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Effects of Different Forms and Levels of Selenomethionine on Productive Performance and Antioxidant Status of Broiler Breeders and Its Offspring

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Abstract

This study was conducted to investigate the effects of different selenomethionine (SM) forms and levels on productive performance and antioxidant status of broiler breeders and its offspring. Four hundred eighty 48-week-old Lingnan Yellow broiler breeders were randomly divided into four groups, provided basal diet with 0.15 or 0.30 mg/kg Se coming from two SM forms of DL-SM and L-SM. The experiment included a 4-week pretreatment period and an 8-week trial period. During the trial period, eggs were incubated once a week under standard conditions. The broiler breeders were slaughtered after the trial period. At the same time, 15 1-day-old chicks were selected at random per replicate and killed. The results showed that different SM forms and levels had no significant differences in average egg weight, feed intake, and feed-to-egg ration. The DL-SM group in contrast to the L-SM group induced a notable elevation of glutathione peroxidase (GPx) activity in serum ($P < 0.01$) and liver ($P < 0.05$), and the 0.15 mg/kg group had higher GPx activity than 0.30 mg/kg in serum ($P < 0.01$) and pancreas ($P < 0.05$). Different SM forms showed no significant differences in total antioxidant capability (T-AOC). Diets with 0.15 mg/kg Se exhibited a higher level of T-AOC in serum ($P < 0.01$) and some tissues. Besides, malondialdehyde (MDA) concentrations in serum, liver, and kidney significantly decreased due to the supplementation of DL-SM. Supplemental 0.15 mg/kg Se reduced MDA concentrations in kidney and muscle. The offspring of broiler breeders fed on DL-SM had higher GPx activity in liver and kidney than L-SM treatment. Supplemental 0.15 mg/kg Se also improved GPx activity in kidney and muscle and T-AOC in kidney of 1-day-old chicks. In summary, our study demonstrated that compared with L-SM, DL-SM was more effective for enhancing the antioxidant status of broiler breeders and its offspring. Moreover, the recommended level of Se supplementation was 0.15 mg/kg Se in Lingnan Yellow broiler breeder diets.

Keywords DL-selenomethionine · L-selenomethionine · Broiler breeders · Offspring · Productive performance · Antioxidant status

Introduction

As an essential element for normal life processes [1], selenium (Se) plays a significant role in growth, reproduction, immunization, and anti-oxidative stress [2]. Since its discovery in 1817, Se has been extensively used in industry, agriculture, and people's daily lives. In 1973, Se was found to be an important ingredient in the glutathione peroxidase (GPx), which was identified as a very potent antioxidant protecting the body from damage due to oxidation by free radicals [3]. In the next year, Se was allowed to be added to the animal feed by FDA. It was reported that Se was an important component of the 5′-deferonase activity center in 1990 [4]. In production, studies have shown that Se is also engaged in the development and formation of sperm, regulating meat quality and other processes.

For chickens, it was stated that Se deficiency is linked to a number of diseases, which include exudative diathesis, pancreatic dystrophy, nutritional muscular dystrophy, and suppression of immunity [5]. Besides, deficiency of Se can cause the reduction of reproductive performance of broiler breeders and endanger the growth of the offspring. Accordingly, it is a common practice to supply broiler breeder diets with Se.

Se source added in the diet can be categorized into two forms: inorganic sodium Se (SS) and organic Se such as selenium yeast (SY), selenocysteine, and selenomethionine (SM).

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Compared with inorganic Se, organic Se has a higher absorption rate and biological activity, lower toxicity and environmental pollution, and other characteristics in the animal body [6]. Wang et al. [7] reported that SM intake was superior to SS intake in improving the tissue Se deposition and antioxidant status of broiler breeders, which was in harmony with those of numerous studies performed on broilers and other animals [8–10]. Moreover, DL-SM was allowed to be added into animal feed as a feed additive in 2014 by the European commission. In 2015, L-SM could be produced and used in China. Therefore, the biological effect of SM has attracted more attention in recent years.

Like other amino acids, SM has two isomers, dextrorotatory (D) form and levorotatory (L) form. In nature, SM is found almost exclusively in the L form and reported the active form in animal metabolism process [11]. The amino acids synthesized by the organism are all L form, but most of the synthetic SM products are DL form (D and L isomers are present in equal amounts) and it is difficult to separate them. Thus, the present study was conducted to investigate the effects of SM forms and levels on productive performance and antioxidant status of broiler breeders and its offspring.

