resumo

O micronutriente selênio (Se) é essencial na nutrição de aves e é fornecido principalmente por meio da dieta. Estudos demonstram que fontes orgânicas de Se, como selenometionina, selenocisteína e levedura enriquecida com selênio (SeY), apresentam maior biodisponibilidade do que fontes inorgânicas, como o selenito de sódio. Este estudo teve como objetivo avaliar o desempenho produtivo e o estado antioxidante de codornas japonesas reprodutoras suplementadas com levedura enriquecida com selênio (SeY), isoladamente ou em combinação com um blend antioxidante (AB), bem como o desempenho de sua progênie. Um total de 420 codornas foi distribuído em cinco tratamentos: uma dieta basal (BD) contendo 0,25 mg kg^{-1} de Se proveniente de selenito de sódio (SS); BD + 0,3 mg kg^{-1} de SeY (0,3 SeY); BD + 0,6 mg kg^{-1} de SeY (0,6 SeY); BD + 0,3 mg kg^{-1} de SeY + 6,37 mg kg^{-1} de blend antioxidante (0,3 SeY+AB); e BD + 0,6 mg kg^{-1} de SeY + 13,08 mg kg^{-1} de blend antioxidante (0,6 SeY+AB), com 12 repetições, cada uma composta por dois machos e cinco fêmeas. Nas reprodutoras foram avaliados o desempenho produtivo, a qualidade dos ovos, a bioquímica sérica, a atividade antioxidante e a peroxidação lipídica. O desempenho da progênie foi avaliado do 1º ao 35º dia de idade, utilizando quatro repetições de 25 pintinhos oriundos dos ovos de cada tratamento das reprodutoras. Os dados foram analisados por ANOVA, e as médias foram comparadas pelo teste de Tukey, utilizando o software SAS versão 9.0. Não foram observadas diferenças entre os tratamentos para o desempenho produtivo das reprodutoras nem para a qualidade dos ovos. Nos primeiros 15 dias de vida, a progênie oriunda dos tratamentos com SeY apresentou menor peso corporal (P < 0,05). Com a adição do blend antioxidante (AB), o peso corporal foi semelhante ao observado no grupo da dieta basal (BD). Dos 15 aos 35 dias, a progênie do tratamento 0,3 SeY apresentou menor peso corporal em comparação com a dieta basal e com ambos os grupos suplementados com AB. As reprodutoras alimentadas com dietas contendo SeY, isoladamente ou como parte de um blend antioxidante, apresentaram menores concentrações séricas de colesterol e triglicerídeos do que aquelas alimentadas com a dieta basal. Nas codornas reprodutoras, a capacidade antioxidante (DPPH%) foi maior e a peroxidação lipídica foi menor no soro, fígado e gema dos ovos em todos os grupos suplementados com SeY, independentemente da inclusão do AB. Concluiu-se que a suplementação com SeY, isoladamente ou em combinação com AB, é recomendada para codornas japonesas reprodutoras, devido aos seus efeitos benéficos sobre o estado antioxidante e o perfil lipídico sanguíneo.
Palavras-chave: Ácido ascórbico. Malonaldeído. Minerais orgânicos.

Introduction

Oxidative stress can negatively impact body weight, feed intake, feed efficiency, egg production, and egg quality in laying hens (Ding et al., 2022). Studies have shown that nutritional substances with antioxidant properties in poultry feed can mitigate the adverse effects of oxidative stress on performance (Barbosa et al., 2010; Lu et al., 2020; Teixeira et al., 2023).

Selenium (Se) is widely used as a feed additive to enhance antioxidant capacity, immunity, and overall health. It is a component of the enzyme glutathione peroxidase, which is naturally produced in the body and plays a crucial role in protecting cells against oxidative damage. Selenium is available in both inorganic and organic forms. Inorganic Se sources include sodium selenite. Organic Se is predominantly found as selenomethionine, selenocysteine, and Se-enriched yeast. The organic form of Se has been widely studied as an alternative to its inorganic counterpart (Skrivan et al., 2012).

Among natural antioxidants, ascorbic acid (vitamin C) is one of the most widely studied compounds because of its ability to scavenge free radicals and reduce lipid oxidation (Brito et al., 2023). However, antioxidant supplementation in poultry is often provided through antioxidant blends that combine vitamin C with other bioactive compounds to enhance antioxidant protection. Such blends may contribute to reducing reactive oxygen species (ROS), maintaining egg production and quality, supporting vitamin E recycling, and protecting cellular membranes against oxidative damage (Ames, 2001).

