Supplementation of selenomethionine at different ages and levels on meat quality, tissue deposition, and selenium retention in broiler chickens

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ABSTRACT The aim of the present study was to verify the effect of selenomethionine (SM) supplementation in the diet of chickens on performance, carcass yield, apparent retention, meat quality, and selenium (Se) deposition in tissues. In the first experiment, 2,100 day-old male chicks from the Hubbard Flex strain were randomly distributed in 84 plots with 12 treatments and 7 replicates. The treatments consisted of SM (1,600 ppm) supplementation at levels of 0.3 and 0.5 ppm in substitution of sodium selenite (45.7%) in different preslaughter phases. In the second experiment, 224 day-old male chicks from Hubbard Flex strain were randomly distributed in 28 metabolic cages. Poultry were distributed in 4 treatments with 7 replicates (8 poultry) in the experimental period from 1 to 21 D and experimental plot with 4 poultry aged from 22 to 42 D. Treatments consisted of 4 SM addition levels (0.3, 0.4, 0.5, and 0.6 ppm). In both experiments, the performance (1 to 21 and 1 to 42 D), carcass yield and cuts, apparent retention of Se (33 to 35 D), physical and chemical characteristics of the breast meat were evaluated: objective color, drip loss (DL), cooking loss (CL), pH, peroxide value, and Se deposition in tissues. In experiment I, it was found that SM at 0.3 ppm improved the weight gain and feed conversion of 1 to 42 D. The use of SM at 0.5 ppm resulted in lower DL and CL. The highest Se deposition in muscles was obtained using the SM at 0.5 ppm of 1 to 42 D. Using the SM at 0.5 ppm, only in the last week there was a deposition similar to the use of SM at 0.3 ppm of 1 to 42 D. In experiment II, it can be observed that increased SM levels provided lower DL and lower pH values. Se deposition in tissues of broiler chickens increased linearly at the SM level from 0.3 to 0.6 ppm.

Key words: organic selenium, cooking loss, selenium deposition

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INTRODUCTION

The adequate intake of selenium (**Se**) by animals and humans is extremely important for the maintenance of oxidative balance and hence prevention against damage to cell membranes. According to Huang et al. (2017), its deficiency may induce oxidative stress and apoptosis, besides causing structural and functional disorders in the tissues and muscles of animals.

The use of organic sources of Se in broiler chicken diets has been increasingly disseminated in order to improve the physical and chemical characteristics of the meat and hence a longer useful life of these foods, since they are more bioavailable than the inorganic sources (Perić et al., 2009; Gomes et al., 2011; Boiago et al., 2014; Oliveira et al., 2014; Kieliszek and Błazejak, 2016; Li et al., 2017). The collapse of the enzymatic and post-mortem oxidative systems occurs rapidly and, throughout the process of storage and processing of meats, significant loss of moisture may occur, leading to weight loss of the product and hence economic loss, which is greatly due to the loss of cell membrane integrity (Downs et al., 2000).

Among the most commonly used organic sources, selenomethionine (**SM**) is highlighted. This source is considered as more bioavailable than inorganic sources mainly due to its similarity with methionine even in the form of absorption (Schrauzer, 2000).

There is no consensus on the adequate levels of SM supplementation in broiler chicken diets. Rostagno et al. (2017) recommended that the addition of organic Se sources for broiler chickens should be performed at the level of 0.15 to 0.08 ppm according to the poultry age. However, several authors (Downs et al., 2000; Perić et al., 2009; Gomes et al., 2011; Boiago et al., 2014; Oliveira et al., 2014; Li et al., 2017) worked with higher levels of Se (from 0.15 to 0.6 ppm) and observed higher deposition in tissues and better meat quality, with the highest levels, without any damage to poultry

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Table 1. Treatments of experiment I.

Treatments	
T1	1–42 D SS[1] 0.3 ppm (control)
T2	1–42 D SS 0.5 ppm
T3	1–42 D SM[2] 0.3 ppm
T4	1–42 D SM 0.5 ppm
T5	1–14 D SS 0.3 ppm and 15–42 D SM 0.3 ppm
T6	1–14 D SS 0.3 ppm and 15–42 D SM 0.5 ppm
T7	1–21 D SS 0.3 ppm and 22–42 D SM 0.3 ppm
T8	1–21 D SS 0.3 ppm and 22–42 D SM 0.5 ppm
T9	1–28 D SS 0.3 ppm and 29–42 D SM 0.3 ppm
T10	1–28 D SS 0.3 ppm and 29–42 D SM 0.5 ppm
T11	1–35 D SS 0.3 ppm and 36–42 D SM 0.3 ppm
T12	1–35 D SS 0.3 ppm and 36–42 D SM 0.5 ppm

[1]SS: Sodium selenite (45.7% Se).
[2]SM: Selenomethionine (1,600 ppm Se).

performance. There is no information on the minimum time necessary for using the SM form to achieve good tissue enrichment in broiler chickens.

Therefore, the aim of the present study was to determine the effects of the use of different SM levels in the broiler chicken diet and its supplementation at different ages on the performance, meat quality, retention, and Se deposition in tissues.

MATERIAL AND METHODS

The study was performed in the city of Lavras, MG, Brazil, located at 21° 14′ 43″ S, 44° 59′ 59″ W, and 919 m altitude. The experimental procedures were approved by the Ethics Committee on Animal Use of the Federal University of Lavras under the protocol No. 006/16.

Experiment I

A total of 2,100 day-old male chicks from the Hubbard Flex strain were distributed in a completely randomized design in 84 experimental plots with 12 treatments and 7 replicates. The experimental treatments were constituted according to Table 1. The used sources of selenium were SM (1,600 ppm) and sodium selenite (**SS**, 45.7%), using selenium levels of 0.300 and 0.500 ppm.