Materials and Methods

The project was conducted under the supervision of Zhejiang University Animal Care and Use Committee (Hangzhou, China), which has adopted animal care and use guidelines governing all animal use in experimental producers.

Experimental Birds and Treatment

Four hundred eighty 48-week-old Lingnan Yellow broiler breeders were randomly divided into four groups, each of which was replicated three times with 40 birds per replicate. A corn-soybean meal basal diet containing 0.04 mg/kg Se was formulated to meet the nutrient requirement guidelines of the NRC (National Research Council) (1994) except Se. Broiler breeders were provided basal diets with 0.15 or 0.30 mg/kg Se coming from two SM forms of DL-SM and L-SM. DL-SM and L-SM were sourced from Sigma (MI, USA) with product nos. S3875 and S3132. The ingredients and nutrient content of the maternal basal diets are shown in Table 1. The birds were housed in laying battery cages, two hens per cage in the same house and provided with clean water and fed ad libitum during the experimental period, including a 4-week pretreatment period and an 8-week trial period. The room was environmentally controlled. Temperature was maintained at 22 °C and continuous lighting was provided.

Table 1 Ingredients and nutrient content of the maternal basal diets

Ingredients (g/kg)		Composition (g/kg)	
Corn	646	ME (MJ/kg)[b]	11.24
Soybean meal	250	CP	161.1
Dicalcium phosphate	18	Calcium	30.2
Limestone	70	Total phosphorus	6.5
Met	3	Lysine	8.2
Salt	3	Methionine	5.5
Vitamin-mineral premix[a]	10	Methionine + cysteine	8.1

The DL-selenomethionine and L-selenomethionine were premixed in corn and added to the diets at 0.15 mg/kg Se or 0.3 mg/kg Se to achieve the appropriate treatment level

[a] The vitamin-mineral premix supplied the followings per kilogram of diet: vitamin A, 10,800 IU; vitamin D_3, 2160 IU; vitamin E, 27 IU; vitamin K_3, 1.4 mg; vitamin B_1, 1.8 mg; vitamin B_2, 8 mg; vitamin B_6, 4.1 mg; vitamin B_{12}, 0.01 mg; nicotinic acid, 32 mg; calcium pantothenate, 11 mg; folic acid, 1.08 mg; biotin, 0.18 mg; Fe, 72 mg; Cu, 7 mg; Zn, 72 mg; Mn, 90 mg; I, 0.9 mg

[b] ME was calculated from data provided by China Feed Database

Sample Collection and Preparation

Daily egg production records were kept and summarized. All eggs collected were weighed and recorded for each replicate every day and incubated once a week under standard conditions in a forced-draft incubator with automatic egg turning (model FTKCFC10, The 41st Electronic Inst., Qingdao, Shandong, China). At the end of the 8-week experiment, six broiler breeders were randomly selected per replicate from each treatment. Feed was withdrawn from the birds approximately 12 h before slaughter. Blood sample (10.0 mL per birds) was collected from the main wing vein and placed in a coagulant tube. Serum was then separated by centrifugation at 4 °C, 3000 rpm/min for 10 min. Then, the birds were slaughtered and breast muscle, liver, kidney, and pancreas tissue samples were obtained.

At the same time, 15 1-day-old chicks were selected at random per replicate and killed to obtain breast muscle, liver, and kidney tissue samples. All samples were frozen directly in liquid nitrogen and stored at − 80 °C for further analysis.

Determination of Antioxidant Enzyme Activity

Glutathione peroxidase (GPx) activity, total antioxidant capability (T-AOC), and malondialdehyde (MDA) and protein concentration were measured in serum, liver, kidney, muscle, and pancreas tissues of broiler breeders and breast muscle, liver, and kidney tissue of 1-day-old chicks. Antioxidant enzyme analysis and protein concentration were performed using kits (Nanjing Jiancheng Bioengineering Company, Jiangsu, China). The GPx and MDA were determined using colorimetric methods according to the procedures of Rotruck

et al. [12] and Yagi [13], respectively. The spectrometric method was applied to evaluate T-AOC.