Dietary supplementation with SeY alone or in combination with an antioxidant blend is commonly used to enhance poultry antioxidant status by counteracting the negative effects of oxidative stress (Abd El-Hack et al., 2017). Since both SeY and antioxidant blends contribute to biological antioxidant defenses (Khan et al., 2016), their combined use may provide complementary mechanisms of cellular protection.The objective of the present study was to evaluate the productive performance, egg quality, progeny performance, and serum antioxidant activity effects of Japanese quail breeders supplemented with SeY alone or in combination with antoxidant blend.

Material and Methods

This study was approved and conducted in accordance with the specifications of the Ethics Committee on Animal Use (approval no. 8841300920) at the State University of Maringá, Paraná, Brazil.

A total of 420 Japanese quails (*Coturnix coturnix japonica*) (300 females and 120 males), aged 16 weeks, were selected based on weight (females: 140 g; males: 120 g) and egg-laying performance. The breeders were housed in galvanized wire cages (30 × 38 × 25 cm; height, width, depth) equipped with nipple drinkers and trough feeders, under a 17-h light program (natural + artificial). During the experimental period, the average temperature and humidity were 25.61 °C (max 31.47 °C; min 19.75 °C) and 64%, respectively.

Experimental design and diets

A completely randomized design was used, consisting of five dietary treatments with 12 replicates each. Each replicate included seven birds (five females and two males). The basal diet (BD) contained 0.25 mg kg^{-1} inorganic Se from sodium selenite (SS), and in the other four treatments, SS was replaced with SeY: BD + 0.3 mg kg^{-1} SeY (0.3 SeY); BD + 0.6 mg kg^{-1} SeY (0.6 SeY); BD + 0.3 mg kg^{-1} SeY + 6.37 mg kg^{-1} antioxidant blend (0.3 SeY+AB); and BD + 0.6 mg kg^{-1} SeY + 13.08 mg kg^{-1} antioxidant blend (0.6 SeY+AB) (Table 1). The mineral and vitamin premix used in this study did not contain selenium or antioxidant compounds provided by the antioxidant blend used in the experimental diets. Therefore, selenium and the antioxidant blend were supplemented separately according to the experimental design.

Table 1
Composition of experimental diets for laying quails and growing quails

Ingredient (%)	Breeders					Progeny	
	BD6	0.3SeY	0.6SeY	0.3SeY+AB	0.6SeY+AB	1-14 d	15-35 d
Corn 7.86% CP	59.903	59.903	59.903	59.903	59.903	54.03	58.55
Soybean meal 45% CP	29.588	29.588	29.588	29.588	29.588	38.90	35.94
Limestone	6.765	6.765	6.765	6.765	6.765	1.05	0.89
Soybean oil	0.842	0.842	0.842	0.842	0.842	2.23	1.28
Dicalcium phosphate	1.334	1.334	1.334	1.334	1.334	2.20	1.75
Vit and mineral premix[1, 2]	0.200	0.200	0.200	0.200	0.200	1.00	1.00
Common salt	0.340	0.340	0.340	0.340	0.340	0.43	0.46
Dl-methionine	0.558	0.558	0.558	0.558	0.558	0.15	0.12
L-lysine (HCl 99%)	0.366	0.366	0.366	0.366	0.366	0.01	0.01
Inert[3]	0.100	0.070	0.040	0.080	0.060	-	-
Selenium yeast[4]	-	0.030	0.060	-	-	-	-
Antioxidant blend[5]	-	-	-	0.020	0.040	-	-
Calculated composition							
Crude protein (g kg^{-1})	190.00	190.00	190.00	190.00	190.00	220.00	210.00
Metabolizable energy (Kcal/ kg^{-1})	2,800.00	2,800.00	2,800.00	2.800,00	2,800.00	2,900.00	2,900.00
Methionine (digestible) (g kg^{-1})	8.03	8.03	8.03	8.03	8.03	4.47	4.10

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Met. + cys. (digestible) (g kg^{-1})	9.42	9.42	9.42	9.42	9.42	7.44	6.90
Lysine (digestible) (g kg^{-1})	11.49	11.49	11.49	11.49	11.49	10.95	10.30
Sodium (g kg^{-1})	1.47	1.47	1.47	1.47	1.47	2.05	2.10
Calcium (g kg^{-1})	29.90	29.90	29.90	29.90	29.90	10.92	9.10
Phosphorus (available) (g kg^{-1})	3.09	3.09	3.09	3.09	3.09	5.13	4.30
Selenium (mg kg^{-1})	0.250	0.300	0.600	0.300	0.600	0.257	0.257
Antioxidant blend (mg kg^{-1})	-	-	-	6.37	13.08	-	-