Experimental diets were formulated on the basis of corn and soybean meal, according to the recommendations of Bertechini (2013), following a feeding program of 1 to 21 D and 22 to 42 D. Mineral and vitamin supplements were free from Se (Table 2).

The animals received feed and water ad libitum and were kept warm up to 14 D of age. Maximum and minimum temperatures recorded during the experimental period after 15 D were 28.7°C and 16.4°C, respectively. 16L:8D was used as the illumination program.

Excreta Collection At 28 d, 4 poultry per plot were taken from treatments 1 to 4, in which they received only one source of Se throughout the experimental period. These chickens were transferred to metabolic cages in order to determine the Se retention through total collection of excreta. There were 5 D of adaptation and 3 D of excreta collection on days 33, 34, and 35.

Table 2. Percent composition of the basal feeds for broiler chickens in different stages.

Ingredients	1–21 D	22–42 D
Corn	60.11	64.75
Soy bran	34.54	29.53
Soybean oil	2.03	2.56
Dicalcium phosphate	1.02	1.06
Limestone	1.04	0.78
Common salt	0.48	0.48
DL-methionine	0.24	0.22
L-lysine HCl	0.15	0.23
L-threonine	0.02	0.02
Vitamin premix[1]	0.10	0.10
Mineral premix[2]	0.10	0.10
Choline chloride (60%)	0.04	0.04
Salinomycin (12%)	0.05	0.05
Zinc bacitracin (10%)	0.03	0.03
Phytase 10,000 FTU	0.01	0.01
Inert[3]	0.04	0.04
Metabolizable energy Kcal/kg	3007	3100
Crude protein	20.64	18.80
Digestible methionine	0.54	0.50
Met + Cis	0.87	0.81
Lysine	1.22	1.15
Threonine	0.83	0.75
Tryptophan	0.25	0.22
Arginine	1.38	1.23
Isoleucine	0.89	0.80
Gly+Ser	1.96	1.76
Sodium	0.21	0.21
Calcium	0.85	0.75
Available phosphorus	0.45	0.45
Analyzed selenium[4], ppm	0.093	0.086

[1]Supplemented per kg of feed: Vit. A 12,000 IU, Vit. D3 2,400 IU, Vit. E 40 mg, Vit. K 31.8 mg, Vit. B1 2.5 mg, Vit. B2 4.0 mg, Vit. B6 2.0 mg, Vit. B12 15 μg, biotin 60 μg, niacin 30 mg, folic acid 1.8 mg.
[2]Supplemented per kg of feed: Fe 80 mg, Zn 70 mg, Mn 70 mg, I 1 mg, Cu 10 mg.
[3]Kaolin: used for addition of treatments.
[4]Analyzed by atomic absorption spectroscopy equipped with 77 VGA hydride generator system.

Performance and Carcass Yield Performance evaluations were made in the stages 1 to 21 and 1 to 42 D of the age of the poultry. At 42 D, 2 poultry per replicate were fasted for 8 h and soon after, they were stunned by cervical dislocation, bled, and eviscerated. The carcass was weighed and the prime cuts were separated for the determination of yields relative to carcass weight. Subsequently, the breasts and livers of the poultry were separated to determine the meat quality and Se deposition in tissues.

Physical and Chemical Characteristics of the Meat Breasts were boned and stored on ice for 90 min, and later the quality of meat was analyzed.

Objective Color The luminosity indices (L*), red (a*), and yellow (b*) were measured. The readings were made using the CM-700d colorimeter (Konica Minolta Sensing Inc., Osaka, Japan) at 3 points on the dorsal surface of each breast sample after 30 min exposure to ambient air.

The color indexes were established with illuminant A at a 10° angle to the observer, specular component was excluded, and CIELAB color system was used.

Drip Loss It was determined from 2 samples per plot, according to the methodology described by Rasmussen and Anderson (1996). The samples were cut into 2.5 cm^3 cubes, placed in hermetically sealed containers, and kept in a refrigerator at 4°C for 48 h. Subsequently, samples were taken from the refrigerator and weighed for the calculation of drip loss (**DL**), expressed as percentage.

Cooking Loss The breast meat samples were weighed and wrapped in aluminum foil for baking. After the external temperature reached 85°C, the samples were kept in an electric plate until reaching the internal temperature of 72 ± 2°C. The cooked meat samples were cooled for 30 min until room temperature and then reweighed for the determination of cooking loss (**CL**), according to the methodology described by Oliveira et al. (2014).

pH It was measured with a Digimed DM-20 potentiometer using a punch electrode and a temperature calibration device inserted into the pectoralis major muscle.

Determination of Peroxide Value The peroxide value (**PV**) was determined by the PCA-FOX (perchloric acid ferrous oxidation in xylenol orange) method described by Gay and Gebicki (2002), cited by Massingue (2012), and the analyses were performed in duplicates. A total of 6 g breast meat sample was weighed and 25 mL refrigerated methanol (–18°C) was added, and then ground in a Turrax (Turratec Te102) disperser for 30 s. The homogenate was centrifuged for 3 min at 1,400 × g (Mettich centrifuge, Zentrifuger EBA21). After centrifugation, flasks used for sample homogenization were washed with 5 mL cooled methanol.

Then, 100 and 200 μL aliquots taken from the supernatant were transferred to test tubes containing 200 μL analytical solution (2.5 mmol/L xylenol orange, 2.5 mmol/L ferrous sulfate hexahydrate) and the volume fulfilled to 2 mL with distilled water. The tubes were capped and incubated in a dark environment at 20 to 25°C for 30 min. Absorbances were read at 560 nm (A_{560nm}) against blank, and PV was obtained by a cumene hydroperoxide (**CHP**) analytical curve. The results were expressed as mg CHP per kilogram of the sample.