Statistical Analysis

Replicate was considered as the experimental unit for performance determined. Data were further analyzed as a 2 × 2 (form × level) factorial arrangement of treatments by two-way analysis of variance with a model including the main effects of Se form, level, and their interaction using the general linear model (GLM) procedure of the SPSS 19.0. Differences among means were tested using Duncan's multiple-range tests. The values were expressed as means ± standard error. A significance level of $P < 0.05$ was used.

Results

Productive Performance

Productive performance of broiler breeders is presented in Table 2. Our results showed that different SM forms and levels had no significant differences in average egg weight, feed intake, and feed-to-egg ration.

Antioxidant Status of Serum and Tissue of Broiler Breeders

As is shown in Tables 3, 4, and 5, antioxidant status of serum, liver, kidney, muscle, and pancreas of broiler breeders was influenced by SM forms and levels.

Table 3 showed that the DL-SM group in contrast to the L-SM group induced a notable elevation of GPx activity in serum ($P < 0.01$) and liver ($P < 0.05$), and the 0.15 mg/kg group had higher GPx activity than 0.30 mg/kg in serum ($P < 0.01$) and pancreas ($P < 0.05$). The interaction between SM forms and levels did not affect GPx activity except in serum ($P < 0.01$).

In Table 4, different SM forms showed no significant differences in T-AOC. Broiler breeders fed 0.15 mg/kg Se diets exhibited a higher level of T-AOC in serum ($P < 0.01$), kidney, pancreas, and muscle than 0.30 mg/kg ($P < 0.05$). In serum, SM forms and levels had an interactive effect on T-AOC ($P < 0.01$).

As is shown in Table 5, MDA concentrations in serum ($P < 0.05$), liver ($P < 0.01$), and kidney ($P < 0.05$) significantly decreased due to the supplementation of DL-SM in contrast to those of L-SM group. Moreover, supplemental 0.15 mg/kg Se reduced MDA concentrations in kidney ($P < 0.01$) and muscle ($P < 0.05$) compared with supplemental 0.30 mg/kg Se. No interaction was shown between SM forms and levels.

Antioxidant Status of Tissues of 1-Day-Old Chicks

Results about effects of SM forms and levels on antioxidant status of 1-day-old chicks are shown in Tables 6 and 7. The offspring of broiler breeders fed on DL-SM had higher GPx activity in liver and kidney than L-SM treatment. Supplemental 0.15 mg/kg Se also improved GPx activity in kidney and muscle and T-AOC in kidney of 1-day-old chicks. The interaction between SM forms and levels did not affect antioxidant status of 1-day-old chicks.

Discussion

Results of this experiment showed that basal diets supplemented different SM forms and levels had no effect on average egg weight, feed intake, and feed-to-egg ration, which

Table 2 Effects of different SM forms and levels on productive performance of broiler breeders

Item	Se level (mg/kg)	Average egg weight (g)	Feed intake (g/d)	Feed-to-egg ration (F/E, g:g)
DL-SM	0.15	60.57 ± 1.02	123.94 ± 1.65	3.18 ± 0.12
	0.30	59.63 ± 0.90	123.67 ± 2.29	3.34 ± 0.27
L-SM	0.15	60.77 ± 0.20	119.17 ± 1.55	2.99 ± 0.20
	0.30	60.51 ± 0.98	122.51 ± 3.75	3.35 ± 0.27
DL-SM		59.12 ± 0.79	123.81 ± 2.00	3.26 ± 0.19
L-SM		60.16 ± 0.63	120.84 ± 3.32	3.17 ± 0.25
	0.15	59.57 ± 0.67	121.56 ± 2.87	3.08 ± 0.13
	0.30	59.70 ± 1.05	123.10 ± 3.16	3.35 ± 0.22
P value	Se form	0.303	0.128	0.463
	Se level	0.256	0.404	0.059
	Se form × level	0.508	0.331	0.421

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

Table 3 Effects of different SM forms and levels on glutathione peroxidase (GPx) activity in serum and tissues of broiler breeders