[1]Layer premix quantity per kg of feed: Vitamin A 2,500,000 IU; Vitamin D3: 500,000 IU; Vitamin E: 6,250 mg; Vitamin K3: 750 mg; Vitamin B1: 625 mg; Vitamin B2: 1,500 mg; Vitamin B6: 1,250 mg; Vitamin B12: 5,000 mg; Calcium: 3,000 mg; Niacin: 6,000 mg; Folic acid: 250 mg; Biotin: 50 mg; Choline: 75 g; Zn: 13 g; Fe: 13 g; Mn: 15 g; Cu: 3,000 mg; I: 250 mg; Co: 50 mg; Butylated hydroxytoluene (BHT): 1,000 mg.
[2]Growth premix quantity per kg of feed: – Vitamin A 931,000 IU; Vitamin D3: 189,000 IU; Vitamin E: 1,500 mg; Vitamin K3: 156 mg; Vitamin B1: 150 mg; Vitamin B2: 500 mg; Vitamin B6: 310 mg; Vitamin B12: 1,200 mg; Calcium pantothenate: 1,250 mg; Niacin: 3,000 mg; Sodium selenite 130 mg; Folic acid: 75 mg; Biotin: 4 mg; Choline: 45 g; Zinc: 5 g; Iron: 5 g; Manganese: 6.05 g; Copper: 600 mg; Iodine: 77.5 mg; Zinc bacitracin: 2,200 mg; Butylated hydroxytoluene (BHT).: 1.500 mg; Vehicle q.s. (kaolin) 1,000 g kg^{-1}.
[3]Inert – kaolin.
[4]Sel-Plex® Alltech (Selenium-enriched yeast, minimum 1000 g kg^{-1} and dried brewer yeast.
[5]Economase™ Alltech (Selenium-enriched yeast, minimum 1500 g kg^{-1} inactivated yeast, ascorbic acid, minimum 49 g/kg), Schizochytrium sp., algae flour, Aspergillus niger (NCIMB 30289) fermentation product, Trichoderma longibrachiatum (NCIMB 30245) fermentation product, sodium chloride (common salt).
[6]In the basal diet, the amount of selenium was measured (0.25 g kg^{-1}) by the atomic absorption method using CBO laboratory analyses, Campinas, Brazil.

Productive performance and egg quality

The study included a seven-day adaptation period followed by a 63-day experimental phase. The experimental period was divided into three 21-day production cycles. The variables analyzed included daily feed intake (DFI, g bird^{-1}), egg weight (EW, g), and feed conversion (FC, g g^{-1} and g dozen^{-1}). As males and females were housed together, DFI and FC values refer to the mixed-sex groups.

Egg quality variables were evaluated on the last three consecutive days of each production cycle. Three eggs per cage per day were collected to assess egg weight (g); relative weights of the shell, yolk, and albumen; shell thickness (μm); specific gravity (g L^{-1}); Haugh unit (HU); and yolk index (YI). Specific gravity was determined following Pym (1969), by immersing eggs in saline solutions with densities ranging from 1.050 to 1.090 g L^{-1} (at 0.005 intervals); the density at which the egg floated indicated its specific gravity. Subsequently, the eggs were weighed using a semi-analytical scale (±0.001 g) and cracked on a flat glass surface. Albumen and yolk heights (mm) and yolk diameter (mm)

were measured with a digital caliper (±0.05 mm) mounted on a metal stand. The HU was calculated using the formula:

$$HU = 100\log (H + 7.57 - 1.7\, W^{0.37}),$$

where H is the albumen height (mm) and W is the egg weight (g). The yolk index was calculated as the ratio of yolk height to yolk width. Eggshells were washed, oven-dried at 55 °C for 24 h, weighed, and measured for thickness using a digital micrometer (Mitutoyo Co., Model 700s, Kawasaki, Japan). After weighing the shell, yolk, and albumen, the component weights were used to calculate their relative proportions.