Selenium Content Analysis A sample of liver and breast from each plot, as well as excreta and feeds, was oven-dried at 105°C to determine the Se deposition by the atomic absorption spectroscopy method and generation of hydrides using a quartz tube atomizer at 850°C. A VARIAN model 2000-SpectrAA atomic absorption spectrometer (Palo Alto, CA) and a Varian model VGA hydride generator were used for the measurements. The reducing reagent was sodium borohydride (alkaline solution). The source of electromagnetic radiation was a selenium hollow cathode lamp (Photron brand), and the used wavelength was 196.0 nm. The detection limit for this method is 3 μg/L.

Table 3. Treatments of experiment II.

Treatments	
T1	SM[1]—0.3 ppm
T2	SM—0.4 ppm
T3	SM—0.5 ppm
T4	SM—0.6 ppm

[1]SM: selenomethionine (1,600 ppm Se).

Statistical Analysis

The results were subjected to ANOVA using the SAS® statistical package (2002) and, when necessary to compare the averages, the Student–Newman–Keuls test at 5% probability was used.

Experiment II

A total of 224 day-old male chicks from Hubbard Flex strain were randomly distributed in 28 metabolic cages (75 × 60 × 50 cm). The animals were distributed in 4 treatments with 7 replicates (8 poultry) in the experimental period from 1 to 21 D and experimental plot with 4 poultry aged from 22 to 42 D. Treatments are described in Table 3.

Feeds were formulated on the basis of corn and soybean meal, following the recommendations of Bertechini (2013), as described in Table 2. The contents of Se in basal diets were 0.093 and 0.086 ppm for 1 to 21 and 22 to 42 D, respectively.

Performance evaluations were made in the stages 1 to 21 and 1 to 42 D of the age of the poultry. The period of excreta collection was from 33 to 35 D, with total collection in order to determine the retention of Se. At 42 D, 2 poultry per replicate were slaughtered for determination of carcass yield and cuts. The breasts were taken for evaluation of meat quality: objective color, CL, DL, pH, and PV. Liver, breast, excreta, and feed samples were collected for the determination of Se content. The methodologies of the analyses of this experiment were similar to the ones described in experiment I.

Statistical Analysis

The results were subjected to ANOVA using the SAS® statistical package (2002), and when necessary, regression test at 5% probability was used.

RESULTS

Experiment I

Performance and Yield of Carcass and Cuts The performance indices in the period from 1 to 21 D were not influenced ($P > 0.05$) by the substitution of the inorganic source of Se by SM; however, in the total period from 1 to 42 D, it was observed that the use of the SS at the level of 0.30 ppm Se provided lower weight gain in relation to the other treatments ($P < 0.05$) and

Table 4. Performance of broiler chickens fed with selenomethionine at different ages.

	Experiment I					
	Performance 1–21 D			Performance 1–42 D		
Treatments	FI[3]	WG[4]	FC[5]	FI	WG	FC
1–42 D SS[1] 0.3 ppm	1.246	1.005	1.240	4.820^{b}	2.894^{b}	1.665^{c}
1–42 D SS 0.5 ppm	1.248	1.007	1.239	4.799^{b}	2.969^{a}	1.616^{a,b}
1–42 D SM[2] 0.3 ppm	1.245	1.012	1.230	4.848^{a,b}	2.973^{a}	1.630$^{a–c}$
1–42 D SM 0.5 ppm	1.255	1.004	1.251	4.815^{b}	2.998^{a}	1.606^{a}
1–14 D SS 0.3 ppm and 15–42 D SM 0.3 ppm	1.248	1.023	1.220	4.871^{a,b}	2.960^{a}	1.646$^{a–c}$
1–14 D SS 0.3 ppm and 15–42 D SM 0.5 ppm	1.245	0.987	1.261	4.909^{a,b}	2.968^{a}	1.653^{b,c}
1–21 D SS 0.3 ppm and 22–42 D SM 0.3 ppm	1.252	0.990	1.265	4.903^{a,b}	2.967^{a}	1.652^{b,c}
1–21 D SS 0.3 ppm and 22–42 D SM 0.5 ppm	1.262	1.016	1.242	4.845^{a,b}	2.952^{a}	1.640$^{a–c}$
1–28 D SS 0.3 ppm and 29–42 D SM 0.3 ppm	1.258	1.021	1.232	4.977^{a}	2.988^{a}	1.665^{c}
1–28 D SS 0.3 ppm and 29–42 D SM 0.5 ppm	1.251	1.001	1.250	4.886^{a,b}	2.955^{a}	1.653^{b,c}
1–35 D SS 0.3 ppm and 36–42 D SM 0.3 ppm	1.248	0.998	1.250	4.919^{a,b}	2.967^{a}	1.657^{b,c}
1–35 D SS 0.3 ppm and 36–42 D SM 0.5 ppm	1.256	0.999	1.257	4.859^{a,b}	2.988^{a}	1.626$^{a–c}$
Overall average	1.251	1.005	1.245	4.871	2.965	1.642
CV (%)	0.85	2.43	2.16	1.75	1.34	1.67

Averages followed by the same letter on the column do not differ statistically among themselves by the Student–Newman–Keuls test at 5% significance level.
[1]SS: sodium selenite (45.7% Se).
[2]SM: selenomethionine (1,600 ppm Se).
[3]FI: feed intake (kg).
[4]WG: weight gain (kg).
[5]FC: feed conversion (kg/kg).

Table 5. Carcass yield and broiler chicken cuts fed with selenomethionine at different ages, expressed as a percentage.