Item	Se level (mg/kg)	Serum (U/mL)	Liver (U/mg prot)	Kidney (U/mg prot)	Pancreas (U/mg prot)	Muscle (U/mg prot)
DL-SM	0.15	246.49 ± 36.55^{a}	33.12 ± 3.40^{a}	5.31 ± 0.88	28.13 ± 7.52^{a}	5.23 ± 0.96
	0.30	175.20 ± 11.54^{b}	30.88 ± 3.48^{b}	5.36 ± 0.68	26.43 ± 5.64^{ab}	4.98 ± 1.02
L-SM	0.15	142.11 ± 12.79^{c}	29.30 ± 4.92^{b}	4.72 ± 0.73	28.71 ± 5.72^{a}	5.53 ± 0.10
	0.30	136.96 ± 8.72^{c}	25.90 ± 3.96^{b}	5.03 ± 1.01	20.28 ± 3.20^{b}	4.63 ± 0.88
DL-SM		210.85 ± 45.32^{a}	32.15 ± 3.54^{a}	5.33 ± 0.76	27.28 ± 6.40	5.11 ± 0.96
L-SM		139.53 ± 10.78^{b}	27.60 ± 4.61^{b}	4.87 ± 0.86	24.49 ± 6.24	5.08 ± 0.77
	0.15	194.30 ± 60.44^{a}	31.36 ± 4.57	5.02 ± 0.83	28.42 ± 6.38^{a}	5.38 ± 0.67
	0.30	156.08 ± 22.23^{b}	28.39 ± 4.40	5.19 ± 0.85	23.35 ± 5.42^{b}	4.81 ± 0.93
P value	Se form	0.000	0.011	0.198	0.248	0.944
	Se level	0.000	0.083	0.607	0.043	0.105
	Se form × level	0.001	0.794	0.711	0.166	0.350

Within rows with different superscript letters differ significantly ($P < 0.05$)

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

were consistent with the findings of Wang [14] and Song [15] that Se sources and levels had no significant effect on performance of broilers. Lum also found that feed intake and ADG were not affected by dietary Se concentrations in growing Holstein bull calves [16]. Results about the effect of SM forms on productive performance are limited.

Selenium in diets can enhance the body's antioxidant status and protect the body from peroxide and free radical damage, so as to keep the body healthy. As a trace element necessary for animals, the main physiological and biochemical function of Se is as an essential component of GPx in the antioxidant system. Data obtained from the present experiment exhibited that GPx activity was higher in serum and liver of broiler breeders fed with DL-SM diet. In addition, our results showed that T-AOC in serum and tissues was not affected by SM forms.

MDA is one of the final products of polyunsaturated fatty acid peroxidation in the cells. Its level is commonly known as a marker of oxidative stress and the antioxidant status [17]. Our study found that supplementation of DL-SM also caused a significant decrease in serum and liver MDA concentrations compared to dietary L-SM. However, a study by Wang et al. showed that Ross 308 broilers supplementation with L-SM significantly increased GSH concentration in liver and breast muscle ($P < 0.05$), SOD activity in liver ($P < 0.01$), and T-AOC in liver, pancreas,

Table 4 Effects of different SM forms and levels on total antioxidant capability (T-AOC) in serum and tissues of broiler breeders

Item	Se level (mg/kg)	Serum (U/mL)	Liver (U/mg prot)	Kidney (U/mg prot)	Pancreas (U/mg prot)	Muscle (U/mg prot)
DL-SM	0.15	20.44 ± 0.24^{a}	7.80 ± 0.45	3.80 ± 0.69	3.37 ± 0.72^{a}	3.57 ± 0.57^{a}
	0.30	13.60 ± 2.36^{c}	8.88 ± 1.62	3.09 ± 0.60	2.33 ± 0.39^{b}	2.94 ± 0.78^{ab}
L-SM	0.15	17.03 ± 1.61^{b}	8.11 ± 1.36	3.39 ± 0.26	3.27 ± 0.71^{a}	3.18 ± 0.50^{ab}
	0.30	15.62 ± 1.25^{b}	9.37 ± 1.79	2.97 ± 0.60	3.07 ± 0.32^{a}	2.78 ± 0.44^{b}
DL-SM		17.02 ± 0.91	8.34 ± 1.27	3.44 ± 0.72	2.85 ± 0.77^{b}	3.26 ± 0.73
L-SM		16.33 ± 1.56	8.74 ± 1.65	3.18 ± 0.49	3.17 ± 0.54^{a}	2.98 ± 0.49
	0.15	18.73 ± 2.09^{a}	7.96 ± 0.98	3.55 ± 0.75^{a}	3.32 ± 0.68^{a}	3.37 ± 0.55^{a}
	0.30	14.61 ± 2.09^{b}	9.13 ± 1.65	3.04 ± 0.47^{b}	2.70 ± 0.52^{b}	2.85 ± 0.61^{b}
P value	Se form	0.294	0.495	0.266	0.174	0.258
	Se level	0.000	0.055	0.022	0.014	0.043
	Se form × level	0.000	0.868	0.527	0.083	0.634