Progeny performance

Eggs from each treatment were incubated to evaluate the influence of breeders' diets on progeny performance. Over a period of five days, an average of 250 eggs/treatment were collected and incubated in a vertical incubator (Petersime®, Labo 13 model) using a single-stage program with 60% humidity and a temperature of 37.4 °C/99.75 °F, with automatic turning. After 348 h of incubation, the eggs were transferred to the hatching chamber (Petersime®, Labo 9 model) for 72 h (temperature of 37.0 °C/98.60 °F and 70% humidity). Following hatching, chicks from each breeder diet were randomly distributed into four replicates (n = 25 birds per replicate, mixed sex). Productive performance, including daily weight gain (DWG, g), daily feed intake (DFI, g), and feed conversion ratio (FCR, g g^{-1}), was evaluated from 1 to 35 days of age, considering the starter phase (1-14 days) and the grower phase (15-35 days). From day 14 to day 35, and for the total period (1-35 days), the male-to-female ratio was included as a covariate in the statistical analysis. The quails were housed in boxes (2 × 1 m) with rice husk bedding. Water was supplied using infant drinkers in the first week, which were later replaced with pendulum drinkers. Feed was provided *ad libitum* using a trough-type infant feeder. During the first 15 days, infrared lamps were used to provide an initial temperature of 35 °C, which was gradually reduced to room temperature. All chicks received the same diet, formulated according to the Brazilian Tables for Poultry and Swine (Rostagno, 2017) for growing quails.

Sample collection

At the end of the experimental period, one breeder male and one female per experimental unit were used for blood collection. Blood samples were centrifuged at 3000 rpm for 15 min, and the resulting serum aliquots were frozen for later analysis of antioxidant activity and lipid peroxidation. Birds were euthanized by cervical dislocation, and liver samples were collected, promptly frozen in liquid nitrogen, and stored in an ultra-freezer at −80 °C for subsequent antioxidant activity analyses. Liver and yolk samples were placed in cryogenic tubes, lyophilized, and stored at −80 °C.

Serum biochemistry

Serum cholesterol and triglyceride levels were determined using commercial kits (Gold Analisa), following the procedures described by the manufacturer.

DPPH radical inhibition

The antioxidant activity of serum and liver was assessed by measuring the inhibition (%) of the DPPH radical (2,2-diphenyl-1-picryl-hydrazyl). Extracts were prepared from 100 mg of sample (1:10; w/v in methanol) or 100 µL of serum (1:10; v/v in methanol). Extracts were homogenized (Phoenix Luferco, AP 22, Araraquara, Brazil), centrifuged at 3000 rpm for 20 min (MPW Med. Instruments, MPW-351R, Warsaw, Poland), and the supernatant was collected. The DPPH radical inhibition analysis (%) followed a methodology adapted from Li et al. (2009) a DPPH solution (Sigma-Aldrich, D9132, Saint Louis, USA) was prepared in methanol (60 µM) and 2850 µL of the solution was added to 150 µL of sample extract. Absorbance readings were taken at the beginning and after 30 min (protected from light) at 515 nm. Antioxidant activity was calculated by the following equation:

$$\textit{DPPH radical inhibition}\ (\%) = (1 - (\textit{Abs sample} / \textit{Abs DPPH}))x\ 100,$$

where Abs sample = absorbance of the sample after 30 min; and Abs DPPH = absorbance of the DPPH.

Lipid peroxidation

Lipid peroxidation was determined using the thiobarbituric acid reactive substances (TBARs) method, which measures malondialdehyde (MDA) production, following the protocol adapted from Vital et al. (2016). Lyophilized samples (300 mg of liver or yolk) or 100 µL of serum were mixed in a trichloroacetic acid (TCA) solution (15% TCA, 0.1% ethylenediaminetetraacetic acid, and 0.1% gallic acid) (1:10, w/v), centrifuged at 4 °C for 15 min at 3000 rpm (MPW Med. Instruments, MPW-351R, Warsaw, Poland), and the supernatant was collected. In a light-protected tube, an equal volume (1:1, v/v) of thiobarbituric acid (TBA) solution (1% TBA, 562.5 µM HCl, and 15% TCA in distilled water) was added to the extract, followed by boiling (Marconi, MA-184, Piracicaba, Brazil) at 100 °C for 15 min. Samples were then cooled, and absorbance was read at 532 nm using a spectrophotometer (Thermo Scientific™, Evolution™ 300 UV-VIS, Waltham, USA). Lipid peroxidation was expressed as MDA µg g^{-1} of tissue, calculated using a standard curve of 1,1,3,3-tetramethoxypropane (TMP) 1 mM as the reference.

Statistical analysis

Data were analyzed using SAS software (Statistical Analysis System, Institute [SAS Institute], 1989) at a significance level of 5%. Differences among treatments were determined by analysis of variance, and when significant, means were compared using Tukey's test.