	Experiment I			
Treatments	Carcass	Breast	Leg quarters	Wings
1–42 D SS[1] 0.3 ppm	76.38	26.66	22.79	8.51
1–42 D SS 0.5 ppm	77.45	27.09	22.77	8.34
1–42 D SM[2] 0.3 ppm	76.91	27.17	23.04	8.70
1–42 D SM 0.5 ppm	76.38	27.04	23.16	8.28
1–14 D SS 0.3 ppm and 15–42 D SM 0.3 ppm	77.09	27.06	22.58	8.13
1–14 D SS 0.3 ppm and 15–42 D SM 0.5 ppm	76.90	27.33	22.28	8.14
1–21 D SS 0.3 ppm and 22–42 D SM 0.3 ppm	75.93	26.80	22.34	8.01
1–21 D SS 0.3 ppm and 22–42 D SM 0.5 ppm	76.11	26.39	22.41	8.07
1–28 D SS 0.3 ppm and 29–42 D SM 0.3 ppm	75.63	27.80	22.31	8.42
1–28 D SS 0.3 ppm and 29–42 D SM 0.5 ppm	75.14	26.83	21.85	7.87
1–35 D SS 0.3 ppm and 36–42 D SM 0.3 ppm	75.99	27.15	22.38	8.18
1–35 D SS 0.3 ppm and 36–42 D SM 0.5 ppm	77.01	27.00	22.62	8.20
Overall average	76.42	27.03	22.54	8.24
CV (%)	2.47	5.09	6.28	7.07

[1]SS: sodium selenite (45.7% Se).
[2]SM: selenomethionine (1,600 ppm Se).

worse feed conversion ($P < 0.05$) when compared to the treatment containing SM at 0.5 ppm Se (Table 4).

For carcass and cut yields, it was observed that the addition of SM in the diet of broiler chickens at levels 0.3 and 0.5 ppm in any stages before slaughter does not provide significant differences ($P > 0.05$), as shown in Table 5.

Retention of Selenium For the retention of Se, no significant differences ($P > 0.05$) were observed between the sources (SS and SM) or between dietary levels (0.3 and 0.5 ppm) as shown in Figure 1.

Physical and Chemical Characteristics of the Meat The results are described in Table 6.

For luminosity index (L*), only the treatment that received SM at 0.5 ppm from 29 D of age showed a higher

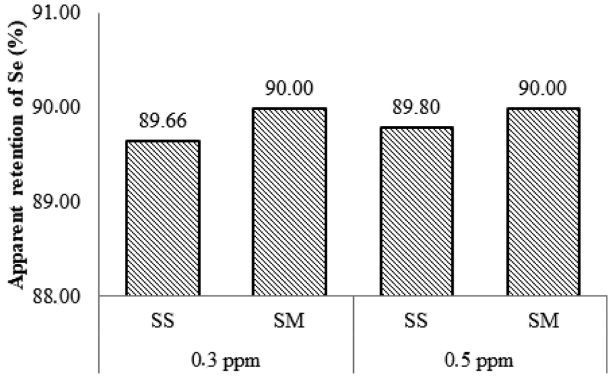

Figure 1. Apparent retention of selenium for broilers fed with sodium selenite (SS) and selenomethionine (SM) at levels of 0.3 and 0.5 ppm aged from 28 to 35 D.

Table 6. Meat quality of broiler chickens fed with selenomethionine at different ages.*

	Experiment I						
	Objective color						
Treatments	L*	a*	b*	DL[3]	CL[4]	pH	PI[5]
1–42 D SS[1] 0.3 ppm	52.84[a,b]	6.01[a,b]	11.81[a,b]	3.27[a]	26.22[b]	6.33	26.44
1–42 D SS 0.5 ppm	52.66[a,b]	7.17[a]	12.61[a]	2.32[b,c]	23.33[a,b]	6.34	26.55
1–42 D SM[2] 0.3 ppm	50.91[b]	6.01[a,b]	11.16[a,b]	2.34[b,c]	22.88[a,b]	6.31	27.12
1–42 D SM 0.5 ppm	50.50[b]	6.11[a,b]	11.45[a,B]	2.02[c]	21.11[a]	6.24	24.14
1–14 D SS 0.3 ppm and 15–42 D SM 0.3 ppm	51.50[a,b]	6.43[a]	11.12[a,b]	2.63[a–c]	24.03[a,b]	6.46	29.11
1–14 D SS 0.3 ppm and 15–42 D SM 0.5 ppm	51.96[a,b]	6.11[a,b]	11.22[a,b]	2.53[a–c]	23.27[a,b]	6.50	26.92
1–21 D SS 0.3 ppm and 22–42 D SM 0.3 ppm	50.91[a,b]	6.55[a]	10.97[a,b]	2.82[a–c]	25,23[b]	6.32	29.97
1–21 D SS 0.3 ppm and 22–42 D SM 0.5 ppm	50.76[a,b]	6.42[a]	10.11[a,b]	2.68[a–c]	23.37[a,b]	6.38	24.89
1–28 D SS 0.3 ppm and 29–42 D SM 0.3 ppm	51.34[a,b]	6.62[a]	12.07[a]	2.28[b,c]	23.87[a,b]	6.31	22.77
1–28 D SS 0.3 ppm and 29–42 D SM 0.5 ppm	53.53[a]	7.09[a]	12.40[a]	2.51[a–c]	22.81[a,b]	6.43	24.53
1–35 D SS 0.3 ppm and 36–42 D SM 0.3 ppm	52.14[a,b]	6.93[a]	12.39[a]	2.99[a,b]	24.22[a,b]	6.48	27.17
1–35 D SS 0.3 ppm and 36–42 D SM 0.5 ppm	52.53[a,b]	5.14[b]	10.14[b]	2.69[a–c]	23.62[a,b]	6.45	27.48
Overall average	51.58	6.38	11.54	2.59	23.66	6.38	26.42
CV (%)	2.89	11.94	9.28	16.69	7.04	2.08	10.14