Within rows with different superscript letters differ significantly ($P < 0.05$)

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

Table 5 Effects of different SM forms and levels on serum and tissues malondialdehyde (MDA) concentrations of broiler breeders

Item	Se level (mg/kg)	Serum (U/mL)	Liver (U/mg prot)	Kidney (U/mg prot)	Pancreas (U/mg prot)	Muscle (U/mg prot)
DL-SM	0.15	5.09 ± 0.33^{ab}	0.89 ± 0.16^{b}	0.99 ± 0.11^{c}	1.07 ± 0.11	0.77 ± 0.15^{b}
	0.30	4.68 ± 0.34^{b}	0.94 ± 0.21^{b}	1.23 ± 0.21^{b}	1.08 ± 0.04	0.90 ± 0.10^{a}
L-SM	0.15	5.33 ± 0.82^{a}	1.25 ± 0.21^{a}	1.01 ± 0.12^{c}	1.13 ± 0.21	0.71 ± 0.15^{b}
	0.30	5.40 ± 0.44^{a}	1.17 ± 0.22^{a}	1.45 ± 0.03^{a}	1.15 ± 0.22	0.93 ± 0.18^{a}
DL-SM		4.88 ± 0.38^{b}	0.92 ± 0.18^{b}	1.05 ± 0.35	1.07 ± 0.08	0.84 ± 0.14
L-SM		5.37 ± 0.63^{a}	1.21 ± 0.21^{a}	1.23 ± 0.25	1.14 ± 0.20	0.85 ± 0.18
	0.15	5.21 ± 0.61	1.07 ± 0.26	0.94 ± 0.29^{b}	1.10 ± 0.16	0.77 ± 0.14^{b}
	0.30	5.05 ± 0.53	1.06 ± 0.24	1.34 ± 0.18^{a}	1.10 ± 0.15	0.92 ± 0.14^{a}
P value	Se form	0.034	0.002	0.047	0.347	0.788
	Se level	0.453	0.854	0.000	0.959	0.025
	Se form × level	0.272	0.436	0.078	0.959	0.841

Within rows with different superscript letters differ significantly ($P < 0.05$)

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

and breast muscle ($P < 0.05$) and decreased MDA concentrations in kidney and breast muscle compared with D-SM [18]. Different results may be due to different breeds and different breeding stages.

While the biological activity of D-SM is not yet confirmed in livestock and poultry, the results of this experiment showed that DL-SM can enhance the body's antioxidant status compared to L-SM. This suggests that although D-SM and L-SM may have different metabolic pathways in broiler breeders, they can effectively improve the antioxidant status of broiler breeders.

The selenium level of broiler breeder diets recommended by NRC (1994) is 0.15 mg/kg. However, it does not mean that the higher the Se level added to the feed, the better the effect will be. Zhou reported that among the basal diet supplemented with 0.00, 0.10, 0.30, and 0.50 mg/kg of nano-Se, the 0.30 mg/kg group was most effective in increasing the growth performance and feed conversion ratios of chickens, the Se content of tissues, and the quality of the meat [19]. The same results were obtained by Cai [20], who found 0.3 to 0.5 mg/kg was suggested to be the optimum level of supplementation of nano-Se, and the maximum supplementation of nano-Se could not be more than 1.0 mg/kg in broilers. What's more, Oliveira stated dietary supplementation with 0.15 mg/kg of Se can maintain normal bird performance [21]. Similar findings were also reported in male Wistar rats by Bunglavan [22]. Our results also revealed that GPx activity and T-AOC increased and MDA concentrations decreased in serum and tissue fed with 0.15 mg/kg Se compared with 0.30 mg/kg Se. The

Table 6 Effects of different SM forms and levels on glutathione peroxidase (GPx) activity in tissues of 1-day-old chicks