Results

No significant differences ($P > 0.05$) were observed among treatments for breeder productive performance and egg quality variables (Table 2). Progeny performance, based on breeders' diets, was evaluated during the starter (1-14 days), grower (15-35 days), and total (1-35 days) phases (Table 3). In the starter phase (1-14 days), significant differences ($P < 0.05$) were observed for day 14 body weight and weight

gain. Progeny from breeders fed the 0.6 SeY diet had lower body weight and weight gain than those from breeders fed the 0.6 SeY+C diet. In the grower phase (15-35 days), body weight of birds fed 0.3 SeY was lower than that of birds fed the BD and both antioxidants blend supplemented groups. Over the total period (1-35 days), progeny from breeders fed 0.3 SeY had lower weight gain and higher feed conversion than those from the BD and 0.3 SeY+AB groups. Progeny from 0.6 SeY and both antioxidants blend supplemented diets had performance comparable to BD.

Table 2
Productive performance and egg quality of Japanese quail breeders fed with selenium-enriched yeast alone or in an antioxidant blend (16-25 weeks)

Variable	BD[1]	0.3SeY[2]	0.6SeY[3]	0.3SeY+AB[4]	0.6SeY+AB[5]	P-value
Productive performance						
DFI[6] (g bird^{-1} day^{-1})	23.29±0.51	23.29±0.51	23.30±0.36	23.59±0.521	23.31±0.34	0.365
FC[7] (g g^{-1})	2.33±0.20	2.33±0.20	2.34±0.10	2.44±0.260	2.30±0.13	0.371
FC (g dozen^{-1})	476.63±33.85	476.63±33.85	472.06±15.77	457.99±29.37	478.28±19.56	0.280
EW[8] (g)	10.06±0.69	10.06±0.69	9.96±0.48	9.78±0.776	10.16±0.53	0.497
LR[9] (%)	94.01±1.58	94.01±1.58	93.05±2.34	93.39±2.304	93.63±2.75	0.068
Viability (%)	99.38±1.92	99.38±1.92	100.00±0.00	99.81±0.643	99.94±0.19	0.433
Egg quality						
Egg weight (g)	10.84±0.35	10.90±0.27	10.82±0.17	10.91±0.29	10.90±0.26	0.874
Shell (%)	8.09±0.26	7.92±0.16	8.04±0.21	8.02±0.24	8.09±0.16	0.292
Yolk (%)	30.38±1.24	29.70±0.87	30.27±0.78	30.16±1.06	29.87±0.65	0.383
Albumen (%)	61.42±1.54	62.49±0.93	61.82±0.97	61.64±1.14	61.98±0.72	0.185
ST[10] (mm)	0.21±0.01	0.25±0.14	0.21±0.01	0.23±01	0.20±0.01	0.482
HU[11]	87.53±0.81	87.25±0.74	87.20±0.93	87.06±0.73	86.64±1.29	0.220
YI[12]	0.46±0.01	0.46±0.02	0.46±0.02	0.46±0.01	0.46±0.02	0.949
SG[13] (g L^{-1})	1.069±1.50	1.069±1.69	1.068±1.29	1.066±1.93	1.069±1.97	0.319

[1]BD: basal diet: 0.25 mg kg^{-1} of sodium selenite; 0.3 SeY (basal+0.3 mg kg^{-1}of selenium-enriched yeast); 0.6 SeY: (basal+0.6 mg kg^{-1}of selenium-enriched yeast); 0.3 SeY+ AB: : (basal+0.3 mg kg^{-1}of selenium-enriched yeast+6.37 mg kg^{-1} of antioxidant blend); 0.6 SeY+ AB: : (basal+0.6 mg kg^{-1}of selenium-enriched yeast+13.08 mg kg^{-1}of antioxidant blend); DFI[6] (g bird^{-1} day^{-1}): daily feed intake; FC[7] (g g^{-1}): feed conversion; EW[8] (g): egg weight; LR[9] (%): laying rate; ST[10] (mm): shell thickness; HU[11]: Haugh unit; YI[12]: yolk index; SG[13](g L^{-1}): specific gravity.