Averages followed by the same letter on the column do not differ statistically among themselves by the Student–Newman–Keuls test at 5% significance level.
[1]SS: sodium selenite (45.7% Se).
[2]SM: selenomethionine (1,600 ppm Se).
[3]CL: cooking loss (%).
[4]DL: drip loss.
[5]PI: peroxide value (mg cumene hydroperoxide/kg).

value than the other treatments, which in turn did not differ from each other ($P > 0.05$). The response variables a* and b* presented similar behavior for the treatments. The treatment in which the poultry received SM at the 0.5 ppm level only in the last week showed the lowest values ($P < 0.05$), while the other treatments did not differ among themselves ($P > 0.05$) for red and yellow.

Drip loss was higher ($P < 0.05$) for the treatment in which the animals received the SS at 0.3 ppm throughout the experimental period. In contrast, treatment with SM at 0.5 ppm throughout the experimental period provided the lowest exudation loss ($P < 0.05$). It was also observed that the addition of 0.5 ppm SS and 0.3 ppm SM from 1 to 42 D as well as the substitutions throughout the productive period of broiler chickens did not differ from each other.

The use of SS at 0.3 ppm throughout experimental period provided the highest CL ($P < 0.05$) when compared to the other treatments. However, the SM at 0.5 ppm of 1 to 42 D was more efficient in reducing CLs.

No significant differences ($P > 0.05$) were observed for the pH of broiler chicken meats.

The PV was also not influenced by dietary source of Se, level, or addition period ($P > 0.05$).

Selenium Content The results of Se deposition in liver and muscle in broiler chickens are presented in Table 7. Regardless of the source, the dietary levels of Se were significantly different ($P < 0.05$) in broiler chicken meat, being 0.435 and 0.537 mg/kg for levels 0.3 and 0.5 ppm from 1 to 42 D, respectively, based on natural matter (Figure 5). Se deposition in liver was not affected by Se levels ($P > 0.05$).

However, in relation to the sources of Se, it is found that the use of 0.5 ppm SM throughout the period provided a higher deposition ($P < 0.05$) of Se in broiler chicken breasts (0.712 mg/kg) based on dry matter. It was found that 0.03 ppm SS provided lower Se deposition in liver ($P < 0.05$). It can also be observed that the use of SM at 0.5 ppm Se in the last week provided a similar result to the use of 0.3 ppm Se in the form of SM all the time; however, it does not reach the deposition of Se using SM at 0.5 ppm from 1 to 42 D of the age of poultry. The use of SM (0.5 ppm) from 15 D of age provided the second higher deposition ($P < 0.05$) of Se in the breast meat (0.659 mg/kg). The depositions were changed according to the treatments, following the logic of this higher level of supplementation and longer time of SM use, resulting in greater enrichment.

Experiment II

Performance and Yield of Carcass and Cuts No significant differences ($P > 0.05$) were observed for performance indices: feed intake, weight gain, and feed conversion of broiler chickens in none stage (Table 8).

For the carcass and cut yields, no significant differences ($P > 0.05$) were observed for none of the studied SM levels (Table 9).

Selenium Retention The addition levels of SM did not alter ($P > 0.05$) the retention of Se for broiler chickens (Figure 2).

Physical and Chemical Characteristics of the Meat The results of objective color, CL, and PV are described in Table 10.

There was no significant difference for any of the evaluated objective color indexes ($P > 0.05$).

Table 7. Deposition of muscle and liver selenium in broiler chickens fed with selenomethionine at different ages, expressed as mg/kg.*

	Experiment I			
	Breast		Liver	
Treatments	Dry matter	Natural matter	Dry matter	Natural matter
1–42 D SS[1] 0.3 ppm	0.334[d]	0.089[c]	1.553[b]	0.462[d]
1–42 D SS 0.5 ppm	0.362[c,d]	0.096[b,c]	1.697[b,d]	0.522[c,d]
1–42 D SM[2] 0.3 ppm	0.536[f,g]	0.147[d,f]	1.867[b–d]	0.570[b–d]
1–42 D SM 0.5 ppm	0.712[a]	0.189[a]	1.926[b–d]	0.576[b–d]
1–14 D SS 0.3 ppm and 15–42 D SM 0.3 ppm	0.532[f,g]	0.141[d–f]	2.148[c,d]	0.651[b,c]
1–14 D SS 0.3 ppm and 15–42 D SM 0.5 ppm	0.659[b]	0.180[a]	1.907[b–d]	0.566[b–d]
1–21 D SS 0.3 ppm and 22–42 D SM 0.3 ppm	0.507[g]	0.134[d,e]	1.907[b–d]	0.545[b–d]
1–21 D SS 0.3 ppm and 22–42 D SM 0.5 ppm	0.590[e,f]	0.154[f]	2.063[b–d]	0.629[b,c]
1–28 D SS 0.3 ppm and 29–42 D SM 0.3 ppm	0.570[e–g]	0.153[f]	2.206[c,d]	0.678[b]
1–28 D SS 0.3 ppm and 29–42 D SM 0.5 ppm	0.602[e]	0.158[f]	3.496[a]	1.05[a]
1–35 D SS 0.3 ppm and 36–42 D SM 0.3 ppm	0.397[c]	0.105[b]	2.176[c,d]	0.660[b,c]
1–35 D SS 0.3 ppm and 36–42 D SM 0.5 ppm	0.508[g]	0.130[e]	2.291[c]	0.685[b]
Overall average	0.525	0.139	2.103	0.633
CV (%)	8.25	8.20	15.22	14.08

Averages followed by the same letter on the column do not differ statistically among themselves by the Student–Newman–Keuls test at 5% significance level.
[1]SS: sodium selenite (45.7% Se).
[2]SM: selenomethionine (1,600 ppm Se).