Item	Se level (mg/kg)	Liver (U/mg prot)	Kidney (U/mg prot)	Muscle (U/mg prot)
DL-SM	0.15	54.84 ± 4.66^{a}	42.92 ± 7.29^{a}	68.68 ± 4.14^{a}
	0.30	54.52 ± 5.37^{a}	30.20 ± 4.32^{b}	62.74 ± 5.50^{b}
L-SM	0.15	34.99 ± 3.15^{b}	30.58 ± 6.47^{b}	64.92 ± 2.90^{ab}
	0.30	35.77 ± 4.46^{b}	27.81 ± 1.22^{c}	61.20 ± 2.60^{b}
DL-SM		54.68 ± 4.80^{a}	36.56 ± 8.77^{a}	65.71 ± 5.58
L-SM		35.38 ± 3.70^{b}	29.19 ± 4.72^{b}	63.06 ± 3.27
	0.15	44.92 ± 11.04	36.75 ± 9.26^{a}	66.80 ± 3.93^{a}
	0.30	45.15 ± 10.87	29.01 ± 3.21^{b}	61.97 ± 4.18^{b}
P value	Se form	0.000	0.019	0.116
	Se level	0.902	0.015	0.007
	Se form × level	0.767	0.093	0.688

Within rows with different superscript letters differ significantly ($P < 0.05$)

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

Table 7 Effects of different SM forms and levels on total antioxidant capability (T-AOC) in tissues of 1-day-old chicks

Item	Se level (mg/kg)	Liver (U/mg prot)	Kidney (U/mg prot)	Muscle (U/mg prot)
DL-SM	0.15	4.68 ± 0.80	12.76 ± 0.71[a]	0.519 ± 0.008
	0.30	4.11 ± 0.40	11.72 ± 0.68[b]	0.517 ± 0.010
L-SM	0.15	4.62 ± 0.41	12.44 ± 0.51[a]	0.522 ± 0.003
	0.30	4.50 ± 0.38	12.40 ± 0.45[ab]	0.510 ± 0.013
DL-SM		4.39 ± 0.67	12.24 ± 0.46	0.518 ± 0.009
L-SM		4.56 ± 0.67	12.42 ± 0.53	0.516 ± 0.011
	0.15	4.65 ± 0.60	12.60 ± 0.61[a]	0.520 ± 0.006
	0.30	4.30 ± 0.42	12.06 ± 0.65[b]	0.514 ± 0.011
P value	Se form	0.445	0.457	0.688
	Se level	0.122	0.037	0.108
	Se form × level	0.301	0.054	0.200

Within rows with different superscript letters differ significantly ($P < 0.05$)

DL-SM, DL-selenomethionine; *L-SM*, L-selenomethionine

Values are means of three replicates ($n = 3$)

differences in the optimal Se level may be caused by different breeds of chicken.

During the growth process of animals, the embryonic stage is a critical period. The role of maternal nutritional status is crucial in several aspects of embryonic development, and this phenomenon is called maternal effect. When some nutrients in the diets of broiler breeder are deficient or insufficient, shortage of corresponding nutrients in the eggs and offspring may occur [23]. We noticed that 1-day-old chicks in the 0.15 mg/kg Se group and DL-SM group had better antioxidant status. The results were in agreement with our findings in broiler breeders. Wilaison indicated that a high level of Se in the maternal diet has an adverse effect on embryonic development because he found that the hatchability was increased in eggs from quail fed 0.25 mg/kg Se, but it was decreased in eggs from quail fed 0.5 or 1 mg/kg Se. Besides, cellular GPx mRNA levels of the hatchlings originating from the quail fed 0.25 mg/kg Se were higher than those from the quail fed regular diet [24]. This may explain our results.

Conclusion

In summary, our study demonstrated that basal diets supplemented with different SM forms and levels did not indicate any significant differences in average egg weight, feed intake, and feed-to-egg ration. Compared with L-SM, DL-SM was more effective for enhancing the antioxidant status of broiler breeders and its offspring. Moreover, the recommended level of Se supplementation was 0.15 mg/kg Se in Lingnan Yellow broiler breeder diets.

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Compliance with Ethical Standards

The project was conducted under the supervision of Zhejiang University Animal Care and Use Committee (Hangzhou, China), which has adopted animal care and use guidelines governing all animal use in experimental producers.

Conflict of Interest The authors declare that they have no conflict of interest.

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