Table 3
Productive performance (mean ± standard deviation) of progeny (1 to 35 days) of age from Japanese quail breeders fed with selenium-enriched yeast alone or in an antioxidant blend

Variable	BD[1]	0.3SeY[2]	0.6SeY[3]	0.3SeY+AB[4]	0.6SeY+AB[5]	P-value
Starter, 1 to 14 days						
Body weight 1 d, g	7.60±0.06	7.54±0.04	7.54±0.04	7.56±0.04	7.54±0.04	0.463
Body weight 14 d, g	51.10±0.79^{ab}	48.59±1.48^{ab}	47.75±2.36^{b}	51.28±1.12^{a}	50.28±1.44^{ab}	0.031
Feed intake, g	122.63±7.50	124.93±2.50	124.74±8.38	122.57±4.33	127.53±4.55	0.783
Weight gain, g	43.50±0.82^{ab}	41.04±1.48^{ab}	40.21±2.39^{b}	43.72±1.15^{a}	42.52±1.44^{ab}	0.036
Feed conversion g g^{-1}	2.82±0.15	3.04±0.16	3.10±0.18	2.80±0.13	3.00±0.09	0.039
Grower, 15 to 35 days						
Body weight 35 d, g	127.45±4.45^{a}	117.70±2.69^{b}	124.41±6.07^{ab}	128.23±2.47^{a}	128.36±4.51^{a}	0.019
Feed intake, g	306.22±4.62	318.95±7.13	315.33±9.80	321.40±6.62	319.89±9.77	0.040
Weight gain, g	76.34±4.68	69.11±3.85	76.55±5.05	76.94±2.12	78.30±5.06	0.097
Feed conversion, g g^{-1}	4.02±0.22	4.63±0.37	4.13±0.39	4.17±0.12	4.09±0.27	0.134
Total, 1 to 35 days						
Feed intake, g	428.84±9.35	443.89±7.14	440.08±10.32	443.97±5.64	447.42±14.01	0.145
Weight gain, g	119.85±4.42^{a}	110.15±2.66^{b}	116.87±6.08^{ab}	120.67±2.46^{a}	120.82±4.54^{a}	0.020
Feed conversion, g g^{-1}	3.58±0.08^{b}	4.03±0.16^{a}	3.77±0.24^{ab}	3.67±0.04^{b}	3.70±0.12^{ab}	0.019

[1]BD: basal diet: 0.25 mg kg^{-1} sodium selenite; [2]0.3 SeY: (BD + 0.3 mg kg^{-1} selenium-enriched yeast) [3]0.6 SeY: (BD + 0.6 mg kg^{-1} selenium-enriched yeast); [4]0.3 SeY+ AB: : (BD + 0.3 mg kg^{-1} selenium-enriched yeast + 6.37 mg kg^{-1} of antioxidant blend); [5]0.6 SeY+ AB: : (BD + 0.6 mg kg^{-1} selenium-enriched yeast + 13.08 mg kg^{-1} of antioxidant blend).
^{ab}Lowercase letters indicate that means differ by Tukey's test at the 5% significance level.

Differences in serum triglyceride and cholesterol levels were observed in both male and female breeders at 28 weeks of age (Table 4). In diets supplemented with SeY, with or without antioxidants blend, cholesterol and triglyceride levels were lower in both sexes compared to birds fed the BD. Among males, those receiving 0.6 SeY had the lowest cholesterol levels, significantly lower than those receiving 0.3 SeY.

Table 4
Serum blood variables of female and male Japanese quail breeders (n=10) fed with selenium-enriched yeast alone or in an antioxidant blend

Variable	BD[1]	0.3SeY[2]	0.6SeY[3]	0.3SeY+AB[4]	0.6SeY+AB[5]	P-value
Females						
Cholesterol, mg dL^{-1}	184.24± 9.88^{a}	151.83± 9.69^{b}	138.21± 13.29^{b}	139.43± 23.72^{b}	140.96± 12.30^{b}	<0.001
Triglycerides, mg dL^{-1}	859.21± 132.28^{a}	617.68± 56.52^{b}	554.78± 23.10^{b}	575.48± 20.48^{b}	597.75± 28.71^{b}	<0.001
Males						
Cholesterol, mg dL^{-1}	278.55± 15.40^{a}	228.89 ±6.53^{b}	205.69± 8.24^{c}	212.95± 11.69^{bc}	214.96± 20.99^{bc}	<0.001
Triglycerides, mg dL^{-1}	226.17± 29.49^{a}	175.45± 5.82^{b}	173.60± 3.60^{b}	173.73± 5.84^{b}	178.65± 20.18^{b}	<0.001

[1]BD: basal diet: 0.25 mg kg^{-1} sodium selenite; [2]0.3 SeY: (BD + 0.3 mg kg^{-1} selenium-enriched yeast) [3]0.6 SeY: (BD + 0.6 mg kg^{-1} selenium-enriched yeast); [4]0.3 SeY+AB: (BD + 0.3 mg kg^{-1} selenium-enriched yeast + 6.37 mg kg^{-1} of antioxidant blend); [5]0.6 SeY+AB: (BD + 0.6 mg kg^{-1} selenium-enriched yeast + 13.08 mg kg^{-1} of antioxidant blend).
[abc]Lowercase letters indicate that means differ by Tukey's test at the 5% significance level.