Table 8. Performance of broiler chickens fed with different levels of selenomethionine.

	Experiment II					
	Performance 1–21 D			Performance 1–42 D		
Treatments	FI[2]	WG[3]	FC[4]	FI	WG	FC
SM[1] 0.3 ppm	1.248	1.043	1.248	4.736	2.916	1.630
SM 0.4 ppm	1.232	1.037	1.232	4.816	2.906	1.637
SM 0.5 ppm	1.267	1.014	1.267	4.747	2.929	1.644
SM 0.6 ppm	1.255	1.019	1.232	4.865	2.932	1.651
Overall average	1.250	1.028	1.220	4.791	2.921	1.640
CV (%)	4.09	3.57	4.63	3.25	2.91	3.51

[1]SM: selenomethionine (1,600 ppm Se).
[2]FI: feed intake (kg).
[3]WG: weight gain (kg).
[4]FC: feed conversion (kg/kg).

Table 9. Carcass yield and broiler chicken cuts fed with different levels of selenomethionine.

	Experiment II			
Treatments	Carcass	Breast	Leg quarters[2]	Wings
SM[1] 0.3 ppm	76.91	27.17	23.04	8.52
SM 0.4 ppm	75.94	26.39	22.52	8.39
SM 0.5 ppm	76.54	27.04	23.16	8.29
SM 0.6 ppm	77.68	27.56	23.48	8.13
Overall average	76.77	27.04	23.05	8.33
CV (%)	2.24	4.91	5.54	6.44

[1]SM: selenomethionine (1,600 ppm Se).
[2]Leg quarters: drumstick+thigh.

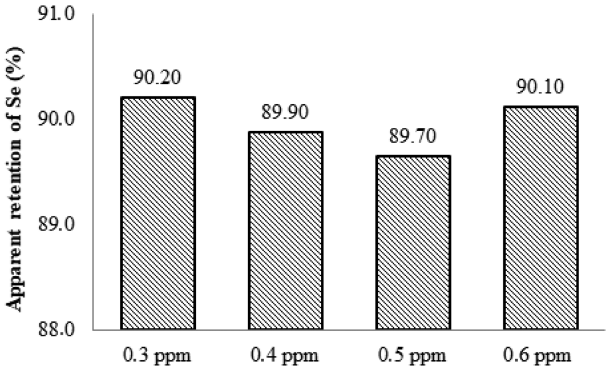

Figure 2. Apparent retention of selenium in broilers fed with different levels of selenomethionine.

Table 10. Physical and chemical characteristics of broiler chicken breasts fed with different levels of selenomethionine.

	Experiment II				
	Objective color				
Treatments	L*	a*	b*	CL[2]	PV[3]
SM[1] 0.3 ppm	51.28 [NS]	6.01 [NS]	11.35 [NS]	23.11[NS]	26.44[NS]
SM 0.4 ppm	50.33 [NS]	5.60 [NS]	11.89 [NS]	22.91[NS]	25.07[NS]
SM 0.5 ppm	50.50 [NS]	6.11 [NS]	11.45 [NS]	22.00[NS]	26.55[NS]
SM 0.6 ppm	51.23 [NS]	6.54 [NS]	11.33 [NS]	21.43[NS]	24.26[NS]
Overall average	50.83	6.06	11.50	22.36	25.58
CV (%)	2.36	11.54	8.07	6.73	6.91

[1]SM: selenomethionine (1,600 ppm Se).
[2]CL: cooking loss (%).
[3]PV: peroxide value (mg cumene hydroperoxide/kg).
NS: not significant.

For DL, a linear effect ($P < 0.05$) was observed according to the increase in SM levels (Figure 3), the higher the addition, the lower the exudation losses.

The CL was not influenced ($P > 0.05$) by the increase in dietary levels of SM.

The pH values of meats showed a linear effect ($P < 0.05$) according to the increase in dietary levels of SM (Figure 4). It was observed that the increase of SM levels in the diets favors the decrease of the pH in chicken breast meats.

The PV was not influenced ($P > 0.05$) by the increase in dietary levels of SM.

Selenium Content The deposition showed a positive correlation with the increase of dietary addition of

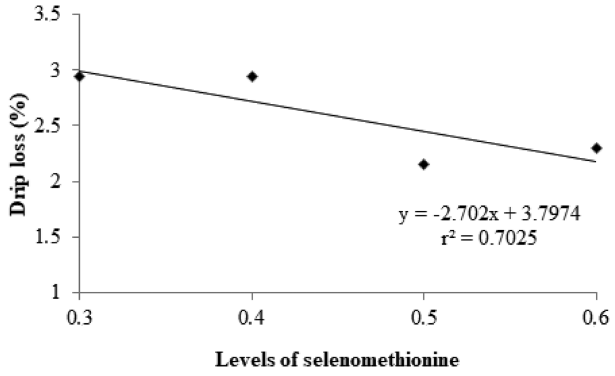

Figure 3. Drip loss of broilers fed with different levels of SM.

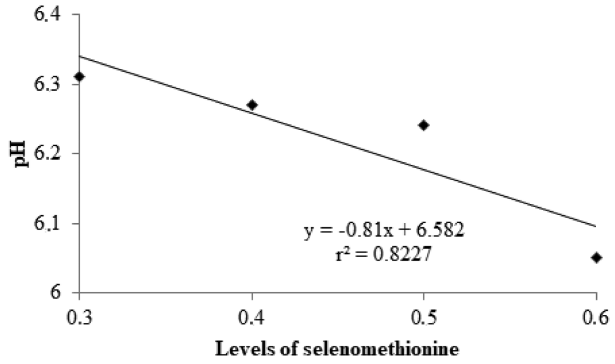

Figure 4. pH values of broilers breasts according to dietary SM levels.