Antioxidant capacity was evaluated by the percentage of DPPH radical inhibition in the serum of males and females, in the liver of females, and in the yolk content. Significant differences in DPPH radical inhibition ($p < 0.05$) were observed in the female blood serum, liver, and yolk content, with higher means in all SeY-supplemented diets compared to the BD (Table 5). For males, no differences in blood serum antioxidant activity were found among treatments ($p > 0.05$).

Table 5
Antioxidant profile measured by DPPH radical inhibition (%) and lipid peroxidation by in the freeze-dried liver, yolk, and serum of Japanese quail breeders fed with selenium-enriched yeast alone or in an antioxidant blend (n=10)

Variable	BD[1]	0.3SeY[2]	0.6SeY[3]	0.3SeY+AB[4]	0.6SeY+AB[5]	P-value
DPPH (%)						
Serum (males)	23.17±2.95	28.31±4.62	28.44±1.74	28.69±3.36	28.03±1.54	0.103
Serum (females)	32.22±3.47^{b}	47.74±1.91^{a}	48.15±1.48^{a}	48.56±1.58^{a}	47.96±1.30^{a}	<0.001
Liver (female)	32.76±4.77^{b}	46.87±1.17^{a}	47.34±1.57^{a}	47.43±3.44^{a}	46.84±2.13^{a}	<0.001
Yolk	15.58±4.80^{b}	29.72±4.56^{a}	30.13±4.45^{a}	30.72±5.15^{a}	30.53±4.74^{a}	<0.001
MDA						
Serum (males), nmol mL^{-1}	1.89±0.21^{a}	1.18±0.13^{b}	0.85±0.09^{c}	0.80±0.09^{c}	0.99±0.08^{bc}	<0.001
Serum (females), nmol mL^{-1}	1.22±0.21^{a}	0.84±0.12^{bc}	0.73±0.08^{bc}	0.59±0.07^{c}	1.06±0.19^{ab}	<0.001
Liver (females), nmol mg^{-1}	2.72±0.12^{a}	2.00±0.10^{b}	1.43±0.11^{c}	0.94±0.20^{d}	1.79±0.14^{b}	<0.001
Yolk, µmol mg^{-1}	1.74±0.24^{a}	1.01±0.11^{bc}	0.89±0.14^{bc}	0.77±0.09^{c}	1.24±0.17^{b}	<0.001

[1]BD: basal diet: 0.25 mg kg^{-1}sodium selenite; [2]0.3 SeY: (BD + 0.3 mg kg^{-1}selenium-enriched yeast) [3]0.6 SeY: (BD + 0.6 mg kg^{-1}selenium-enriched yeast); [4]0.3 SeY+ AB: (BD + 0.3 mg kg^{-1}selenium-enriched yeast + 6.37 mg kg^{-1}of antioxidant blend); [5]0.6 SeY+AB: (BD + 0.6 mg kg^{-1}selenium-enriched yeast + 13.08 mg kg^{-1}of antioxidant blend).
[abc]Lowercase letters indicate that means differ by Tukey's test at the 5% significance level.

Lipid peroxidation was estimated by quantifying malondialdehyde (MDA) production in the serum of males and females, the liver of females, and the yolk content (Table 5). Differences in lipid peroxidation ($p < 0.05$) were detected in all tissues analyzed, with the highest means generally observed in the BD group and the lowest in the 0.3 SeY+AB group. The other treatments showed intermediate values, with varying significant differences depending on the material analyzed.

Discussion

This study was based on the hypothesis that dietary supplementation with selenium-enriched yeast (SeY), either alone or in combination with an antioxidant blend (AB) could improve the productive responses of Japanese quail breeders and their progeny by enhancing antioxidant protection. However, no performance or egg quality differences were found in the breeder quails. This lack of response may be explained by the adequate nutritional and environmental conditions maintained throughout the experimental period, as breeder quails exhibited high viability and laying rates above 91%. Under non-challenging conditions, antioxidant supplementation may support redox status without necessarily resulting in measurable changes in feed intake, egg production, feed conversion ratio, or egg quality.

The absence of productive differences does not indicate a lack of biological activity of SeY or an antioxidant blend but rather suggests that their effects were primarily physiological. This interpretation is supported by studies demonstrating that organic selenium sources, including SeY and selenomethionine, are retained and deposited more efficiently in eggs and body tissues than sodium selenite, whereas their effects on laying performance are variable and depend on factors such as bird age, basal selenium supply, physiological status, and environmental challenges (Surai & Kochish, 2019; Chen et al., 2023, 2025). In poultry, SeY supplementation has consistently been shown to enhance selenium deposition and antioxidant capacity without differences in feed intake, egg production, or egg weight, indicating that the primary advantage of organic selenium lies in supporting antioxidant protection and selenium transfer rather than directly stimulating productive performance under normal rearing conditions (Chen et al., 2023; Wang et al., 2025).

The lack of egg quality differences in the present study is also consistent with previous studies in Japanese quails and laying hens, in which selenium supplementation did not consistently improve eggshell or internal egg quality parameters when basal diets were nutritionally adequate and birds were not exposed to marked oxidative or heat stress (Sarmiento-García et al., 2022; Torga et al., 2024; Wang et al., 2025). Therefore, the lack of effects on egg quality observed in the present study suggests that SeY and the antioxidant blend exerted a greater influence on antioxidant protection than on the structural characteristics of eggs.

Although breeder productive performance was not differed among treatments, some responses were observed in the progeny. Progeny from breeders fed 0.3 SeY had lower body weight, lower weight gain, and higher feed conversion than those from the basal diet and antioxidant blend-supplemented groups, whereas progeny from breeders receiving 0.6 SeY or antioxidant blend supplementation showed performance comparable to the basal diet. These findings suggest that maternal antioxidant supplementation may influence progeny development, possibly through improved antioxidant transfer to the egg and greater protection against oxidative stress during embryonic development. However, because these responses were limited and not consistently observed across all treatments, further studies are needed to clarify the mechanisms involved.

Despite the absence of productive performance and egg quality differences, breeder quails fed SeY-containing diets exhibited lower serum cholesterol and triglyceride concentrations than birds receiving sodium selenite. This response may be associated with differences in selenium metabolism and tissue utilization between organic and inorganic selenium sources. Selenium-enriched yeast contains selenium predominantly in organic forms, particularly selenomethionine, which can be absorbed through amino acid transport pathways, incorporated into body proteins, and subsequently serve as a selenium reserve for selenoprotein synthesis (Schrauzer, 2000; Sunde et al., 2016; Surai & Kochish, 2019). In contrast, sodium selenite follows a different metabolic pathway, is retained less efficiently

in tissues, and depends on reduction reactions before being incorporated into selenoproteins (Surai & Kochish, 2019; Chen et al., 2023).

The most consistent response observed in the present study was the improvement in oxidative status. particularly glutathione peroxidases (GPx), which catalyze the reduction of hydrogen peroxide and lipid hydroperoxides, thereby protecting cellular membranes against oxidative damage (Surai & Kochish, 2019; Chen et al., 2023, 2025). In laying hens, dietary supplementation with organic selenium has consistently been shown to enhance antioxidant enzyme activity and reduce malondialdehyde (MDA) concentrations in serum and egg yolk, confirming its effectiveness in mitigating lipid peroxidation and improving oxidative stability (Wang et al., 2025; Liu et al., 2023; Chen et al., 2025).

The combined supplementation of SeY and the antioxidant blend may have enhanced antioxidant protection through complementary mechanisms. Selenium primarily exerts its antioxidant effects through selenoprotein-dependent enzymatic defense systems, whereas the antioxidant blend provides additional antioxidant compounds, including vitamin C, that are capable of directly scavenging reactive oxygen species and contributing to the regeneration of other antioxidants (Surai & Fisinin, 2015; Surai & Kochish, 2019). Therefore, the lower lipid peroxidation observed across different biological matrices suggests that combined supplementation has strong benefits to systemic antioxidant capacity, even in the absence of measurable improvements in productive performance.

Conclusion

Supplementation with SeY, either alone or in combination with an antioxidant blend in Japanese quails breeder diets resulted in greater antioxidant status and less lipid peroxidation in serum and tissues. Based on the results of this trial, dietary supplementation with 0.3 mg kg^{-1} Se as SeY in combination with 6.37 mg kg^{-1} antioxidant blend is recommended for quail breeders.

Acknowledgments

This study was financed by the Brazilian National Council for Scientific and Technological Development (CNPq) and the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES; Finance Code 001).

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