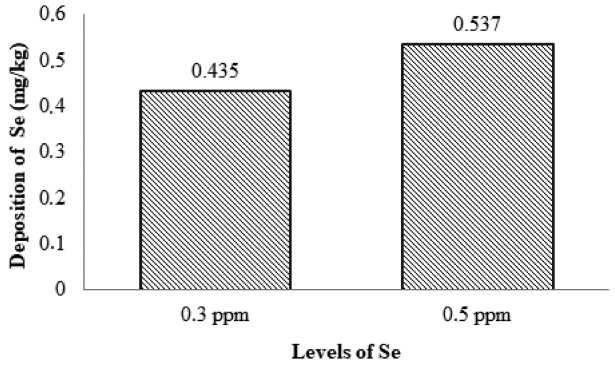

Figure 5. Selenium deposition in breast muscle of broilers according to the addition level, based on dry matter.

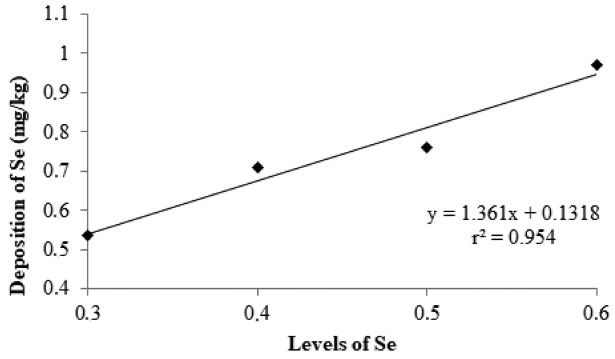

Figure 6. Selenium deposition in broilers breasts fed with different levels of selenomethionine, expressed as mg/kg based on dry matter.

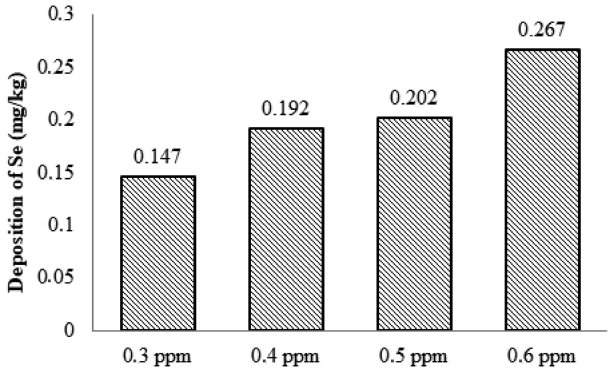

Figure 7. Selenium deposition in broilers breasts fed with different levels of selenomethionine, expressed as mg/kg based on natural matter.

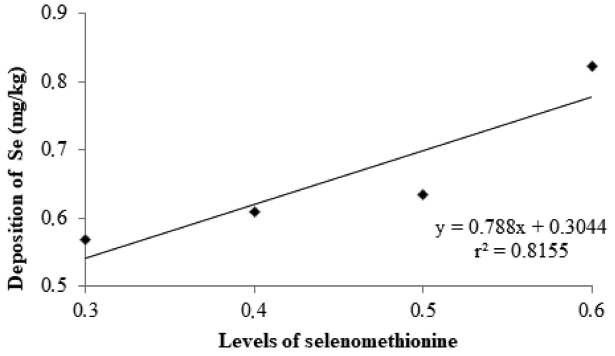

Figure 8. Selenium deposition in broilers livers fed with different levels of selenomethionine, expressed as mg/kg based on natural matter.

SM, being represented by dry matter (Figure 6) and based on natural matter (Figure 7).

The values of Se deposition in liver also showed positive linear behavior ($P < 0.05$) according to the dietary addition of SM (Figure 8).

DISCUSSION

Performance and Yield of Carcass and Cuts

The differences in performance were found in experiment I. Supplementation with organic selenium resulted in better weight gain and feed conversion. The use of organic Se presents better bioavailability (Kieliszek and Błazejak, 2013). On the other hand, several authors indicated that sources of Se are not able to alter the performance of broiler chickens (Perić et al., 2009; Medeiros et al., 2012; Boiago et al., 2014; Rajashree et al., 2014; Dalia et al., 2017; Li et al. 2017). Regarding the influence of SM levels on these response variables, the nutritional requirements of the poultry at 0.3 ppm were met in both experiments (NRC, 1994; Rostagno et al. 2017), from 0.351 to 0.204 ppm for the inorganic forms and from 0.153 to 0.089 for organic sources for the initial and final phases, respectively.

Apparent Retention of Selenium

No significant differences in apparent retention of Se for sources or for addition levels were observed. Gomes et al. (2011) worked with 2 sources of Se yeast and SS at 0.3 ppm and did not verify differences for apparent retention of Se; however, the 2 organic sources at 0.45 ppm showed higher retention of Se in relation to the SS. Yoon et al. (2007) found differences in the retention of Se between both sources, and at 0.1 and 0.2 ppm level of Se yeast showed higher retention than the addition of 0.3 ppm from the same source, being that the SS at 0.3 ppm showed the lowest retention. These results suggest that inorganic sources are less retained than organic sources, and, according to Gomes et al. (2011), the absorption of Se is not the limiting factor for its retention, but rather the conversion to the biologically active form in the tissues. The results from the present study do not corroborate with the results found by the cited authors. In the present study, the bioavailability was not calculated but the apparent retention of Se. According to Dumont et al. (2006), SM is more bioavailable than is inorganic Se; however, this source can be nonspecifically incorporated in body proteins and serve as a pool of Se, which can be used at times of depletion or increasing need.

Physical and Chemical Characteristics of Meat

In general, SM was more effective than SS to prevent weight loss by exudation of chicken meats in relation to the additions of the 2 sources at 0.3 ppm, being necessary an addition of 0.5 ppm SS to obtain a similar result to SM at 0.3 ppm. These results are similar to the Perić et al. (2009) and Boiago et al. (2014), which verified a better action of organic sources of Se on the maintenance of muscle cell integrity, promoting lower exudation loss and greater retention capacity. Another important observation of the present study was that, using organic sources only in the last week before slaughter, it is possible to obtain statistically similar results ($P > 0.05$) to the use of SM at 0.3 ppm level throughout raising period, providing lower costs for addition of SM. The dietary increase of SM at levels from 0.3 to 0.6 ppm provided a linear decrease in DL.

The CL results in experiment I showed similar behavior to those found for DL, reinforcing the hypothesis that the organic sources are more effective in combating oxidation and hence preserving cell membranes. These results corroborate with Oliveira et al. (2014) and Li et al. (2017). However, addition levels of SM did not significantly affect the CL.

The pH of meats was not influenced by the Se source or by the addition of SM in the different pre-slaughter phases. These results corroborate with Perić et al. (2009) and Oliveira et al. (2014). However, other studies have shown that the use of organic sources promotes an increase in pH of chicken and pork in relation to SS (Kieliszek and Błazejak, 2013; Boiago et al., 2014; Calvo et al., 2017; Li et al., 2017). When comparing the dietary levels of SM, a negative linear effect was observed between the increase in SM levels and the pH of breast meats. Calvo et al. (2017) observed a positive correlation between the higher pH values and the lower DL for pork, which is contrary to the present study in which the treatments that provided lower pH also provided lower DL.

Although the performance of organic sources of Se in the prevention of oxidation in chicken meat is well evidenced (Perić et al. 2009; Wang et al., 2011; Ahmad et al. 2012; Boiago et al. 2014; Rajashree et al., 2014), in the present study, no significant differences were found for the PV with the use of different sources and levels of dietary Se. Li et al. (2017) did not find significant differences for the TBARS index using 4 different sources of Se (SS, Se yeast, SM, and nano-selenium).

Selenium Content

Several authors have found that organic sources promote higher Se deposition in tissue when compared with SS for broiler chickens and swine (Perić et al., 2009; Gomes et al., 2011; Wang et al., 2011; Rajashree et al., 2014; Dalia et al., 2017, Jiang et al., 2017; Li et al., 2017).

According to Schrauzer (2000), this is due to the similarity between SM and methionine, making possible for SM to be used in protein synthesis indifferently, since the RNA transporter to methionine cannot discriminate the 2 amino acids. According to Schrauzer (2003), any SM that is not metabolized immediately is incorporated into organs with high protein synthesis rate such as muscle, pancreas, liver, kidney, and intestinal mucosa.

When comparing the dietary sources of Se, there was lower deposition in liver for the treatments containing SS with addition of 0.3 ppm. Payne and Southern (2005), Wang et al. (2011), and Rajashree et al. (2014) also found a higher Se deposition in muscle using organic sources. The rate of Se deposition in liver when compared with deposition in muscle is higher for SS regardless of the used level. In the present study, it was observed that at 0.3 ppm, Se deposition in liver is 5.19 times greater than deposition in muscle, while this ratio is 3.87 for SM. For the 0.5 ppm level, the behavior is similar, being the ratio between deposition in liver and muscle for SS and SM is 5.43 and 3.04, respectively. According to Rajashree et al. (2014), this behavior can be explained by the detoxification process of the organism, since organic sources are more bioavailable. Particularity of Se has very narrow safety margin between toxicity and deficiency, and inorganic sources exhibit higher toxicity as compared to the organic forms (Kieliszek and Błazejak, 2016). In this work, apparent symptoms of Se intoxication were not observed because the supplementation values are very low.

In the second experiment, a linear increase for Se deposition in muscle and liver was observed in relation to the addition level of SM. Oliveira et al. (2014) also verified linear Se deposition in broiler chicken breasts with increased dietary Se yeast levels (0.15 to 0.6 ppm). In the present study, the use of SM at 0.6 ppm provided 81.64% increase in muscle deposition when compared with the dietary level of 0.3 ppm.

CONCLUSION

The use of different SM levels did not influence the performance of broiler chickens; however, comparing the sources, the SS at 0.3 ppm promoted lower weight gain and worse feed conversion. Carcass and cut yields were not influenced by sources and/or levels of supplementary Se.

The apparent retention was not influenced by the source or by the level of Se.

Sources and levels of dietary Se influence meat quality characteristics, being that DL and CL were lower for the treatment in which SM at 0.5 ppm was provided for 1 to 42 D, which is similar to the use of SM only in the last week of raising. The increase in SM levels promoted a linear decrease in exudation loss and in the pH of chicken breasts.

Se deposition in muscle using SM at 0.3 ppm from 1 to 42 D was similar to supplementation of SM at 0.5 ppm only in the last week prior to slaughter, and the increase in dietary levels of SM promoted a linear increase in the Se deposition in muscle and liver.

Supplementation of 0.6 ppm SM for broiler chickens promoted the deposition of 0.267 mg per kg of breast meat. When considering the consumption of a fillet of 150 g, the Se deposition corresponds to 40.05 μg, about 70% of the requirement for adult humans (55 μg per day), according to the Institute of Medicine, Food and Nutrition Board (2000).

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